Industrial Activity in Indian States: The Role of Infrastructure

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Abstract

We use panel data for fourteen Indian states to assess the influence of public infrastructure on industrial activity, namely productivity, employment, real wages and investment, at the state level, over the period 1974-1998. Our results indicate that the length of national highways has on average the greatest impact on each of the four measures of industrial activity. While the length of national highways and electricity generating capacity are found to be important determinants of state real wages and productivity, total highway length is a key variable in determining the level of investment in fixed capital in each state.

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1 General Background

Over the last decade, a considerable amount of research effort has been expended on the evaluation of the impact of public sector spending on infrastructure on economic activity. One particular strand of literature has focused on the investigation of the effects of the provision of public infrastructure on private sector output (see *inter alia* Munnell [1990]; Boarnet [1998]; and Roller and Waverman [2001]). The debate of whether public physical infrastructure increases private sector returns can be traced back to Aschauer [1989], who argued that the decline of US productivity in the 1970s was partly due to the decline in public sector investment. While the majority of the literature has considered developed countries, there is a growing emphasis placed on the role of public sector investment in developing economies (Looney [1997]).

Government intervention is driven by market failures and by issues of social welfare. Public sector investment raises efficiency and equity considerations, with a plausible trade-off between certain objectives. Economic theory suggests that governments should concentrate resources in markets that fail to produce an efficient outcome and where returns are the highest. However, there are other considerations as any increase in public infrastructure investment will trigger regional and industrial impacts due to the immobility of certain forms of public capital, the geographical location of roads and railways being a case in point. From an equity perspective, public investment may have a positive impact on regional output and so might be used to reduce differences in living standards between areas. In doing so, the decision to allocate public investment among regions may improve the growth potential of the whole country, especially when one takes into account recent evidence on the harmful effects of income inequality on long-run growth (Barro [2000]; and Persson and Tabellini [1994]). The overall level of development prospects may be further improved by creating the conditions for increased productivity by providing amenities, some of which are public, that improve the quality of life .

Public infrastructure investment may increase the productive capacity of a region, both by increasing the amount of resources available to firms and by enhancing the productive capacity of existing resources. From that point of view, the building of a public highway should be expected to boost regional productivity by providing firms with (i) lower distribution costs, facilitated by easier access to suppliers, intermediaries and other input markets; (ii) proximity to a wider pool of consumers and final good markets; (iii) easier access to a wider pool of workers, including human capital. In addition to its direct impact on production, public infrastructure "crowds in" private investment, through external economies , in a particular geographical area. With time, multiplier effects are activated, leading to increased employment, output and ancillary developments.

The theoretical literature provides two competing views of the influence of public sector expenditure on regional activities. From the perspective of endogenous growth and new economic geography, policies aimed at increasing overall growth could lead to greater divergence between regions, via the uneven distribution of infrastructure spending (Faini [1984]; Martin [1999]; and Martin and Rogers [1995]), the concentration of human capital (Lucas [1988]) and the location of innovation (Grossman and Helpman [1991, 1994]; Romer [1990]). The actual outcome depends on the existence of increasing returns to scale and the strength of centripetal forces leading to the concentration of economic activity. Alternatively, public investment may lead to a reduction in regional inequality. Investment in the public physical infrastructure may increase private sector output in those localities with a lower initial capital stock, resulting from constant or decreasing returns to scales. The empirical literature on developed nations has tended to emphasize the positive returns to public investment and their positive impact on backward areas, although the empirical evidence from developing countries is at best mixed.

During the late 1970s and early 1980s, India experienced an increase in economic growth. In the 1960s and 1970s the annual proportional increase of real gross domestic product averaged 3.5 per cent . Over the last twenty years the growth rate has increased, especially during the 1990s, averaging 5 per cent per annum. In an attempt to obtain a better understanding of the growth process, attention has been focused on regional Indian data. Goldar and Seth [1989] analyzed the growth patterns of the registered manufacturing sector of 12 states and found considerable differences in the economic performance of each state in India. Further studies have focused on factors responsible for the variation in the regional development of India and emphasized the link between infrastructure and output (see *inter alia* Barnes and Binswanger [1986]; Elhance and Lakshamanan [1988]; Das and Barua [1996]; Ghosh and De [2005]; and Datt and Ravallion [1998]). Moreover, the issue of the allocation of public resources between states has always been an issue of political discussion in large federal economies like India: "*..[I]n our view, the availability of infrastructure plays a crucial role in attracting investments, and States which are backward with low levels of infrastructure need to be helped so that these are able to come up* " (Government of India Report [p.58, 2000])

The aim of this study is to investigate whether the different levels of economic activity in Indian states can be attributed to the differences in the public provision of infrastructure. Attention is focused on the extent to which private responses, such as employment, wage setting and investment in capital stock, amplify regional effects of public infrastructure. Our study is a unique examination of the *ex post* effects on registered manufacturing of the public provision of highways and electricity generation capacity. In doing so, we appraise the contribution of public infrastructure to the development process.

The remainder of this paper is as follows. Section 2 provides an overview of the evolution of economic activity in India during the past two decades and briefly discusses the different patterns of investment in public infrastructure across states. Section 3 sets out the theoretical model which identifies the key relationships to be empirically tested. Section 4 introduces the data and the econometric techniques that we employ in our subsequent estimations. The results are presented and discussed in the following section. Finally, section 6 concludes the analysis and considers policy implications.

2 The Growth of Indian States: Stylized Facts

The regional allocation of public infrastructure spending by the government is commonly believed to have an impact on the distribution of economic activity between regions in a country. Whether the decision making process is moderated by political considerations or by the desire to maximize the long-run growth potential of the whole economy, public investment decisions have implications for regional output.

The link between infrastructure and economic growth is complex as, directly and indirectly, it results in the activation of a series of externalities, involving flows of expenditure with employment considerations. The empirical evidence suggests that public infrastructure investment leads to greater output, employment and improved quality of life (Bougheas et al [1999]; Cutanda and Patricio [1994]; Esfahani et al [2003]; Looney [1997]). However, in less developed economies, the unequal distribution of basic infrastructure between regions may be so great that it acts as an impediment to their economic development, often forcing these regions into a perpetual path of poor economic performance.

The Indian industrial sector can be divided into three broad categories, namely *mining and quarrying*, *utilities* and *manufacturing*, with the Annual Survey of Industries (ASI) providing data on the last two sectors. Under the Factories Act 1948, Factories are included in the survey if they employ 10 or more workers with the aid of power or 20 or more workers without power. Our study focuses on the registered manufacturing firms in India covered by the ASI. Hence, we analyze the more technically advanced sectors of the Indian economy and exclude the traditionally less technologically sophisticated ones, such as agriculture and services. One of the main advantages of this dataset is that factories covered by the ASI are more likely to be single firm units rather than companies, which tended to be multi-plant firms. Hence the number of factories, an important variable in our empirical analysis, should be an accurate measure of the number of production units in each state in India.

