CHAPTER 5

INFRASTRUCTURE - OUTPUT NEXUS: REGIONAL EXPERIENCE FROM INDIA

5.1 Introduction

At an all-India level, infrastructure development has been found to play an important role in explaining aggregate and sectoral growth. However, India is a vast country and growing regional disparities are a cause for concern. Imbalance in India’s growth especially inter-state disparities in income and growth rates are confounding considering that the country has common political institutions, no political barriers to migration of labour, and years of equity and welfare maximising policies forming major thrust of planning process. Understanding the reasons for this differential growth experience of the states in the form of infrastructure differences and the role played by infrastructure in impacting state-level output then becomes an interesting empirical exercise.

The relative position of states in terms of their income levels and growth rates has not remained static over time. This has been shown even in Chapter 3, that states that had low income in the 1980s were growing at a faster rate in the 2000s and some high income states were showing a decline in their growth rates. What then is the role played by changes in infrastructure development in such cases? Output’s elasticity with respect to infrastructure sectors could change as states invest in different kinds of infrastructure sectors and increase their stock. The differing economic structure of the state could also result in different returns from different infrastructure sectors. This kind of understanding on the changing role of infrastructure over time and across states could not be traced in literature. The focus of this study is also to consider along with long run impact of infrastructure development, the role played by infrastructure in influencing sectoral output within states. The economic structure of the states could determine the output elasticity of infrastructure variables as there may be certain infrastructure sectors that generate higher returns for certain industries. If this is the case, and considering that infrastructure provision is mostly a government responsibility, it can provide a clear understanding of how best to use the public resources and investment policies be accordingly conceived.
In this vein, this chapter looks at the impact of infrastructure on output both in the long term as well as how the impact has evolved over time by considering three separate time periods. Each of these time periods differed in terms of the infrastructural policies being followed. These differences have been highlighted in Chapter 3.

An examination of the economic relation of infrastructure and output with respect to the Indian states would be of great use to policy makers and researchers. In order to consider the long term impacts of infrastructure, this study analyses a panel of 17 major Indian states over the time period 1980-81 to 2011-12. The data series consists of continuous annual data for output as well as infrastructure variables and not just a few time points. It is very important to follow appropriate econometric methodologies when dealing with 30 year data period in order to obtain reliable estimates. This study has taken care of panel data properties and followed appropriate econometric estimation techniques. The study begins the analysis by using basic descriptive statistics followed by panel econometric techniques.

The remainder of the chapter is structured as follows; an overview of differences in per capita income and growth performance of Indian states is presented in Section 2. Section 3 presents the empirical results obtained from the panel co-integration and panel fully modified OLS regression estimation technique that generates long run output elasticities. The next section focuses on nature and strength of the relationship between infrastructure and per capita Net State Domestic Product (PCNSDP) for three different decades of 1980s, 1990s and 2000s. The last section offers concluding remarks.

5.2 Basic Stylised Facts
India is a union of 28 states and 7 union territories but the analysis in this chapter is confined to 17 major states - Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal. These 17 states account for about 90 percent of national net domestic product, 92 percent of national gross fixed capital formation (GFCF) and 93.5 percent of total labor force in 2009-10 and are therefore representative.
These 17 states vary in terms of the level of development each has reached and the economic growth pattern have evolved over time with some of the low income states having the highest growth rate in the decade of 2000s. Hence, the impact of infrastructure will not necessarily be uniform across states and over time. In this respect, in order to understand the impact of infrastructure on different regions in India, the states were grouped as High income, Medium income and Low income states in each of the three time periods. The basis for this stratification was states with average PCNSDP above (National average PCNDP – 0.5*(standard deviation of national income)) were classified as high income; those less than this were categorised as Low income and states with average PCNSDP between the two ranges were put in the Middle income category (Bajar, 2014).

In this section, data from 1981 till 2011 has been selected and state-wise disparities in PCNSDP and its growth rate in the above mentioned 17 states were computed. To begin with, Figure 5.1 presents the trend in level of PCNSDP in the following years – 1980-81, 1990-91, 2000-01 and 2013-14. There has been an increase in PCNSDP across all states and time period. Maharashtra had the highest PCNSDP followed by Haryana 2013-14 whereas Bihar, Uttar Pradesh and Madhya Pradesh were amongst the ‘poorest’ state in per capita NSDP terms in India in all the four years.

The share of India’s population living with per capita NDP less than half the aggregate per capita NDP for India has increased marginally from 10.2 per cent in the
1980s to 10.7 per cent in the 2000s (assuming all households within a state are the same). Interestingly, the proportion of India’s population that earned more than half but less than the aggregate per capita NDP for India first increased in the 1990s and then fell even below the 1980s level (49% in 1980s to 51 % in 1999s to 44% in 2000s). Almost the same set of states fell in this category in all the three decades - Uttar Pradesh, Madhya Pradesh, Orissa, Rajasthan and West Bengal, with the exception of Andhra Pradesh that saw an improvement in its NSDP which led to its exit from this group in the decade of 2000s which is significant as it constitutes around 7% of population in India. The states that earned more than the aggregate India’s PCNDP have remained consistent - Gujarat, Haryana, Punjab, Maharashtra, Tamil Nadu, Karnataka, Kerala.

It is important to realise that states like Uttar Pradesh, Madhya Pradesh, Bihar and Rajasthan, which have a large population base seem to perform badly in per capita terms. In 2011-12, Uttar Pradesh produced 9.15 of India’s NSDP (following only Maharashtra’s contribution), but almost 17% of India’s population lived in this state which brings the per capita NSDP of the state down to second lowest in the country (following Bihar) (See Table 5.1). Whereas, states like Punjab, Haryana and Kerala considered the rich states of India contribute 3 to 4 per cent of India’s NDP but have low population base thus raising their per capita income (Table 5.1). Maharashtra (highly industrialised state) had the highest NSDP trend growth rate for the entire period. In the 1980s it was Haryana, Maharashtra and Punjab that had high NSDP growth rates. The success story of Punjab and Haryana in this period rests mainly on their high growth of agricultural output productivity. However, this situation changed drastically after the 1991 reforms and opening up of the economy. Surprisingly, Bihar grew at close to 10 per cent in the 1990s and the trend continued in the 2000s as well. The growth of Bihar is primarily from a lower base and supported mainly by the construction sector. The huge growth in construction activities was largely propelled by public investment in the last few years which included construction of roads, bridges and government buildings. Majority of the growth is occurring in the tertiary sector whereas agriculture and allied sectors, on which about 80 per cent of the state’s population depends, have registered very low growth rates.

