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Impact of Infrastructure on Productivity: Case of Indian Registered Manufacturing

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Abstract

This study is primarily focused on the productivity impacts of the provision of infrastructure on the registered manufacturing sector in India. This is analyzed by estimating the cost elasticity of infrastructure inputs. For this purpose we postulate a variable cost function model for the manufacturing sector with cost as a function of the prices of the variable inputs, levels of output and infrastructure stocks. Variable inputs include capital, labour and intermediate input. Infrastructure is assumed to be a quasi-fixed input since its provision is done mainly by the public sector and it cannot be instantaneously adjusted in the short-run. The cost function model estimated consists of the variable translog cost function and the cost share equations for the variable inputs. We have used time series data and it pertains to the period 1965-1999. Twenty-three infrastructure variables are used in this study which, are aggregated using the principal component methodology. Three alternative specifications of the quasi-fixed inputs are explored. The alternatives are economic infrastructure, social infrastructure and aggregate infrastructure. Estimated results suggest that infrastructure provision enhances the productivity in the manufacturing sector and it helps to lower the costs in the sector. Apart from this it also has several bias effects with respect to the variable inputs.

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SECTION I : INTRODUCTION

As India has entered the new millennium after half a century of policy focussed on import substituting industrialization, the global trend towards greater liberalization and openness has forced the industrial sector to confront new standards of price and product competition.

By implementation of economic reforms in 1991, such as, deregulation of domestic industry, liberalizing rules for foreign investment and reducing tariff and non-tariff barriers on imports, government focussed on an outward looking development strategy. Apart from the focus on external sector, policy changes were also initiated in the industrial sector in July 1991, which may have contributed to restructuring and growth.

Manufacturing sector has witnessed an upward trend in growth rates in 90's. After being relatively sluggish in 1993-94, growth in industrial production reached about 12% in 1995-96 as compared to 5.5% in 1993-94. However the more recent performance of the economy in 1996-97 indicates a slowdown in industrial production and decline in the level of exports.

Since recovery in industrial growth has been an important factor behind the resumption of GDP growth, slowdown in industrial growth raised concerns about the feasibility of a high target for annual GDP growth.

The slowdown in industrial production and exports may indicate that Indian industry is being constrained both by capacity bottlenecks and by institutional obstacles. Capacity bottlenecks could arise form lacking core infrastructure. World Development Report (1994, 1996), Ahluwalia (1991), and others have identified infrastructure problems as a main factor threatening the sustainability of economic recovery. Such bottlenecks create significant impediments to the expansion of industrial output. They considerably weaken the supply-side response and the export capacity of the Indian industry. Moreover weak social infrastructure, leading to a lack of skilled labor may be another factor limiting growth and productivity for Indian manufacturing. Improving productivity in manufacturing is an important challenge in

India because without an adequate level of productivity, the country could remain a supplier of cheap-labor goods in global markets. This would hamper advances in living standards and could slow down progress in poverty alleviation. Moreover an adequate level of manufacturing productivity is needed both to attract foreign direct investment and to increase domestic investment so that industry may be developed in more backward areas. This will ensure a more balanced growth pattern in the economy.

Infrastructure is generally defined as the physical framework of facilities through which goods and services are provided to the public. Its linkages to the economy are multiple and complex, because it affects production and consumption directly, creates positive and negative spillover effects and involves large inflow of expenditure.

Infrastructure that makes more sense from an economics standpoint consists of large capital intensive natural monopolies such as highways, other transportation facilities, water and sewer lines and communications system. An alternative version that focuses on ownership defines infrastructure, as the tangible capital stock owned by the public sector.

World Development Report (1994) divides infrastructure stock into economic or physical infrastructure and social infrastructure. Former includes services such as electricity, transport, roads, water system, communications, irrigation etc, while latter includes education and health facilities. Other forms of infrastructure may be identified as institutional infrastructure as banking and civil administration.

Infrastructure provision is dominated by the public sector. Because infrastructure investments are lumpy, it is difficult for planners to match the availability of supply of infrastructure with demand at all times. Moreover they are usually non-rival and non-excludable in nature, which implies that consumption of a service by one consumer does not exclude other from consuming it and nor does this consumption invokes rivalry on the basis of purchasing power or any other feature. The consumers do not voluntarily pay for these services and these necessarily become an “unpaid input”. However government steps in and provides these services through the budget. But quite recently it is argued that government investment in infrastructure has been inadequate, uncertain and inefficient and hence commercialization of infrastructure is important for developing economies to compete with the developed world.

Nevertheless, infrastructure provision enhances the production and distribution network of key sectors in the economy and promotes overall economic growth. In the process they also tend to affect the cost structure and productivity in these sectors, thereby promoting growth and development in each of these sectors.

Substantial research on interrelationships and dynamics of production and infrastructure in national and regional economies has been made. Most of this research is based on neo-classical production function making use of Cobb-Douglas and Constant Elasticity of Substitution (CES) production functions.

A substantial number of studies have also utilized cost function specifications to measure productivity effects of total or specific infrastructure capital on industry and output growth. These approaches come under the econometric modeling methods of measuring productivity growth at firm, industry and aggregate economy level.

Aschauer (1989) who examined the relationship between infrastructure and aggregate productivity in the U.S. economy initiated the interest in the key aspects of infrastructure development. Following this many studies have been undertaken which either used the production function or the cost function specification to study this relationship. Some of the important and the recent studies are by Munnel (1992), Holtz-Eakin (1994), Holtz-Eakin and Schwartz (1995), Shah (1992), Canning (1993), Nadiri and Mamuneas (1994) etc.

Studies for the Indian economy concentrate upon the link of infrastructure with economic growth and the performance of infrastructure at the national and the state level. The studies also point out the inter-state disparities in infrastructure in India. Some of the important studies are Joshi (1990), Ahulwalia (1991, 1995), Anant et. Al (1994, 1999), Mitra et. Al (1998), Das & Barua (1998) et.

However there has been an absence of studies for India, which explore a quantitative link between productivity and infrastructure in India, with special reference to industrial productivity. Elhance and Lakshmanan (1988) make an attempt in this direction but they follow a complicated methodology of dynamic adjustment of infrastructure towards the equilibrium level.

Following Nadiri and Mamuneas (1994), this paper tries to assess the impact of infrastructure provision on the productivity of organized manufacturing sector in India. It makes use of the data for the period 1965-66 to 1998-99.

In order to carry out this analysis, this study makes use of twenty-three infrastructure variables and develops composite indicators of infrastructure using Principal component analysis. These infrastructure indices are grouped into two broad categories:

1.) ***Economic infrastructure***
2.) ***Social infrastructure***

Economic infrastructure includes five sectors namely electricity, banking, irrigation, transport and communications. Social infrastructure includes two sectors education and health. Both economic and social infrastructure indices are combined to construct an aggregate index of infrastructure.