In order to provide a brief overview of industrial development in India, we turn to consider the broad facts of industrial growth in India's states for registered manufacturing, which turns out to differ from the aggregate growth rate for all output. Indeed, the average growth rate of Indian registered manufacturing has been 8.5 per cent per year over the period 1974/5-1997/8, with data given at mid-year intervals. Moreover, table 1 shows that the growth rate has fluctuated widely over the sample period. With the exception of 1978/9 and 1979/80, the annual percentage change of industrial output has been positive. The 1990s saw a slowdown in the average performance compared to the 1980s, although the average being higher than that for the 1970s.

Table 1: Annual Growth Rates: Indian Registered Manufacturing Output

Year	Growth rate (%)	Year	Growth rate (%)	Year	Growth rate (%)
1974-75	7.9	1982-83	11.8	1990-91	6.5
1975-76	15.7	1983-84	3.2	1991-92	3.4
1976-77	10.9	1984-85	5.9	1992-93	8.5
1977-78	11.2	1985-86	8.7	1993-94	5.9
1978-79	-5.2	1986-87	7.1	1994-95	8.4
1979-80	-0.2	1987-88	9.8	1995-96	16.9
1980-81	10.5	1988-89	10.1	1996-97	2.2
1981-82	19.9	1989-90	10.2	1997-98	11.9

Source: Authors' calculations using ASI data on output

Table 2 summarizes the growth rates of inputs and the growth rate of output by state between 1973/4 and 1997/8. One of the most notable features that can be discerned from that table is that the growth of the capital stock tends to fluctuate noticeably across states. By comparison, the growth of employment has been less than half of the growth of output. In certain states, namely West Bengal and Bihar, there has been virtually no growth in employment, leading to the *jobless growth* phenomenon that was experienced by certain states following the deregulation of the labour market. One argument that has often been claimed to account for this peculiar pattern of development has been the substitution of capital for labour, mainly through the adoption of labour saving technologies. It must

Table 2: Average Growth Rates by State: 1974-98

State	Growth in Mfg Employment (%)	Growth of Mfg Capital Stock (%)	Growth of Number of Mfg Factories (%)	Growth of Mfg Output (%)
Andhra Pradesh	4.83	10.3	4.58	8.84
Bihar	0.12	6.9	0.84	6.61
Gujarat	2.26	12.5	2.38	8.92
Haryana	4.15	7.7	4.83	9.9
Himanchal Pradesh	5.49	13.5	5.64	12.51
Jammu & Kashmir	3.49	7.12	2.6	6.57
Karnataka	3.43	9.9	2.58	8.81
Kerala	2.16	6.0	2.8	7.9
Madhya Pradesh	3.06	8.8	1.73	8.68
Maharashtra	1.41	8.5	2.07	7.2
Orissa	2.58	8.8	1.24	8.5
Punjab	4.36	7.9	1.76	8.52
Rajasthan	3.56	9.8	5	10.12
Tamil Nadu	2.98	7.6	3.91	8.2
Uttar Pradesh	2.5	11.0	3.17	8.81
West Bengal	-0.06	6.7	0.28	4.4

Note: Mfg is an abbreviation for *manufacturing*.
Source: Authors' calculations using ASI data.

be noted that jobless growth, when present even in segments of the dataset, may impose problems in the modelling of employment. Considerable variation is also observed in the distribution of factories across states: Rajasthan and Himanchal Pradesh have experienced average (annual) growth rates of 5 per cent and above; whereas the number of factories in Bihar and West Bengal increased much slower at an average rate of less than 1 per cent per annum.

The picture on investment in public infrastructure is equally diverse at the regional level. We consider two forms of investment in infrastructure: road networks (distinguishing between state and national highways) and electricity generation capacity. Both forms of infrastructure have been discussed in earlier studies and deemed to be crucial determinants of the long-term performance of manufacturing in the context of both developed and developing economies [1].

The most important aspect of the road network for commercial and industrial activities is the availability of a sufficiently developed system of highways (Holtz-Eakin and Schwartz [1995]; Bougheas et al [1999]; Fernald [1999]; Yao and Zhang [2001]). For India, as well as other federal economies, highways can be broken down into national and state highways, with each serving a different purpose in the road network: national highways are designed to connect the major urban conurbations in India and result in a national road network linking major hubs in the entire country. On the other hand, state highways connect the various cities and trade centers within a state whilst providing access to the national highways network.

The number of traffic lanes for national and state highways has often been reported as a crucial determinant of the commercial effectiveness of the overall road network, as greater availability of traffic lanes tends to reduce the cogestion and transport costs for goods, while enabling greater mobility rates for labour (Weisbrod and Beckwith [1992]; Downs [2004]). From this point of view, a width-adjusted measure of length may be more appropriate proxy of the road networks' efficiency. Table 3 presents the average annual growth rate of the lane-adjusted highway length for fourteen states in India, using adjustment factors in line with the ones proposed by the Indian Ministry of Highways.

[1] See, for instance, Cutanda and Paricio [1994] for an earlier discussion on the role of public infrastructure for the uneven development of Spanish regions; Fernald [1999] for a discussion on the impact of public road networks to US productivity for 29 sectors; and Seitz and Licht [1995] for the effect of public infrastructure on manufacturing production cost in 11 (West) German states.

The growth rate of the width-adjusted length of national highways clearly differs between states. In certain instances these differences are strikingly large (see for instance Haryana versus Kerala). Given our earlier figures about the state performances in industrial activity, it also comes as a surprise that Bihar, a laggard in terms of output growth, has exhibited very high growth rates of its share on the width-adjusted length of national highways, with 6.28 per cent per annuum, being second only to Haryana with 6.29 per cent. Gujarat, on the other hand, one of the leading states in terms of the growth rate of the number of firms operating within its borders, takes up the fourth place in the league, with an average annual growth rate of 5.45 per cent. In four states, namely Karnataka, Kerala, Madhya Pradesh and Maharashtra, the growth of the adjusted length of national highways was less than 2 per cent per year.

This pattern of cross-state diversity persists when state highways are considered. Jammu and Kashmir exhibit an unusual negative annual growth rate, which, however, can be explained when one takes into account the military conflict that occurred in the region during the latter part of the sample period. Gujarat and Haryana, both having experienced stellar output growth in the 1990s, stand at the opposite ends of the rate of growth of state highways. Such discrepancies can possibly be partially explained if differences in the industry mix of each state are taken into consideration. Alternatively, this casual observation may simply suggest that is it the adjusted road-length, rather than its growth rate, that drives the distribution of economic activity between states.

