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Astha Agarwalla[1]

Abstract

There does not seem to be a consensus on the importance of infrastructure investments in the process of economic development. With persistent regional disparities, and increasing regional identities, there is a need to determine the drivers of regional growth. Contribution of infrastructure to regional productivity growth is analyzed in this paper. Empirical analysis using data from 25 states in India for the past two decades suggests that composition of infrastructure investment is important in facilitating economic growth. Empirical results also highlight that investments in economic infrastructure have the closest linkage with regional productivity growth.

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Estimating the Contribution of Infrastructure in Regional Productivity Growth in India

1 Introduction

Infrastructure capital, apart from being a key consumption item for consumers, is consumed intermediately, by firms. Availability of these can expand the productive capacity of an area, both by increasing resources and by enhancing productivity of existing resources. That is why infrastructure investments have been widely used as instruments of regional development policies and programs.

There have been attempts in the literature to show the significant contribution of infrastructural capital, on national output, growth, productivity and interregional competitiveness. The response to these claims has been cautious. It has been argued that these contributions are overstated while ignoring other factors. That there also lies an inverse causality in the argument and that even if the historical relationships are estimated correctly; they provide no clear direction for future policy.

Present paper is not an attempt to answer all these criticisms. It is just an attempt to provide one more brush stroke to the emerging relationship of infrastructure availability and productivity growth. It does so by measuring the impact of availability of different type of infrastructural facilities on growth of total factor productivity in state economies in India. The paper consists of four parts. First part discusses the main findings in the present literature. Since there is no comprehensive measure of infrastructure availability at state level, the second section presents the construction of such data and describes the regional distribution of these facilities. Third section deals with generation of comprehensive measure of productivity in a growth accounting framework for state economies in India. Fourth section then uses these data to estimate the relationship empirically.

The conclusion is that infrastructure availability contributes significantly and positively to productivity growth. This evidence supports the results found in earlier studies. However, economic infrastructure (i.e. transport and power infrastructure in the present study) has a greater positive impact on productivity growth than social infrastructure (i.e. health and education).

2 Literature Review

Research on links between infrastructure and economic growth dates back to Hirschman (1958) on theories of unbalanced growth and other development theories regarding the role of economic and social overhead capital in national and regional development. Renewed interest over the past few years is based on numerous econometric studies where infrastructure enters as an input in aggregate production functions.

There has been a long-standing body of empirical work analyzing the interrelationship between infrastructure investments and economic development. There are a variety of methods used in the literature to study the relationship, including production function, cross country regressions, cost functions, and growth accounting. As for the dependent variable being explained, it is output, productivity, or regional inequality. The independent variables used, as a proxy for infrastructure is either some measure of public capital or a physical indicator (Straub, 2008).

The related literature is in three main strands: one directly estimating the impact of some measure of infrastructure on output. The other, estimating optimal stock of infrastructure and the third strand attempts to differentiate between permanent and transitory impacts of infrastructure services. We limit ourselves to the first kind of question in this present study, and therefore discuss only this strand of literature in detail here.

Mera (1975) made the pioneering effort to include public capital in a regression with output as the dependent variable, and private capital, labor and level of technology as the other independent variables. His work is regarded as a significant contribution, for drawing attention to the importance of public infrastructure. Successive efforts in this direction have suggested that the impact of public capital on output and productivity is very large. Munnell (1990) indicates for United States national economy that a 1 percent increase in the stock of public capital would increase output by 0.34 percent. Munnell (1992) in a similar exercise for state economies in United States found that public capital had a significant, positive impact on output, although the output elasticity was roughly one-half the size of the national estimate. Aschauer (1990) found an elasticity estimate of 0.39 for U.S.A. national data, whereas Duffy-Deno and Eberts (1989) studied the same relationship (however, using personal income as the dependent variable, and not output) at the metropolitan level, and found a much lower elasticity estimate of 0.08. Recent study by Hulten et al. (2006) uses a growth accounting framework to arrive at elasticity of total factor productivity with respect to expenditure on highways to be 0.04, and that with respect to electricity to be 0.02.

In Indian context, attempts have been sparse to study the link between infrastructure availability and economic development. However, the main problem encountered by all is availability of robust data. In absence of reliable data, most of the Indian studies have limited themselves to simple tools of analysis. Shah (1970) studies the pattern and level of infrastructural facilities inherited by India on her independence, and the trends during the first fifteen years. He also attempts to relate the level of per capita income of Indian states with their level of infrastructural development and suggests that a strong correlation exists between them. Tewari (1984) examines the interrelationship between economic infrastructure and development, and tries to identify the role of the former in the latter through analysis of state level data at two time points – 1970-71, and 1980-81. He obtains a significantly positive relationship between infrastructure and development, and especially economic infrastructure. Dadibhavi (1991) surveys levels of social infrastructure in the states of India over the period 1970-71 to 1984-85 using educational and health facilities as indicators. Therefore, although empirical studies in the Indian context indicate that infrastructure plays significant roles in shaping the development profile, scope of the studies have been limited with limited availability of data.

The present paper attempts to reexamine the issue in Indian context, within a growth accounting framework, and using panel data for a long time span of 27 years (1980-81 to 2006-07). Attempt here is to include all the state economies in the analysis, unlike earlier state level studies limited to analysis of only a few major state economies.