By using the Principal Component methodology of aggregation of infrastructure we calculate the weights of individual components of infrastructures in each of the sectors such as electricity, banking, transport, communications etc.

Following Nadiri and Mamuneas (1994), we postulate a variable cost function model for the manufacturing sector with cost as a function of the prices of the variable inputs, levels of output and infrastructure stocks. Infrastructure is assumed to be a quasi-fixed input since its provision is done mainly by the public sector and it cannot be instantaneously adjusted in the short-run. The cost function model estimated consists of the variable translog cost function and the cost share equations for the variable inputs. Three alternative specifications of the quasi-fixed inputs are explored. The alternatives are economic infrastructure, social infrastructure and aggregate infrastructure. Aggregate infrastructure is an aggregate of economic infrastructure and social infrastructure.

Impact of infrastructure on the productivity of manufacturing sector in India is analysed by calculating the cost elasticity with respect to infrastructure inputs. In addition we also calculate the factor bias effect and the total effect of infrastructure inputs.

This paper is organised as follows:

Section II discusses the principal component methodology. Section III provides a survey of literature of infrastructure and productivity in countries other than India and the Indian economy. Methodology to study the impact of infrastructure on productivity is presented in section IV. Section V outlines the definitions of the variables used in the study and their data sources. Productivity effects of infrastructure are discussed in section VI. Finally section VII consolidates the main findings of the study.

SECTION II : PRINCIPAL COMPONENT ANALYSIS

This section deals with the construction and analysis of the principal components of the twenty-three infrastructure variables included in the study.

In order to study the interlinkages between infrastructure and productivity in the manufacturing sector, this study makes use of twenty-three infrastructure variables. Each infrastructure variable was first standardized with the help of a suitable deflator. In some cases the choice of the deflator was governed by natural deflators such as number of villages where such natural deflators were not available we have used either population or geographical area as deflators. The choice is based on the consideration that both distance and congestion are access costs. (Anant, Krishna and Choudhury (1994))

Principal Component Analysis follows from the fact that every set of correlated variables can be replaced by a set of uncorrelated variables. These new variables are obtained as linear combinations of original variables. They are referred to as principal components of the given set of variables. Since the number of variables is large in relation to the number of observations at our disposal and to reduce dimensionality, we develop composite infrastructure indicators using Principal Component Analysis. The analysis is based on the correlation matrix rather than the covariance matrix.

DERIVATION AND INTERPRETATION OF THE FIRST PRINCIPAL COMPONENT

Principal component (PC) analysis is concerned with explaining the variance-covariance structure through a few linear combinations of the original variables. Although as many components as the number of original variables are required to produce the total system variability, often much of this variability can be explained by a much smaller number of principal components say k. The k PC's can then replace the initial p variables and the original data set consisting of n measurements on p variables is reduced to one consisting of n measurements on k PC's, where k is considerably smaller than p.

Principal components are particular linear combinations of p random variables $X_1, X_2, \ldots, X_p$. Geometrically, these linear combinations represent the selection of a new coordinate system by rotating the original system with $X_1, X_2, \ldots, X_p$ as the coordinate axes.

As discussed by Anant, Krishna and Choudhary (1994), suppose that the vector of random variables $X = (X_1, X_2, \ldots, X_p)$ of interest have a certain multivariate distribution with mean vector μ and covariance matrix Σ. From the population a sample of n independent observation vectors has been drawn. The observations can be represented as X_{ij} where $i = 1,2,\ldots n$ and $j = 1,2, \ldots p$.

Let $Z_{ij} = X_{ij} - \overline{X_j} / S_j$

Where i = 1,2….,n and j= 1,2,…p be the standardized score where $\overline{X_j}$ and S_j are the sample mean and standard deviation respectively for variable j. Let R be the p×p sample correlation matrix.

The first principal component of the variables X_j is that linear compound

$$Y_1 = a_{11}Z_1 + a_{21}Z_2 + ... + a_{p1}Z_p$$
$$= a_1' Z$$

Of the standardized variables (Z_j) whose sample variance

$$\mathrm{Var}(Y) = \sum\sum a_{ij} a_{ji} r_{ij}$$
$$= a_1' R a_1$$

is greatest for all coefficient vectors a_1 normalized so that $a_1'a_1=1$.

Constrained maximisation implies the p simultaneous linear equations $(R-l_1I)=0$, where $l_1$is langrangean multiplier.

The value of l_1 must be chosen so that $|R- l_1I|=0$

l_1 is thus a characteristic root of the correlation matrix R and a_1 is the associated characteristic (eigen) vector. Given that $a_1'a_1=1$, it follows that

$$l = a_1'R a_1$$
$$= \mathrm{Var}(Y_1)$$

Since Var (Y_1) is being maximised, l_1 must be the largest characteristic root of R.

The a's called loadings are chosen so that:

The PC's are uncorrelated (orthogonal)

The first PC absorbs and accounts for the maximum possible proportion of the total variation in the set of all X's, the second PC absorbs the maximum of the remaining variation in X's and so on.

The ratio $l_1\backslash p$ measures the proportion of the total "variance" in the p variables X= (X1, X2, ….,Xp) attributable to the first principal component (Y_1).

The algebraic sign and magnitude of a_{i1} indicates the direction and importance of the contribution of X_i to the first principal component Y_1. $a_{11}\sqrt{\ } l_1$ is the correlation between X_i and Y_1.

OTHER PRINCIPAL COMPONENTS

Second, third etc. principal components can also be constructed. The process can be summarised in the following definition:

$$Y_j = a_{ij} Z_1 + \dots\dots\dots\dots + a_{pj} Z_p$$

The coefficients a's of the second principal component are the elements of the characteristic vector of the sample covariance matrix R corresponding to the j^{th} largest characteristic root l_j. The importance of the j^{th} component in a more parsimonious description of the data is measured by $l_j \backslash p$. a_j is the eigen vector corresponding to l_j. The sign and magnitude of a_{ij} indicate the direction and importance of the i^{th} variable (x_i) to the j^{th} component.

In this paper, we first compute the sectoral indices which are combined into an economic infrastructure index, social infrastructure index and finally into an aggregate infrastructure index. Various components of economic and social infrastructure and the weights used are shown in table 2.1.

The table suggests that economic infrastructure enters the aggregate infrastructure index with a weight of 70% and social infrastructure with a weight of 30%. In the aggregate index irrigation and banking infrastructures have low weights of 5% and 7% respectively. The weights of electricity infrastructure and communications infrastructure are 12% and 19% respectively. Transport infrastructure accounts for the largest share of 27%. Within social infrastructure, education and health account for 12% and 18% weight respectively in the aggregate index.

