Infrastructure and Economic Growth: An Empirical Examination

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This paper explores the relationship between the gross domestic product and stock of infrastructural services in India by estimating a vector autoregressive (VAR) model for the period 1970-71 to 2000-01. Various stocks of infrastructure *viz.*, transport, electricity, gas, water supply and communication facilities are included as inputs in the model whereas gross domestic product at factor cost is considered as output in a Cobb-Douglas production function framework. The estimated model is also used for forecasting by measuring the impulse responses of gross domestic product to one per cent standard deviation shock in the infrastructural sectors. From the impulse response analysis, it was found that though the initial impact of increase in the stocks of infrastructure is diminishing, it continues to have a positive impact on real output in the medium-to-long run. Among all the infrastructural sectors, electricity, gas, water supply and communication sectors play a key role in explaining the movements in the gross domestic product.

Introduction

The recent slowdown of the Indian economy has triggered serious concern among the policy makers while exploring the possibilities for revitalising growth. Though the slowdown of the Indian economy coincided with that of the major industrial countries as reflected in the global slowdown, the former was largely ascribed to its relatively domestic conditions, *i.e.*, demand slowdown, sluggishness in supply responses and supply side constraints, given the relatively low degree of openness of the Indian economy. Among the demand-side factors impeding growth are uncertain pace of investment demand, the relatively low requirement of bank credit, the decline in import demand and the high-carrying costs of inventories being incurred by some industries. The supply-side factors, on the other hand, are sluggish agricultural growth, absolute deficiencies in physical and social infrastructure and other structural constraints (Reserve Bank of India, 2001, p.125). Among the supply side factors, the role of infrastructure in the process of economic development in India is highly crucial.

Infrastructure services, *e.g.*, transport, electricity, gas, water supply, communication and storage facilities play an important role in economic development of a nation. Recognising their importance for the society as a whole, they are also referred as 'social overheads'[1] due to low backward linkages and high forward linkages. Initially, after independence, these sectors were reserved for the public sector whereas private participation has been allowed in these sectors recently.

In the production process, infrastructure facilities are considered to be intermediate inputs though they are output of their own industry. Their availability in adequate quantity and quality reduces input cost and raises the profitability, thus, permitting higher level of output, income and employment. Infrastructure has also a role to play in economic growth, poverty alleviation and environmental up-gradation. In this context, the World Development Report (1994) says, "infrastructure can deliver major benefits in economic growth, poverty alleviation, and environmental sustainability - but only when it provides services that respond to effective demand and does so efficiently” (p. 2). It further says, “infrastructure represents, if not the ‘engine’, then the ‘wheels’ of economic activity” (p. 14).

Against the backdrop of recent deceleration in economic activity, this paper makes an attempt to explore the interaction between the various stocks of infrastructure and GDP. The rest of the paper consists of four sections. The first section provides a brief review of the earlier studies on infrastructure and economic development. Section II discusses the various developments in the infrastructure sectors with special reference to the post-reform period. The third section discusses the methodology and presents the empirical findings. The final section offers a concluding remark.

Section I
Infrastructure and Economic Development: A Review of Literature

Evidence on the link between infrastructure and economic development is found to be sketchy in the literature. In the recent years, however, many attempts have been made both in econometric and input-output framework for estimating the link between productivity of investments in infrastructure and economic development. In the input-output framework, forward and backward linkages, and direct and indirect multipliers were estimated using the Leontief inverse, which captures both the direct and indirect effects of a unit change in final demand. On the other hand, the econometric approach considers output growth as the dependent variable and investment or stock of infrastructure along with labour and level of technology as the independent variables. Many economists, however, argue that a high growth in the economy may encourage more investment in infrastructure.

In the Aschauer’s (1989a, 1989b) pioneering work, a Cobb-Douglas production function was estimated with stocks of various infrastructure as capital and labour as the other input. He found that military capital had insignificant relationship with productivity. However, the ‘core’ infrastructure such as streets, highways, airports, mass transit, sewers, water systems, *etc.*, had the most explanatory power for productivity.

Munnell (1990a, 1990b) examined the relationship between public capital and economic activity at the State level in the US. In the first analysis, public capital was found to have a significant and positive impact on output although the output elasticity was roughly one-half the size of the national estimate. In the second analysis, public capital was found to enhance the productivity of private capital, raising its rate of return and encouraging more investment. On the other hand, from the investors’ perspective, public capital was looked upon as a substitute for private capital which crowded out private investment.