8 In this study states are considered as rich (or poor) if their PCNSDP is more (or less) than mean NDP (India)+ Standard Deviation (or (mean –std dev )India NDP).
Table 5.1: Contribution to Aggregate NSDP and Population

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>6.98</td>
<td>7.82</td>
<td>7.84</td>
<td>7.15</td>
</tr>
<tr>
<td>ASSAM</td>
<td>2.90</td>
<td>2.64</td>
<td>1.53</td>
<td>2.57</td>
</tr>
<tr>
<td>BIHAR Tot</td>
<td>4.01</td>
<td>10.20</td>
<td>4.52</td>
<td>10.83</td>
</tr>
<tr>
<td>GUJARAT</td>
<td>5.87</td>
<td>4.97</td>
<td>7.10</td>
<td>4.95</td>
</tr>
<tr>
<td>HARYANA</td>
<td>2.88</td>
<td>1.88</td>
<td>3.45</td>
<td>2.10</td>
</tr>
<tr>
<td>HIMACHAL PRADESH</td>
<td>0.79</td>
<td>0.62</td>
<td>0.73</td>
<td>0.60</td>
</tr>
<tr>
<td>JAMMU &amp; KASHMIR</td>
<td>1.37</td>
<td>0.87</td>
<td>0.77</td>
<td>0.98</td>
</tr>
<tr>
<td>KARNATAKA</td>
<td>5.47</td>
<td>5.41</td>
<td>5.72</td>
<td>5.00</td>
</tr>
<tr>
<td>KERALA</td>
<td>4.70</td>
<td>3.74</td>
<td>3.97</td>
<td>2.92</td>
</tr>
<tr>
<td>MP Tot</td>
<td>5.16</td>
<td>7.61</td>
<td>5.29</td>
<td>9.44</td>
</tr>
<tr>
<td>MAHARASHTRA</td>
<td>12.48</td>
<td>9.17</td>
<td>16.05</td>
<td>8.13</td>
</tr>
<tr>
<td>ORISSA</td>
<td>3.70</td>
<td>3.86</td>
<td>2.52</td>
<td>3.45</td>
</tr>
<tr>
<td>PUNJAB</td>
<td>3.97</td>
<td>2.45</td>
<td>3.08</td>
<td>2.44</td>
</tr>
<tr>
<td>RAJASTHAN</td>
<td>3.95</td>
<td>4.97</td>
<td>4.05</td>
<td>5.67</td>
</tr>
<tr>
<td>TAMIL NADU</td>
<td>7.38</td>
<td>7.10</td>
<td>7.89</td>
<td>5.71</td>
</tr>
<tr>
<td>UP TOTAL</td>
<td>12.81</td>
<td>16.15</td>
<td>9.15</td>
<td>16.74</td>
</tr>
<tr>
<td>WEST BENGAL</td>
<td>7.40</td>
<td>7.97</td>
<td>6.78</td>
<td>7.55</td>
</tr>
</tbody>
</table>

Source: Author’s Calculation

It is gathered from the above analysis that the growth pattern of the 17 major states has been quite diverse. In Chapter 3 an attempt was made to group the states based on their average level of PCNSDP and trend growth rate of NSDP for the three time periods: 1980s, 1990s and 2000s into poor/middle-income/rich states and low/middle/high growth states. And based upon this classification the infrastructure development was compared based on both income levels and growth rate for three different time period. The main observations from the analysis are repeated here.

The initially rich states were also the ones best endowed with infrastructure facilities – roads, electricity, railways and telecommunication infrastructure. These states also continued to remain in the rich income category in the decade 2001-10 with average PCNSDP much above India’s average PCNSDP. These states also managed to grow in terms of their infrastructure endowments, which is noteworthy considering that these states had a relatively wider base to begin with. This can also
imply that although infrastructure facilities were better developed in these states compared to the poor or middle income states, but in absolute terms there still is a huge scope for development and with an increase in availability of infrastructure these states continue to further increase and grow their PCNSDP.

Second, poor states like Bihar, Madhya Pradesh and Orissa improved their growth performance in the later decades, mainly due to the low base they started off with, and also managed to increase their infrastructure endowments (some of these states were the worst endowed states in the country). The trend growth rate of electricity, road and even tele density has been amongst the highest for most of these initially poor states but they still lag much behind the rich in income and rich in infrastructure availability states.

Keeping the detailed observations from Chapter 3 in mind, attempt is made to establish the relationship between infrastructure and economic growth of states in India. The basis on which states were segregated has been already presented and in the following section emphasis is on the econometric specification and empirical estimation.

5.3 Empirical Analysis and Econometric Methodology

In order to understand better the long run linkages between infrastructure and per capita NSDP for a panel of 17 states in India, we start by making use of a multivariate panel approach based on panel cointegration and error correction techniques. To achieve econometrically appropriate results three steps were followed. Firstly, stationarity property of individual series in the panel was examined using panel unit root tests. Second step involved testing for a long-term cointegration relation between the main variables. A long-run relationship using appropriate panel long-run estimates (Fully Modified OLS) has then been developed.

5.3.1 Panel Unit Root and Co-integration Tests

This study uses several panel unit root testing methodologies to determine the order of integration of all the variables. If the order of integration is zero, the series is considered to be stationary and thus free from a unit root. The more reliable and well-behaved panel unit root tests (as opposed to traditional DF or ADF tests that suffer from low power in rejecting the null hypothesis of a non-stationary series as well as
limiting distributions) such as those developed by Levin, Lin and Chu, 2002 (LLC); Im, Pesaran and Shin, 2003 (IPS); Breitung, 2000 were applied. These econometricians have shown that panel unit root tests are more powerful than unit root tests applied to individual series because the information is enhanced when adding cross section to time series data. The IPS, LLC and Breitung tests have the null hypothesis of a unit root and are based on the following AR(1) panel regression model:

\[ x_{i,t} = \delta_i x_{i,t-1} + \gamma_i z_{i,t} + u_{i,t} \quad i = 1, 2, \ldots, N; t = 1, 2, \ldots, T \]  

(5.1)

where \( x_{i,t} \) is the variable being tested; \( \delta_i \) are the exogenous autoregressive parameters, \( z_{i,t-1} \) represents exogenous variables and fixed effects and cross section specific time trends, while \( u_{i,t} \) are the stationary error terms. The series \( x_i \) is said to be weakly trend stationary if \( |\delta_i| < 1 \), and it is believed to be a unit root process if \( |\delta_i| = 1 \). The LLC and Breitung tests assume that all cross sections have a common unit root, whereas, IPS test assumes that \( \delta_i \) can be heterogeneous across cross sections.