Although power capacity is claimed to play a key role in rapid industrialization (Barnes and Binswanger [1986]; Boarnet [1998]), scheduled power cuts and fluctuating voltages are frequently observed phenomena for many of the major Indian states [2]. Poor and unreliable electricity supply imposes a large economic cost on registered manufacturers at the national level. As no data is readily available for the peak power demand at the state level, table 4 uses information on the national power use and the ability of India to meet the escalating demand. Given the vast size of the country, it comes as no surprise that even after all the increased investment in electricity generating capacity, peak demand for electricity exceeds supply, leading to power shortages which are reported to be common in most states.

[2]A detailed account on the post-reform performance of India's power sector, its current deficiencies and the the extent to which these deficiencies distort day-to-day industrial operations is provided by Arun and Nixson [1998].

Table 3: Average Annual Growth Rates of Infrastructure: All States, 1974-1998

	Growth of Width-adjusted National Highways (%)	**Growth of Width-adjusted State Highways (%)**	**Growth of Electricity Generating Capacity (%)**
Andhra Pradesh	4.79	5.19	10.04
Bihar	6.28	1.56	5.35
Gujarat	5.45	7.80	8.58
Haryana	6.29	1.35	5.66
Himachal Pradesh	5.21	6.63	9.87
Jammu & Kashmir	4.66	-0.39	6.96
Karnataka	1.23	3.84	5.60
Kerala	1.33	7.02	4.82
Madhya Pradesh	1.84	1.12	7.27
Maharashtra	1.60	4.32	7.58
Orissa	4.60	3.35	4.03
Punjab	2.53	5.30	7.11
Rajasthan	5.45	5.61	5.57
Tamil Nadu	5.30	4.64	5.48
Uttar Pradesh	6.02	3.18	6.08
West Bengal	3.34	1.62	4.70

Source: Indian Ministry of Transport: *Basic Roads in India* [2006].

Table 4: Power Peak Demand and Supply (All India, in GW/h)

	Peak Demand	**Peak Supply**	**Deficit**	**Deficit (%)**
1993-4	54,875	44,830	10,045	18.30
1994-5	57,530	48,066	9,464	16.50
1995-6	60,981	49,836	11,145	18.30
1996-7	63,853	52,376	11,477	18.00
1997-8	65,435	58,042	7,393	11.30
2000-1	79,856	69,475	10,381	13.00

Note 1: Demand and supply measured in GigaWatts per hour (1GW=10^6 KW)
Source: Central Electricity Authority of India

It is also true to say that the power sector in India is undergoing a long and painful process of reforms. Up to 1991 electricity generation was a highly protected industry, attached to, staffed and serviced entirely by the public sector. As a result, decisions about the distribution and supply of electricity (including investment on new equipment) had to be made at the state government level. In an attempt to increase power supply, the sector was deregulated (though not fully) and opened up to independent, private power producers [3].

Finally, table 5 presents the share of wages in total value added, α, for each state and for the mid-years 1970/1, 1980/1 and 1997/8. A careful comparison of the computed wage shares across time periods reveals a considerable decline for almost all states over the sample period. More particularly, over the period 1974 to 1998, the wage share fell from an average value of 51.7 to 32.8 per cent. In proportionate terms, the decline in wage share was between 30 to 40 per cent for each state. The period of analysis divides into two phases: The pre-liberalization (1970-91) and the past-liberalization (1992-98) era. During the first phase, the wage share declined by more than five percentage points, while the fall accelerated after 1991, and the decline from 1991-98 was by almost 13 per cent.

3 The Model

In this section we develop a simple theoretical framework to illustrate the relationship between employment, real wages and the provision of public infrastructure. The equations that are obtained in this section are then used to guide the estimated equations that are presented and discussed in section 5.

[3] It should be noted that, despite an increase in private generating capacity, the public sector is by large the main supplier of electric power in India. Indeed, by 2006 more than 85% of total installed generating capacity was still operated by the public sector (at the national and state level).

Table 5: The Share of Wages in Total Value Added (%)

State	1970/71	1980/81	1990/91	1997/98
Andhra Pradesh	52.19	57.72	40.73	30.93
Bihar	59.95	74.1	48.35	21.93
Gujarat	47.4	45.97	34.56	31.19
Haryana	45.41	36.3	38.46	40.58
Himachal Pradesh	39.63	25.03	34.62	31.89
Jammu & Kashmir	123.3	80.01	27.09	78.82
Karnataka	39	49.64	41.18	35.36
Kerala	47.58	43.49	42.67	45.13
Madhya Pradesh	59.76	41.42	35.11	31.24
Maharashtra	48.71	46.34	38.24	32.54
Orissa	57.87	61.58	34.57	29.11
Punjab	47.86	39.36	45.04	40.85
Rajasthan	44.34	44.75	38.89	27.81
Tamil Nadu	51.67	47.21	36.25	42.27
Uttar Pradesh	50.65	60.78	40.08	29.85
West Bengal	73.68	68.24	63.43	44.09

Source: Authors' calculations using ASI data on output and wages

Consider an economy that is populated by a continuous mass of $\bar{L}$ identical individuals. At any point in time t the total population of the economy is $\bar{L}_t$, a fraction ϕ of individuals are employed as workers (i.e. $L_t = \phi_t \bar{L},\ 0 \leq \phi_t \leq 1$) in one of the factories that operate in the economy. Each factory produces a single homogeneous good using capital, labour and a single composite intermediate input, public infrastructure, which could be provided by the public sector or privately.

To investigate how spatial differences across regions influence the employment and production decisions of a firm, we assume that the economy can be divided into N regions (each region in our case representing a state). Regions differ from each other in terms of infrastructure and labour market conditions. Capital and labour are assumed to be immobile across regions and each firm is allowed to operate in only one region. The output of firm j operating in location i at time t will then follow the neoclassical technology:

$$Y_{ijt}(L_{ijt}, K_{ijt}, A_{it}) = A_{it} L_{ijt}^{\alpha} K_{ijt}^{\beta}$$

where both parameters are assumed to be positive and increasing returns are ruled out by the parameter restriction $\alpha + \beta \leq 1$. The labour and capital stock used by firm j, based in state i, at time t is denoted by L_{ijt} and K_{ijt}. The technology variable A_{it} is assumed to be region-specific and an implicit function of (public) investment on infrastructure. In particular, the value of A in state i at time t is defined according to :

$$A_{it} = Z_i X_{it}^{\gamma} Y_{i,t-1}^{\lambda} \tag{1}$$

with $\gamma > 0$ and $\lambda > 0$. Z_i denotes a vector of unobserved time invariant and location specific fixed effects that may have *a priori* impact on productivity (e.g. climate and literacy rates); X_{it} captures the effect of the provision of public infrastructure (e.g transport and electricity); and $Y_{i,t-1}$ stands for inter-temporal spillovers on productivity [4]. It should be noted that the parameter γ captures the infrastructure elasticity of output and is the focal point for the econometric work that is presented in the next section.