Shah (1992) estimated a *translog* cost function for the Mexican economy in a restricted equilibrium framework to examine the contribution of public investment in infrastructure to private sector profitability. Labour and materials were treated as variable inputs whereas private capital and public sector capital stock in transportation, communication and electricity were considered quasi-fixed inputs. The Mexican industrial structure was found to be characterised by increasing returns to scale, short-run deficiency in capital capacity, involuntary unemployment and declining productivity growth. A small degree of complementarity between labour and infrastructure, and capital and infrastructure was also detected. The factor demand response to input price changes was found to be quite limited with technical change being a capital-using and labour-saving variety.

Feltenstein and Ha (1995) examined the relationship between infrastructure and private output in 16 sectors for Mexico in terms of sectoral elasticities in a framework of *translog* production function augmented by the nominal stocks of infrastructure. They found that availability of better quality infrastructures in electricity and communication generally reduces the cost of production, but transportation infrastructure tends to increase costs of production. They further conclude that Mexican public expenditure on electricity and communications has enhanced the productivity of private production, but expenditure on transport might actually had detrimental effect on private output. In addition, general labour and infrastructure were found to be substitutes, however, in the case of electricity and communications, capital and infrastructure were complements. In the case of transport infrastructure, however, these conclusions were reversed.

There are few studies conducted at the regional level using cross-section data. Costa *et. al.* (1987) tested the relationship between public capital and regional output using *translog* production function for 48 States of the USA for the year 1972. Three sectoral aggregates were considered in the study *viz.,* all economic sectors, non-agricultural sectors and manufacturing. Labour and public capital were found to be complementary inputs with diminishing returns. Some of the later studies by Duffy-Deno and Eberts (1989), Eberts (1986, 1990), and Eisner (1991) were also conducted at the regional level. All these studies found a positive relationship between infrastructure and economic growth.

In the Indian case, there are hardly any empirical studies undertaken to examine the impact of infrastructure on economic growth. Jha and Sahni (1992) have examined the efficiency of the gas, electricity and railways sectors by estimating *translog* cost functions. They have estimated the factor elasticities with respect to output, and cross elasticities among the factors of production. However, they have not examined the impact of these sectors either on industrial productivity or on economic growth.

The India Infrastructure Report (1996) [Chairman: Dr. Rakesh Mohan] brought out by the Government of India has made investment projections for the infrastructure sectors in the next decade. Assuming incremental capital output ratio (ICOR) reduces to 3.5 resulting in GDP growth rate of 6.2 per cent in 1996-97, rising to 7.5 per cent in 2000-01 and 8.5 per cent in 2005-06, the Report has estimated an investment requirement at around Rs. 4,000 billion to Rs. 4,500 billion (US $ 115 to US $ 130 billion) over the next five years (1996-97 to 2000-01) and this would rise to about Rs. 7,500 billion (US $ 215 billion) in the following five years (2001-02 to 2005-06). The Report has made an in-depth study of the investment requirements and regulatory practices in six major sectors, *viz.*, urban infrastructure, power, telecommunications, roads, industrial parks and ports. The Report has further provided sector-specific recommendations for their commercialisation.

Other studies such as Raghuraman (1995), Sankaran (1995), Somers (1995), Nair (1995), Amitabh and Rajan (1995), Purkayastha and Ghosh (1997), Ramanathan (1997), and Shah (1997), 3-I Network (2002) found the problems related to various infrastructural sectors in India.

None of these studies have, however, empirically examined the impact of infrastructure on industrial productivity.

Most of the empirical studies reviewed in this section so far have all used non-stationary data and are, therefore, faced with certain limitations. The existence of common trends in the output and infrastructure data might have given rise to a spurious correlation. Critics like Aaroan (1990), Hulten and Schwab (1991), Hulten (1996), Jorgenson (1991), and Tatom (1991) suggest that one should estimate the regressions in first differences while dealing with non-stationary time series. The first-differencing specification, however, has its own problems. No one would expect the growth in infrastructure stock in one year to be correlated with the growth in output in the same year. In fact, equations estimated in this form often yield implausible coefficients for stocks of infrastructure and labour [Hulten and Schwab (1991), Tatom (1991)]. In addition, the first differencing destroys any long-term relationship in the data, which is exactly what one is trying to estimate. Instead of just first differencing, the variables should be tested for cointegration, adjusted and estimated accordingly.

