Public Infrastructure Investment and Economic Growth : A Sector Wise Investigation for India Using Westerlund Panel Cointegration Approach

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The paper aims to empirically analyze the relationship between Public Infrastructure Investment and economic growth for India using yearly data for its twenty-eight states (excluding Telangana) over the time-period of 1999-00 to 2014-15. We have aimed to assess this eye catching issue after the recent focus of Indian government to devote a majority of public funds to finance Infrastructure. For all the states, we have taken Public Investment data for six major sub sectors falling under overall Infrastructure sector: Transport, Education, Sports, Art and Culture, Medical and Public Health, Water supply and sanitation, Irrigation, Energy/Power. The Per Capita Gross State Domestic Product is taken as an indicator to represent economic growth. For

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empirical analysis, we apply panel unit root and cointegration tests, and estimate a panel error correction model. The Per Capita Gross State Domestic Product along with Public Investment in analyzed sectors have a unit root at their levels suggesting that there is presence of long-term relationships among the variables for the whole sample. Finally, Granger causality tests are applied to check for the presence of causal relationships between Per Capita Gross State Domestic Product and Public Investment in different sub sectors of Infrastructure. The research study proposes that the state governments across India should focus upon private as well as foreign direct investment options which would ultimately help in improving the landscape of India's Infrastructure sector.

Keywords: Public Infrastructure Investment, Westerlund Cointegration, Stationarity, Causality, Economic growth
JEL Classifications: H54, H72, O11

Introduction

The whole world has seen the rise of Indian economy as one of the fastest growing economies and a major global force to be reckoned with. Certain sectors like manufacturing and services have enhanced India's economic growth process and this has led to a wave of positive sentiments, both inside the nation as well as abroad. With this boost in investment as well as the support of strong macroeconomic essentials, the future prospects of India's economy are clearly positive and upbeat. Going by what economic experts and policymakers have to say, India can tap its full potential as a major economic power, if it is to focus on one fundamental exercise i.e improve its infrastructural facilities which are currently not sufficient enough to meet the ever increasing demands of the economy. Failure to improve the infrastructure levels will surely constrain India's growth momentum. While we are talking about Infrastructure and its resounding role in bringing economic growth, what needs to be looked at is how much are we actually investing in Infrastructure. This leads us to the critical issue of Public Infrastructure Investment and how it is related to economic growth. The last decade gone by has been a spectator of the revival of focus and attention that has gone in terms of analyzing the role of Public Infrastructure Investment, particularly from an Indian context. The State governments all across India have identified this crucial need of boosting up the Public Infrastructure Investment levels. Many factors like the ever increasing pace of urbanization and the related infrastructure demands, taking due advantage of various technological changes and ultimate aim to achieve high economic growth, are behind this recent shift in focus. Even the recent financial crisis has further strengthened the focus on Public Infrastructure Investment as a prospective countercyclical policy tool which can serve the dual purpose of creating jobs as well as laying the foundation for creating and sustaining economic growth.

While this fact is established that Public Infrastructure Investment is a critical input for economic growth and that there is a need for a substantial increase in the Infrastructure Investment, particularly in low income countries where there is urgent need to deal with these issues and ultimately tackle multiple policy challenges. However, as nations around the globe continue to grow and develop there is increasing interest in elucidating more comprehensively this dynamic relationship. This paper presents an empirical investigation of the relationship between Public Infrastructure Investment and economic growth in India using a panel dataset for a 16-year period i.e 1999-2000 to 2014-15 for the 28 Indian states. We have performed a sectoral analysis taking Public Investment data for six major sub sectors falling under overall Infrastructure sector. Section 2 summarizes the Literature Review on this topic. Data and Methodology have been discussed in the Section 3. Section 4 illustrates the results of Empirical Analysis. The Conclusions and Policy Implications of the study are presented in Section 5 and

Section 6 respectively. Finally, the Scope for Further Research is mentioned under Section 7 of the paper.

Review of the scientific literature

It is a well known fact that spending on Infrastructure forms a major part in public capital investment. Therefore, Public Infrastructure Investment is always counted to be a crucial component of economic development and growth. According to World Development Report - Infrastructure for Development (1994), in the low and middle-income countries, all the services related with infrastructure account for only a meager 7-9 % of GDP. Infrastructure in these nations typically represents about 20 % of total investment and 40 to 60 % of Public Investment. Further, the report highlighted the importance of infrastructure by postulating that a 1 % increase in the stock of infrastructure is associated with 1 % increase in GDP across all observed countries. However, when it comes to analyze the quantitative impact of Public Infrastructure Investment on economic growth, the issue at hand is still ambiguous and needs to be analyzed further.

The debate on assessing the impact of Public Infrastructure Investment on economic growth was revived by Aschauer's (1989) work which made an echoing impact and led the researchers around the world to start thinking about the association between the Public Infrastructure Investment and economic growth. In his research, Aschauer observed that the productivity slowdown of US, post 1973, was "*matched or slightly preceded by a precipitous decline in additions to the net stock of public non-military structures and equipment*". After this, large numbers of empirical studies aimed at analyzing the effects of public infrastructure took off. However, Gramlich (1994) in his review essay pointed out many plausible endogeneity issues and concluded that many researchers on this subject failed in their attempt to give conclusive results which could confirm Aschauer's results. But this did not suppress the interest of researchers, either in terms of analyzing the role of Public Investment or with the challenging task of assessing its impact empirically.