Taking logarithms of (1) yields:

$$\ln A_{it} = \ln Z_i + \gamma \ln X_{it} + \lambda \ln Y_{i,t-1} \tag{2}$$

Equation (2) can then be used to quantify the impact of public infrastructure on state-specific productivity and provides the basis to explain regional variation in productivity rates in terms of spatial differences in the public provision of infrastructure.

Using N_{it} to denote the total number of firms operating in state i at time t and assuming that firms are symmetric, the total number of workers available for employment in that state is given by:

$$L_{it} = \sum_{j=1}^{N_{it}} L_{ijt} = N_{it} L_{ijt}$$

Similarly, the location's total capital endowment is given by:

$$K_{it} = \sum_{j=1}^{N_{it}} K_{ijt} = N_{it} K_{ijt}$$

Assuming symmetry across firms implies that $L_{ijt} = L_{it}/N_{it}$ and $K_{ijt} = K_{it}/N_{it}$ which can be substituted into the production function to give the output of firm j as:

$$Y_{jit} = A_{it} \left(\frac{L_{it}}{N_{it}}\right)^{\alpha} \left(\frac{K_{it}}{N_{it}}\right)^{\beta}$$

[4]This may also be seen as the impact of *learning-by-doing*, implying that higher levels of industrial activity in a region have a positive effect on future productivity.

The aggregate output in region i at time t can then be obtained by summing the output of each firm's production in the state:

$$Y_{it} = \sum_{j=1}^{N_{it}} Y_{jit} = N_{it} A_{it} \Big(\frac{L_{it}}{N_{it}}\Big)^{\alpha} \Big(\frac{K_{it}}{N_{it}}\Big)^{\beta}$$

which simplifies to

$$Y_{it} = N_{it}^{1-\alpha-\beta} A_{it} L_{it}^{\alpha} K_{it}^{\beta}$$

Demand for labour in state i can then be obtained by considering the profit-maximizing level of state output as it is described by the first-order condition with respect to L:

$$\alpha N_{it}^{1-\alpha-\beta} A_{it} L_{it}^{\alpha-1} K_{it}^{\beta} = \frac{w_{it}}{P_{it}} \tag{3}$$

where w_{it} and P_{it} are used to denote wages and prices for state i at time t. Essentially, equation (3) indicates that the compensation for labour should be set to equate their marginal product. It follows that the demand for labour can be expressed according to:

$$L_{it} = \Big(\frac{\alpha N_{it}^{1-\alpha} A_{it} \big(\frac{K_{it}}{N_{it}}\big)^{\beta}}{\frac{w_{it}}{P_{it}}}\Big)^{\frac{1}{1-\alpha}}$$

Taking logarithms of both sides simplifies the expression to:

$$\ln L_{it} = \frac{1}{1-\alpha}\Big[\ln\alpha + (1-\alpha)\ln N_{it} + \beta \ln\Big(\frac{K_{it}}{N_{it}}\Big) + \ln A_{it} - \ln\Big(\frac{w_{it}}{P_{it}}\Big)\Big] \tag{4}$$

The supply of labour for region i is given by:

$$L_{it} = \bar{L}_{it}\Big(\frac{w_{it}}{P_{it}}\Big)^{\delta} \tag{5}$$

with $\bar{L}$ denoting total population in region i at time t. Equation (5) can then be used for the computation of real wages function, which, after substituting in for L_{it}, takes the form:

$$\ln\Big(\frac{w_{it}}{P_{it}}\Big) = \frac{1}{1+\delta(1-\alpha)}\Big[\ln\alpha + (1-\alpha)\ln\Big(\frac{N_{it}}{\bar{L}_{it}}\Big) + \ln A_{it} + \beta\ln\Big(\frac{K_{it}}{N_{it}}\Big)\Big] \tag{6}$$

The remaining relationships that need to be estimated can then be derived by substituting the state productivity equation, (2), into the employment and wage equations, (4) and (6). Two versions of the employment equation are considered below: the structural equation and the reduced-form equation - the latter excluding real wages as an explanatory variable.

$$\ln L_{it} = \frac{1}{1-\alpha}\Big[\ln\alpha + (1-\alpha)\ln N_{i,t-1} + \beta\ln\Big(\frac{K_{i,t-1}}{N_{i,t-1}}\Big) + \ln Z_i + \gamma\ln X_{i,t-1} + \lambda\ln Y_{i,t-1} - \ln\Big(\frac{w_{it}}{P_{it}}\Big)\Big] \tag{7}$$

$$\ln\frac{L_{it}}{\bar{L}_{it}} = \frac{\delta}{1+\delta(1-\alpha)}\Big[\ln\alpha + (1-\alpha)\ln\Big(\frac{N_{i,t-1}}{\bar{L}_{i,t-1}}\Big) + \ln Z_i + \gamma\ln X_{i,t-1} + \lambda\ln Y_{i,t-1} + \beta\ln\Big(\frac{K_{i,t-1}}{N_{i,t-1}}\Big)\Big] \tag{8}$$

$$\ln\frac{w_{it}}{P_{it}} = \frac{1}{1+\delta(1-\alpha)}\Big[\ln\alpha + (1-\alpha)\ln\Big(\frac{N_{i,t-1}}{\bar{L}_{i,t-1}}\Big) + \ln Z_i + \gamma\ln X_{i,t-1} + \lambda\ln Y_{i,t-1}\beta\ln\Big(\frac{K_{i,t-1}}{N_{i,t-1}}\Big)\Big] \tag{9}$$

It is important to note that equations (7), (8) and (9) should not be viewed as straitjackets for empirical modelling, but rather as a general guide to the variables that need to be included in the empirical estimation of these relationships. In particular, as it is to be further discussed in the context of the next sections, care is required when considering the inclusion of contemporaneous variables in a regression equation, such as the optimal number of firms within a state or the provision of public infrastructure, due to the possibility of potential endogeneity.

4 Data and Econometric Issues

Using the theoretical model as the general framework for the empirical investigation of the impact of public infrastructure on manufacturing in Indian states, the econometric analysis employs panel data regressions techniques. The industrial series are taken from the Annual Survey of Industries (ASI) and estimated equations use annual data, covering the period 1973/4 to 1997/8. The public infrastructure data are obtained from India's Ministry of Transport report, *"Basic Roads in India"*. Highways are measured by length and are adjusted for road width. Due to consistency problems and data limitations relating to the measurement of the length of state and national highways, our dataset focuses on the following fourteen states: dataset focues Andhra Pradesh, Bihar, Gujarat, Haryana, Himanchal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal.