3 Data

We have used data for four main sectors of infrastructure services, namely, education, health, transport, and power. Many indicators are included in each sector to ensure better representation of different aspects of infrastructure provision and availability. Choice of sectors and indicators of infrastructure availability is highly driven by availability of state-level time series data. For education infrastructure, we have gathered data from publications of department of education, ministry of human resource development, Government of India. Health infrastructure data is obtained from publications of ministry of health and family planning, Government of India. Transport infrastructure statistics are gathered from various issues of Basic road statistics, ministry of surface transport, Government of India. Power-sector infrastructure data is obtained from ministry of power publications. Public infrastructure expenditure data are gathered from state governments' budgets through Reserve bank of India publications. Various issues of statistical abstract of India are used to supplement the data gathered from other sources. Utmost care has been taken in compiling state level time-series data. After cross checking from various sources, doubtful indicators are left out whenever discrepancies are found.

All indicators are then converted to relative measures, in order to facilitate comparisons across states. Population and area are used as two main parameters for conversion of data. A detailed discussion on trends in infrastructure availability across states, and over time is presented in the next section.

3.1 Trends in Infrastructure Availability

Present section provides a summary of these indicators across regions. We have divided India[2] in 6 regions[3] for the purpose of this comparative analysis. In theoretical literature on growth and economic development, infrastructure investments are associated with significant spillover externalities, with benefits accrue outside the target area of investment (Hulten et al, 2006). Therefore, in order to capture any spill-over externalities that might be arising, we present availability of infrastructure across regions.

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[2] At present, India consists of 29 states and 6 union territories. For the purpose of the analysis, we have left Delhi and the 6 union territories, as these are smaller geographical units and therefore do not represent a region. Among the remaining 28 states, 3 were formed in the year 2000, namely Uttaranchal, Jharkhand, and Chhattisgarh, carved out of Uttar Pradesh, Bihar and Madhya Pradesh respectively. We have combined the data for these states with their parent states for the analysis.

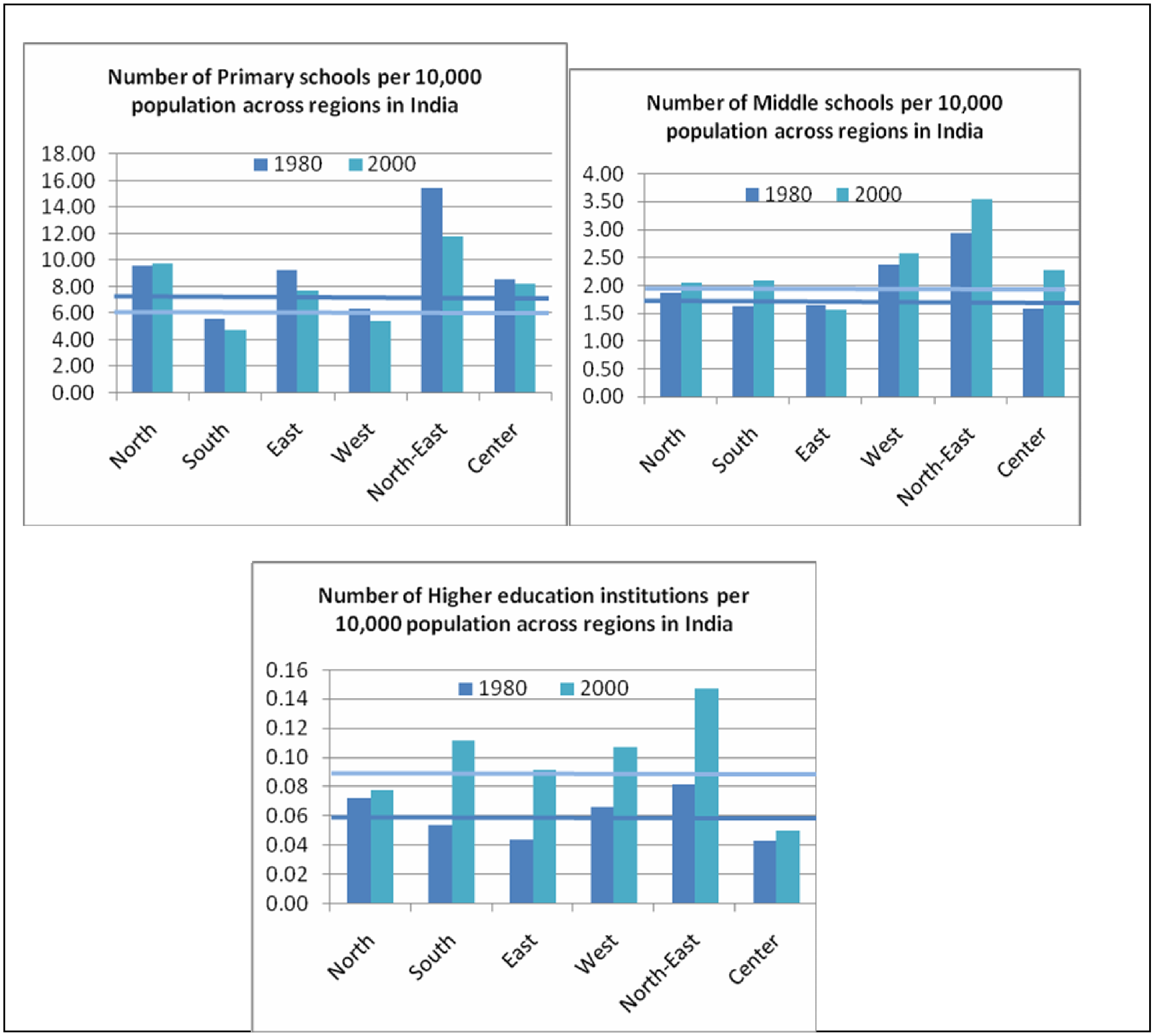
[3] Regions and constituent states as defined for this study are : (i) North – Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab; (ii) West – Goa, Gujarat, Maharashtra, Rajasthan; (iii) East – Bihar, Orissa, West Bengal; (iv) South – Andhra Pradesh, Karnataka, Kerala, Tamilnadu; (v) Centre – Madhya Pradesh, Uttar Pradesh; (vi) North-East – Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura.