Table 5.2 reports the panel unit root tests on the relevant variables and reports the test statistics and corresponding p values. Based on the visual inspection of data, an intercept and a time trend has been added for testing in levels and only an intercept for tests in first differences. As can be seen the results show that all data are integrated of order one when in levels (all variables are in logarithm). That is, we do not reject the panel unit root hypothesis at the conventional significance levels and hence indicate an order of integration of atleast one. It can also be seen that the null of non-stationarity is rejected at first difference at the 1% level of significance for all the variables.

The results of the panel unit root tests suggest that all the relevant variables in levels are integrated of order one. If the presence of a unit root is detected in the variables, then it is necessary to check for co-integrating relationship between the variables.
### Table 5.2: Panel unit root tests result

<table>
<thead>
<tr>
<th></th>
<th>NSDP</th>
<th>SecNSDP</th>
<th>ServNSDP</th>
<th>Elec</th>
<th>Road</th>
<th>Rail</th>
<th>Tele</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LLC Level</strong></td>
<td>0.02</td>
<td>2.31</td>
<td>0.21</td>
<td>15.1</td>
<td>2.65</td>
<td>-0.02</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>(0.50)</td>
<td>(0.98)</td>
<td>(0.58)</td>
<td>(1.00)</td>
<td>(0.996)</td>
<td>(0.49)</td>
<td>(0.64)</td>
</tr>
<tr>
<td><strong>Δ</strong></td>
<td>-20.5*</td>
<td>-22.1*</td>
<td>-16.3*</td>
<td>-21.3*</td>
<td>-12.7*</td>
<td>-14.3*</td>
<td>-9.38*</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td><strong>Breitung Level</strong></td>
<td>4.73</td>
<td>1.52</td>
<td>5.51</td>
<td>-4.44*</td>
<td>2.85</td>
<td>-0.65</td>
<td>6.24</td>
</tr>
<tr>
<td></td>
<td>(1.00)</td>
<td>(0.93)</td>
<td>(1.00)</td>
<td>(0.00)</td>
<td>(0.997)</td>
<td>(0.25)</td>
<td>(1.00)</td>
</tr>
<tr>
<td><strong>Δ</strong></td>
<td>-8.23*</td>
<td>-10.3*</td>
<td>-13.02*</td>
<td>-12.8*</td>
<td>-5.14*</td>
<td>-6.42*</td>
<td>-7.4*</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td><strong>IPS Level</strong></td>
<td>2.00</td>
<td>5.63</td>
<td>4.68</td>
<td>4.13</td>
<td>2.7</td>
<td>0.94</td>
<td>5.14</td>
</tr>
<tr>
<td></td>
<td>(0.97)</td>
<td>(1.00)</td>
<td>(1.00)</td>
<td>(1.00)</td>
<td>(0.996)</td>
<td>(0.82)</td>
<td>(1.00)</td>
</tr>
<tr>
<td><strong>Δ</strong></td>
<td>-21.4*</td>
<td>-22.2*</td>
<td>-16.9*</td>
<td>-20.3*</td>
<td>-12.4*</td>
<td>-14.7*</td>
<td>-9.4*</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td><strong>ADF Level</strong></td>
<td>22.7</td>
<td>33.4</td>
<td>11.1</td>
<td>0.02</td>
<td>22.0</td>
<td>27.1</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>(0.92)</td>
<td>(0.49)</td>
<td>(0.99)</td>
<td>(1.00)</td>
<td>(0.94)</td>
<td>(0.79)</td>
<td>(0.99)</td>
</tr>
<tr>
<td><strong>Fisher</strong></td>
<td>382.5*</td>
<td>364.7*</td>
<td>268.1*</td>
<td>347.4*</td>
<td>205.5*</td>
<td>236.2*</td>
<td>138.1*</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

All variables are in natural logarithms. Δ is the first difference operator. The null hypothesis of Breitung, LLC and IPS tests examines non-stationary. Lag selection (Automatic) is based on Schwarz Information Criteria (SIC). * denotes statistical significance at the 1% level (P-values are presented in parentheses). NSDP = ln(per capita NSDP); SecNSDP = ln(per capita NSDP from Secondary sector); ServNSDP = ln(per capita NSDP from services sector); Elec = ln(electricity generation); Road = ln(road density); Rail = ln(Rail density); Tele = ln(Tele-density).

From econometric theory we know that if any two variables X or Y are integrated of same order and if we estimate them by OLS and their residuals are found to be stationary then they are said to be co-integrated and have a long run equilibrium relationship (Engle and Granger, 1987). Similar approach of testing the non-stationarity properties of the residual for a panel data setting was developed by Pedroni (1999, 2004) which extends Engle and Granger (1987) approach as it is based on examining the stationarity properties of the residuals from a regression using I(1) variables, to a panel data framework. In this case upon estimating equation 5.2 by OLS, and obtaining the residuals $e_{i,t}$:

$$x_{i,t} = a_i + b_{1i} y_{i,t} + b_{2i} z_{i,t} + e_{i,t} \quad i = 1, 2, \ldots, N ; t = 1, 2, \ldots, T \quad (5.2)$$

where, $a_i$ are state specific fixed effects and $e_{i,t}$ are the residuals and $x, y, z$ are the variables of interest in logarithm, the coefficients $b_1$ and $b_2$ are the slope coefficients that are the long run elasticities to be estimated. The residuals obtained thus are used for the following auxiliary autoregression for every $i$:

$$\hat{e}_{i,t} = \phi_1 \hat{e}_{i,t-1} + \sum \phi_{i,t} \Delta \hat{e}_{i,t-j} + w_{i,t} \quad (5.3)$$
where, $\rho_i$ are the auto-regressive parameters, and $w_i$ are the stationary error terms. If the series is to be considered not cointegrated (With the null hypothesis of no cointegration), the $\hat{e}_{it}$ should be found to be $I(1)$: $H_0: \rho_i = 1$, and in Pedroni’s test for cointegration the seven test statistics, four of them (Panel v, Panel rho, Panel PP, Panel ADF) showing in-group test statistics and the other three (Group rho, Group PP, Group ADF) showing between group test statistics (if the null is rejected in the panel case, then the variables are cointegrated for all states whereas, if null is rejected in the group panel case, then cointegration among the relevant variables exists for at least one of the cases) we have this as the null hypothesis.