To overcome the aforesaid limitations, Sahoo and Saxena (1999) estimated a Cobb-Douglas production function to measure the elasticity of various stocks of infrastructure with respect to output. Various stocks of infrastructure like railways, other transport, electricity, gas and water supply, communication and storage facilities along with total employment were included as inputs in the model, whereas gross domestic product at factor cost was considered as output. The transport, electricity, gas, water supply and communication sectors were found to be positively related to output, whereas storage was found to be inversely related with output. All the variables were non-stationary at levels and were first-differenced stationary or I(1). The existence of a long-run relationship was validated by using cointegration analysis in a multivariate framework. From the cointegrated model it was also found that there exists increasing returns to scale.

The time series model estimated through the cointegration approach, however, just establishes the long-run relationship between output and various stocks of infrastructure. The cointegration approach also does not talk about the historical behaviour of the series and has poor predictive power. As first suggested by Sims (1980), vector autoregressive (VAR) model is used in this study in order to overcome the limitations associated with the traditional macroeconometric models.

Section II
Developments in Infrastructure in India – Stylised Facts

Power

Among the infrastructure facilities, electricity generation, transmission and distribution possess certain inherent advantages due to their commercialisation, marketability of the products and services, and availability of the basic organisational structures for such purposes. Till the introduction of the New Economic Policy during the early 1990s, production, provision and management of electricity was reserved for the public sector. Subsequently, it has been opened up for the private sector.

There has been a phenomenal growth in electricity generation and utilisation since independence. Electricity generation, which increased from only 4.1 billion kwh in 1947-48 to 467.4 billion kwh in 2000-01 recorded a growth of 3.7 per cent over 1999-2000. Power generation in April-December, 2001 at 383.2 billion kwh recorded a growth of 2.8 per cent over the corresponding period in 2000. The installed generating capacity which was only 1,362 mw in 1947, increased to 1,01,630 mw as on end-March 2001 and further crossed 1,02,907 mw as on October 31, 2001. The per capita consumption of electricity, which was less than 15 units at the time of independence, increased to about 314 units by 2000.

The State Electricity Boards (SEBs) have continued to incur high transmission and distribution (T&D) losses, which stood at 24.8 per cent in 1997-98 and further increased to 25.6 per cent in 1998-99. The T&D losses are due to a variety of reasons, *viz.*, substantial energy sold at low voltage, sparsely distributed loads over rural areas, inadequate investment in distribution system, improper billing and high pilferage. Besides, the managerial and financial inefficiencies in the State sector utilities have in turn adversely affected future capacity addition and system improvement programme. On the other hand, the SEBs do not have enough resources to finance future programmes and their ability to raise investible funds from alternate sources is limited due to their poor financial and commercial performance.

The gap between demand and supply in the power sector has remained significant, notwithstanding the fact that several reforms, including private participation, have been undertaken to boost growth of the power sector. The demand-supply gap in power sector widened to 11.5 per cent in 1996-97 from 7.8 per cent in 1991-92, although there was some decline thereafter (Table 1).

Table 1 : Demand Supply Gap in the Power Sector in India

(Million kwh)

Year	Demand	Availability	Shortfall	Shortfall as % of Demand
1991-92	2,88,974	2,66,432	22,542	7.8
1996-97	4,13,490	3,65,900	47,590	11.5
1997-98	4,24,505	3,90,330	34,175	8.1
1998-99	4,64,584	4,20,235	26,349	5.9
1999-00	4,80,430	4,50,594	29,836	6.2
2000-01	5,07,213	4,67,401	39,812	7.8

Source : Annual Reports, Ministry of Power, Government of India, Various Issues.

The power sector has witnessed a series of reforms in the recent period in line with recommendations of the India Infrastructure Report (Chairman: Dr. Rakesh Mohan). The performance of the SEBs has been reviewed. In view of the paucity of resources with Central and State Public Sector Undertakings (PSUs) as well as the SEBs and the need to bridge the gap between the rapidly growing demand for and supply of electricity, all the States have been encouraging private enterprises in the power sector covering areas of transmission and distribution besides generation.

In terms of institutional improvements and transparency practices, Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commission (SERC) have been established in 18 States so far, which is expected to ensure rationalisation of tariffs, fair competition and protection of the consumer interest. The SEBs have been unbundled/corporatised in 6 States. A comprehensive Electricity Bill, 2001 has been introduced in the Parliament. The Central Government took measures to accelerate the programme of reforms in SEBs anchored in Centre-State partnership on: (i) a time-bound programme for installation of 100 per cent metering, (ii) energy audit at all levels, (iii) commercialisation of distribution and (iv) restructuring of SEBs.