The public infrastructure variables, namely *length of highways* and *electricity capacity* for each state, are stock variables. This raises the issue about the order of integration of these variables and, in particular, whether non-stationary panel techniques should be employed. However, preliminary unit-root tests suggested that the data do not appear to be integrated of order one. This finding is consistent with the view that the increase in the public infrastructure is only measured when a new project, such as the construction of a new road or power station, comes on line. As such, infrastructure variables for most states should be expected to follow a step-like function. The other variables in the three key equations, namely employment, productivity and real wages, do not appear to be non-stationary, which is also consistent with the findings of Besley and Burgess [2004]. Fixed effects are employed to capture the impact of the unobserved, state-specific, time-invariant components (e.g. climate, distance from the coast) entering the theoretical spcification through variable Z.

The modelling of equations (7),(8) and (9) takes place on an equation-by-equation basis, and lagged values are employed either indirectly (as instruments) or directly (as explanatory variables, thus making the corresponding variables pre-determined) to deal with potentially endogenous variables. When the versions of each model include past realizations of the dependent variable, the *Arrelano-Bond* estimator is applied to deal with potential issues of endogeneity. Finally, it should be noted that states in India vary in relation to size and it is likely that this will impact on the error variance. Consequently, generalized least squares (GLS) is used as the regression estimation technique for the wage, employment and investment equations, with account taken for the possibility of serially correlated residuals.

5 Results

In this section we summarize and discuss our results on an equation-by-equation basis.

5.1 Productivity

Following standard growth accounting techniques we define the Solow residual A_{it} according to:

$$\ln A_{it} = \ln Y_{it} - \beta_{it} \ln K_{it} - \alpha_{it} \ln L_{it}$$

where the share of output going to labour is allowed to vary for each state and can be calculated as:

$$\alpha_{it} = \frac{w_{it} L_{it}}{P_{it} Y_{it}}$$

and β_i is used to describe the share of output going to capital.

Notice that, given the definition above, the share of labour is a function of time-dependent variables. As such, it should be expected to be a time-dependent variable itself. However, when the time-variance of α_i was examined, we did not find any changes of significant magnitude for any of the states included in our estimations, over time. As such, from here on and for our estimations we will treat α as a fixed parameter, allowed to differ across regions, but held constant for a specific region across time (i.e. α_i). Indeed, as table 5 shows, the shares of each state are not uniform and so there is a different α for each state. The estimated shares appear to be of plausible value for all states, with the exception of the war-plagued Jammu and Kashmir. Public infrastructure is thought to have a positive influence on the Solow residuals, although the evidence in the literature is mixed (see Griliches [1997] for some further discussion).

The productivity equation reflects the effect of three "hard infrastructure" variables, namely the length of state highways, national highways and total electricity generating capacity on the productivity in each state:

$$\begin{aligned}\ln A_{it} &= \beta_{0j} + \beta_1 \ln(NHIGHWAY_{i,t-1}) + \beta_2 \ln(SHIGHWAY_{i,t-1}) \\ &\quad + \beta_3 \ln(ELECTRICITY_{i,t-1}) + \beta_4 \ln(Y_{i,t-1}) + v_i + u_t + \epsilon_{it}\end{aligned}$$

where v and u are state and time dummies, respectively; $NHIGHWAY_{it}$ and $SHIGHWAY_{it}$ stand for the width-adjusted length of national and state highways, respectively, in state i at time t; and $ELECTRICITY_{it}$ denotes the publicly provided electricity generating capacity for each state in a given year. Table 6 provides an overview of the estimated parameters for the productivity equation. The spillover is captured in the equations (i)-(iv) by the lags of the Solow residuals, requiring the Arellano-Bond estimator to be used. The remaining two equations include intertemporal spillovers measured by the lagged growth of real output in the manufacturing sector, by applying a GLS estimator.

In both versions of the model, spillover effects are found to be present, suggesting a lagged response to the effect of changes in infrastructure. Electricity generation capacity, normalized by the number of factories, has a positive and significant influence on the productivity in Indian manufacturing. The coefficient is robust for all the various model specifications and econometric estimators that we tried. $NHIGHWAYS$, rather than total highways (defined as $NHIGHWHAYS + SHIGHWAYS$) turns out to be an important variable in those versions of the productivity equations in which a past realization of the Solow residual is included. Again, the coefficient does not vary greatly with the inclusion of other explanatory variables. However, both measures of road length, although signed in line with intuition, do not have significant coefficients when productivity spillovers are proxied by the lagged growth of output.

It is commonly believed that increases in productivity require a fair supply of skilled labour, the impact of which we capture by the inclusion of the growth of the real wage paid to technical workers, $\Delta \ln TWAGES$. In those equations in which lagged Solow residuals are included as an explanatory variable, the growth of the technical wage is found to be positive and significant suggesting that the composition of the labour market and, more specifically, the share of skilled labour in total workforce is an important determinant for regional productivity gains.

Table 6: Estimation of the Solow Residual

Dependent Variable:	Solow Residual					
	(i)	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
SOLOW $_{i,t-1}$	0.392	0.376	0.356	0.367		
	(6.66)	(6.42)	(8.61)	(6.18)		
SOLOW $_{i,t-2}$	0.163	0.18	0.191	0.183		
	(3.00)	(3.32)	(2.38)	(3.34)		
$\ln\left(\frac{ELECTRICITY}{FACTORIES}\right)_{i,t-1}$	0.146	0.158	0.16	0.157	0.151	0.142
	(3.17)	(3.43)	(3.21)	(2.97)	(3.19)	(3.01)
$\ln(NHIGHWAY)_{i,t-1}$		0.198	0.201	0.222	0.098	
		(3.81)	(3.65)	(3.90)	(1.50)	
$\ln(THIGHWAY)_{i,t-1}$	0.082					0.115
	(1.04)					(1.50)
$\Delta\ln(TWAGES)_{i,t-1}$	0.11	0.106		0.106	0.058	0.06
	(2.42)	(2.34)		(2.08)	(1.74)	(1.8)
$\Delta\ln(\mathrm{OUTPUT})_{i,t-1}$					0.137	0.134
					(2.05)	(2.05)
Estimator	ABOND	ABOND	ABOND	ABOND	GLS	GLS
Fixed Effects	YES	YES	YES	YES	YES	YES
Time Effects	TREND	TREND	TREND	FIXED	TREND	TREND

Note: t-ratio in parentheses

5.2 Employment

Following closely equation (8), we next proceed with the econometric estimation of the structural equation for labour demand. Our results are presented in table 7. Given that current real wages are endogenous in our model, an instrumental variable estimator is used for all the estimated versions of the labour demand equation. The dependent variable for the first six specifications is the number of workers employed in the registered manufacturing sector in each state. In the labour demand versions of the employment equation real wages appear as highly significant, with an elasticity ranging from -0.396 to -0.556.