In this case panel cointegration for the time period 1980-81 to 2011-12 were estimated to determine the long run relationships among the following variables: Log of PCNSDP, Log of per capita electricity consumption (alternatively, per capita electricity generation and electricity generating capacity were also used, however, the results are similar and not reported here), Log of road density, log of rail density, and log of tele-density employing residual based cointegration tests suggested by Pedroni (1997). The results for both the within- and the between-dimension tests are summarised in Table 5.3. Out of the seven tests, four test statistics are significant and reject the null of no-cointegration and suggesting the existence of long run equilibrium relationship among the relevant variables. Thus, the tests show that for the 17 states, there seems to be a long run equilibrium relation between per capita NSDP and the given infrastructure indicators. To estimate this long run relationship the next section involves using FMOLS estimation technique. The results that the causality between variables exist and whether it is uni directional causality or bi-directional causality is also determined. The results from Granger Causality test between output and infrastructure indicators are presented in Appendix 5.
Table 5.3: Pedroni Panel co-integration test results

<table>
<thead>
<tr>
<th></th>
<th>Panel with PCNSDP</th>
<th>Panel with SecNSDP</th>
<th>Panel with ServNSDP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test stat</td>
<td>Prob.</td>
<td>Test stat</td>
</tr>
<tr>
<td><strong>Within Dimension</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panel v-stat</td>
<td>-0.632 (0.736)</td>
<td></td>
<td>-2.655 (0.996)</td>
</tr>
<tr>
<td>Panel rho-stat</td>
<td>0.595 (0.724)</td>
<td>2.202 (0.986)</td>
<td>2.938 (0.998)</td>
</tr>
<tr>
<td>Panel pp-stat</td>
<td>-3.868*** (0.000)</td>
<td>-5.557*** (0.000)</td>
<td>-1.834*** (0.000)</td>
</tr>
<tr>
<td>Panel ADF-stat</td>
<td>-4.089*** (0.000)</td>
<td>-7.770*** (0.000)</td>
<td>-2.641*** (0.004)</td>
</tr>
<tr>
<td><strong>Between Dimension</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group rho stat</td>
<td>2.717 (0.996)</td>
<td>3.885 (0.999)</td>
<td>4.630 (1.000)</td>
</tr>
<tr>
<td>Group pp-stat</td>
<td>-3.963*** (0.000)</td>
<td>-9.555*** (0.000)</td>
<td>-5.854*** (0.000)</td>
</tr>
<tr>
<td>Group ADF stat</td>
<td>-3.967*** (0.000)</td>
<td>-6.037*** (0.000)</td>
<td>-5.087*** (0.000)</td>
</tr>
</tbody>
</table>

The null hypothesis of Pedroni test examines the absence of cointegration. Lag selection (Automatic) is based on SIC with a max lag of 5. *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. PCNSDP = ln(per capita NSDP); SecNSDP = ln(per capita NSDP from Secondary sector); ServNSDP = ln(per capita NSDP from services sector)

5.3.2 Panel FMOLS Estimation

In order to estimate the long run elasticity between infrastructure and output, use has been made of fully modified OLS (FMOLS). FMOLS was originally designed by Phillips and Hansen (1990) to provide optimal estimates of cointegrating regressions. This method modifies the least squares method and accounts for serial correlation effects and for the endogeneity in the regressors that result from the existence of a cointegrating relationship. The estimators obtained allow for standard normal inference and employs a semi-parametric correction in the following simple panel regression model:

\[ x_{it} = a_i + b_i y_{it} + e_{it} \] \hspace{1cm} (5.4)

\[ y_{it} = y_{it-1} + e_{it} \] \hspace{1cm} (5.5)

and the coefficient of FMOLS estimator could be obtained from the following equations:

\[ \beta_{FMOLS} = \left[ \sum_{i=1}^{N} \sum_{t=T}^{T} (y_{it} - \bar{y}_{it}) (x_{it} - \bar{x}_{it}) \right]' \left[ \sum_{i=1}^{N} \sum_{t=T}^{T} (y_{it} - \bar{y}_{it}) \right] x_{it} + T x_{it}' \] \hspace{1cm} (5.6)
where, $x_i^*$ is the serial correlation term and $x_{it}^+$ is the transformation of $x_{it}$ in for eliminating endogeneity problem.

In order to estimate the short run elasticities and the speed of adjustment to long run equilibrium, the residuals from the cointegrating regressions are used as the error correction terms (ECT) in state-specific and panel error correction models (ECM) and the following equation is estimated

$$\Delta x_{it} = \gamma_{0,i} + \alpha_i ECT_{i,t-1} + \gamma_{y,i} \Delta y_{it} + \gamma_{z,i} \Delta z_{it} + \nu_{it}$$  \hspace{1cm} (5.7)

Where, $\gamma_0$ is a state-specific constant, $\alpha_i$ is the speed of adjustment, ECT is the abovementioned error correction term lagged by one period, $\gamma_{y,i}$ and $\gamma_{z,i}$ are the short run elasticities and $\nu_{it}$ is the error term. Table 5.4 reports the result of panel group means FMOLS with coefficient estimates and corresponding t statistics and all the variables have been expressed in natural logarithms. The estimated coefficients from the long-run cointegration relationship can be interpreted as long-run elasticities. In all cases, the parameters are quite significant at the 1% level for the overall economy.

From the table we can conclude that there is a strong and positive long-run relationship between Output (PCNSDP, secondary sector’s PCNSDP and services sector PCNSDP) and infrastructure variables. The results indicate that with a 1% increase in Electricity consumption, overall economy’s output (PCNSDP) increases by 0.26%. In the long run the elasticity of output with road infrastructure is also significant with a 1 percentage point increase in road density contributing approx. 0.37% increase in output. The long run elasticity from tele density is also significant and positive for the overall economy with an increase in teledensity by 1%, output rises by 0.03%. The railways elasticity was found to be negative but not significant. Similarly, for the tertiary (Services) sector and secondary (industry), the elasticity with electricity (0.26 and 0.43, respectively), road (0.40 and 0.61, respectively) and telecommunication (0.04 and 0.02, respectively) was found to be positive and significant.
Table 5.4: Panel FM-OLS results

<table>
<thead>
<tr>
<th></th>
<th>NSDP</th>
<th>Independent Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Elec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.26***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7.29)</td>
</tr>
<tr>
<td></td>
<td>ServNSDP</td>
<td>0.26***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6.67)</td>
</tr>
<tr>
<td></td>
<td>SecNSDP</td>
<td>0.43***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(14.02)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Short run</th>
<th>ΔElec</th>
<th>ΔRoad</th>
<th>ΔRail</th>
<th>ΔTele</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>elasticity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔNSDP</td>
<td></td>
<td>0.02</td>
<td>-0.04</td>
<td>-0.19</td>
<td>0.15***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.9)</td>
<td>(-0.97)</td>
<td>(-2.3)</td>
<td>(11.4)</td>
</tr>
<tr>
<td>ΔServNSDP</td>
<td></td>
<td>0.02</td>
<td>-0.05</td>
<td>0.08</td>
<td>0.16***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.66)</td>
<td>(-0.75)</td>
<td>(0.58)</td>
<td>(7.13)</td>
</tr>
<tr>
<td>ΔSecNSDP</td>
<td></td>
<td>-0.01</td>
<td>0.06*</td>
<td>-0.38*</td>
<td>0.12***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.84)</td>
<td>(1.77)</td>
<td>(-1.7)</td>
<td>(9.67)</td>
</tr>
</tbody>
</table>

_t-statistics are in parentheses. ***Indicates that the estimated parameters are significant at 1% level. 
NSDP = ln(per capita NSDP); ServNSDP = ln(per capita NSDP from Secondary sector); SecNSDP = ln(per capita NSDP from services sector); Elec = ln(electricity generation); Road = ln(road density); Rail = ln(Rail density); Tele = ln(Tele-density). Δ represents first difference.