Calderon and Serven (2010), in a World Bank study found evidence to significant positive contribution from Public Investments in four basic infrastructure sectors: telecommunications, land transportation, water and sanitation and electricity. These authors put forth the view that curtailing the infrastructure spending decreased the long term growth by approximately 3 percentage points a year in Argentina and Brazil and by 1.5 to 2 percentage points per year in Mexico, Chile and Peru. Sutherland et al. (2009) in their study on network Infrastructure Investments in the Organisation for Economic Co-operation and Development (OECD) member countries, investigated whether the Infrastructural Investment has an impact on output, over and above those from just adding to the productive capital stock. They pointed out that through its various channels, Infrastructural Investment exerts a positive impact on economic output. In terms of panel studies, Isaksson (2009) employed a panel data regression model in order to examine a group of 57 advanced and developing countries over the time period of 1970–2000. According to his analysis, public capital growth has the strongest impact on both on rapidly emerging economies as well as high-income economies. Scandizzo and Sanguinetti (2009) underlined one important impact of Public Infrastructure Investment i.e. its effect on the quality of life, especially in low income and emerging economies like India.

Coming to the Indian context, there have been very few studies which have examined this important relationship. Elhance and Lakshamanan (1988) highlighted the importance of Infrastructure Investment from an Indian prospective. In a more exhaustive study, Datt and Ravallion (1992) concluded that Indian states which are possessed with better infrastructure and human resources, when compared with other facilities, usually have observed higher growth rates and faster poverty reduction. Ahluwalia (2000) analyzed the determinants of economic growth for Indian states by using plan expenditure as proxy for Public Investment. Jena (2004) did a state level study and examined the impact of public expenditure on economic growth for the period 1980–2000 using the simple pooled panel regression model. He concluded that Indian States have diverse cultures, infrastructure, natural endowments, etc., which have the ability to influence their local economic growth either directly or indirectly.

Though there have been studies which have analyzed the different aspects of the role of infrastructure in terms of achieving economic growth, however, there is still insufficiency of research works when it comes to particularly analyze the Public Infrastructure Investment and economic growth relationship. This forms the basis for this study i.e empirically analyze the critical relationship between Public Infrastructure Investment and Economic Growth of India using yearly data for its twenty-eight states over the time-period of 1999-00 to 2014-15.

Research methodology

Data and Variables:

In this study, we have examined the relationship between Public Infrastructure Investment and economic growth by using three time series econometric techniques - unit root testing, cointegration and the related Error Correction (EC) model , to analyze a panel data set for 28 Indian states. For all the states, we have taken Public Investment data (in Crores) for six major sub sectors falling under overall Infrastructure sector: (i) Transport (PTRANS), (ii) Education, Sports, Art and Culture (PEDU), (iii) Medical and Public Health (PMED), (iv) Water supply and sanitation (PDW), (v) Irrigation (PIRRI) and (vi) Energy/Power (PENG). To evaluate the effects of Public Investment in infrastructure on economic growth, a quantifiable indicator to fairly accurate economic development is required. When the data is at state level like in our case, Per Capita Gross State Domestic Product (PCGSDP) is used as an indicator variable to represent the respective state's economic growth. The PCGSDP data is taken in Crores for all the 28 states.

The analyzed data set consists of a data panel covering 28 Indian states for the period 1999–2000 to 2014-15. For historical period i.e 1999-00 to 2012-13, actual expenditure values are available. For 2013-14, revised estimates and for 2014-15 budget estimate values have been taken to indicate Public Infrastructure Investment. The basic question which arises here is that which kind of expenditure can be classified as Public Investment. The answer to this question seems less obvious than what actually it appears to be at first look. Broadly, the normal distinction between capital and current outlays would hold, with capital outlays pertaining to any kind of expenditure whose productive life extends into the future. Therefore, we can say that Public Infrastructure Investment takes the form of infrastructural outlays for different sub categories of infrastructure like Transport (road and rail networks, ports, bridges etc.), energy, water and sanitation networks, government structures and buildings etc., all of which possess a productive life of many decades.

The basis of our empirical analysis is the technique proposed by Westerlund (2007), in which a panel Error correction – Cointegration approach is employed to test whether the variables under study are cointegrated i.e whether there is any sort of stationary linear combination of the random variables PCGSDP and PTRANS,PEDU,PMED,PDW,PIRRI,PENG. The heterogeneous panel unit root test developed by Im, Pesaran and Shin (2003) is applied to check for stationarity. Since every state is different in terms of their population and area, therefore to set a leveling field certain computations were performed so that disparities in terms of population and area can be taken out of picture and we can do comparisons among states. With this view, Public Investment data for sectors - Education, Sports, Art and Culture (PEDU), Medical and Public Health (PMED), Drinking water and sanitation (PDW), and Energy/Power (PENG) was divided with respective state's population (in lakhs) so as to make the resulting values in terms of Crores per one lakh of population. Similarly, Public Investment data for Transport and Irrigation was divided with respective state's area (in square Km) so as to make the resulting values in terms of Crores per square Km.