3.1.1 Education infrastructure

The indicators used to access the availability of education infrastructure in India are number of primary schools, middle schools, and higher education institutions across states. These indicators are converted on per 10,000 population basis to facilitate comparisons among states.

Figure 3-1 shows the average values of education indicators across regions in India. Few interesting results emerge – North-eastern states perform better in all the indicators than others. Western states (Goa, Gujarat, Maharashtra, and Rajasthan) are next to follow. Number of primary schools per 10,000 people has gone down in the country as a whole, and across all the regions, which is a serious finding. Eastern states experience a dip in the number of primary as well as middle schools over the years. Southern states perform not so well in terms of primary and secondary education; however, these states have experienced significant growth in the number of higher education institutions over the years.

Figure 3-1: Education Infrastructure Indicators



3.1.2 Health Infrastructure

Physical indicators for the study are chosen based on data availability, and reliability. Indicators such as number of hospitals are ignored, because of differences in definition of a hospital across states, and data sources. We have chosen indicators, where state-wise time series data were available from the same source. Therefore, number of primary health centers (PHCs), health sub centers (HSCs), and registered medical practitioners (RMPs) are analyzed in the study.

Figure 3-2 below presents the average values for these indicators across regions in India, in years 1980-81 and 2000-2001. At all-India average level, the number of primary health centers has achieved a 2.5 times increase. Southern states have registered the highest increase in average number of PHCs. Northern states had the highest ratio of PHCs in the beginning of the period, however the region could not sustain this advantage, as the growth in the ratio is the lowest in northern region. Western India has the lowest ratio in the year 2000 among all the regions.

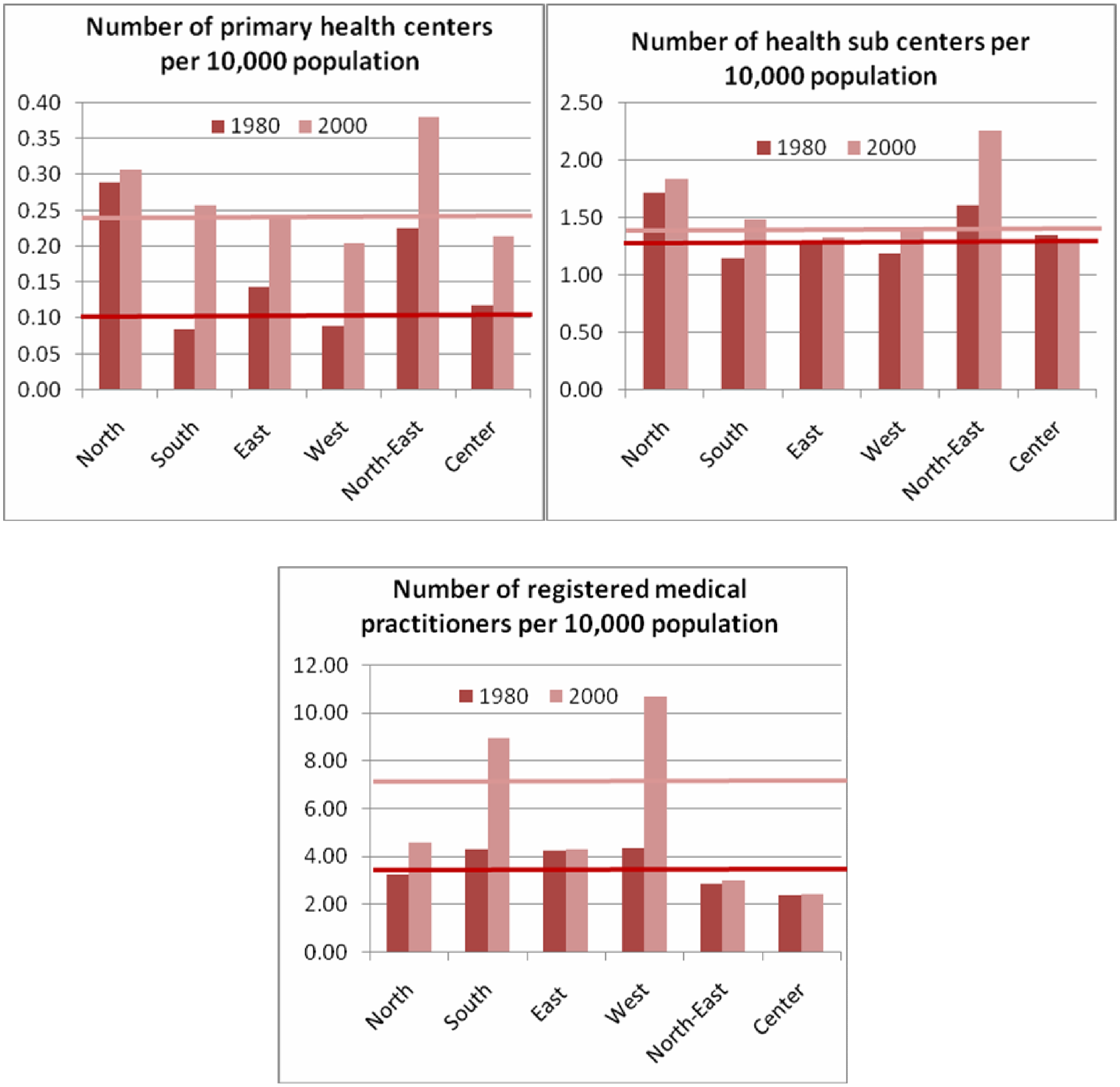
Growth in the numbers of HSCs in India is not remarkable, probably due to the fact that the numbers were high even in 1980-81[4]. By far, the highest increase in number of HSCs is experienced by the North-eastern region. Central region on the other hand, experienced a dip in the ratio over the years.