Transport

Railways

The Indian railways is one of the largest railways network in the world under a single management. It consists of an extensive network spread over 63,028 kilometres comprising 44,776 kilometres (71.0 per cent of total) on broad gauge, 14,987 kilometres (23.8 per cent of total) on metre gauge and 3,265 kilometres (5.2 per cent of total) on narrow gauge. The electrified network constitutes about 15,062 kilometres, accounting for 24 per cent of the total route kilometre. The railways employ more than 1.6 million people, which is about 6 per cent of the total employment in the organised sector. While staff productivity in terms of traffic units per worker, asset productivity in terms of net tonne kilometre per wagon day, wagon turn-around time, loco-utilisation, *etc.*, have improved over the years, they remain far from satisfactory.

The recent policy initiatives in railways include, among others, introduction of joint ventures with the State Governments in accelerating the process of building up rail infrastructure. RailTel Corporation has become functional to harness the optical fibre network alongside the railway track. Commercial utilisation of land and airspace of railways has been initiated by identifying eight sites. More powers have been delegated to the General Managers of Zonal Railways to finalise the contracts as also the freight rate reducing power to quote station-to-station rates to attract the retail traffic on commercial consideration.

Road Transport

India has the third largest road network in the world with a network of 2.7 million kilometres. However, this network is inadequate for speedy and efficient transportation. The National Highways network of 34,298 kilometres at the end of 1995-96 constitutes less than 2 per cent of the total road network, but carries nearly 40 per cent of the total traffic. The share of roads in the movement of goods and passengers has increased significantly during the recent years. In 1950-51, roads carried only 12 per cent of freight and 25.8 per cent of passenger traffic. By 1991-92, it carried 53.4 per cent of freight and 79.2 per cent of passenger traffic. In 1995-96, the share of goods and passenger traffic has marginally increased to 60 per cent and 80 per cent, respectively, of the total traffic.

A number of initiatives have been taken to upgrade the road transport facility. The National Highways Development Project (NHDP) has been launched to achieve a turnaround in the road sector. The NHDP comprises the 6000 km long Golden Quadrilateral (GQ) connecting the four metros of Delhi, Mumbai, Chennai and Kolkata and the 7000 km long North-South and East-West corridors connecting Srinagar-Kanyakumari and Silchar-Porbandar, respectively. The GQ is expected to be completed by 2003 and the corridors by 2007. The Central Road Development Fund was revamped by crediting a cess of Rupees one per petrol and diesel and by enacting the Central Road Fund Act, 2000 in December 2000.

Water-Ways Transport

The Indian water-ways transport consists of shipping, ports and inland water transport. Almost 98 per cent of the India's overseas trade in terms of volume are moved by sea. India has 11 major ports and 148 operable minor ports. Major ports are governed by the Major Port Trust Act, 1963, which enables them to conduct regulatory as well as commercial functions. The intermediate and minor ports are administratively under the State governments and are governed by the Indian Port Act, 1908, which delineates the regulatory powers of the port authority.

The major ports handled approximately 76 per cent of the total operations during 2000-01. During 2000-01, the total cargo handled at major ports was about 3 per cent more than the traffic handled during 1999-2000. About 83 per cent of the total volume of port traffic handled was in the form of dry and liquid bulk, while the remaining 17 per cent consisted of general cargo and containers. During April-November 2001, cargo handled by major ports registered growth of 2.3 per cent as compared with the corresponding period of 2000-01.

In terms of capacity utilisation, most of the Indian ports are operating at more than 100 per cent utilisation and are still inefficient as compared to the ports of the developed countries. Major ports at Madras, Kandla, Tuticorin, Marmugao, Paradip, Mumbai and Vizag have consistently handled more cargo traffic than their operated capacity. In terms of capacity, major ports have virtually reached the saturation point, however, the potential for future growth is still high. In terms of commodity traffic, as against the total capacity of 292 million tonnes on March 31, 2001, major ports have handled 281 million tonnes cargo during 2000-01 implying that there is a need to augment the port capacity.

The Indian ports, besides their excess capacity utilisation, have indicated improved performance and productivity in the recent years. The average pre-berthing waiting came down from 0.9 days in 1999-2000 to 0.5 days in 2000-01. The Average Ship Berth Output (ASBO) increased from 2,314 tonnes per day in 1984-85 to 6,488 tonnes per day in 2000-01. The Average Ship Turn Around (ASTA) has also fallen from 11.9 days in 1984-85 to 5.1 days in 1999-2000 and further declined to 4.3 days in 2000-01.