Looking at the short run elasticities (reported in the same Table 5.4) that were computed using the residuals of FMOLS we find that the adjustment coefficients are all negative and mostly significant. In the short run, we find that it is only the telecommunication infrastructure that was found to be positive and highly significant.

5.3.3 Period-wise Analysis of Impact of Infrastructure on Output

In the above sections the analysis was done using the entire 31 year period from 1980 to 2011. Attempt was made to understand the nature of relation between infrastructure and output and to look at the issues of possible endogeneity between the variables that may arise due to reverse causality using FM-OLS analysis. In this section, we divide the entire period into three decades and analyse the impact of infrastructure (after controlling for other factors) on output⁹. As has been mentioned elsewhere in this thesis (Chapter 3), infrastructure policy in India has seen several developments which differed over the decades depending upon the nature of the overall economic policy. In order to gauge if the impact of different infrastructure variables has been different

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⁹ We have not tested for presence of unit root as the time period of 10 years is a very short one.
in each of these three decades, separate equations were estimated and the estimates are presented in the following sections.

In this vein, the following equation using panel of 17 Indian states for respective time periods is estimated:

\[
\ln(y) = \ln(a) + \beta \ln(w) + \gamma \ln(Credit) + a_1 \ln(El) + a_2 \ln(RR) + a_3 \ln(Tele) + a_4 \ln(Schl) + a_5 \ln(Health) + \mu_i + \varepsilon_{it}
\]

Where, \(\ln(y)\) = log of per capita net state domestic product; \(\ln(w)\) = log of worker to population ratio; \(\ln(Credit)\) = log of per capita credit disbursed by all Scheduled Commercial Banks; \(\ln(El)\) = log of per capita electricity consumption; \(\ln(R)\) = log of density of surfaced road per 1000 sq km (Alternatively, the variable \(\ln(RR)\) = log of density of total density of surface transport and includes surfaced road and rail density was used with similar results; \(\ln(Tele)\) = log of tele density per 10000 people. In order to augment the model, human capital is treated as additional explanatory variables and included as index for education institutions and index for health centres all variables in per 100000 population (\(\ln(schl)\) and \(\ln(health)\)). In order to coherently present the results from panel data analysis they have been segregated and presented for 1980-89, 1990-1999 and 2000-2011 time periods.

The relationship between PCNSDP, Secondary and Tertiary sector PCNSDP and infrastructure variables for the states is described for each of these periods along with the regional impact of infrastructure.\(^\text{10}\) Regressions were run using pooled OLS, fixed effects and random effects but only the more econometrically correct results are shown (based on Hausman test (Hausman, 1978) for between fixed and random effect. Test results are provided in Table 5.5). Post estimation test for heteroskedasticity and autocorrelation were conducted and the results presented in each of the tables. However, the estimates presented are corrected estimates. In case where heteroscedasticity was found to be present, robust standard errors were used. And, cases where first order autocorrelation was also found to be present, use was made of Driscall and Kraay (Hoechle, 2007) standard errors.

\(^\text{10}\) In these models, results for lags of infrastructure variables are not presented. This is because there is no theoretical criterion for how many lags to include for specific infrastructure variables. The impact of social infrastructure indicators like schools could possibly have lag effects, but by how many years is not clear. It is not possible to include too many lags for different infrastructure as it will lead to loss of degrees of freedoms as well.
### TABLE 5.5: Results from Hausman test to decide between Fixed effect or Random effect model

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LnPCNDP</td>
<td>18.41***</td>
<td>27.43***</td>
<td>13.9***</td>
</tr>
<tr>
<td>LnSecPCNDP</td>
<td>17.8***</td>
<td>9.11</td>
<td>37.9***</td>
</tr>
<tr>
<td>LnServNDP</td>
<td>29.0***</td>
<td>20.8***</td>
<td>21.8***</td>
</tr>
</tbody>
</table>

Hausman test has the null hypothesis: difference in coefficients not systematic. If null is rejected, fixed effect model is used. Chi square values are provided. ***, ** and * represents 1%, 5% and 10% significance values.

#### 5.3.3.1 Aggregate Output and Infrastructure Indicators

For the period 1980-89, there was significant and positive impact of energy infrastructure indicator – electricity consumption – even after correcting for heteroskedasticity and serial autocorrelation (Table 5.6). Electricity has a huge impact on output and one percentage increase in electricity consumption increases output by 0.14 per cent. However, the output elasticity of electricity was highest in the 1990s with a 1 percentage increase in electricity, output increase by 0.33 per cent. This is significant as when we move to the 2000s the impact of electricity becomes insignificant. This was the decade when even though output growth was high, but electricity bottlenecks were being felt. Electricity supply in India has continually lagged demand. “Infrastructure quality and subsidy trap” are often presented as the main reasons for this shortage in power sector in India (McRae. 2015). 26% of electricity generated was getting lost in transmission and distribution losses even in 2010. Faced with such constraints there is underinvestment in new generation capacity and supply hasn’t kept pace with demand causing major bottlenecks (Allcott et al, 2015).

Telecommunication revolution is evident in India and output elasticity of teledensity was 0.15 in 1990s, but it declined to 0.10 in 2000s (Table 5.6). This could mean three things: either declining marginal returns to this infrastructure sector were beginning to be felt in 2000s or that there was scope for further development of the sector in terms of increased ICT diffusion in order for further impact of this technology to be felt, or thirdly, there were shortages in other infrastructure sectors or institutional factors were having a dampening effect.
If we look at the impact of private capital (or credit disbursed by scheduled commercial banks) we find that the output elasticity was 0.12 in 1990s which was less than that for infrastructure indicators, and in 2000s its output elasticity was the highest at 0.27. This could be attributed to shift from Monopoly Restrictive Trade Practices Act (MRTPA) era to a time when private sector no longer had to seek permission from government to establish new investment projects. The proxy for private investment used in this study is actually underestimation of private sector capital at state level as it excludes loans by various non-financial institutions and foreign investors in the states. Thus, the output elasticity with private capital will be even higher than estimated here. Additionally, at gross fixed capital formation in the private sector had been increasing in 2000s.