These two indicators represent reach of health facilities primarily to rural areas. There are serious issues raised by studies (Patel, 2005) related to quality of services provided by these centers. A discussion on these issues and adjusting these indicators for quality is desirable for more efficient measurement of infrastructure availability. However, this paper has more modest aim.

The third health infrastructure indicator used in the study is number of registered medical practitioners. This indicator represents availability of health services to rural as well as urban areas, and therefore is a better representative. Overall, the numbers are alarmingly low, in 1980-81, there were less than 4 RMPs per 10000 populations. This means that a large share of the population was dependent on illegal, non-professional health service providers. The number in the year 2000 is still below 8. However, states in Western and Southern parts of India have registered remarkable increase in the number of RMPs.

[4] As per Government directives, there need to be around 6 HSCs for 1, 00,000 population, which translates to 0.6 HSCs per 10,000 population, whereas the average all-India number is greater than one. (Source: India.gov.in; the national portal of India, accessed on 10.05.2011.

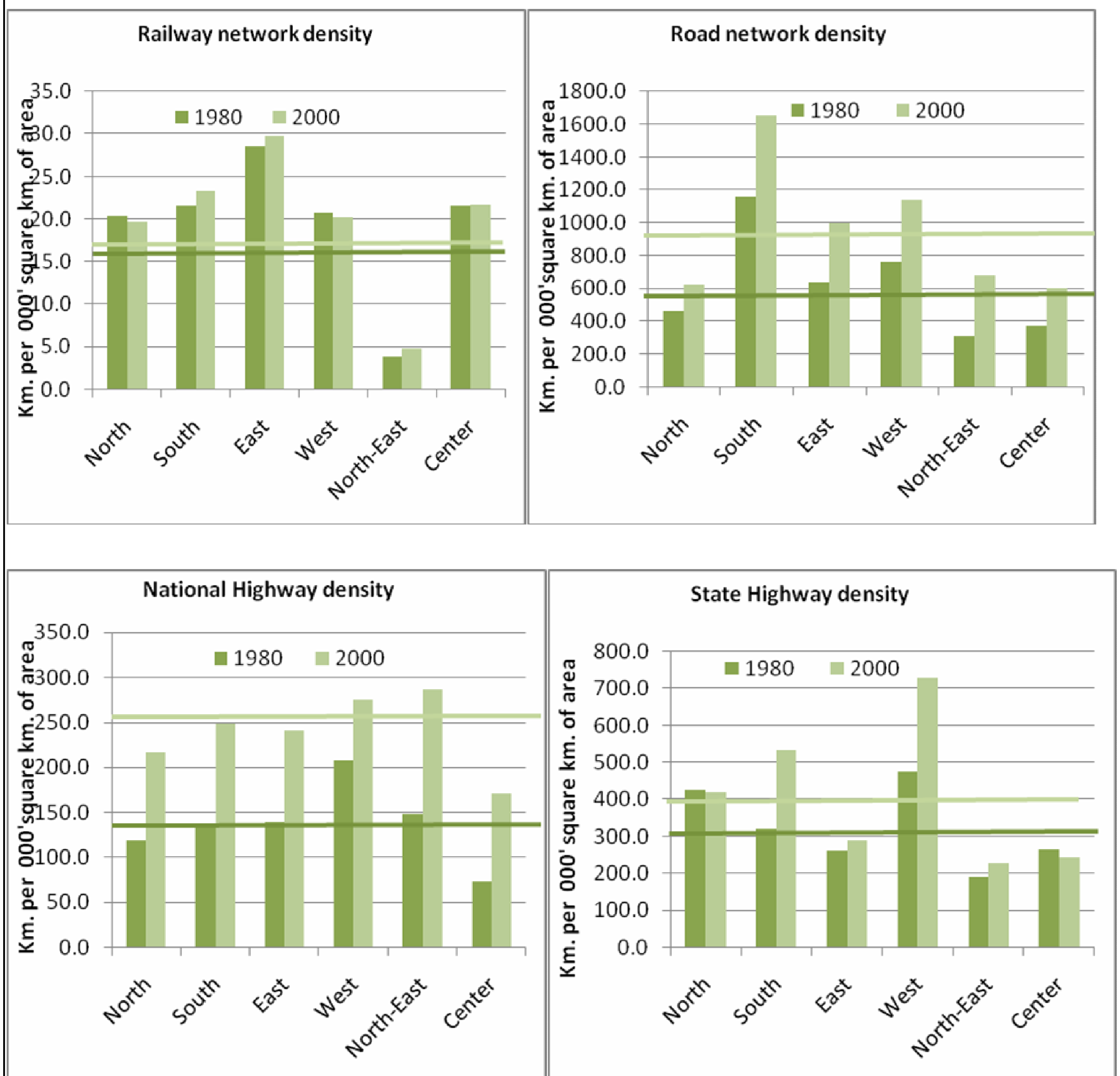
Figure 3-2: Health infrastructure availability indicators – summary across regions



3.1.3 Transport Infrastructure

Figure 3-3 below presents indicators of transport infrastructure availability across regions in India. Indicators used are railway network density[5], Road network density, length of national and state highways in the state.