However, these indicators suggests the performance of Indian ports are quite low as compared to ports of other countries in the Asian region. The port's productivity also depends to a very large extent on the productivity of the entire logistic chain of other services to which the port is linked. For example, poor road-railway linkages and lack of adequate inland warehousing facilities may affect the port's productivity.

Telecommunication

The Indian telecommunications is one of the oldest systems in the world operating since 1851. Telephone services in the country were originally operated by private companies, which were taken over by the Government of India in 1943. Since then, telecommunications in India has been a public utility.

There has been a phenomenal growth in the telecommunications sector in the last two decades. The annual growth rates of providing new telephone connections have been increasing steadily from 14.5 per cent in 1991-92 to 22.3 per cent in 1995-96 and further to 29.8 per cent during April-December 2000. This impressive growth of connections was the outcome of substantial expansion in switching capacities and adoption of electronic exchanges. In terms of geographical spread, telecommunication infrastructure is more developed in the urban areas as compared to the rural areas.

In terms of institutional set-up, there has been a phenomenal change in the telecommunication sector. The two service providing Departments of the Telecom sector were corporatised, *viz.*, Department of Telecom Services (DTS) and Department of Telecom Operations (DTO). A Public Sector company "Bharat Sanchar Nigam Limited (BSNL)" has now taken up all service providing functions of these two Departments with effect from October 1, 2000.

The demand for telephone connections - aggregate of the lines installed and the waiting list - was 14.26 million as on end-March 1996. This was 19 per cent higher than the previous year. The demand for telephone connections increased at a rate of 11 per cent during 1985-90. The growth in demand declined to 9.1 per cent in 1993-94. During 1994-95, though the waiting list continued to shrink, the demand moved up by 13.6 per cent. There have been sharp improvements in meeting the demand for telephone connections since 1993-94 with 84 percent attained in 1995-96 as against 82 per cent in 1994-95.

In terms of modernisation, telecommunication services in India have undergone tremendous changes in the recent years. The National Telecom Policy (NTP) was announced in May 1994. The policy affirmed the need to give the highest priority to the development of telecom services in the country and for the first time indicated the Government's intention to allow private sector entry into basic services. The Communication Convergence Bill, 2001 has also been introduced in the Parliament. Value added services like Electronic-Mail, Voice-Mail, 64 kbps Domestic Data Service using VSAT, Videotex, Video-Conferencing, Credit Card Authorisation, *etc.*, facilities have already been opened up for the private sector. There has been dramatic reduction in tariff rate for long distance Subscriber Trunk Dialling (STD) and International Subscriber Dialling (ISD). Fixed telephone lines have more than doubled over the last five years, apart from fast expansion of cellular services.

As a prelude to the vector autoregression (VAR) analysis, attempted in the next section, the co-movement between infrastructure and gross domestic product at factor cost (GDPFC) has been examined by tracking the share of infrastructure in the GDPFC and graphical exposition. It is observed that there has been a gradual increase in the share of real output from the various infrastructure sectors to the GDPFC during the last three decades. The share of total infrastructure comprising electricity, gas and water supply (EGWS); railways (RAIL); other transport (OTRANS); storage facilities (STORE); and communication (COMN), which was about 6 per cent in 1970-71 increased to 8 per cent in 1980-81 and further increased to about 9.8 per cent in 2000-01 as against about 8.5 per cent in 1990-91 (Table 2).

Table 2 : Share of Infrastructure to GDPFC

(Per cent)