Looking at the results for worker-population ratio, we find that for time period 2000-2011, worker-population ratio had a negative sign. The reasons for the same as highlighted in the literature are that in this time period especially in the latter half of the decade the employment growth rate has been very low whereas output has been increasing at a high rate. Service sector whose share in the aggregate output has been increasing steadily saw a high employment generation in this period but it was not commensurate with its output growth leading to a decline in employment elasticity especially since 2004-05. The primary sector and in some years even the manufacturing sector actually registered a negative employment elasticity (Papola and Sahu, 2012). All these reasons substantiate the results we obtained for worker-population ratio.

Another noteworthy observation that can be made from this table is the insignificant contribution of transport infrastructure for this period. Possible explanations for this phenomenon that stem from the literature and existing theories could be the following: a) according to the political business cycle theory (proposed by Rogoff, 1990; Dixit and Londregan, 1996 etc.) the geographic distribution, timing and composition of infrastructure development is decided upon in such a manner that they coincide with elections and their geographical distribution is directed towards those areas that are considered critical for re-election bid rather than based on development criterion; this could mean that roads were built in more visible and electorally important areas or b) the investment decisions to build roads are politically
driven and depart from efficiency criterion resulting in over accumulation of stock resulting in negative returns; or c) although the roads exist but their quality is is not satisfactory and so it may not have the expected impact on increasing access to productive opportunities or productivity (Bajar, 2015). These are just potential explanations for the observed result and cannot be proved with the existing dataset.

5.3.3.2 Sectoral Output and Infrastructure

In this section relation between the per capita NSDP from Secondary sector or Tertiary sector and various infrastructure sectors is presented. Secondary sector includes- Manufacturing; Construction; Electricity, gas and water supply and Mining and Quarrying. Similarly, tertiary sector comprises of Transport, storage and communication; Trade, hotels and restaurants; banking and Insurance; real estate, ownership of dwellings and business services; Public Administration and other services. The worker-population ratio is for respective sectors and excludes Assam and Jammu and Kashmir due to unavailability of data.

Hausman test is conducted to test for the using fixed or random model. Hetersokedasticity and first order autocorrelation is a problem and to correct for the same Driscoll and Kraay standard errors were used (Hoechle, 2007). The output elasticity for electricity consumption for secondary sector was 0.30 in 1980s and the highest in 1990s at 0.6 (Table 5.7). Mid-1990s had also witnessed the highest manufacturing sector output growth. In 2000s, its elasticity becomes insignificant pointing again towards the shortages appearing in the sector. Interestingly, the only period and sector when roads was found to be significant and positive was in 1980s.

Teledensity was also important factor contributing to industrial output with its contribution at 0.10 in 1980s that increased to 0.19 in the 2000s (Table 5.7). When compared to the contribution to services sector we find that the elasticity of teledensity was at 0.26 in 1990s, however, it declined to 0.12 in 2000s (Table 5.8). Health infrastructure however showed a negative and significant elasticity with industrial and services output in 1990s and 2000s. This is a confusing result that goes against existing theories pointing towards the important role played by health indicators. We are not denying the role played by health services in contributing towards output growth, however, for most states during this period there was a decline in government spending on health (public expenditure elasticity with respect to NSDP.
for this period was less than one which is amongst the lowest in the world), and, there were definitional changes in what encompassed as primary health centre, community health centres and hospitals which led to several discrepancies in data. Apart from the low level of access to health facilities in terms of number of health centres per capita, there were large vacancies for doctors and paramedical staff. Part of the reason for the large vacancies is the low availability of health workers. These are several factors that the data is unable to capture but may have an indirect impact on output.

For services sector, private capital showed a positive and significant impact on output which was increasing over the three time periods – from 0.04 in 1980s to 0.22 in 2000s. Both electricity and telecommunication infrastructure have played an important role in propelling this sector at state-level (Table 5.8).

As a separate exercise dummies were created according to high, low and medium (two dummies were created – for high income and low income group) income group and these were interacted with infrastructure variables to understand the regional differences in the influence of infrastructure on output but these were found to be not significant except for high income states. In the 1990s, although the impact of infrastructure was almost the same for both the high and low-income regions, it was insignificant. In the 2000s, high-income regions had a significantly positive impact from telecom infrastructure but low-income regions had negative impact from infrastructure on output even for telecommunication. Overall, this exercise showed that no clear differences emerged from the differences in infrastructure availability and different income regions except for the telecommunication sector. Most of the interaction dummies were insignificant and not presented in the tables.
### TABLE 5.6: Panel Estimation Results for per capita NSDP and Infrastructure variables

Dependent variable: ln(PCNSDP) and for Sample of 17 Indian states

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>(1) FE (Robust) 1980-89</th>
<th>(2) FE(Robust) 1990-99</th>
<th>(3) FE(Robust) 2000-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>9.8</td>
<td>4.86</td>
<td>6.19</td>
</tr>
<tr>
<td></td>
<td>(9.27)***</td>
<td>(4.32)***</td>
<td>(4.82)***</td>
</tr>
<tr>
<td>LnCredit</td>
<td>0.04</td>
<td>0.12</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>(1.55)</td>
<td>(2.25)**</td>
<td>(4.64)***</td>
</tr>
<tr>
<td>Ln(W/P)</td>
<td>0.35</td>
<td>0.32</td>
<td>-0.27</td>
</tr>
<tr>
<td></td>
<td>(2.47)***</td>
<td>(2.89)***</td>
<td>(-2.32)***</td>
</tr>
<tr>
<td>Ln(elec)</td>
<td>0.14</td>
<td>0.33</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(2.0)**</td>
<td>(3.84)***</td>
<td>(0.38)</td>
</tr>
<tr>
<td>Ln(road)</td>
<td>0.10</td>
<td>0.05</td>
<td>-0.09</td>
</tr>
<tr>
<td></td>
<td>(1.03)</td>
<td>(0.52)</td>
<td>(-0.09)</td>
</tr>
<tr>
<td>Ln(tele)</td>
<td>0.15</td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5.77)***</td>
<td>(2.53)***</td>
</tr>
<tr>
<td>Ln(School)</td>
<td>-0.44</td>
<td>0.19</td>
<td>-0.03</td>
</tr>
<tr>
<td></td>
<td>(-2.03)*</td>
<td>(2.81)***</td>
<td>(-0.42)</td>
</tr>
<tr>
<td>Ln(health)</td>
<td>0.08</td>
<td>-0.15</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>(4.36)***</td>
<td>(0.15)</td>
<td>(0.18)</td>
</tr>
<tr>
<td>Observations</td>
<td>120</td>
<td>151</td>
<td>150</td>
</tr>
<tr>
<td>R²</td>
<td>0.56</td>
<td>0.75</td>
<td>0.85</td>
</tr>
<tr>
<td>Hausman test</td>
<td>18.41***</td>
<td>27.43***</td>
<td>13.99**</td>
</tr>
<tr>
<td>F-statistic</td>
<td>53.0(0.000)</td>
<td>112.3(0.00)</td>
<td>0.000</td>
</tr>
<tr>
<td>Modified Wald</td>
<td>1146***</td>
<td>152.5***</td>
<td>532.4***</td>
</tr>
<tr>
<td>Test for serial AC</td>
<td>0.01</td>
<td>2.26</td>
<td>2.29</td>
</tr>
</tbody>
</table>