The state-level data, i.e. Per Capita Gross State Domestic Product was obtained from Reserve Bank of India and Planning commission. Public Investment data for different sub sectors of Infrastructure was obtained from the Reserve Bank of India database, annual financial statements (Appendix IV: Capital expenditure of Individual states) for the time period 1999-00 to 2014-15.

Econometric Technique:

Panel Unit root test:

As already indicated above, this paper analyzes the relationship among PCGSDP, PTRANS, PEDU, PMED, PDW, PIRRI and PENG. To address the stationarity properties of these time series, a panel data unit root test is applied i.e Im, Pesaran and Shin (2003), which is appropriate for balanced panels (as in our case) , so as to verify whether or not these state specific time series exhibit stochastic trends or not. Further, cointegration analysis is done to investigate whether the variables under study are cointegrated (i.e. whether there is presence of stable long-term equilibrium relationships among them or not). Lastly, an Error Correction Model (ECM) is estimated, to test the short-term causality relationships among PCGSDP, PTRANS, PEDU, PMED, PDW, PIRRI and PENG.

Error Correction based Panel Cointegration test :

As a following step, we move on to apply the panel cointegration tests developed by Westerlund (2007) and Persyn and Westerlund (2008). The logic behind these tests is to test for the absence of cointegration by determining whether Error Correction exists for individual panel members or for the panel as a whole. Consider the Error Correction

Models described by below mentioned equations (1), (2), (3), (4), (5) ,(6) and (7) in which all variables in levels are assumed to be I(1):

$$\Delta PCSGDP_{i,t} = \alpha_i^{PCSGDP} + \lambda_i^{PCSGDDP}\,(PCSGDP_{i,t-1} - \beta_i^{PCSGDP} PTRANS_{i,t-1} - \gamma_i^{PCSGDP} PEDU_{i,t-1} - \pi_i^{PCSGDP} PMED_{i,t-1} - \tau_i^{PCSGDP} PDW_{i,t-1} - \omega_i^{PCSGDP} PIRRI_{i,t-1} - \psi_i^{PCSGDP} PENG_{i,t-1}) + \sum_{j=1}^{n} \theta_{i,j}^{PCSGDP} \Delta PCSGDP_{i,t-j} + \sum_{j=1}^{n} \phi_{i,j}^{PCSGDP} \Delta PTRANS_{i,t-j} + \sum_{j=1}^{n} \delta_{i,j}^{PCSGDP} \Delta PEDU_{i,t-j} + \sum_{j=1}^{n} £_{i,j}^{PCSGDP} \Delta PMED_{i,t-j} + \sum_{j=1}^{n} \chi_{i,j}^{PCSGDP} \Delta PDW_{i,t-j} + \sum_{j=1}^{n} ¥_{i,j}^{PCSGDP} \Delta PIRRI_{i,t-j} + \sum_{j=1}^{n} ¢_{i,j}^{PCSGDP} \Delta PENG_{i,t-j} + A_{i,t} \quad (1)$$

$$\Delta PTRANS_{i,t} = \alpha_i^{PTRANS} + \lambda_i^{PTRANS}\,(PTRANS_{i,t-1} - \beta_i^{PTRANS} PCSGDP_{i,t-1} - \gamma_i^{PTRANS} PEDU_{i,t-1} - \pi_i^{PTRANS} PMED_{i,t-1} - \tau_i^{PTRANS} PDW_{i,t-1} - \omega_i^{PTRANS} PIRRI_{i,t-1} - \psi_i^{PTRANS} PENG_{i,t-1}) + \sum_{j=1}^{n} \phi_{i,j}^{PTRANS} \Delta PTRANS_{i,t-j} + \sum_{j=1}^{n} \theta_{i,j}^{PTRANS} \Delta PCSGDP_{i,t-j} + \sum_{j=1}^{n} \delta_{i,j}^{PTRANS} \Delta PEDU_{i,t-j} + \sum_{j=1}^{n} £_{i,j}^{PTRANS} \Delta PMED_{i,t-j} + \sum_{j=1}^{n} \chi_{i,j}^{PTRANS} \Delta PDW_{i,t-j} + \sum_{j=1}^{n} ¥_{i,j}^{PTRANS} \Delta PIRRI_{i,t-j} + \sum_{j=1}^{n} ¢_{i,j}^{PTRANS} \Delta PENG_{i,t-j} + B_{i,t} \quad (2)$$

$$\Delta PEDU_{i,t} = \alpha_i^{PEDU} + \lambda_i^{PEDU}\,(PEDU_{i,t-1} - \beta_i^{PEDU} PCSGDP_{i,t-1} - \gamma_i^{PTEDU} PTRANS_{i,t-1} - \pi_i^{PEDU} PMED_{i,t-1} - \tau_i^{PTEDU} PDW_{i,t-1} - \omega_i^{PEDU} PIRRI_{i,t-1} - \psi_i^{PEDU} PENG_{i,t-1}) + \sum_{j=1}^{n} \delta_{i,j}^{PEDU} \Delta PEDU_{i,t-j} + \sum_{j=1}^{n} \theta_{i,j}^{PEDU} \Delta PCGSDP_{i,t-j} + \sum_{j=1}^{n} \phi_{i,j}^{PEDU} \Delta PTRANS_{i,t-j} + \sum_{j=1}^{n} £_{i,j}^{PEDU} \Delta PMED_{i,t-j} +$$