YEAR	EGWS	RAIL	OTRANS	STORE	COMN	TOTAL
1970-71	1.2	1.5	2.5	0.1	0.7	5.9
1971-72	1.2	1.5	2.5	0.1	0.7	5.9
1972-73	1.3	1.5	2.5	0.1	0.7	6.1
1973-74	1.3	1.6	2.8	0.1	0.8	6.5
1974-75	1.3	1.4	2.9	0.1	0.8	6.4
1975-76	1.3	1.4	3.2	0.1	0.8	6.9
1976-77	1.4	1.5	3.2	0.1	0.8	6.9
1977-78	1.6	1.6	3.3	0.1	0.9	7.4
1978-79	1.5	1.5	3.1	0.1	0.8	7.1
1979-80	1.6	1.4	3.2	0.1	0.8	7.2
1980-81	1.7	1.5	3.6	0.1	1.0	8.0
1981-82	1.7	1.5	3.7	0.1	1.0	7.9
1982-83	1.7	1.5	3.6	0.1	1.0	8.0
1983-84	1.8	1.5	3.6	0.1	1.0	8.0
1984-85	1.8	1.4	3.5	0.1	1.0	7.8
1985-86	1.9	1.4	3.7	0.1	1.0	8.1
1986-87	2.0	1.5	3.7	0.1	1.0	8.3
1987-88	2.1	1.5	3.8	0.1	1.0	8.5
1988-89	2.2	1.5	3.9	0.1	1.0	8.8
1989-90	2.2	1.4	3.8	0.1	1.0	8.5
1990-91	2.3	1.4	3.8	0.1	1.0	8.5
1991-92	2.3	1.4	3.8	0.1	1.0	8.5
1992-93	2.5	1.4	3.9	0.1	1.1	9.0
1993-94	2.6	1.3	3.9	0.1	1.1	9.1
1994-95	2.4	1.2	4.0	0.1	1.2	9.0
1995-96	2.5	1.2	4.1	0.1	1.3	9.2
1996-97	2.5	1.2	4.2	0.1	1.4	9.4
1997-98	2.4	1.2	4.2	0.1	1.5	9.4
1998-99	2.5	1.1	4.3	0.1	1.7	9.6
1999-00	2.5	1.1	4.2	0.1	1.9	9.7
2000-01	2.5	1.1	4.2	0.1	2.0	9.8

Source: National Accounts Statistics, Central Statistical Organisation, New Delhi.

Sector-wise, the shares of the other transport sector (excluding railways) and the communication sector to GDPFC have increased substantially during the past three decades. The share of OTRANS to GDPFC increased from 2.5 per cent in 1970-71 to 3.8 per cent in 1990-91 and further increased to 4.2 per cent in 2000-01. The share of communications sector to GDPFC increased from 0.7 per cent in 1970-71 to 1.0 per cent in 1990-91 and further increased to 2.0 per cent in 2000-01. The share of the EGWS sector to GDPFC increased from 1.2 per cent in 1970-71 to 2.3 per cent in 1990-91 and marginally increased to 2.5 per cent in 2000-01. The share of the railways to GDPFC, however, declined to 1.1 per cent in 2000-01 from 1.5 per cent in 1970-

71. The share of the storage facilities to GDPFC, however, remained at 0.1 per cent throughout the last three decades. A possible relationship between real output in the infrastructure sectors and GDPFC is exhibited by plotting the two (Chart 1).

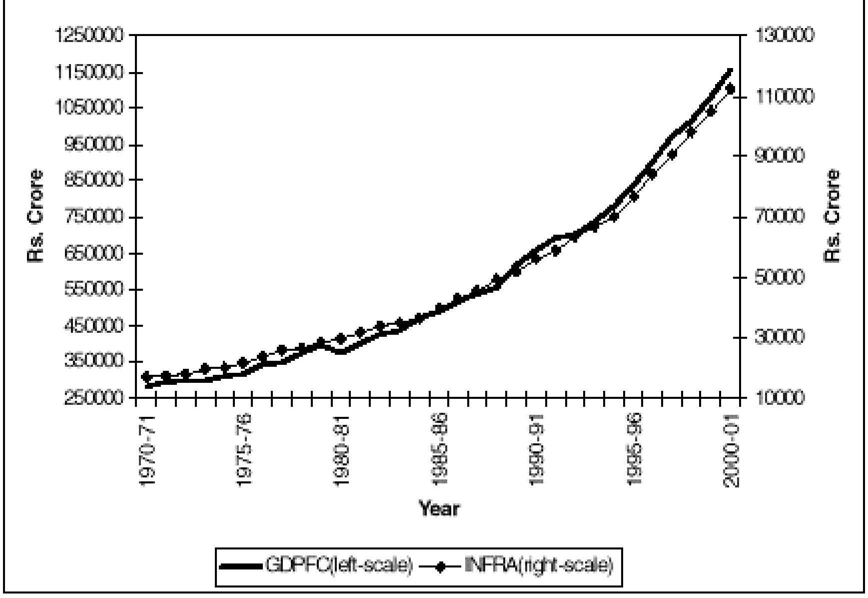


Chart 1 : Infrastructure and GDPFC

Section III
The Empirical Model

Treating the various stocks of infrastructure and labour as inputs and the gross domestic product at factor cost (GDPFC) as output at the aggregate level, yields the following equation for the production function,