TABLE 2.1: WEIGHTS USED IN INFRASTRUCTURE INDICES

SUB SECTORS OF INFRASTRUCTURE	WEIGHTS	
ECONOMIC INFRASTRUCTURE	0.70	
IRRIGATION	0.05	
Net irrigated area as % of net sown area		
BANKING	0.07	
Commercial bank offices per 1000 sq. km of area	0.41	
Co-operative bank offices per 1000 sq. km of the area	0.59	
COMMUNICATION	0.12	
Telephones per 100,000 population	0.62	
Post offices per 100,000 population	0.38	
ELECTRICITY	0.19	
Installed capacity per capita	0.24	
Transmission and distribution lines per unit area	0.26	
Consumption of electricity per capita	0.20	
% of villages electrified to total villages	0.29	
TRANSPORT	0.27	
Total road length per 1000 sq. km of area	0.20	
Surfaced road length per 1000 sq. km of area	0.21	
Registered vehicles per unit area	0.23	
Rail route length per 1000 sq. km of area	0.16	
Number of ships	0.16	
Gross registered tonnage per lakh of population	0.04	
SOCIAL INFRASTRUCTURE	0.30	
EDUCATION	0.12	
Teacher pupil ratio in primary schools	0.22	
Primary schools per 1000 sq. km of area	0.49	
All educational institutions per 1000 sq. km of area	0.29	
HEALTH	0.18	
Hospitals per 1000 sq. km of area	0.19	
Beds per 100, 000 population	0.09	
Doctors per 100, 000 population	0.14	
Infant mortality rate	0.58	

SECTION III : REVIEW OF LITERATURE : IMPACT OF INFRASTRUCTURE ON PRODUCTIVITY

In this section we attempt a review of the studies dealing with the productivity impact of infrastructure and of the studies, which link infrastructure to economic growth with the help of review conducted by Anant et Al (2000). Most of the studies have estimated production functions and the elasticity estimates derived from these ascertain the impact. Some recent studies have used the cost function approach to analyse whether the provision of infrastructure helps in reducing the costs in industrial sector or not.

The growing interest in infrastructure was triggered by Aschauer (1989a) who has considered the relationship between aggregate productivity and stock and flow of government spending variables in the US economy for the period 1949-85. He estimates a general Cobb-Douglas production function and treated government spending on public capital as one of the input in the production function. Estimation has been done using OLS and from this equation, productivity estimates are also derived. His results suggest that there is a strong positive relationship between output per unit of capital input, the private labour capital ratio and the ratio of the public capital stock to the private capital stock.

Aschauer (1989b) focuses on the question that does higher public capital accumulation ‘crowd out’ private investment? He argues that higher public capital accumulation raises the national investment rate above the level chosen by rational agents and induces an ex-ante crowding out of private investment. An increase in public capital stock also raises the return to private capital, which crowds in private capital accumulation. He carries out the empirical analysis for the U.S. economy and the results suggest that private capital accumulation respond positively to an increase in the rate of return to capital.

Munnell (1992) points out that the implied impact of public infrastructure investment on private sector output is too large to be credible. He looked at the relationship between public capital and measures of economic activity at the state level for U.S. economy. He found that public capital had a significant positive impact on output, although the output elasticity was one-half the size of national estimate. Public capital enhances the productivity of private capital, raising its rate of return and encouraging more investment. But on the other hand, from an investor’s perspective public capital acts as a substitute for private capital and “crowds out” private investment.

Holtz-Eakin and Schwartz (1995) attempt to assess the empirical contribution of infrastructure capital to productivity using an explicit model of economic growth and a panel of state level data for forty eight contiguous states in the U.S. economy for the period 1971-1986. Structural form of the model used for the analysis is:

$$Y_t = K_t^{\alpha} G_t^{\beta} (\psi_t L_t)^{1-\alpha-\beta}$$

$where\ \mathrm{Y_t} = \text{total output}$

$K_t = \text{private capital}$

$L = \text{physical quantity of labour}$

$\psi_{\mathrm{t}} = \text{index of technical efficiency}$

$\mathrm{t} = \text{time period}$

ψ_t is assumed to grow at a constant rate of λ. Empirical results of the study do not imply an important quantitative role for public infrastructure in explaining the growth pattern of states. The authors conclude that the link between infrastructure and productivity growth remains controversial.

Lynde and Richmond (1992) also analyse the impact of the stock of public capital on costs of production in the private sector using annual data for US non-financial corporate sector over the period 1958-1989. They estimate a translog cost function and found public capital to be a significant input. This also implies that public capital has an important role to play in the productivity of the private sector.

Lynde and Richmond (1993) present evidence which shows that stock of public capital has played a significant role in production in the manufacturing sector of the U.K. economy.

Shah (1992) has utilized a restricted equilibrium framework to analyse the contribution of public investment in infrastructure to private sector profitability. A restricted cost function in translog form is estimated, which treats labour and materials as variable inputs and private capital and public sector as quasi-fixed inputs. A system of non-linear equations comprising of variable cost function and derived input demand equations is estimated using data from 1970-1987 for twenty-six Mexican three-digit industries. Empirical results suggest that Mexican industrial structure has increasing returns to scale, short-run deficient capital capacity and declining productivity growth. Results indicate that public infrastructure has a weak complimentarity with infrastructure in both short and long run with degree of complimentarity being higher in short run as compared to the long run. Public infrastructure is observed to have a small but positive effect on output.

Teresa Garcia and McGuire (1992) investigate the productive contribution of publicly provided goods and services in the US economy. They specify a long run production function that relates a measure of aggregate output to a set of publicly provided inputs and aggregate of private inputs. Their results suggest that both highways and education are productive inputs with latter having a stronger impact on output.

Canning (1993) which, is an outcome of a World Bank funded research project on infrastructure and growth describes an annual database of physical infrastructure stocks constructed for 152 countries for the period 1950-95. This paper presents correlation of infrastructure levels in 1985, regression of infrastructure on urbanization and log of population, GDP per capita, area for the year 1985. GDP growth regression indicate that the number of telephone main lines per capita has a significant effect on subsequent growth rates of GDP per capita but that the other infrastructure variables do not have.

Mas et al. (1996) reports the regional dimension and temporal dimension of the impact of public capital on productivity gains. Using data for Spanish regions over the period 1964-91, it estimates cobb-douglas type production function by means of panel data techniques to control for unobserved state- specific characteristics. This paper concludes that economic infrastructure has a significant positive effect on productivity, but social infrastructure does not. There are spillover effects associated with public infrastructure and the effect of public capital on productivity has tended to decline over time.

Nadiri and Mamuneas (1994) have examined the effects of publicly financed infrastructure and R&D capitals on the cost structure and productivity performance of twelve two-digit US manufacturing industries. The result suggests that there are significant productive effects from these two types of capital as shown by cost elasticity estimates which ranges from 0.02 to –0.21 for infrastructure and –0.04 to –

0.01 for R&D capital. Their effects on the cost structure vary across industries. Not only is the cost function shifted downward in each industry, generating productive effects but factor demand in each industry is also affected by two types of public capital suggesting bias effect.