Looking closer at each of the specifications, the basic model (equation (i)) yields coefficients of a correct sign and plausible magnitude for all of the included variables. Physical public infrastructure appears to be of importance due to the width-adjust road length of national highways. Electricity generation capacity, on the other hand, does not have a significant impact on manufacturing employment. The key variable driving employment is the number of firms located in each state. This influence is fairly robust and appears not to be sensitive to the other independent variables included in the employment equation. Assuming that the size of factories does not change, an increase in their number should lead to an increase in labour demand[5]. Although the coefficient on fixed capital per factory is lower than that on national highways, it indicates its importance on the number of workers employed in Indian states.

As registered manufacturing is concentrated in cities, the employment of workers in this sector is likely to exhibit a positive correlation to the proportion of the population living in the urban areas of each state. The main form of employment in the non-urban centres is agriculture and related activities (ASI, [2000]), a sector not covered by our data set. An alternative interpretation of the urbanization variable is as a measure of comparative development for each state: if a state is highly urbanized, and for a given population, workers will not have to travel long distances for employment. Furthermore, the more urbanized a state is, the more likely that the population will be employed in registered manufacturing rather than rural employment, partly because the alternative will not be readily available. Indeed, in specification (ii) we investigate these conjectures by including urbanization and population as additional variables. As expected, urbanization is highly significant but population, although correctly signed, is not significantly different, at a conventional statistical level. The coefficient of urbanization varies according to what

[5]This finding can also be justified by the use of labour-intensive technology in the 14 Indian states under examination. The relatively low rates of penetration of labour-substituting technology in Indian manufacturing has been reported extensively in previous studies (see for instance Bassant and Fikkert [1996]; Tybout [2000]; and Megginson and Netter [2001]).

other independent variables are included in the equation, a fact that may in turn point out that this variable captures more than the mere concentration of the state's city population.

Specifications (iii) and (iv) include additional variables for the two versions of the productivity equation, allowing for intertemporal productivity spillovers as captured by the lagged Solow residuals and the growth of real output. Lagged Solow residuals capture the extra effect on labour demand and, in line with the results presented in table 6, show up as a better proxy for spillovers than mere output growth.

For the specifications (vii) to (ix) the dependent variable changes to the number of workers per population, thus imposing a unit elasticity of workers with respect to population which, from the results presented in the first set of six equations, appears to be a strong restriction to impose. The main difference from the previous equations now is that current real wages are excluded from the reduced-form of the labour demand equation. More specifically, specification (vii) includes lagged real wages in the basic formulation, but is found not to have a significant effect. Although still an important determinant of the number of workers employed, the coefficient on the number of factories has now decreased in magnitude. Furthermore, the elasticity of capital stock per factory is no longer significantly different from zero. Urbanization, as discussed previously, is the key factor in explaining the number of workers employed in Indian registered manufacturing and its impact is larger than in the structural equation.

The adjusted length of national highways appears significant in all of the versions of the employment equation. State highways and electricity capacity do not appear to have an influence on employment, a finding that has implications from a policy perspective. The lack of evidence of productivity spillovers in the reduced-form employment equation is not surprising given that jobless growth has been a key feature of Indian labour markets over the period considered in this study (Bhalotra [1998]; Mazumdar [2003]; and Dutta-Roy [2004]). It is, therefore, likely that any potential spillovers would not be translated to an increase in the number of workers employed. However, their effect might be more apparent in wages, where an increase in productivity leads to firms paying more for their labour.

Table 7: Estimation Results for the Employment Equation, 1974-1998

Dependent Variable:	No of Workers						Participation Rate		
	(i)	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**	**(vii)**	**(viii)**	**(ix)**
SOLOW $_{i,t-1}$			0.092		0.051	0.053		-0.035	
			(2.07)		(1.15)	(1.22)		(-1.28)	
$\Delta\ln(OUTPUT)_{i,t-1}$				-0.023					-0.029
				(-0.26)					(-0.84)
$\ln(\frac{\text{CAPITAL}}{\text{FACTORIES}})_{i,t-1}$	0.117	0.12	0.137	0.134	0.125	0.143	0.037	0.011	0.022
	(3.36)	(3.54)	(3.91)	(3.97)	(3.62)	(4.97)	(1.42)	(0.43)	(0.91)
$\ln(\text{FACTORIES})_{i,t-1}$	0.721	0.704	0.740	0.661	0.681	0.712	0.266	0.225	0.238
	(11.63)	(11.48)	(11.60)	(12.69)	(10.95)	(14.35)	(4.71)	(5.66)	(6.00)
$\ln(\text{WAGES})_{i,t-1}$							-0.0896		
							(-1.90)		
$\ln(\text{WAGES})_{i,t}$	-0.451	-0.498	-0.556	-0.489	-0.473	-0.396			
	(-3.68)	(-3.97)	(-4.3)	(-4.08)	(-3.62)	(-4.75)			
$\ln(\frac{ELECTRICITY}{FACTORIES})_{i,t-1}$	0.031	0.075	0.075		0.063	0.077	0.0144		
	(0.61)	(1.43)	(1.43)		(1.36)	(1.88)	(0.38)		
$\ln(\text{NHIGHWAY})_{i,t-1}$	0.138	0.149	0.16	0.147		0.152	0.073	0.075	0.077
	(2.88)	(3.19)	(3.38)	(3.14)		(3.26)	(1.75)	(2.00)	(2.05)
$\ln(THIGHWAY)_{i,t-1}$					-0.053				
					(-0.96)				
$\ln(\text{POPULATION})_{i,t-1}$		0.173	0.264		0.322				
		(0.58)	(0.87)		(1.01)				
$\ln(\text{URBANIZATION})_{i,t-1}$		0.923	0.974	0.822	0.987			1.593	1.604
		(4.66)	(4.87)	(4.51)	(4.67)			(7.85)	(7.94)
ESTIMATOR	IV	IV	IV	IV	IV	IV	GLS	GLS	GLS
STATE FIXED EFFECTS	YES	YES	YES	YES	YES	YES	YES	YES	YES
TIME EFFECTS	FIXED	FIXED	FIXED	FIXED	TREND		FIXED	TREND	FIXED

Notes:
(i) Dependent variable for (i)-(vi) is the number of workers employed in manufacturing; and for (vii)-(ix) the participation rate (ratio of the number of workers to population).
(ii) t-ratio in parentheses

5.3 Wages

Table 8 presents the estimated coefficients for six specifications of the reduced-form equations for wages in registered manufacturing, as suggested by equation (9). All specifications contain similar explanatory variables and definitions as the reduced-form employment equations presented earlier in table 7. One slight modification is that we now include, as an extra variable, the lagged value of the number of workers in registered manufacturing divided by state population (labour participation): increases in the participation rate should reduce the wages paid by firms in Indian states. Specification (i) presents the basic equation with Solow residuals. The estimated parameters are signed in accordance with the theoretical model and common intuition, with the number of factories per capita having the largest effect: As more firms opt to locate in a particular state, the demand for labour increases and, for a given population, the wage for workers is bid up.