$$\sum_{j=1}^{n} \chi_{i,j}^{PEDU} \Delta PDW_{i,t-j} + \sum_{j=1}^{n} ¥_{i,j}^{PEDU} \Delta PIRRI_{i,t-j} + \sum_{j=1}^{n} ¢_{i,j}^{PEDU} \Delta PENG_{i,t-j} + C_{i,t} \quad (3)$$

$$\Delta PMED_{i,t} = \alpha_i^{PMED} + \lambda_i^{PMED} (PMED_{i,t-1} - \beta_i^{PMED} PCSGDP_{i,t-1} - \gamma_i^{PMED} PTRANS_{i,t-1} - \pi_i^{PMED} PEDU_{i,t-1} - \tau_i^{PMED} PDW_{i,t-1} - \omega_i^{PMED} PIRRI_{i,t-1} - \psi_i^{PMED} PENG_{i,t-1}) + \sum_{j=1}^{n} £_{i,j}^{PMED} \Delta PMED_{i,t-j} + \sum_{j=1}^{n} \theta_{i,j}^{PMED} \Delta PCGSDP_{i,t-j} + \sum_{j=1}^{n} \phi_{i,j}^{PMED} \Delta PTRANS_{i,t-j} + \sum_{j=1}^{n} \delta_{i,j}^{PMED} \Delta PEDU_{i,t-j} + \sum_{j=1}^{n} \chi_{i,j}^{PMED} \Delta PDW_{i,t-j} + \sum_{j=1}^{n} ¥_{i,j}^{PMED} \Delta PIRRI_{i,t-j} + \sum_{j=1}^{n} ¢_{i,j}^{PMED} \Delta PENG_{i,t-j} + D_{i,t} \quad (4)$$

$$\Delta \mathrm{PDW}_{i,t} = \alpha_i^{PDW} + \lambda_i^{PDW} (\mathrm{PDW}_{i,t-1} - \beta_i^{PDW} PCSGDP_{i,t-1} - \gamma_i^{PDW} PTRANS_{i,t-1} - \pi_i^{PDW} PEDU_{i,t-1} - \tau_i^{PDW} PMED_{i,t-1} - \omega_i^{PDW} PIRRI_{i,t-1} - \psi_i^{PDW} PENG_{i,t-1}) + \sum_{j=1}^{n} \chi_{i,j}^{PDW} \Delta PDW_{i,t-j} + \sum_{j=1}^{n} \theta_{i,j}^{PDW} \Delta PCGSDP_{i,t-j} + \sum_{j=1}^{n} \phi_{i,j}^{PDW} \Delta PTRANS_{i,t-j} + \sum_{j=1}^{n} \delta_{i,j}^{PDW} \Delta PEDU_{i,t-j} + \sum_{j=1}^{n} £_{i,j}^{PDW} \Delta PMED_{i,t-j} + \sum_{j=1}^{n} ¥_{i,j}^{PDW} \Delta PIRRI_{i,t-j} + \sum_{j=1}^{n} ¢_{i,j}^{PDW} \Delta PENG_{i,t-j} + E_{i,t} \quad (5)$$

$$\Delta PIRRI_{i,t} = \alpha_i^{PIRRI} + \lambda_i^{PIRRI} (PIRRI_{i,t-1} - \beta_i^{PIRRI} PCSGDP_{i,t-1} - \gamma_i^{PIRRI} PTRANS_{i,t-1} - \pi_i^{PIRRI} PEDU_{i,t-1} - \tau_i^{PIRRI} PMED_{i,t-1} - \omega_i^{PIRRI} PDW_{i,t-1} - \psi_i^{PIRRI} PENG_{i,t-1}) + \sum_{j=1}^{n} ¥_{i,j}^{PIRRI} \Delta PIRRI_{i,t-j} + \sum_{j=1}^{n} \theta_{i,j}^{PIRRI} \Delta PCGSDP_{i,t-j} + \sum_{j=1}^{n} \phi_{i,j}^{PIRRI} \Delta PTRANS_{i,t-j} + \sum_{j=1}^{n} \delta_{i,j}^{PIRRI} \Delta PEDU_{i,t-j} + \sum_{j=1}^{n} £_{i,j}^{PIRRI} \Delta PMED_{i,t-j} + \sum_{j=1}^{n} \chi_{i,j}^{PIRRI} \Delta PDW_{i,t-j} + \sum_{j=1}^{n} ¢_{i,j}^{PIRRI} \Delta PENG_{i,t-j} + F_{i,t} \quad (6)$$