Demetriades and Mamuneas (2000) utilise an intertemporal optimisation framework to study the effects of public infrastructure capital on output supply and input demands in twelve OECD countries. They find that in all the twelve countries, public capital has positive long run effects on both output supply and input demands and infrastructure has been sub-optimally provided in most countries examined. Both in the short-run and long run private capital was found to be more productive than the public capital.

There are a considerable number of studies that have been conducted for the Indian economy regarding the impact of infrastructural development on overall economic growth.

Joshi (1990) provides a comprehensive account of the development of infrastructure in India. He shows that interstate disparities in level of development did not decline between 1960-61 and 1985-86. Joshi finds a clear and strong association between the level of infrastructure and the level of development.

Ahluwalia (1991) has cited infrastructure as an important factor in explaining the variations in Indian manufacturing. According to her, public investment in India has not only been a major instrument for generating demand for capital goods but its crucial importance arises from the fact that it has exclusive responsibility for the development of infrastructure.

Anant et. Al (1994) has constructed indices of infrastructure availability for twenty-five Indian states for the year 1985-90. They consider twenty-four infrastructure variables classified into eight sectors namely, agriculture, banking, electricity, communications, transport, education, health and civil-administration. The first five sectors constitute economic infrastructure and the next two constitute social infrastructure, which have been aggregated using principal component analysis.

The indices show that interstate variability in social infrastructure exceeds that in economic infrastructure.

Mitra et. Al (1998) has used annual data for the period 1976-1992 for seventeen industries in fifteen Indian states. Their estimates are based on a conditional convergence equation in which the long run equilibrium productivity level of each state is supposed to depend on the level of infrastructure that this state possesses. Using long-run elasticities, they conclude that social infrastructure measured by education and health shows greatest impact on total factor productivity in Indian manufacturing.

Ghosh and De (1998) study the impact of public investment and physical infrastructure on regional economic development in Indian states over the plan period using OLS regression. The results indicate that regional disparity has been rising in the recent period and plan outlay has not played a major role in this context.

Elhance and Lakshmanan (1988) treat infrastructure inputs as quasi-fixed in the short run and derives a multi-equation econometric model of production-infrastructure linkages and adjustments based on a flexible functional form. Model is estimated with regional and national data from India over the period 1950-51 to 1978-79. Empirical results suggest that model estimated for nation does not have a high R^2 and parameters are found to be statistically insignificant at 10% level of significance.

Lall (1999) attempts to test the efficiency of public infrastructure investments in development pattern of Indian states. He uses data for fifteen Indian states and fits a Cobb-Douglas production function separately with labour, private capital, economic infrastructure and social infrastructure as inputs to panel data sets for lagging states, intermediate states and leading states. Results suggest that social infrastructure has a positive and significant impact on output while economic infrastructure does not. However these results seem implausible in the light of other studies.

Krishna Rao Akkina (1999) tests various propositions of the neo-classical growth model of Solow and Swan to ascertain the role of infrastructure and power shortages on the rate of growth of per capita income using cross-section data on

Indian states for the period 1970-90. Results confirm that absolute convergence of per capita income across states is not consistent, while conditional convergence hypothesis is consistent.

Unni et. Al (2001) analyses the trends in growth and efficiency in the utilisation of resources in the Indian manufacturing industry before and after the introduction of economic reforms. It uses a comparative analysis of all-India figures with Gujarat, one of the most industrially developed states of the country. The study shows that both the organised and unorganised sectors in Gujarat seemed to be doing better than the all-India average in terms of growth of value added. Gujarat's strategy of physical infrastructure development, leading to industrialisation, has been the main reason for the growth of the state's manufacturing sector.

Abusaleh Shariff, Prabir Ghosh, S K Mondal (2002) presents trends in public expenditure on social sector and poverty alleviation programs from 1990-91. A considerable proportion of these expenditures is undertaken by the states but the central share seems to be increasing over time. The state governments seem to be easing out of their constitutional commitment to sustain programs in the social sectors, which is a matter of concern. One major development has been that large funds that were allocated to employment generation have now been diverted to the rural road construction program implying serious considerations for employment generation.

Murali Patibandla, B V Phani (2002) brings out the factors that determine micro level firm level productivity in the context of a developing economy that had undertaken policy reforms towards a freer market. It econometrically tests a few hypothesis on the basis of firm level panel data for a set of Indian industries. Results suggest that firm level outward orientation of exports and imports contribute significantly and positively to firm level productivity. This finding supports one of the propositions of the new growth theory that developing economies benefit significantly from free trade with developed economies through free flow of new ideas and technologies and externalities.

In this paper we attempt to study the linkages between infrastructure and productivity for the registered manufacturing sector in India for the period 1965-66 to 1998-99

SECTION-IV : METHODOLOGY FOR THE PRESENT EXERCISE

In this section we present the econometric methodology for analysing the impact of infrastructure on productivity. Following Nadiri and Mamuneas (1994) we make use of a multi-equation framework. This comprises of a variable cost function and the corresponding share equations for variable inputs. This system of equations helps us in estimating the spillover effects of infrastructure on the industrial sector.

For this study we specify a functional form of the cost function and derive the productivity effects of infrastructure. Let C=C (P_K, P_L, P_I, S_k, Y) be the cost function.

Thus cost is assumed to be a function of prices of three variable inputs, capital (K), labour (L) and intermediate inputs (I), and the quantity of quasi-fixed input(s), that is the infrastructure input(s) (S_k), and output (Y).

Motive behind using infrastructure as a quasi-fixed input is that since these are public goods and are provided mostly by the government, there might be time lag involved in their provision and their use by the manufacturing sector. Industrial sector cannot make instantaneous adjustments to the requirements of infrastructure inputs and thus there are implications for the productivity of this sector.