$$Y = f(K, L, t) \qquad \ldots(1)$$

where t stands for time trend. Assuming a generalised Cobb-Douglas form of technology yields a more specific relationship between inputs and output:

$$Y = AK^{a}\ L^{b} \qquad \ldots(2)$$

Translating this equation into logarithms produces a linear function that can be estimated:

$$\text{In}\ Y = A + a\ \text{In} + b\ \text{In}\ L \qquad ...(3)$$

where Y is output, K and L are capital and labour inputs, respectively, while a and b are the corresponding parameters measuring output elasticity of factor inputs. In other words, the coefficients indicate the percentage change in output for one percentage change in factor input. The estimated equation in the paper is:

$$LGDPFC_t = a_0 + LEGWS_t + LTRANS_t + LCOMN_t + LEMP_t + u_t \ldots \qquad (4)$$

Where TRANS is defined as total transport, EMP as employment and L denotes logarithm of the variables. The other variables have been defined earlier.

This study uses annual data for the period 1970-71 to 2000-01. Data on capital stock on infrastructure at new base (1993-94=100) are obtained from the various issues of National Accounts Statistics published by the Central Statistical Organisation (CSO), India. The employment data are obtained from the various issues of Economic Survey published by the Government of India. It may be mentioned that capital stock data taken for all the infrastructural sectors include both private and public capital.

Stationarity and Causality Analysis

The test of unit roots using the conventional Dickey-Fuller (DF) and the Augmented Dickey-Fuller (ADF) test statistics indicate that the series on GDPFC, EGWS, TRANS, COMN and EMP are all non-stationary and I(1), *i.e.*, their first differences are stationary (Table 3). As mentioned earlier, the non-stationarity involved in the data series prompted to use the cointegrating VAR analysis to avoid spurious estimates.

Table 3 : Unit Root Tests

Variable	**At Levels**		**At First Differences**	
	DF	**ADF**	**DF**	**ADF**
GDPFC	7.0448	4.8162	-5.3630	-3.7582
EGWS	1.4499	0.9919	-3.9701	-2.8366
TRANS	-1.7380	-1.6960	-5.2713	-3.7026
COMN	15.7172	2.5270	-2.5222	-1.9592
EMP	0.4212	0.4362	-5.2401	-4.55208

Note : The 95% critical value for the ADF statistic is -2.9665 for the regression at levels and -2.9706 at first differences.

Before going for the cointegration and VAR analysis, the direction of causality between GDPFC and various stocks of infrastructure was estimated. While examining the causal relationship between the GDPFC and each of the infrastructure variables, the equations were estimated in a multivariate VAR framework. It may be mentioned that $\_^2$-test of block causality in a VAR framework is equivalent to Granger (1969) causality tests. The $\_^2$-test for the dependent variable GDPFC shows that both the lagged terms of GDPFC and EGWS, TRANS, COMN and EMP are statistically different from zero. Similarly, in each case, at least one lagged gross domestic product has a positive and significant impact on the infrastructure variables. Overall, there exists a bi-directional relationship between GDPFC and infrastructure facilities (Table 4).

Table 4 : Test of Granger's Block Causality in a VAR Framework

Null Hypothesis	Test-Statistic -x^2	Accept/ Reject Null Hypothesis	Inference

I.	EGWS does not Granger cause GDPFC	31.1968*	Reject	Bi-directional
	GDPFC does not Granger cause EGWS	23.5879*	Reject	causality
II.	TRANS does not Granger cause GDPFC	45.8715*	Reject	Bi-directional
	GDPFC does not Granger cause TRANS	23.5879*	Reject	causality
III.	COMN does not Granger cause GDPFC	45.4112*	Reject	Bi-directional
	GDPFC does not Granger cause COMN	23.5879*	Reject	causality
IV.	EMP does not Granger cause GDPFC	16.3277**	Reject	Bi-directional
	GDPFC does not Granger cause GDPFC	23.5879*	Reject	causality

* Significant at 1 per cent level. ** Significant at 5 per cent level.

Cointegration Analysis

Given the non-stationarity involved in all the data series, equation (4) was estimated in a multivariate cointegrating VAR framework, better known as the vector error correction model (VECM), in order to throw light on the long-run relationship between infrastructure and economic growth:

$$\Delta y_t = \alpha_{0y} + \alpha_{ty} t - \Pi_y z_{t-1} + \Sigma \Gamma_{ty} \Delta z_{t-1} + \in_t \qquad ...(5)$$

where z_t is a vector of jointly determined (endogenous) I(1) variables, t is the time trend and $\in_t$ is the error term.