Figure 3-3: Transport infrastructure availability indicators - regions-wise summary



[5] density is defined in kilometers, per 1000 square kilometers of area

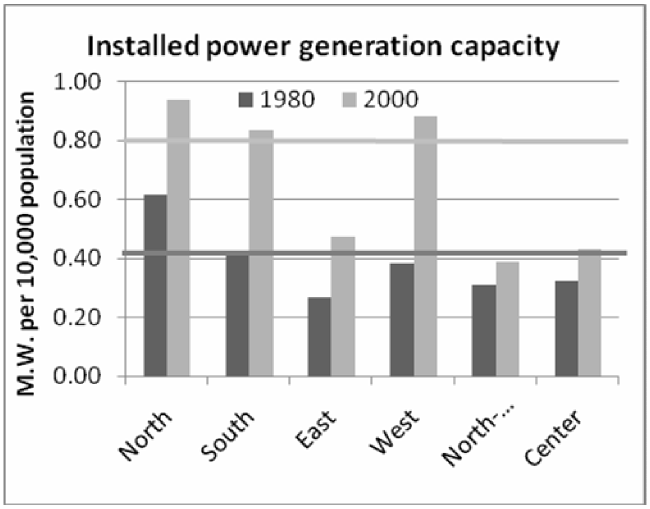
Figure 3-3 shows the averages across regions. It is clearly revealed by the figure that South and Western regions have the highest road density in India, and railway density is the highest in the eastern region. However, over the year, railway network density has not registered a significant growth, in spite of Railways being a governmental enterprise[6]. On the other hand, national highway density has increased significantly over the years. More important is the observation that national highway density is almost equal among regions, in spite of the fact that eastern and northern states have a difficult terrain. State highway density has achieved high growth in South and West regions. State highway density, among all indicators, shows the efforts by respective state governments in augmenting transport infrastructure. Southern states have achieved high economic growth, especially Tamilnadu and Karnataka. Similarly, western states of Gujarat and Goa have been high growth states.

3.1.4 Power Infrastructure

Figure 3-4 presents the averages of installed power generation capacity in M.W. per 10,000 people across regions. North, west, and southern regions have higher than average capacity, whereas east, center, and northeast lag behind. Western region has achieved highest growth over the years. However, it is surprising to note that in spite of having the largest share of country's natural resources, eastern, and central regions do not have high installed capacity.

[6] For West and Northern regions, railway network density has actually come down over the years. This is due to the conversion of meter gauge and narrow gauge lines to broad gauge. The route length taken into consideration here is total length, composition in terms of share of broad, meter and narrow gauge has changed over the years. In west, Gujarat and in north, Punjab, have shown a decrease in total route length, however broad gauge length has increased. With completion of conversion projects, railway network length will go up for all the states.

Figure 3-4: Power Infrastructure Indicators



Data for social and economic infrastructure in India clearly indicates towards the link between economic growth and availability of infrastructure. Further empirical analysis validates this hypothesis.

4 Infrastructure and total factor productivity growth

In this section, we attempt to analyze the contribution of infrastructure availability to output growth. Based on the endogenous growth theory, we measure the spillover externality generated by infrastructure availability, by measuring its contribution to total factor productivity growth.

In the growth accounting literature, any exogenous parameter leading to productivity enhancement, is measured as a part of the Hicksian efficiency term, which represents a shift in the production function (Mitra, 2000). We have attempted to measure the contribution of infrastructure availability to the total factor productivity in India. The analytical framework for the empirical estimation is presented below:

Let the production function for the regional economy be:

Equation 4-1

$$Q = A(X, t). F(K, L)$$

Where Q denotes gross output, X is a vector of Infrastructure services, K capital, and L labor input. The term A (X, t) is the standard Hicks-neutral efficiency function that allows for exogenous shift in production function. Contribution of Infrastructure to productivity will be manifested as an outward shift in the production function (Hulten et. al. 2006).

Assuming that the terms in the production function above are multiplicative:

Equation 4-2

$$Q_{i,t} = A_0 . e^{\sum_{k=1}^{p} \gamma_k X_{i,t,k}} . F(K_{i,t}, L_{i,t})$$

Where, subscript t denotes time, and i denotes region. The parameter A_0 indicates the initial level of productive efficiency; γ_k is the parameter of interest here, measuring the impact of infrastructure availability on productivity.

The Hicksian shift term, A (X, t) is measured in the growth accounting literature with the help of Solow model of residual total factor productivity growth. Total factor productivity is defined as the ratio of output to the direct inputs, used in the process of production (Hulten et.al. 2006). Therefore:

Equation 4-3

$$TP_{i,t} = Q_{i,t} / F(K_{i,t}, L_{i,t}) = A_0 . e^{\sum_{k=1}^{p} \gamma_k X_{i,t,k}}$$

Therefore, measurement of total factor productivity across regions, over time provides us with the required data and framework for the measurement of contribution of infrastructure to productivity.

4.1 Measuring Total Factor Productivity

We use the production function framework first, to measure the total factor productivity levels for the states over the years, and then to measure the elasticity of total factor productivity with respect to availability of infrastructure services.