The Translog variable cost function with infrastructure stock assumed as quasi-fixed input, used for estimation is as follows:

$$\ln \mathrm{VC} = \alpha_0 + \sum_i \alpha_i \ln \mathrm{p_i} + \alpha_y \ln y + \sum_k \alpha_k \ln S_k + \frac{1}{2}\sum_i \sum_i \beta_{ii} (\ln p_i)^2 \frac{1}{2}\sum_k \sum_k \beta_{kk} (\ln S_K)^2 + \frac{1}{2}\beta_{yy} (\ln y)^2 +$$
$$\sum_i \sum_j \beta_{ij} \ln p_i \ln p_j + \sum_k \sum_l \beta_{kl} \ln S_k \ln S_l + \sum_i \sum_k \beta_{ik} \ln p_i \ln S_k + \sum_i \beta_{iy} \ln p_i \ln y + \sum_k \beta_{ky} \ln S_k \ln y \quad (1)$$

where VC= P_L*L+P_K*K+P_I*I

i. j= variable inputs (K, L, I)

k, l= fixed inputs (S_1, S_2) or S_3 or S_4

y= level of output

Applying the symmetry restrictions and homogeneity of degree one in input prices, that is, dividing the prices of capital and labour input by price of intermediate input and dropping the share equation with respect to the intermediate input. Share equations are obtained by applying the Shepherd’s lemma. After imposing the restrictions the variable cost function becomes:

$$\ln \mathrm{VC} = \alpha_0 + \sum_i \alpha_i \ln\left(\mathrm{p_i}/\mathrm{p_I}\right) + \alpha_y \ln y + \sum_k \alpha_k \ln S_k + \frac{1}{2}\sum_i\sum_i \beta_{ii}\left[\ln\left(p_i/p_I\right)\right]^2 \frac{1}{2}\sum_k\sum_k \beta_{kk}(\ln S_K)^2 + \frac{1}{2}\beta_{yy}(\ln y)^2 +$$
$$\beta_{KL}\ln\left(p_K/p_I\right)\ln\left(p_L/p_I\right) + \sum_k\sum_l \beta_{kl}\ln S_k \ln S_l + \sum_i\sum_k \beta_{ik}\ln\left(p_i/p_I\right)\ln S_k + \sum_i \beta_{iy}\ln\left(p_i/p_I\right)\ln y + \sum_k \beta_{ky}\ln S_k \ln y \quad (2)$$

Shepherd’s lemma implies that if we differentiate the cost function with respect to prices of inputs used in the production, then we obtain the input demand function. After applying Shepherd’s lemma we get:

$$S_1 = \frac{\partial \ln C}{\partial \ln p_1} = \alpha_1 + \beta_{11}\ln p_1 + \beta_{12}\ln p_2 + \ldots\ldots. + \beta_{1m}\ln p_m + \beta_{1k}\ln S_k + \beta_y \ln Y$$
$$S_2 = \frac{\partial \ln C}{\partial \ln p_2} = \alpha_2 + \beta_{12}\ln p_1 + \beta_{22}\ln p_2 + \ldots\ldots. + \beta_{2m}\ln p_m + \beta_{2k}\ln S_k + \beta_y \ln Y$$

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$$S_m = \frac{\partial \ln C}{\partial \ln p_m} = \alpha_m + \beta_{1m}\ln p_1 + \beta_{2m}\ln p_2 + \ldots\ldots. + \beta_{mm}\ln p_m + \beta_{mk}\ln S_k + \beta_y \ln Y$$

The cost shares must sum to one, which requires in addition to the symmetry restrictions that:

$$\beta_1 + \beta_2 + \ldots\ldots. + \beta_m = 1$$

$$\sum_m \beta_{mn} = 0 \qquad \text{(column sums equal zero)} \qquad 4)$$

$$\sum_{\mathrm{n}} \beta_{\mathrm{mn}} = 0 \qquad \text{(row sums equal zero)}$$

If we estimate, translog cost function on its own, it is likely that parameter estimates will not be efficient due to multicollinearity. To avoid this problem, cost function is estimated jointly with the cost share equations for each variable input. The cost function and the set of share equations provide a Seemingly Unrelated Regressions (SURE) model. To make this model operational, we must impose the symmetry restrictions in 3) and solve the problem of singularity of the disturbance covariance-matrix of the share equations. The first is accomplished by dividing the first M-1 prices by the price of M$^{\text{th}}$ input and we obtain a non-singular system by dropping the share equation corresponding to the M$^{\text{th}}$ input.

Including the cost share equations in the estimation procedure has the effect of adding many additional degrees of freedom without adding any additional parameters. The system can be estimated by maximum likelihood technique. The disturbances of the cost function and share equations are presumed to be inter-temporally independent, multivariate normal with zero mean and non-zero contemporaneous covariances. It has been shown that maximum likelihood estimates of a system of equations with one equation deleted are invariant to which equation is dropped (Greene (1993)).

If the translog variable cost function represented above is estimated on its own, it is likely that parameter estimates will not be efficient due to multi-collinearity. To reduce the problem of multi-collinearity, and to use additional information without introducing new parameters, the cost function is estimated jointly with the cost share equations for each variable input (Christensen and Greene (1976)).

After applying the Shepherd’s lemma we obtain the cost share equations for the variable inputs capital and labour, which are as follows:

$$s_K = \alpha_K + \beta_{KK} \ln\left({p_K}/{p_I} \right) + \beta_{KL} \ln\left({p_K}/{p_I} \right) + \beta_{KY} \ln y + \beta_{Kk} \ln S_k$$

$$s_L = \alpha_L + \beta_{LL} \ln\left({p_L}/{p_I} \right) + \beta_{KL} \ln\left({p_L}/{p_I} \right) + \beta_{LY} \ln y + \beta_{Lk} \ln S_k$$

where k= quasi-fixed inputs

The share equation alongwith the cost function constitutes a multiequation framework and it is estimated using SURE technique and iterated to obtain the maximum likelihood estimates.

We now comment on the methodology involved in calculating the productivity effects of infrastructure, which is outlined as follows:

Measure of cost elasticity with respect to economic and social infrastructure measures the "*productivity effect*" of these public sector capital services. They can be calculated by differentiating the translog cost function with respect to economic and social infrastructure variable as follows:

$$\frac{\partial \ln C}{\partial \ln S_K} = \eta_{C_{GK}} = \beta_K + \sum_{K \neq L} \beta_{KK} \ln S_K \sum_{K \neq L} \beta_{KL} \ln S_2 + \sum_I \sum_K \beta_{IK} \ln P_I + \sum_K \beta_{KY} \ln Y$$

$$\begin{aligned} \textit{where}\ & \mathrm{i} = \text{variable input} \\ & \mathrm{k} = \text{quasi} = \text{fixed input} \end{aligned}$$

Further the "*factor bias effect*" is also calculated which shows the bias of the quasi-fixed inputs for the variable inputs. This is calculated by differentiating the share equations with respect to the infrastructure input as follows:

$$\frac{\partial S_I}{\partial \ln S_K} = \beta_{IK}$$

$$\begin{aligned} \textit{where}\ & \mathrm{i} = \text{variable inputs} \\ & \mathrm{k} = \text{quasi - fixed inputs} \end{aligned}$$

Sign of these coefficient suggests the direction of the bias, that is, if the factor share increases, decreases or does not change, then publicly financed infrastructure capital is private input using, saving or neutral respectively.

The *"total effect"* shows the combination of the quasi-fixed inputs with the variable inputs in improving the productivity in the industrial sector also including the bias of the quasi-fixed input for the variable input.