In equation (i) investment in public physical infrastructure is represented by the length of national highways and electricity generation capacity normalised by the number of factories operating in that state. The first lag of capital stock per factories is not found to have a significant impact on real wages, although the coefficient sign is in line with expectations. When firms increase their capital stock two competing effects may be triggered. Firstly, firms may be substituting capital for workers, which would lead to a decline in the demand for labour and would push state wages downwards . Alternatively, an increase in the capital stock per firm should result in increased labour productivity, driving state wages upwards[6]. The effect of investment on physical capital on wages becomes even more ambiguous, when the division of the work force between skilled and unskilled labour is considered. As our dependent variable is the average wage of workers there is no allowance for skill premium and therefore the overall effect on wages may be washed out, thus explaining the weak statistical significance of the estimated coefficient on capital per firm, as witnessed in specifications (i) to (v). However, when capital per firm is lagged by two periods (specification (vi)), the impact on wages is significant which could be explained by the existence of adjustment lags[7]. Such a finding is consistent with the importance of lagged electricity generating capacity contributing to real wages in the In-

[6]The labour substitution effect should be most profound if the state has reached a sufficient level of development to become attractive to technologically sophisticated manufacturers. Moreover, when labour is assumed to be homogeneous (not skill-differentiated) the identification of a persistently positive relationship between physical capital and wages may also be seen as further evidence for relatively low rates of adoption of labour-saving technology in the manufacturing sector of the states that we hereby examine.

[7]This may also be read as supportive evidence for the existence of technological adjustment costs: Productivity boosts triggered by the introduction of new technologies are not instantaneous. A certain period of time is usually required for the successful familiarization of the workforce and the management with new technology, during which no productivity gains (or even losses) may incur. Similar findings are reported for the US and UK manufacturing widely in the literature (see, for instance, Haskel et al [2003] for UK and Dunne [1994] for US).

dian manufacturing sector.

Moreover, and unlike the results we obtained when estimating equations (7) and (8), the length of width-adjusted state highways is found to have a significant impact on wages, with the coefficient being of similar magnitude to that of national highways. Specifications (iii) to (v) combine these effects and include the width-adjusted total highway length as a dependent variable. Along with the electricity capacity, these results indicate that public infrastructure has a greater impact on wages than employment over the sample period.

It is also interesting that, while urbanization showed up to be a key determinant for productivity and the number of workers employed in Indian registered manufacturing, it does not appear to be as important for real wages.

Table 8: Estimation Results for the Real Wage Equation, 1974/5-1997/8

Dependent Variable:	Real Wages					
	(i)	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
$\text{SOLOW}_{i,t-1}$	0.005	0.008	0.004			
	(0.13)	(0.21)	(0.09)			
$\Delta \ln(OUTPUT)_{i,t-1}$				0.096		
				(1.96)		
$\ln(\frac{WORKERS}{POP})_{i,t-1}$	-0.207	-0.210	-0.207	-0.208	-0.208	-0.172
	(-4.14)	(-4.40)	(-4.42)	(-4.73)	(-4.58)	(-4.53)
$\ln(\frac{CAPITAL}{FACTORIES})_{i,t-1}$	0.034	0.029	0.027	0.018	0.026	
	(1.31)	(1.16)	(1.10)	(0.79)	(1.12)	
$\ln(\frac{CAPITAL}{FACTORIES})_{i,t-2}$						0.066
						(2.77)
$\ln(\frac{FACTORIES}{POP})_{i,t-1}$	0.341	0.265	0.294	0.278	0.293	0.215
	(8.56)	(5.90)	(6.72)	(6.78)	(6.81)	(5.91)
$\ln(\frac{ELECTRICITY}{POP})_{i,t-1}$	0.274	0.216	0.241	0.249	0.24	0.203
	(8.07)	(5.96)	(6.53)	(6.75)	(6.50)	(5.75)
$\ln(NHIGHWAY)_{i,t-1}$	0.161	0.141				0.101
	(3.91)	(3.50)				(2.47)
$\ln(SHIGHWAY)_{i,t-1}$		0.156				0.13
		(3.85)				(3.23)
$\ln(THIGHWAY)_{i,t-1}$			0.238	0.24	0.241	
			(4.89)	(4.87)	(4.91)	
ESTIMATOR	GLS	GLS	GLS	GLS	GLS	GLS
STATE FIXED EFFECTS	YES	YES	YES	YES	YES	YES
TIME EFFECTS						

Note: t-ratio in parentheses

5.4 Investment

Our theoretical exercise and the subsequent empirical work have neglected a very important element of economic activity and growth, namely private investment in new physical capital. Indeed, there is a long literature describing the channels through which new investment in private physical capital triggers productivity growth and stimulates country-wide economic activity (Rodrik [2004]; Rajan et al [2006]). Most of this literature focuses on the context of already developed economies or, when developing countries are considered, the interaction between private and public investment is not explicitly analyzed. The direction and magnitude of such a pattern of interaction between the two types of investment, qualifies as an interesting question. Indeed, from a policy perspective, one issue of interest is whether investment in public infrastructure acts as a complement or a substitute for private sector investment. An increase in the investment in public infrastructure may lower private investment in physical capital, by providing the entrepreneurs access to capital goods that they previously had to provide by themselves (e.g. roads or electricity generators). On the other hand, public and private physical capital investments may act as complements, the first stimulating the second by providing firms access to new markets and production techniques, thus encouraging them to invest further on technical and physical equipment. We here turn to investigate the relationship between the two forms of capital investment by estimating the equation:

$$
\begin{aligned}
\Delta \ln K_{it} &= \delta_0 + \delta_1 \ln \left(\text{ELECTRICITY}\right)_{i,t-1} + \delta_2 \ln \left(\text{THIGHWAY}\right)_{i,t-1} \\
&\quad + \delta_3 \ln \left(\text{WAGES}\right)_{i,t-1} + \delta_4 \ln \left(\text{SOLOW}\right)_{i,t-1} \\
&\quad + \delta_5 \ln \left(\text{URBANIZATION}\right)_{i,t-1} + \epsilon_{it} \qquad (10)
\end{aligned}
$$

The results are shown in table 9. Electricity generation capacity does not appear to have a significant influence on private investment, which is admittedly surprising given the anecdotal evidence on the frequency of blackouts and power shortages experienced in several Indian states from our sample. The finding still holds when electricity capacity is deflated by the number of factories (specification (iii))and by population (specification (v)) [8]. This may in turn indicate that factories tend to invest in their own private electricity generation systems, despite increases in the investment in public infrastructure, in order to secure a continuous supply of power. Unfortunately, this conjecture cannot be tested due to the lack of data on the private provision of power at the state level.