$$\Delta PENG_{i,t} = \alpha_i^{PENG} + \lambda_i^{PENG} (PENG_{i,t-1} - \beta_i^{PENG} PCSGDP_{i,t-1} - \gamma_i^{PENG} PTRANS_{i,t-1} - \pi_i^{PENG} PEDU_{i,t-1} - \tau_i^{PENG} PMED_{i,t-1} - \omega_i^{PENG} PDW_{i,t-1} - \psi_i^{PENG} PIRRI_{i,t-1}) + \sum_{j=1}^{n} ¢_{i,j}^{PENG} \Delta PENG_{i,t-j} + \sum_{j=1}^{n} \theta_{i,j}^{PENG} \Delta PCGSDP_{i,t-j} + \sum_{j=1}^{n} \phi_{i,j}^{PENG} \Delta PTRANS_{i,t-j} + \sum_{j=1}^{n} \delta_{i,j}^{PENG} \Delta PEDU_{i,t-j} + \sum_{j=1}^{n} £_{i,j}^{PENG} \Delta PMED_{i,t-j} + \sum_{j=1}^{n} \chi_{i,j}^{PENG} \Delta PDW_{i,t-j} + \sum_{j=1}^{n} ¥_{i,j}^{PENG} \Delta PIRRI_{i,t-j} + G_{i,t} \quad (7)$$

Here, the parameters λ_i^k, k ϵ (PCGSDP, PTRANS, PEDU, PMED, PDW, PIRRI, PENG) are the parameters of the Error Correction (EC) term and give us the estimates of the speed of error correction towards the long run equilibrium for state i , while $A_{i,t}, B_{i,t}, C_{i,t}, D_{i,t}, E_{i,t}, F_{i,t}, G_{i,t}$ are white noise random disturbances. Our main focus is on Equation (1) i.e analyzing the relationship between Public Infrastructure Investment in six major sectors of infrastructure and economic growth. In other words, we are focusing on PCGSDP and its relation to PTRANS, PEDU, PMED, PDW, PIRRI and PENG. The null hypothesis of no cointegration and alternative hypothesis of cointegration can be tested by two different types of tests i.e group mean tests and panel tests. Westerlund (2007) developed four panel cointegration test statistics (G_a, G_t P_a, P_t) based on the Error Correction Model (ECM). The group-mean tests are based on weighted sums of the λ_i^k estimated for individual states of India, whereas the panel tests are based on an estimate of λ^k for the panel as a whole. All these four test statistics are normally distributed. The two tests (G_t, P_t) are calculated with the standard errors of λ_i^k estimated in a customary way, while the other statistics (G_a, P_a) are based on Newey and West (1994) standard errors, which are adjusted for heteroskedasticity and autocorrelation. When we apply an Error-Correction Model to a particular case where all analyzed variables are assumed to be I(1), the tests proposed by Westerlund (2007) investigate whether cointegration

is present or not by determining whether error-correction is present for individual panel members and for the panel as a whole.
If $\lambda_i^k < 0$, then it confirms the presence of error correction, and hence we can infer that $PCGSDP_{i,t}$ and $PTRANS_{i,t}, PEDU_{i,t}, PMED_{i,t}, PDW_{i,t}, PIRRI_{i,t}, PENG_{i,t}$ are cointegrated. However when we have $\lambda_i^k = 0$, then there is no error correction and hence no cointegration. Therefore, the null hypothesis of no cointegration for the group-mean tests (G_a, G_tstatistics) is: $H_0^G: \lambda_i^k = 0$ for all i, which is tested against $H_1^G: \lambda_i^k < 0$: 0 for at least one i. Putting this in other words, for the two group mean based tests, the alternative hypothesis says that there is cointegration in at least one of the cross-section unit. So, the adjustment coefficient λ_i^k may be heterogeneous across the cross-section units. Therefore, if H_0 is rejected, then it can be taken as evidence of cointegration in at least one of the cross-sectional units. The panel tests (P_a, P_tstatistics) as an alternative assume that $\lambda_i^k = \lambda^k$for all i, so the alternative hypothesis says that adjustment to equilibrium is homogenous across cross-section units. In that case, we proceed to test $H_0^P: \lambda^k = 0$ against$H_1^P: \lambda^k < 0$. If H0 is rejected, then it can be taken as evidence of cointegration for the panel as a whole.
We are basically focused in the long run behavior of our specified model so the next thing is to calculate the coefficients of the conditional long-run relationships between PCGSDP, PTRANS, PEDU, PMED, PDW, PIRRI and PENG when the short-run terms are set to zero.
We can estimate the long-run coefficients from the following long-run equation, which has been obtained from the reduced form of equation (1) when the terms representing short-run changes are ΔPCGSDP= ΔPTRANS= ΔPEDU= ΔPMED= ΔPDW=ΔPIRRI=ΔPENG=0, as:

$$PCGSDP_{i,t} = -\frac{\alpha_i^{PCGSDP}}{\lambda_i^{PCGSDP}} + \beta_i^{PCGSDP} PTRANS_{i,t} + \gamma_i^{PCGSDP} PEDU_{i,t} + \pi_i^{PCGSDP} PMED_{i,t} + \tau_i^{PCGSDP} PDW_{i,t} + \omega_i^{PCGSDP} PIRRI_{i,t} + \psi_i^{PCGSDP} PENG_{i,t} \quad (8)$$

Further, we also proceed to check for short run causality. In other words, we have to test the significance of the coefficients of the lagged difference of the variables by employing the Wald restriction test for the equations (1), (2), (3) , (4) , (5) , (6) and (7). The assumed causality of individual associations and relationships is checked by analyzing the significance of the t-statistic for the coefficient of the lagged variable, whereas the joint causality is checked as: let's say we wish to examine whether there is presence of causality from PTRANS and PENG to PCGSDP in equation 1, then we will test the null hypothesis, $H_0: \phi_i^{PCGSDP} = ¢_i^{PCGSDP} = 0$ for all i. If this null hypothesis is rejected, we can conclude that PTRANS and PENG are causally related to PCGSDP.