This effect is calculated as the sum of "productivity effect" and "factor bias effect". Sign of the coefficients suggest that whether infrastructure input and ith private input are complements, substitutes, or neutral if the sign is positive, negative or zero respectively. It is calculated as:

$$\eta_{IS_K} = \eta_{CS_K} + \frac{\beta_{IK}}{s_I}$$

We also calculate the marginal benefit and social rate of return (SRR) of infrastructure input, that is at margin how much benefit is derived from the use of a particular public sector capital and rate of return derived for employing an additional unit of public sector capital. They are calculated as follows:

Marginal benefit: $b_{s_K} = -\frac{\partial C}{\partial S_K} = \eta_{CS_K} \frac{C}{S_K}$ where k= quasi-fixed input

SRR: $r_{S_K} = \frac{b_{S_K}}{q_S}$ where $\mathrm{q}_S = p_K (r + d)$ according to Jorgen's model

Finally we test the hypothesis that industry chooses the public capital services to the point where their marginal benefits are zero. For this we also estimate the cost share equation with respect to fixed inputs as:

$$\frac{\partial \ln C}{\partial \ln S_K} == \alpha_K + \sum_i \beta_{ik} \ln\left({p_i}/{p_I} \right) + \beta_{kk} \ln S_k + \sum_K \beta_{KY} \ln Y$$

This test is carried out by estimating the system of equations including cost function and share equations with respect to variable inputs and then estimating system of equations including cost function and share equations with respect to variable inputs and also with respect to quasi-fixed factors.

Then the test statistic is calculated as:

$$M = \left(\hat{\beta} - \tilde{\beta}\right)\left\{\left[\operatorname{cov}\left(\hat{\beta}\right) - \operatorname{cov}\left(\tilde{\beta}\right)\right]\right\}^{-1}\left(\hat{\beta} - \tilde{\beta}\right)$$

where $\hat{\beta} =$ *parameter* estimate obtained by estimating cost function and share equations with respect to variable inputs.

$\tilde{\beta} =$ *parameter* estimate obtained by estimating cost function and share equations with respect to variable inputs and quasi - fixed factors.

This is asymptotically distributed as chi-square (χ^2) with degrees of freedom equal to the number of parameters of the imposed conditions.

SECTION-V : DATA SOURCES AND MEASUREMENT OF QUANTITIES AND PRICES

This section outlines the definition of data and sources from which they have been derived, for the three variable inputs, that is, capital, labour and intermediate inputs and the infrastructure stock for the purpose of model estimation. This also describes the method of constructing the price indices of various variable inputs.

Capital stock: There is no universally accepted method of measuring capital stock. Ahluwalia (1991) estimates gross fixed capital stock at constant prices using the perpetual inventory accumulation method. Since her method attempts to resolve computational problems, capital stock is estimated by this method only.

In this method, we first obtained the gross net ratios for land, buildings and construction, plant and machinery and other equipment. Source for this is “RBI Bulletin”, Reserve Bank of India, September 1975. Since these ratios were not available for all industries level and it was available for two-digit industries, therefore a weighted average was calculated for all these industries. The procedure is described as follows:

Data on gross fixed assets and net fixed assets including land, buildings and construction, plant and machinery and other equipment was available for 19 industries and for each gross net ratio was calculated. To calculate the weighted average, the weights used were calculated as:

$GFA_i \big/ \sum GFA_i$ where $\mathrm{GFA_i}$ is gross fixed assets for industry i and $\mathrm{i} = 1.......19$

and $\sum \mathrm{GFA_i}$ = summation of gross fixed assets of all industries.

Then book value of fixed capital stock at purchase prices for the benchmark year 1973-74 is calculated as $A=NFKS_{73\text{-}74}*(GFA/NFA)$, where data for NFKS is collected from "ASI", various issues and GFA/NFA is the gross net ratio. Gross fixed capital stock at constant prices for the benchmark year is calculated as $Z=(A*100)/Price_K$. For successive years gross fixed capital stock at constant prices = $Z+[(I_T*100)/Price_K]$ where I_T = $(NFKS_T-NFKS_{T-1})+Depreciation_T$, that is gross investment at current prices.

The main limitation of this method is that this method will automatically overstate the size of capital stock as a consequence of failing to account properly for discards of old technology capital induced by technical changes embodied in new capital.

Labour input: We use "total persons engaged in the process" as a measure of the labour input. Number of persons engaged is computed by taking the total attendance of persons in all the shifts on all days during the year and dividing it by the number of days worked.

Source: Statistical Abstract of India (SAI), CSO, Ministry of Planning, Government of India, various issues.

Materials input: this includes both energy and material inputs. They have been combined using the Tornquist index. Tornquist index is a measure of the growth rate of the aggregate. It is defined as the weighted sum of log differences in the variables of the consecutive periods with arithmetic average of value shares over the two periods as the weight. We first calculate the average share of both energy and materials as:

$$\left(S_{WI}(t)+S_{WI}(t-1)\right)/2$$

where I= energy, material

Then growth rate of each one of them is calculated as:

$$\ln W_i(t)-\ln W_i(t-1)$$

Then growth of the aggregate of energy and materials is calculated as:

$Z_{(t)}$ = Average share of energy * growth rate of energy + average share of materials * growth rate of materials.

Tornquist index is then calculated as $INDEX_{(t)} = INDEX_{(t-1)} [1+Z_t]$ with INDEX (0)= 1.0

Data for both energy and materials is collected from "ASI", Ministry of Industry, Government of India, various issues.

Prices of variable inputs: Price of capital is proxied by WPI of machinery and machine tools as suggested by Goldar (1986) and Ahluwalia (1991). The series has been extracted from various issues of "Statistical Abstract of India", CSO, Ministry of Planning, Government of India. The price of labour is obtained by dividing total emoluments by total persons engaged. The series for total emoluments is obtained from various issues of "Annual Survey of Industries" Ministry of Industry, Government of India. The series for price of materials is constructed as a weighted average of the price indices of various material inputs used by the manufacturing sector by suitable weights derived from Input-Output table 1991.

Infrastructure input (s): Data for economic infrastructure is mainly collected from "Centre for Monitoring Indian Economy", various issues on agriculture, energy and infrastructure. The main limitation of the data from this source is that CMIE does not describe the methodology involved in compilation of various sets of variables. Moreover it does not describe whether the data is based on complete enumeration or on sample surveys. For this reason the reliability of the data is in doubt. Data on length of transmission and distribution lines and number of villages electrified as components of the electricity sector, is obtained from the "Public Electricity Supply, All India Statistics", General review, 1997. Data on the banking sector is obtained from RBI publications namely, “Report on Currency and Finance” and “Statistical Tables Relating to Banks in India”.

In case of social infrastructure, for education the main source of data was “Selected Educational Statistics”, GOI, various issues. This source does not mention the method of data collection, whether it is a survey or is it based on census population projections. Main source of data for Health infrastructure is “Health Information of India”, Ministry of Health and Family Welfare, various issues.