Numbers in parenthesis below the coefficient estimates are t statistics. P values for the null hypothesis of the usual diagnostic tests are also reported in parenthesis.*,** and *** indicate that the variable is significant at 10, 5 and 1 per cent level. Dependent variable is the log of per capita NSDP; or log of per capita secondary sector NSDP; or log of per capita tertiary sector NSDP And ln(w/p) = log of worker population ratio; ln(credit) = log of per capita credit given by SCBs; ln(elec) = log of per capita electricity consumption; ln(road) = log of road density per thousand sqkm area; ln(tele) = log of tele density per ten thousand people; ln(school) = log of number of school per 1000000 population, ln(health) = log of number of health centres per 1000000 population. Hausman test to decide between fixed effect and random effect. Modified Wald Test for heteroskedasticity; the null of homoskedasticity and Wooldridge test for first order serial autocorrelation: the null of no autocorrelation.
TABLE 5.7: Panel Estimation Results for per capita Secondary sector NSDP and Infrastructure variables

Dependent variable: ln(Secondary PCNSDP) and for Sample of 17 Indian states

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>(1) FE (Driscall and Kraay)1980-89</th>
<th>(2) Random Effect 1990-99</th>
<th>(3) FE (Discoll and Kraay)2000-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>4.86 (2.24)***</td>
<td>1.85 (2.29)***</td>
<td>6.17 (7.49)***</td>
</tr>
<tr>
<td>Ln PCSecCredit</td>
<td>0.03 (0.43)</td>
<td>0.03 (1.63)*</td>
<td>0.12 (3.41)***</td>
</tr>
<tr>
<td>Ln(W/P)</td>
<td>0.36 (1.31)</td>
<td>-0.05 (-0.33)</td>
<td>-0.5 (-3.24)***</td>
</tr>
<tr>
<td>Ln(elec)</td>
<td>0.30 (2.23)***</td>
<td>0.61 (6.41)***</td>
<td>0.08 (2.13)</td>
</tr>
<tr>
<td>Ln(road)</td>
<td>0.23 (1.08)**</td>
<td>0.12 (1.32)</td>
<td>-0.13 (-1.4)</td>
</tr>
<tr>
<td>Ln(Tele)</td>
<td>0.10</td>
<td></td>
<td>0.19</td>
</tr>
<tr>
<td>Ln(School)</td>
<td>0.00 (0.01)</td>
<td>0.26 (2.90)***</td>
<td>-0.007 (-0.07)</td>
</tr>
<tr>
<td>Ln(health)</td>
<td>0.09 (1.44)</td>
<td>0.12 (1.31)</td>
<td>-0.31 (-2.5)***</td>
</tr>
<tr>
<td>Observations</td>
<td>120</td>
<td>151</td>
<td>149</td>
</tr>
<tr>
<td>R²</td>
<td>0.63 (2.73)***</td>
<td>0.73 (7.15)***</td>
<td>0.48 (7.15)***</td>
</tr>
<tr>
<td>Hausman test</td>
<td>27.4***</td>
<td>9.11</td>
<td>37.9***</td>
</tr>
<tr>
<td>F-statistic/Wald</td>
<td>56.7***</td>
<td>496.0***</td>
<td>0.000***</td>
</tr>
<tr>
<td>chi2</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Modified Wald</td>
<td>371.1***</td>
<td></td>
<td>378.8***</td>
</tr>
<tr>
<td>Test for serial AC</td>
<td>17.6***</td>
<td>0.09</td>
<td>11.5***</td>
</tr>
</tbody>
</table>

Numbers in parenthesis below the coefficient estimates are t values. P values for the null hypothesis of the usual diagnostic tests are also reported in parenthesis. *, ** and *** indicate that the variable is significant at 10, 5 and 1 per cent level. Dependent variable is the log of per capita NSDP; or log of per capita secondary sector NSDP; or log of per capita tertiary sector NSDP And ln(w/p) = log of worker population ratio; ln(credit) =log of per capita credit given by SCBs; ln(elec) = log of per capita electricity consumption;ln(road) = log of road density per thousand sq km area; ln(tele) = log of teledensity per ten thousand people; ln(school) = log of number of school per 100000 population, ln(health) = log of number of health centres per 100000 population.Hausman test to decide between fixed effect and random effect. Modified Wald Test for heteroskedasticity: the null of homoskedasticity and Wooldridge test for first order serial autocorrelation: the null of no autocorrelation
TABLE 5.8: Panel Estimation Results for per capita tertiary sector NSDP and Infrastructure variables

Dependent variable: ln (Tertiary PCNSDP) and for Sample of 17 Indian states,

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>FE (Driscall and Kraay) 1980-89</th>
<th>Random Effects 1990-99</th>
<th>FE (Driscall) 2000-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.66 (4.5)***</td>
<td>4.26</td>
<td>5.73</td>
</tr>
<tr>
<td>Ln(W/P)</td>
<td>-0.18 (-1.35)</td>
<td>0.26</td>
<td>-0.1</td>
</tr>
<tr>
<td>Ln(PCserv Credit)</td>
<td>0.04 (2.11)**</td>
<td>0.12</td>
<td>0.22</td>
</tr>
<tr>
<td>Ln(elec)</td>
<td>0.21 (4.62)***</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>Ln(road)</td>
<td>0.22 (2.91)***</td>
<td>0.04</td>
<td>0.02</td>
</tr>
<tr>
<td>Ln(Tele)</td>
<td>0.26 (13.5)***</td>
<td>0.26</td>
<td>0.12</td>
</tr>
<tr>
<td>Ln(School)</td>
<td>0.36 (2.91)***</td>
<td>0.25</td>
<td>-0.07</td>
</tr>
<tr>
<td>Ln(health)</td>
<td>0.07 (3.44)***</td>
<td>-0.27</td>
<td>-0.06</td>
</tr>
<tr>
<td>Observations</td>
<td>120</td>
<td>151</td>
<td>149</td>
</tr>
<tr>
<td>R²</td>
<td>0.85</td>
<td>0.91</td>
<td>0.88</td>
</tr>
<tr>
<td>Hausman test</td>
<td>29.0***</td>
<td>20.8***</td>
<td>21.2***</td>
</tr>
<tr>
<td>F-statistic</td>
<td>93.4***</td>
<td>205.2***</td>
<td>262.0***</td>
</tr>
<tr>
<td>Modified Wald</td>
<td>84.6***</td>
<td>35.9***</td>
<td>36.8***</td>
</tr>
<tr>
<td>Test for serial AC</td>
<td>7.51**</td>
<td>9.85***</td>
<td>11.9***</td>
</tr>
</tbody>
</table>