Results and discussion

We check for the presence of unit root in panels for the full sample of 28 Indian states through the Im-Pesaran Shin test. The test results for PCGSDP, PTRANS, PEDU, PMED, PDW, PIRRI and PENG are summarized in Table 1 given below. $W_{[t-bar]}$ Statistic is used to take the decision of whether or not to reject the null hypothesis of unit root for the panel as whole. When expressed in level form (for constant and trend), we fail to reject the null hypothesis of unit root for all the series i.e PCGSDP, PTRANS, PEDU, PMED, PDW, PIRRI and PENG. When we go for first differences, we observe that we are able to strongly reject the null hypothesis of unit root at 5 % significance level for all these series. This implies that all the series are I (1). The Statistical Software STATA has been used for carrying out all the empirical analysis of this paper.

Table 1
Im-Pesaran-Shin Test for Unit Root in Panels for the full sample

	LEVELS	**FIRST DIFFERENCES**
Variable	Constant and Trend	Constant and Trend
	$W_{[t-bar]}$Statistic	
PCGSDP	5.081	-10.118*
PTRANS	9.764	-11.302*
PEDU	1.849	-2.013*
PMED	6.545	-8.295*
PDW	3.991	-7.239*
PIRRI	6.582	-8.972*
PENG	3.623	-5.011*

Note: * indicates significance at $p<0.05$ level.
Source: Computer Software Output

Further, we move on to examine whether PCGSDP, PTRANS, PEDU, PMED, PDW, PIRRI and PENG are cointegrated or not. We make use of the Westerlund-based panel cointegration tests using a single lag and lead, $h_i = q_i = 1$. These lead and lag orders are chosen based on the minimum AIC (Akaike's Information Criterion).We then carry out the cointegration tests. We also consider the robust P-values attained after bootstrapping using 800 replicates following the examination of cross-sectional dependence among residuals.
We obtain results as shown in Table 2, given below. As we can observe, our results for the whole sample, i.e. from the panel co-integration tests signify that there is a long-run cointegrating relationship for PCGSDP among the series under consideration, based on equation (1). As we can infer from the P- values, for the major equation of analysis (PCGSDP, Equation 1) the null hypothesis of no cointegration is rejected (the Gt, Ga, Pt and Pa values specify that the null hypothesis of no cointegration,

and therefore no stationary equilibrium relationship among the variables) should be rejected at 5 % significance level for the individual panel members as well as full panel of 28 Indian states.
Further, the robust P-values also indicate that we should reject the null hypothesis of no cointegration for the equation 1 i.e with PCGSDP as the dependent variable. On the whole, the primary model focused in this study indicates that there are long-run relationships among PCGSDP and PTRANS, PEDU, PMED, PDW, PIRRI, PENG for the whole sample of 28 Indian states as a panel and as individual panel members.

Table 2

Results of the Westerlund-based Panel Cointegration tests (with Constant and Trend)

Model	Test	value of test	Z-value	p-value	Robust p-value
PCGSDP (For eq.1)	Gt	-3.101*	-0.622	0.000	0.002
	Ga	-7.682*	-6.491	0.000	0.001
	Pt	-22.476*	3.909	0.000	0.000
	Pa	-8.391*	4.435	0.000	0.000

Note: * indicates significance at $p<0.05$ level.
Source: Computer Software Output

Error Correction Model estimates:
Once we confirmed for the presence of panel cointegration, we can proceed to estimate the long-run relationships among PCGSDP and PTRANS, PEDU, PMED, PDW, PIRRI, PENG by applying the estimator of Westerlund (2007). Consequently, we estimate equation (1) of the ECM, reparameterized based on panel data. Table 3 given below gives us the results for this equation, as our focus is majorly on this equation with PCGSDP as dependent variable. The regression output given in Table 3 can be interpreted from the viewpoint of short-run fluctuations around a long-run equilibrium relationship. Next, we

present the results for the long run relationships of PCGSDP and PTRANS, PEDU, PMED, PDW, PIRRI, PENG in Table 4 while the results of the test for checking short run causality relationships is given in Table 5.

As we can observe in Table 3, for equation 1 the estimated adjustment parameter (the coefficient of the Error Correction term) is statistically significant and has the expected negative sign. The negative sign of EC term means that it will induce a negative change in PCGSDP back towards the long run equilibrium. In absolute sense, if the value of adjustment parameter is high then it implies that a much longer time will be required for equilibrium to be restored following any fluctuations from the long-run equilibrium of dependent variable with independent ones.