Output: This is measured by gross output at constant prices, which is obtained by adding material inputs, depreciation and value added. Output in current prices is deflated by the ‘Wholesale Price Index’. Data is obtained from ‘Statistical Abstract of India’, CSO, Government of India.

Variable cost: It is defined as the sum of expenditures on variable inputs (capital, labour and intermediate).

User cost of infrastructure: In order to derive the user cost of infrastructure we can use the Jorgenson’s method. It is derived as:

$C = P_K (r+d)$

Where C = user cost of capital

r = rate of interest

d = depreciation rate

P_K = price per unit of capital

This gives the cost per unit of capital. In order to derive the user cost of total capital we do the following:

$C = P_K (r+d)$ * actual level of infrastructure calculated as per section-II.

Data on P is obtained from “National Accounts Statistics”, Government of India, various issues. Rate of interest is proxied by Redemption Yield on Government of India securities (long term) and information is collected from “Report on Currency and Finance”, Reserve Bank of India, various issues. Data on depreciation is again collected from “National Accounts Statistics”, Government of India, various issues.

SECTION-VI : PRODUCTIVITY EFFECTS OF INFRASTRUCTURE

In this section we present the results for the model estimation as well as the "productivity effects" of infrastructure as mentioned in section-IV above.

The results for system estimation for cost function and two share equations are presented in table 6.1:

TABLE 6.1: TRANSLOG MODEL ESTIMATES WITH ECONOMIC AND SOCIAL INFRASTRUCTURE AS QUASI-FIXED INPUTS

PARAMETER	ESTIMATE	STANDARD ERROR	T-RATIO
β_0	-33.6	36.58	-0.918
β_K	0.999	0.002	615.749
β_L	0.007	0.002	4.338
β_I	0.00006	0.0003	0.182
β_Y	11.65	9.73	1.197
β_E	-30.59	13.54	-2.26
β_S	-11.41	3.28	-3.48
β_{KK}	0.0008	0.0002	4.704
β_{LL}	0.0007	0.0001	4.493
β_{II}	0.0002	0.00008	3.163
β_{EE}	-7.93	7.23	-1.096
β_{SS}	-3.20	4.95	0.647
β_{YY}	-1.53	1.29	-1.184
β_{KL}	-0.0006	0.0001	-4.216
β_{KI}	-0.0002	0.00009	-2.345
β_{LI}	-0.00003	0.00004	-0.884
β_{ES}	-8.10	5.37	-1.509
β_{KE}	0.0004	0.0002	2.100
β_{LE}	-0.0004	0.0002	-2.074
β_{IE}	-0.00002	0.00004	-0.534
β_{KS}	-0.001	0.0005	-2.449
β_{LS}	0.001	0.0005	2.408
β_{IS}	0.00007	0.0001	0.679
β_{KY}	-0.001	0.0004	-3.269
β_{LY}	0.001	0.0004	3.506
β_{IY}	-0.00003	0.00008	-0.393
β_{EY}	4.01	3.02	1.330
β_{SY}	1.64	2.09	0.783

Estimates of the translog cost function parameters are all highly significant except that of intermediate input and all coefficients enter with a plausible sign. The coefficients of infrastructure inputs are also statistically significant and hence they suggest negative cost elasticities with respect to infrastructure capital stock. The regularity conditions of the variable cost function required that cost function should be increasing in output and should be non-increasing in fixed input. It should be concave in variable input prices and convex in fixed inputs. Cost function should also be monotonically increasing in variable input prices and decreasing in fixed input.

Coefficient of β_Y is positive and it implies that the cost function is non-decreasing in output. Moreover, the cost function is decreasing in infrastructure input, which is shown by the negative sign of β_E and β_S. For this cost function to be concave in input prices the Hessian matrix $\left[\partial^2 C \big/ \partial p_i p_j\right]_{ij}$ of second order derivatives with respect to variable input prices should be negative semi-definite. However the Hessian matrix of this cost function is positive definite. Moreover, for the cost function to be convex in fixed input $\frac{\partial^2 C}{\partial S_k{}^2} \geq 0$. But this condition is also not satisfied here. For the cost function to be monotonically increasing in variable input prices and decreasing in fixed inputs, $\frac{\partial C}{\partial p_i} \geq 0$ and $\frac{\partial C}{\partial S_k} \leq 0$. For this cost function, it is observed that it is monotonically increasing in variable input prices and decreasing in fixed input.

On the basis of this estimated model we analyzed the spillover effects of infrastructure in respect of the organized manufacturing sector of India for the period 1965-66 to 1998-99. Our discussion of the productivity effects of the infrastructure is based on Nadiri and Mamuneas (1994). Discussion of the results is based on the methodology outlined in section IV.

The estimates of the cost elasticity, factor bias effect, total effect etc, their standard errors and the corresponding t-ratio are given in table 6.2 below.

TABLE 6.2: RESULTS ON PRODUCTIVITY

<table>
<tr><td colspan="6">PRODUCTIVITY EFFECT (Std Error and T-Ratio in parentheses)</td></tr>
<tr><td colspan="3">ECONOMIC INFRASTRUCTURE</td><td colspan="3">SOCIAL INFRASTRUCTURE</td></tr>
<tr><td colspan="3">-0.49
(0.08)
(-6.5)</td><td colspan="3">-0.30
(0.09)
(-3.4)</td></tr>
<tr><td colspan="6">FACTOR BIAS EFFECT W.R.T. ECONOMIC INFRASTRUCTURE (Std Error and T-Ratio in parentheses)</td></tr>
<tr><td colspan="2">CAPITAL</td><td colspan="2">LABOR</td><td colspan="2">INTERMEDIATE</td></tr>
<tr><td colspan="2">0.0004
(0.0002)
(2.1)</td><td colspan="2">-0.0004
(0.0002)
(-2.1)</td><td colspan="2">-0.0002
(0.00004)
(-0.5)</td></tr>
<tr><td colspan="6">FACTOR BIAS EFFECT W.R.T. SOCIAL INFRASTRUCTURE (Std Error and T-Ratio in parentheses)</td></tr>
<tr><td colspan="2">CAPITAL</td><td colspan="2">LABOR</td><td colspan="2">INTERMEDIATE</td></tr>
<tr><td colspan="2">-0.001
(0.0005)
(-2.45)</td><td colspan="2">0.001
(0.0005)
(2.41)</td><td colspan="2">0.00007
(0.0001)
(0.68)</td></tr>
<tr><td colspan="6">TOTAL EFFECT W.R.T. ECONOMIC INFRASTRUCTURE (Std Error and T-Ratio in parentheses)</td></tr>
<tr><td colspan="2">CAPITAL</td><td colspan="2">LABOR</td><td colspan="2">INTERMEDIATE</td></tr>
<tr><td colspan="2">-0.52
(0.0002)
(-2.1)</td><td colspan="2">-3.42
(0.22)
(-15.5)</td><td colspan="2">-1.19
(1.4)
(-0.85)</td></tr>
<tr><td colspan="6">TOTAL EFFECT W.R.T. SOCIAL INFRASTRUCTURE (Std Error and T-Ratio in parentheses)</td></tr>
<tr><td colspan="2">CAPITAL</td><td colspan="2">LABOR</td><td colspan="2">INTERMEDIATE</td></tr>
<tr><td colspan="2">-0.31
(0.09)
(-3.4)</td><td colspan="2">0.41
(0.45)
(0.91)</td><td colspan="2">2.02
(3.42)
(0.59)</td></tr>
<tr><td colspan="6">MARGINAL BENEFIT(Std Error and T-Ratio in parentheses)</td></tr>
<tr><td colspan="3">ECONOMIC INFRASTRUCTURE</td><td colspan="3">SOCIAL INFRASTRUCTURE</td></tr>
<tr><td colspan="3">7.8
(1.2)
(6.5)</td><td colspan="3">9.4
(2.7)
(3.5)</td></tr>
<tr><td colspan="6">SOCIAL RATE OF RETURN (Std Error and T-Ratio in parentheses)</td></tr>
<tr><td colspan="3">ECONOMIC INFRASTRUCTURE</td><td colspan="3">SOCIAL INFRASTRUCTURE</td></tr>
<tr><td colspan="3">0.002
(0.0004)
(5.0)</td><td colspan="3">0.003
(0.0008)
(3.75)</td></tr>
</table>