The first step in estimating $TP_{i,t}$ follows Solow in measuring productivity as a residual output not attributable to the inputs of labor and capital. Analytically, the Solow residual is the growth rate of output less the growth rate of inputs weighted by their relative shares. This yields the expression:

Equation 4-4

$$\frac{\delta \ln TP}{\delta t} = \frac{\delta \ln Q}{\delta t} - \pi_k . \frac{\delta \ln K}{\delta t} - \pi_l . \frac{\delta \ln L}{\delta t}$$

π_k and π_l here represent share of factors capital and labor in income respectively. Each term on the right side of Equation 4-4 can be measured or imputed from published data, yielding an estimate of Total factor productivity growth that can in turn be used, in the context of Equation 4-3 to estimate the size of agglomeration economies.

The problem lies in the fact that in India, factor shares data at the state level is not available. For manufacturing sector alone, factor shares can be calculated with the help of Annual Survey of Industries Data, however, even it requires a lot of attention and care to derive those. For the purpose of this study, we have relied on the methodology suggested by Dholakia (1985). Details of the methodology are given in appendix 2.

Table 4-1: Average Annual Growth Rates - contribution of factors

	Output	**Labor**	**Capital**	**TFPG**
1980 - 2006	0.060	0.008	0.029	0.023
1980 - 1992	0.057	0.006	0.025	0.026
1993 - 2007	0.064	0.009	0.033	0.021
Average Annual Growth Rates - Percent contribution				
	Output	**Labor**	**Capital**	**TFPG**
1980 - 2006	100.00	13.07	47.46	39.47
1980 - 1992	100.00	10.60	46.06	43.34
1993 - 2007	100.00	15.19	48.65	36.15

Using the values of π_k and π_l as estimated in appendix 2, we proceeded to measure the total factor productivity growth (TFPG) for all the states, for all the years from 1980 to 2006. We used Equation 4-4 to arrive at the estimates of TFPG. We used net capital stock at real (1993-94) prices, and no. of workers employed as capital and labor variables in the Equation 4-4. Details of the measurement and estimation of these variables are discussed in appendix 3.

Table 4-1 gives the results of the estimation of TFPG, at the all-India level, for the period, 1980-2006, and the 2 sub-periods; 1980 to 1992, and 1993 to 2006. It is evident from the table that contribution of TFPG to growth has been sizeable, almost $1/3^{rd}$ of the total output growth. This gives us the scope to dissect the TFPG, and find out the contribution of infrastructure availability. However, these results must be cautiously interpreted, as there can be the effect of omitted inputs such as materials and infrastructure. Besides, the effects of quality of labor, human capital, education, health etc are not taken into consideration.

Further, we have estimated the level of total factor productivity, following the translog index procedure, developed by Jorgenston and Nishimizu (1978), and extended by Hulten et. al. (2006). This method computes total factor productivity in each state in some base year as the output of the state relative to the output of all-India, less the inputs in the state, relative to all-India, weighted by the relative cost shares:

Equation 4-5

$$\frac{\frac{\ln \frac{TP_i}{TP_n} = \ln \frac{Q_i}{Q_n} - \overline{\pi_k} \ln K_i}{K_n} - \overline{\pi_L} \ln L_i}{L_n}$$

Since total factor productivity is an index number, it must be normalized to the base value of some year and place (Hulten et al, 2006). We have assumed 1980 as the base year, and average level of total factor productivity across states is taken as the base value. Using these values, we have converted the total factor productivity values for all states in 1980 to indexed values. These values are then grown at the average annual growth rate of TFPG. These values are finally used as the left hand side variable in the Equation 4-3 to measure the parameters related to infrastructural availability.

4.2 Developing Infrastructure indices

Principal component analysis is used to develop indices of infrastructure availability and expenditure in order to avoid multi-collinearity. The analysis resulted in five distinct infrastructure indices, namely (i) Infrastructure expenditure (public) index, (ii) Education infrastructure availability index, (iii) Health infrastructure availability index, (iv) Transport infrastructure availability index, and (v) Power infrastructure availability index. A detailed list of variables[7] used to construct these indices is given in Appendix 1. These five indices are then combined with equal weights to construct an overall infrastructure index for each state in India[8].

4.3 Impact of Infrastructure availability on total factor productivity

After arriving at the estimates of TFP and infrastructure availability, we proceed to estimate the elasticity of output with respect to infrastructure availability parameters. The parameters of Equation 4-3 are estimated by regressing the annual estimates of total productivity levels by state; on each state's own infrastructure parameters, time, and a constant term.

Continuing from Equation 4-3, we take logs and write:

Equation 4-6

$$\ln TP_{i,t} = \ln A + \sum_{k=1}^{p} \gamma_k X_{i,t,k}$$

Or specifically –

Equation 4-7

$$\ln TP_{i,t} = \ln A + \gamma_1 InfraExp_{i,t} + \gamma_2 HealthInfra_{i,t} + \gamma_3 EduInfra_{i,t} + \gamma_4 TransInfra_{i,t} + \gamma_5 PowerInfra_{i,t} + E_{i,t}$$

Where $TP_{i,\,t}$ is the level of total factor productivity in state i, in year t. A is the initial level of productive efficiency, and $X_{i,\,t,\,k}$ are the infrastructure indices representing the availability of k^{th} infrastructural service, in state i, in year t.

Results of the analysis are given in Table 4-2.

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[7] Some of the variables presented in the previous section could not be included in the index, as the results of principal component analysis showed them to be not significantly represented by any of the above five factor indices. Forcefully including those could have resulted in indices, which would have been difficult to interpret. Therefore, we excluded number of registered medical practitioners, and length of state highways from this analysis.

[8] 3 states, Arunachal Pradesh, Goa, and Mizoram are not included in the principal component analysis, because these states obtained status of a 'state' only in the year 1985-86, from their earlier Union territory status. Public expenditure data for these states for the years before 1985-86 thus do not truly reflect state governments' investment decisions based on their ability, willingness, and need of infrastructural facilities.