Table 3

Results of the ECM Estimates

Regressors	**ΔPCGSDP**	**t - values**
Constant	0.308	12.81
$PCGSDP_{t-1}$	-0.035*	12.26
$PTRANS_{t-1}$	0.025	5.72
$PEDU_{t-1}$	0.125**	10.52
$PMED_{t-1}$	0.024***	2.45
PDW_{t-1}	-0.088*	-7.33
$PIRRI_{t-1}$	0.004	0.91
$PENG_{t-1}$	0.015***	3.11
$\Delta PCGSDP_{t-1}$	-0.067	13.64
$\Delta PTRANS_{t-1}$	0.029**	5.73
$\Delta PEDU_{t-1}$	0.132*	10.29
$\Delta PMED_{t-1}$	0.031**	2.39
ΔPDW_{t-1}	-0.092*	-6.93
$\Delta PIRRI_{t-1}$	0.007	0.92
$\Delta PENG_{t-1}$	0.021***	13.77

ΔPCGSDP		
ΔPTRANS	0.041*	6.27
ΔPEDU	0.254*	12.51
ΔPMED	0.075**	3.15
ΔPDW	-1.012*	-7.08
ΔPIRRI	0.023***	1.12
ΔPENG	0.063**	14.42

Note: Significance levels: *, p<0.05; **, p<0.01; ***, p<0.001. Lag and lead lengths both 1.
Source: Computer Software Output

The estimated long-run ECM coefficients are presented in Table 4 given below.

Table 4

Estimated long-run ECM coefficients

Variable	α_i^k	β_i^k	γ_i^k	π_i^k	τ_i^k	ω_i^k	ψ_i^k
PCGSDP	2.75	0.44	0.66	1.05	1.55	1.12	0.08
PTRANS	2.3	0.10	0.15	2.91	1.87	2.05	1.35
PEDU	2.68	2.56	1.39	1.15	2.67	1.42	2.21
PMED	1.15	2.34	1.86	2.54	1.39	2.51	1.19
PDW	2.41	1.98	1.45	0.82	0.47	1.65	2.42
PIRRI	1.71	2.22	1.99	1.25	0.79	1.82	2.11
PENG	1.44	1.30	2.73	0.57	1.55	0.49	2.21

Source: Computer Software Output

According to these results which we got for the full sample of 28 Indian states, a 1% increase in PTRANS will increase PCGSDP by 0.44 Crores, which signifies the long-term effect of PTRANS on PCGSDP over future periods. The increase of PTRANS will cause fluctuations from its equilibrium, causing PCGSDP to be even higher. PCGSDP will then accordingly decrease to correct this disequilibrium, with the deviation decreasing by 3.5% (λ_i^{PCGSDP}) in each consequent time period. In other way, PCGSDP will decrease by on average 0.44 Crores in response, with the decrease taking place over consecutive future measurement intervals at a rate of 3.5% per interval. A one-unit increase in PEDU will increase PCGSDP by 0.66 Crores. Accordingly to re-establish equilibrium, PCGSDP will then decrease by 0.66 Crores over consecutive future measurement intervals at a rate of 3.5% per interval. Likewise, a one-unit increase in PMED will increase PCGSDP by 1.05 Crores. Accordingly to re-establish equilibrium, PCGSDP will then decrease by 1.05 Crores over consecutive future measurement intervals at a rate of 3.5% per interval. On similar lines we can interpret the results for other variables.

The short run causality results are given in Table 5, where the direction of causal relationships is indicated by (→) for unidirectional causal relationships.

Table 5

Results of the short-run causality tests

Causality test	**Null Hypothesis**	**Test statistic value**
ΔPTRANS → ΔPCGSDP	$\phi_i^{PCGSDP} = 0$	7.95*
ΔPTRANS+ΔPENG→ ΔPCGSDP	$\phi_i^{PCGSDP} = ¢_i^{PCGSDP} = 0$	14.49*
ΔPEDU+ΔPMED→ ΔPCGSDP	$\delta_i^{PCGSDP} = £_i^{PCGSDP} = 0$	28.25**
ΔPENG→ ΔPCGSDP	$¢_i^{PCGSDP} = 0$	0.156***
ΔPIRRI → ΔPCGSDP	$¥_i^{PCGSDP} = 0$	0.455***
ΔPTRANS+ΔPIRRI→ ΔPCGSDP	$\phi_i^{PCGSDP} = ¥_i^{PCGSDP} = 0$	0.678***

ΔPCGSDP+ΔPENG→ ΔPTRANS	$\theta_i^{PTRANS} = ¢_i^{PTRANS} = 0$	11.22
ΔPCGSDP+ΔPTRANS→ ΔPENG	$\theta_i^{PENG} = \phi_i^{PENG} = 0$	9.56
ΔPCGSDP → ΔPTRANS	$\theta_i^{PTRANS} = 0$	8.19*
ΔPCGSDP → ΔPENG	$\theta_i^{PENG} = 0$	0.034***
ΔPCGSDP+ΔPIRRI→ ΔPTRANS	$\theta_i^{PTRANS} = ¥_i^{PTRANS} = 0$	1.712
ΔPTRANS+ΔPCGSDP→ ΔPIRRI	$\phi_i^{PIRRI} = \theta_i^{PIRRI} = 0$	1.194
ΔPDW → ΔPEDU	$\chi_i^{PEDU} = 0$	0.098***
ΔPDW → ΔPMED	$\chi_i^{PMED} = 0$	1.45*
ΔPMED → ΔPDW	$£_i^{PDW} = 0$	1.04
ΔPEDU → ΔPDW	$\delta_i^{PDW} = 0$	0.058
ΔPCGSDP→ ΔPIRRI	$\theta_i^{PIRRI} = 0$	1.569
ΔPCGSDP+ΔPEDU→ ΔPMED	$\theta_i^{PMED} = \delta_i^{PMED} = 0$	17.34
ΔPCGSDP+ΔPMED→ ΔPEDU	$\theta_i^{PEDU} = £_i^{PEDU} = 0$	12.79