[8]Population and factories here are used as a normalization factor to control for demands from firms and residents, respectively, on electricity capacity.

The width-adjusted length of highways, national or total, is found to be an important determinant of private sector capital investment. There is some evidence that state highways might have a more significant role on the change in the capital stock. One explanation can be that state highways might constitute a more appropriate route for the distribution and maintenance of parts and machinery. Alternatively, it may be that the linkage between national and state highways depends upon the location of the market for the finished products. If this is the case, the type of roads (national versus state) becomes irrelevant, which may, in turn, explain the importance of the coefficient for the length of total highways.

Moreover, an increase in participation in the registered manufacturing labour market is shown to have a negative impact on investment in this sector. This suggests that firms, on average, are prepared to substitute capital for labour only when workers are in short supply, which is consistent with our earlier results. The investment in the capital stock is strongly influenced by the growth in the number of new factories located in a state. This finding is not surprising as new firms will need plant and machinery to set up production. If there is an ample supply of labour, established firms are unlikely to increase the capital intensity of production or invest heavily to increase capacity.

Finally, real wages have a negative effect on private fixed capital investment, with the size of the coefficient being sensitive to the other independent variables included each time in the equation. A plausible interpretation for this is that, as workers may be required to operate and maintain machinery and other technical equipment, any rise in wages discourages new flows of private capital investment.

Table 9: Estimation Results for the Investment Equation, 1974-1998

Dependent Variable:	Investment in Fixed Capital ($\Delta \ln K_{it}$)					
	(i)	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
$\ln\left(SOLOW\right)_{i,t-1}$					0.056	
					(1.45)	
$\Delta \ln\left(OUTPUT\right)_{i,t-1}$		0.128	0.146			0.083
		(1.92)	(2.13)			(1.25)
$\ln\left(\frac{WORKERS}{POPULATION}\right)_{i,t-1}$	-0.066	-0.074	-0.101	-0.161		
	(-1.95)	(-2.19)	(-2.95)	(-3.21)		
$\ln\left(FACTORIES\right)_{i,t-1}$				0.071		
				(1.54)		
$\Delta \ln\left(FACTORIES\right)_{i,t-1}$	0.320	0.331	0.339			
	(4.49)	(4.64)	(4.70)			
$\ln\left(WAGES\right)_{i,t-1}$				-0.188	-0.174	-0.079
				(-3.45)	(-3.24)	(-2.10)
$\ln\left(\frac{ELECTRICITY}{POPULATION}\right)_{i,t-1}$					0.036	
					(1.17)	
$\ln\left(\frac{ELECTRICITY}{FACTORIES}\right)_{i,t-1}$			0.014			
			(0.53)			
$\ln\left(NHIGHWAY\right)_{i,t-1}$			0.043			
			(1.82)			
$\ln\left(THIGHWAY\right)_{i,t-1}$	0.058	0.055		0.087	0.099	0.119
	(3.31)	(3.08)		(2.34)	(3.00)	(3.76)
$\ln\left(URBANIZATION\right)_{i,t-1}$				0.166	0.377	
				(1.50)	(3.23)	
$\ln\left(POPULATION\right)_{i,t-1}$					0.264	
					(2.49)	
ESTIMATOR	GLS	GLS	GLS	GLS	GLS	GLS
STATE FIXED EFFECTS	YES	YES	YES	YES	YES	YES
TIME EFFECTS	TREND	TREND	TREND	TREND	TREND	TREND

Note: t-ratio in parentheses.

6 Concluding Remarks

The impact of public physical infrastructure on productivity and general economic activity has been discussed widely in the literature in the context of developed economies. Our study contributes to this discussion by focusing on a fast-growing but still developing economy. To do this we construct and analyze a rich regional dataset, distinguishing between fourteen Indian states, which is then used to capture and investigate the impact of public infrastructure, as measured by highway length and electricity generation capacity, on productivity, employment, wages and investment, at the state level.

We develop a simple theoretical framework which we then use as a guide for the equations to be estimated. The effects of highway and electricity capacity on productivity, employment and wages have been identified. Unsurprisingly, it is the national highways, connecting cities between states, rather than state highways, joining locations within the same state, that contribute the most to India's economic activity. Our results imply that highways did have an influence on private fixed capital investment in contrast to electricity generation capacity, for which the evidence was rather weak. The latter could be explained by firms investing in their own power generation capacity to overcome the lack of continuity of power supply.

From a policy perspective, our findings indicate that the location of public infrastructure had an important impact on economic activity and the shaping of regional productivity in India over the period 1974-1998. It follows that a successful regional growth policy would require attention to be placed on the provision of public infrastructure. Moreover, our results point out that different types of infrastructure tend to have a non-uniform impact on industrial activity. From that point of view, regional policies that focus on promoting public investment in certain types of infrastructure, such as national highways and electricity capacity, have resulted on average to more vivid economic activity in the manufacturing sector for the states included in our sample.

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Table 10: Appendix: Notation and Data Sources

Mnemonic	Description	Source
$CAPITAL_{i,t}$	Real capital stock in state i at time t	ASI
$Electricity_{i,t}$	Electricity generating capacity	ASI
$Factories_{i,t}$	Number of factories	ASI
$NHIGHWAY_{i,t}$	Width-adjusted length of national highways .	Indian Ministry of Transport
$OUTPUT_{i,t}$	Real output in registered manufacturing	ASI
$P_{i,t}$	Cost of living price index (state-wide)	Census of India
$POPULATION_{i,t}$	Population in state	Census of India
$SHIGHWAY_{i,t}$	Width-adjusted length of state highways in state	Indian Ministry of Transport
$Solow_{i,t}$	Constructed Solow residual	Constructed
$THIGHWAY_{i,t}$	Width-adjusted length of total highways	Indian Ministry of Transport
$URBANIZATION_{i,t}$	Proportion of the state population living in an urban centre	Census of India
$WAGES_{i,t}$	Real wages to workers, deflated by $P_{i,t}$	ASI
$WORKERS_{i,t}$	Total number of workers in registered manufacturing	ASI