Results suggest that both economic infrastructure and social infrastructure significantly affect the cost and productivity of the registered manufacturing sector in India. Since the elasticities have a negative sign it implies that provision of infrastructure capital in the manufacturing sector helps in reducing the costs in this sector. The estimates suggest that elasticity for economic infrastructure is higher than that for social infrastructure and the estimates are also statistically significant.

Results for factor bias effect shows that economic infrastructure is capital using but labour and intermediate inputs saving. Also factor bias effect is statistically significant with respect to capital and labour and is insignificant with respect to intermediate input, suggesting a neutral effect. Social infrastructure is capital saving but is labour and intermediate input using. This effect is significant with respect to capital and labour, but is insignificant with respect to intermediate input suggesting a neutral effect.

Also the total effect suggests that economic infrastructure is a substitute to all the three variable inputs. Total effect with respect to economic infrastructure is significant with respect to capital and labour and is insignificant with respect to intermediate input thereby suggesting a neutral effect, which further implies that an increase in economic infrastructure leads to a decline in demand for all variable inputs.

However, social infrastructure is a substitute for capital while it is complementary to labour and intermediate input. The effect is again significant with respect to only capital and is insignificant with respect to labour and intermediate input.

Value of marginal benefit of social infrastructure is higher than that for economic infrastructure. This may be due to the fact that magnitude of cost elasticity is very low and that of C/S_k is very high.

Social rate of return on economic infrastructure is 0.2% and that on social infrastructure is 0.3%. These are also statistically significant.

For this model we conduct three tests of static equilibrium:
H_0 : Jointly marginal benefits of economic and social infrastructure are zero
H_1 : not H_0
Test statistic is: $M = \left(\hat{\beta} - \tilde{\beta}\right)\left\{\left[\mathrm{cov}\left(\hat{\beta}\right) - \mathrm{cov}\left(\tilde{\beta}\right)\right]\right\}^{-1}\left(\hat{\beta} - \tilde{\beta}\right) \overset{A}{\approx} \chi^2 underH_0$
H_0 : Marginal benefits of economic infrastructure is zero
H_1 : not H_0

Test statistic is: $Z = \left(\hat{\beta} - \tilde{\beta}\right)\left\{\left[\mathrm{cov}\left(\hat{\beta}\right) - \mathrm{cov}\left(\tilde{\beta}\right)\right]\right\}^{-1}\left(\hat{\beta} - \tilde{\beta}\right) \overset{A}{\approx} \chi^2 underH_0$

H_0 : Marginal benefits of social infrastructure is zero

H_1 : not H_0

Test statistic is: $Q = \left(\hat{\beta} - \tilde{\beta}\right)'\left[\mathrm{cov}\left(\hat{\beta}\right) - \mathrm{cov}\left(\tilde{\beta}\right)\right]^{-1}\left(\hat{\beta} - \tilde{\beta}\right) \overset{A}{\approx} \chi^2 underH_0$

Results are presented in table 6.3 below:

Table 6.3: RESULTS FOR STATIC EQUILIBRIUM OF FIXED FACTORS

TEST STATISTIC	CALCULATED VALUE	CRITICAL VALUE	INFERENCE
M	617.83	χ^2(21)(0.95) = 32.7	Reject the null that jointly marginal benefit of both economic infrastructure and social infrastructure is zero.
Z	556.8	χ^2(21)(0.95) = 32.7	Reject the null that marginal benefit of economic infrastructure is zero.
Q	540.2	χ^2(21)(0.95) = 32.7	Reject the null that marginal benefit of social infrastructure is zero.

SECTION-VII : SUMMARY AND CONCLUSIONS

The present study provides an analysis of the impact of infrastructure development on economic development, through its spillover effect on the productivity in the registered manufacturing sector in India. This study has been conducted for the national economy using annual time series data for the thirty-four year period 1965-99. In order to carry out this study we have made use of data for twenty-three infrastructure variables from the various infrastructure sectors. These sectors are agriculture, banking, communications, electricity, transport, education and health. The first five sectors constitute economic infrastructure while the latter constitutes social infrastructure.

We aggregate various items of infrastructure into economic and social infrastructure using an aggregation method called the Principal Component analysis.

This study is organised along the lines of Nadiri and Mamuneas (1994). This study has primarily focussed on the cost function approach to study the productivity effects of infrastructure. For this we have assumed that the variable cost in the manufacturing sector is a function of the prices of variable inputs, capital, labour and intermediate inputs and levels of quasi-fixed infrastructure inputs. Our econometric model is based on the translog variable cost function.

Estimated productivity effects of infrastructure suggest that both economic and social infrastructure significantly affects the cost and productivity of registered manufacturing sector in India. Moreover our results show that economic infrastructure is capital using but labour saving and intermediate input saving, while social infrastructure is capital saving and labour and intermediate input using. Further, economic infrastructure is a substitute to capital, while complementary to labour and intermediate inputs. Marginal benefit of social infrastructure is higher than that of economic infrastructure and net rates of return are also higher for social infrastructure, Hence we conclude that infrastructure plays a positive and significant role in affecting the productivity in the industrial sector in India and thus contributes towards economic growth.

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