Note: Significance levels: *, p<0.05; **, p<0.01; ***, p<0.001. For the co-joint test, we have used the Wald-test (χ^2).
Source: Computer Software Output

As per the values which we got, the relationship between PTRANS and PCGSDP demonstrates bidirectional causality for full sample of 28 Indian states, i.e. a change in PTRANS will impact PCGSDP and a change in PCGSDP will similarly have an effect on PTRANS. There is also a bi-directional relationship between PENG and PCGSDP. Also, PEDU and PMED are causally related to PCGSDP and there are unidirectional causal relationships from PDW to PEDU and from

PDW to PMED. Moving on, through these results we also confirm that PTRANS and PIRRI are causally related to PCGSDP and there is unidirectional causal relationship from PIRRI to PCGSDP. Finally, PTRANS and PENG are causally related to PCGSDP.

Conclusions

Through this study, we have examined the cointegration and short-run causal relationships between Per Capita Gross State Domestic Product and Public Investment data for sectors: Transport; Education, Sports, Art and Culture; Medical and Public Health; Drinking water and sanitation; Irrigation and Energy/Power based on a panel data set of 28 states of India during the period 1999–2000 to 2014-15. Our analysis suggests that all the seven variables under study i.e PCGSDP and PTRANS, PEDU, PMED, PDW, PIRRI, PENG are cointegrated. As a result, there are long-run equilibrium relationships among these seven variables. This kind of analysis holds lot of importance as it can be helpful in terms of framing and implementing proper investment plans focusing on Infrastructure sector for our rapidly growing economy. Further, the causality results indicate that there is short-run bi-directional causality relationship between Public Investment in Transport sector and Per Capita Gross State Domestic Product. This is quite logical as Transport is one of the major sub sectors of Infrastructure. A particular state's economy is totally dependent on its means of transport like roads, railways, ports etc. and it is through these means only that the whole machinery of the state is able to function. Strengthening and improving the transport means will surely play a major role in improving any Indian state's economic scenario. The reverse also holds true. When a state's GDP is growing, the policy makers can channelize a greater amount in the direction of improving the transport infrastructure. We also find bi-directional causality relationship between Public Investment in Energy sector and Per Capita Gross State Domestic Product. Like Transport, Energy is also one of the most significant sub-sectors of Infrastructure. Rising industrialization, greater focus on renewable sources of energy etc. are some of reasons which make this sector a highly important one and hence any kind of investment in energy sector will have a resulting positive impact on state's gross domestic product. Vice versa, also hold true. The causality results also suggest a causal relationship from Public Investment in Water supply and sanitation to Public Investment in Education and Public Investment in Water supply and sanitation to Public Investment in Medical and Public health. Water supply and sanitation, Education and Medical and Public health, are sub sectors of Social Infrastructure and hence they are bound to have causal relationships among themselves. Causality was also found to be running from Public Investment in Education and Public Investment in Medical and Public health to Per Capita Gross State Domestic Product also. This can also be implied from the fact that Education and Health are the two most dominant social sectors in our nation and they play a dominant role in impacting economic growth.

Policy Implications

The results from this study suggest that economic policies should address each of the above discussed sectors of Infrastructure simultaneously with investment being the top most priority in order to achieve higher economic development. The empirical framework used in this study is highly useful and can be employed to estimate the short- and long-run elasticities of Public Investment in these major Infrastructure sectors, so as to calibrate the developed models and generate scenarios telling how openness policies might stimulate businesses to adopt different types of investment options (like Public Private Partnerships etc.) so as to maximize growth prospects. Along with private investment options, the Indian states can also look towards increasing and sustaining the foreign direct investment which would ultimately help in improving the landscape of India's Infrastructure sector. Given the geographical diversity of population, industries and states in India, an appropriate modal mix of investment is quite necessary in order to promote and achieve economic growth. Therefore, this empirically analysis based on the panel data of Public Investment in major Infrastructure sectors of 28 Indian states suggests that all the states' government top priority should be to vigilantly and proficiently handle their particular state's investment scenario in all Infrastructure sectors. For the above mentioned predictions to occur, the infrastructure sector needs significant interference along with a revamp of existing way of doing business across the different participants like developers, government etc. Even though the central and state governments across India have been consistently increasing their focus on infrastructure sector, still they need to discover ways of keeping the sector moving. Government has moved ahead on the key issue of Public Infrastructure Investment in terms of its positive approach; however lot of work is yet to be done.

Scope for further research

Apart from this analysis, there is further scope of research in terms of carefully examining the inter-state investment patterns in Infrastructure sectors as well as their changes over time in such a way that it can be related and compared with the nature of causality in each particular case. Depending on feasibility and their importance in terms of the objective of the study, more number of Infrastructure sectors can be included so as to make the analysis more comprehensive and exhaustive.

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