Numbers in parenthesis below the coefficient estimates are t values. P values for the null hypothesis of the usual diagnostic tests are also reported in parenthesis. *, ** and *** indicate that the variable is significant at 10, 5 and 1 per cent level. Dependent variable is the log of per capita NSDP; or log of per capita secondary sector NSDP; or log of per capita tertiary sector NSDP. ln(w/p) = log of worker population ratio; ln(credit) = log of per capita credit given by SCBs; ln(elec) = log of per capita electricity consumption; ln(road) = log of road density per thousand sq km area; ln(tele) = log of teledensity per ten thousand people; ln(school) = log of number of school per 100000 population, ln(health) = log of number of health centres per 100000 population. Modified Wald Test for heteroskedasticity: the null of homoskedasticity and Wooldridge test for first order serial autocorrelation: the null of no autocorrelation.

In case presence of heteroskedasticity was found in the regression estimate, robust standard errors were used, in case of presence of first order serial autocorrelation, AR(1) model is estimated. When presence of both heteroskedasticity and autocorrelation is detected, Driscoll and Kraay standard errors are used.
5.4 **Summary**

In this Chapter an attempt was made to provide an empirical evaluation of the impact of infrastructure development – measured by stocks of individual physical infrastructure – on economic output across 17 Indian states over the 1980-2010 time period. The analysis was first done for aggregate PCNSDP, followed by a sectoral impact of infrastructure on secondary and tertiary sector PCNSDP. It was gathered from panel cointegration results that there exists a long term relationship between infrastructure variables and output, however, this relationship is not clear in the short run. As a first step, the direction of causality was tested between output and infrastructure variables. In the long term, it was found that there was uni directional causality running from infrastructure to output (total as well as industry and service sector output), except for electricity consumption where evidence was found for bidirectional causality. And in the short run, there was evidence of uni-directional causality from electricity and telecommunication infrastructure to output. Where electricity and telecommunication infrastructure are found to granger cause output, the same could not be said regarding transport infrastructure. This has serious implications because we know from both theoretical and empirical literature that transport infrastructure plays a crucial role in contributing towards output growth through both direct and indirect channels. In view of these results, Panel group mean FM-OLS was estimated which takes care of endogeniety issue and included indicator of roads infrastructure as well. The long run elasticity was found to be positive and highly significant for electricity consumption, road density and teledensity and ranged between 0.03 for teledensity, 0.37 for roads density and 0.26 for electricity consumption. Thus, we cannot refute the important role played by road infrastructure in the long run.

From the analysis undertaken on shorter time period (thirty year long time period was divided into three decades) the main conclusions drawn are that physical infrastructure variables did not have a uniform influence on output. The relationship not just differed for aggregate output, secondary and tertiary sector output; there was also distinct difference in the impact infrastructure had on the same sector for different time periods. Where the impact of electricity was the highest for secondary sector, the shortages in electricity made their impact felt on output in 2000s. Telecommunication has served as an important contributor for increase in output, both
secondary and telecommunication, however, more needs to be done in terms of increased ICT development for a continuous increasing impact on service sector output.

The impact of social infrastructure – education and health – was not clear cut. Where education infrastructure had a significant contribution to secondary sector output only in the 1990s, for tertiary sector, it had positive elasticities in 1980s and 1990s.

We could not find a significant impact of roads infrastructure, but do not refute its importance as was evident from the important contribution made by roads in the long run. This could warrant taking a look at some usage indicator for transport indicator which would help better understand the channels through which it can impact output.\textsuperscript{11} When different regions were interacted with infrastructure variables we found that although high income regions might have an edge over the low income regions, the results were not conclusive.

However, these results do not point to any uniform relationship between infrastructure availability and output. This possibly entails to the fact that infrastructure development in the country has not been uniform and has seen cycles of infrastructure build-up corresponding to maybe a different political-economy era in each decade. The focus of the corresponding five year plans was shaped in large parts by the changing political priorities of government.

An important question that arises for further examination is that even as growth rates in real infrastructure development have declined, output growth rates have tended to accelerate. This could be due to two possible explanations. First, the build-up of infrastructure stock upto 1990-91 was sufficient to support the growth surge that occurred. Second, in the post-1991 reforms period the drivers of growth changed and were more significant than the declining infrastructure availability growth.

\textsuperscript{11} Attempt was made in this regard by using vehicles density as indicator for usage of roads infrastructure, however, its coefficient also turned out to be insignificant.
Appendix 5

5.A Panel Granger Causality Test Results

While the existence of cointegration implies long-run Granger causality in at least one direction (Granger, 1988), cointegration says nothing about the direction of the causal relationship between the variables. As is common practice a panel VECM is estimated to perform Granger-causality tests (Pesaran et al., 1999). The panel short- and long-run Granger causality results conducted are reported in Table A below. The statistical significance of the coefficients associated with the ECT (error correction term) provides evidence of an error correction mechanism that drives the variables back to their long-run relationship. According to the coefficient on the lagged ECT (negative and significant), there exists a long-run relationship among the output and infrastructure variables. However, in the short run the results indicate that there does not exist bi-directional Granger causality between all variables. There is evidence of uni-direction causality running from Electricity, Railways, Roadways and Telecommunication towards Output. It was also found that in the short run, the PCNSDP (Industry and Service sector) is granger caused by electricity and telecommunication infrastructure.

Table 5.A: Panel Causality Test Results

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Source of causation (Independent variable)</th>
<th>Short Run</th>
<th>Long Run</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ECONOMY</td>
<td>∆NSDP</td>
<td>∆Elec</td>
</tr>
<tr>
<td>∆NSDP</td>
<td>-</td>
<td>23.5***</td>
<td>37.2***</td>
</tr>
<tr>
<td>∆Elec</td>
<td>57.4</td>
<td>-</td>
<td>43.3</td>
</tr>
<tr>
<td>∆Road</td>
<td>3.81</td>
<td>22.41</td>
<td>-</td>
</tr>
<tr>
<td>∆Rail</td>
<td>19.2</td>
<td>14.2</td>
<td>11.2*</td>
</tr>
<tr>
<td>∆Tele</td>
<td>24.58*</td>
<td>45.5</td>
<td>14.8*</td>
</tr>
</tbody>
</table>