Table 4-2: Results of panel data regression

S.N.	Dependent Variable: Total Factor Productivity	1980-2006		1980-1992	1992-2006
		I	II	III	IV
1	Intercept	0.342 *(0.018)**	0.339 *(0.018)**	0.199 *(0.026)**	0.444 *(0.022)**
2	Public Expenditure on Infrastructure		-0.004 *(0.007)*	0.018 *(0.007)***	0.001 *(0.015)*
3	Health Infrastructure Availability	0.061 *(0.007)**	0.058 *(0.008)**	0.049 *(0.010)**	-0.003 *(0.019)*
4	Education Infrastructure Availability	0.028 *(0.009)**	0.028 *(0.009)**	-0.005 *(0.026)*	0.045 *(0.007)**
5	Transport Infrastructure Availability	0.214 *(0.008)**	0.214 *(0.008)**	0.237 *(0.037)**	0.132 *(0.007)**
6	Power Infrastructure Availability	0.077 *(0.009)**	0.078 *(0.009)**	0.054 *(0.011)**	0.030 *(0.009)**
7	R square	0.8704	0.8705	0.8164	0.9383

Note: Standard errors are reported in the parentheses. *, **, *** represent significance at 1%, 5% and 10% levels of significance respectively

I have used two specifications to measure the elasticity of output with respect to different types of infrastructural facilities. In the first specification, we have not included public expenditure on infrastructure as an independent variable. While all the infrastructure indices turned out to be significant and positively related to total factor productivity, transport infrastructure availability has the highest coefficient, followed by power infrastructure. The impact of one unit increase in transport infrastructure availability is almost 24% increase in the index of total factor productivity. The same for power infrastructure is around 8%. What it points to is that economic infrastructure is more important for economic growth than social infrastructure. In the second specification, public expenditure index is included in the analysis, however, it turns out to be insignificant, and order of magnitude of other coefficients remains the same. Since public expenditure included in the analysis here is only revenue expenditure, its insignificance does not raise an alarm.

I have undertaken the analysis separately for years before 1992, when Indian economy embarked upon detailed structural reforms, embracing globalization, privatization, and liberalization as policy objectives. The results suggest that before the reform phase, the base level of total factor productivity was low, since the intercept term is the lowest for the period. Contribution of transport infrastructure is the highest, followed by power infrastructure. During this period, education infrastructure's impact on productivity growth comes out to be insignificant, and that of health infrastructure is lower than in the case of entire period.

Similarly, an analysis for after 1992 shows still the highest and significant contribution by transport sector, although the magnitude of the coefficient declines from earlier period. However, contribution of education sector becomes significant during this period, and follows transport infrastructure. Contribution of health infrastructure becomes insignificant, which might be due to the selection of moribund indicators, which primarily represent rural health care. Overall base level of total factor productivity improves significantly, indicating towards likely positive impact of reforms.

5 Conclusion

The present paper attempts at studying the interactions between regional development and infrastructure availability at state level for India. There exists substantial and significant positive association between levels of development and levels of infrastructure. The question of causation is important, and requires further enquiry. However, the association is clear, and higher for economic infrastructure than social. States with remarkable economic performance are also leaders in terms of availability of transport and power infrastructure. Social infrastructure does not directly appear as an important prerequisite of economic growth.

Applying growth accounting framework to measure the impact of infrastructure availability on total factor productivity provides justifiable results. Analysis of periods before and with reforms embraced in Indian economy, shows significant changes. Education infrastructure increasingly becomes important for productivity growth. Transport and power infrastructure are still significant contributors, but a decline in the magnitude of coefficients indicates towards their limiting role.

From the point of view of policy, results indicate underinvestment in the economic infrastructure sectors. Underdevelopment of eastern and central regions of the country can be associated with low growth in availability of economic infrastructure. Proactive efforts from state governments are required to raise the level of infrastructure availability, as is exhibited by states in South and West India. Railway infrastructure severely needs unbiased augmentation.

The inadequacy of data is fully acknowledged, and also the possibility of biases arising due to misspecification of model. The analysis is done at an aggregate level, which might cause aggregation bias as composition of sectors in states may change over time. Infrastructure services are lumpy networks of interlocked investments. Capacity augmentation often takes place before actual demand rises, and therefore there may be a divergence between stock of infrastructure and corresponding flow of output. There are omitted variables such as human capital, which are very important and highly correlated with productivity, and whose effect might be present in our estimates of infrastructure elasticity.

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Appendix 1: Infrastructure Indices

List of variables included in infrastructure indices

S.N.	Index	Variables included
1	Infrastructure expenditure index	• Per capita revenue expenditure on education (in Rs.) • Per capita revenue expenditure on health (in Rs.) • Per capita capital expenditure on health (in Rs.) • Per capita revenue expenditure on transport (and communication) (in Rs.) • Per capita revenue expenditure on energy (and water) (in Rs.)
2	Education Infra. availability index	• Number of primary schools per 10,000 population • Number of middle schools per 10,000 population • Number of higher education institutions per 10,000 population
3	Health Infra. availability index	• Number of Primary health centers per 10,000 population • Number of Health sub-centers per 10,000 population
4	Transport Infra. availability index	• Road length per 1000 sq. km. area (in km.) • Length of national highways per 1000 sq. km. area (in km.)
5	Power Infra. availability index	• Installed power generation capacity per 10,000 population (in MW)

Appendix 2: Measuring factor shares at the state level

Dholakia (1985) describes why it is different to apply the growth accounting framework to inter-region, within a country comparisons, as against the international comparisons, because in the former case, there is a common national market for factors of production. Especially, capital as a factor of production can be assumed perfectly mobile within a country. Therefore, it can be assumed that marginal product of capital remains uniform across states in India. Labor mobility however, is somewhat restricted by cultural and institutional barriers. As a result, wage rate vary significantly across regions, depending on average productivity of labor among other factors such as qualitative differences. However, several empirical studies have shown that average productivity of labor is an important determinant of wage rate. Dholakia (1985) has therefore assumed that marginal product of labor varies proportionately to average product of labor, an assumption, which leads to a constant labor share across states in India.

We have tested the assumptions above, with cross-section data for 25 Indian states included in the study, over the period 1980-81 to 2006-07. The preliminary test supported both the hypothesis for Indian data. Therefore we used the constant relative shares of labor and capital for our further analysis. Relative share of labor (β) is 0.4798, and relative share of capital is $(1 - \beta)$ 0.5202.

Appendix 3: Measurement of labor and capital inputs

State capital stock

State level data on capital employed in production is not available in public domain in India. Past studies have relied on individual scholars' efforts to estimate capital stock at the state level. From 1988, Central Statistical Organization (CSO) has started publishing capital stock data for the Indian economy as a whole at the sectoral level. First such estimates were provided in 1988, pertaining to the year 1981. We have made use of this all India data to come up with state level capital stock estimates across sectors. The crucial underlying assumption that we had to make is that the sectoral capital-output ratio remains the same for all the states in India in each year. We have tried to widen the sectoral classification as much as possible, in order to increase the representation of the true characteristics of the sector. However, we admit that it is a heroic assumption to make, and limits the accuracy and reliability of our results.

We have obtained net capital stock data from National Accounts Statistics published by CSO for the years 1980-2006, and converted it to 1993-94 prices. We then calculated the capital-output ratios (CORs) for all the sectors in all years for the Indian economy, using net domestic product data for the Indian economy in 1993-94 prices. We applied these sectoral CORs to state level net state domestic product data again at 1993-94 prices, to estimate the net capital stock data at state level in various sectors. The estimates thus obtained are used in the general production function estimation to estimate total factor productivity index. The sectoral classification used for estimating net capital stock is as follows: (1) Agriculture; (2) Forestry and Logging; (3) Fishing; (4) Mining and Querying; (5a) Manufacturing Registered; (5b) Manufacturing Unregistered; (6) Construction; (7) Electricity, Gas, and Water supply; (8a) Railways; (8b) Transport by other means; (8c) Storage; (8d) Communication; (9) Trade, hotels, and restaurants; (10) Banking and insurance; (11) Real estate, ownership of dwellings, and business services; (12) Public administration, and defense ; (13) Other services.

Labor input

Data for labor input at state level in India is available from two main sources, census studies, undertaken in every 10 years, and survey reports of National Sample Survey Organization

(NSSO). Generally, in growth accounting studies, labor input is measured as total man-hours worked, which is considered to be a more realistic and accurate measure than the number of workers employed. However, actual employment figures on an annual basis covering all sectors of the economy and number of hours or even days worked are not available in India, even at all-India level. Annual employment figures are published only for the organized sector; number of person-days worked is available only for manufacturing industries, only from the Annual Survey of Industries. As part of the NSSO surveys, average person-days employed data is available only for usually occupied workers, as per the data collected through the daily status approach. However, that data is also not reliable for generating an annual series, largely due to the presence of self employed and unpaid family workers in the Indian economy. Due to these limitations, in the present study, estimated number in the workforce is used as the measure of the quantity of labor input.

The data available from the two above-mentioned sources shows wide variations[9]. Three census results are available for the period of the current study, in 1981, 1991, and 2001. The definitions of main, marginal and non-workers were same across these censuses. However, in order to ensure the inclusion of unpaid family farm workers, the phrase "including unpaid work on farm or in family enterprise" were added from 1991 onwards (Sivasubramonian, 2004). There were differences in the geographical coverage also. Census 1981 was not conducted in Assam, and Jammu and Kashmir was not included in 1991.

Within the period of this study, five survey reports from NSSO are available, in the years 1983 (38^{th} round), 1987-88(43^{rd} round), 1993-94(50^{th} round), 1999-2000(55^{th} round), and 2005-06(62^{nd} round). Out of the three approaches used by NSSO for data collection, the usual status approach (or activities of the previous year) is considered as comparable to the census results (Sivasubramonian, 2004).

[9] For a detailed discussion on these differences, see Sivasubramonian (2004).

As per the analysis, done by Sivasubramonian (2004), worker population ratios as per the successive census results, show a declining trend in the years 1971, 1981, and 1991, and then return to the previous levels of 1961. These results do not match with the NSSO estimates, which are consistent with the 1961 census. Visaria (1996) has pointed out, "it hardly needs any persuasion to accept that the estimates of WPRs could not be fluctuating downwards in the Census years 1971, 1981, and 1991, and returning to the former level, comparable to the 1961 Census, whenever NSSO conducted its quinquennial surveys. There is little doubt that the NSS investigators have done better than more than million Census enumerators."

In view of this, the present study uses the NSSO estimates from the five quinquennial surveys. Based on these periodic estimates, using inter-period rates of growth, annual estimates of the number in the workforce have been obtained.

The age composition of the workforce could not be considered in the present study, due to inconsistency of the data availability across NSSO reports. The reports in 1983 and 1987-88 do not report the age-distribution of workforce at the state level.