Table 5 : Cointegration Results of the VAR Model

Null	Alternative	Statistic	95% Critical Value
	Based on Maximal Eigenvalue		
r=0	r=1	95.99	37.85
R<=1	r=2	39.23	31.68
R<=2	r=3	22.89	24.88
R<=3	r=4	11.04	18.08
	Based on Trace of the Stochastic Matrix		
r=0	r>=1	169.17	81.20
R<=1	r>=2	73.17	56.43
R<=2	r>=3	33.94	35.37
R<=3	r>=4	11.04	18.08

As shown in Table 5 there exists at least two cointegrating vectors. The first cointegrating vector is chosen due its significance at 1 per cent level. The identified cointegrating relationship between GDPFC as the dependent variable and the stocks of infrastructure along with employment as the independent variables is as follows:

$$LGDPFC_t = 0.1818 - 0.0723\,(LEGWS_t) + 0.2376\,(LTRANS_t) + 0.7387\,(LCOMN_t) + 0.1949\,(LEMP_t)$$

From this relationship it is observed that EGWS, TRANS, COMN and EMP have the elasticities -0.07, 0.24, 0.74 and 0.19, respectively. The negative elasticity (though very low) in the EGWS sector could be due to heavy transmission and distribution (T&D) losses in the power sector and subsidised gas and water supply. They are mostly in the public sector in India with a very low degree of commercialisation.

VAR Analysis

To measure the time profile of the effect of shocks on the future state of a dynamic system, we have made use of an unrestricted VAR model, first suggested by Sims (1980) where all the variables are assumed to be endogenous unlike in the traditional macroeconomic models. Taking two lag values of each variable on the basis of Schwartz Bayesian Criterion (SBC), the following five equations in an unrestricted VAR framework were estimated:

$$LGDPFC_t = \alpha_1 + \sum_{i=1}^{2} \alpha_{1i} LGDPFC_{t-i} + \sum_{j=1}^{2} \beta_{1j} LTRANS_{t-j} + \sum_{k=1}^{2} \theta_{1k} LEGWS_{t-k}$$

$$+ \sum_{l=1}^{2} \delta_{2l} LCOMN_{t-l} + \sum_{m=1}^{2} \phi_{1m} LEMP_{t-m} + u_{1t} \qquad \ldots (6)$$

$$LTRANS_t = \alpha_2 + \sum_{i=1}^{2} \alpha_{2i} LGDPFC_{t-i} + \sum_{j=1}^{2} \beta_{2j} LTRANS_{t-j} + \sum_{k=1}^{2} \theta_{2k} LEGWS_{t-k}$$

$$+ \sum_{l=1}^{2} \delta_{2l} LCOMN_{t-l} + \sum_{m=1}^{2} \phi_{1m} LEMP_{t-m} + u_{2t} \qquad \ldots (7)$$

$$LEGWS_t = \alpha_3 + \sum_{i=1}^{2} \alpha_{3i} LGDPFC_{t-i} + \sum_{j=1}^{2} \beta_{3-j} LTRANS_{t-j} + \sum_{k=1}^{2} \theta_{3k} LEGWS_{t-k}$$

$$+ \sum_{l=1}^{2} \delta_{3l} LCOMN_{t-l} + \sum_{m=1}^{2} \phi_{3m} LEMP_{t-m} + u_{3t} \qquad \ldots (8)$$

$$LCOMN_t = \alpha_4 + \sum_{i=1}^{2} \alpha_{4i} LGDPFC_{t-i} + \sum_{j=1}^{2} \beta_{4-j} LTRANS_{t-j} + \sum_{k=1}^{2} \theta_{4k} LEGWS_{t-k}$$

$$+ \sum_{l=1}^{2} \delta_{4l} LCOMN_{t-l} + \sum_{m=1}^{2} \phi_{4m} LEMP_{t-m} + u_{4t} \qquad \ldots (9)$$

$$LEMP_t = \alpha_5 + \sum_{i=1}^{2} \alpha_{5i} LGDPFC_{t-i} + \sum_{j=1}^{2} \beta_{5-j} LTRANS_{t-j} + \sum_{k=1}^{2} \theta_{5k} LEGWS_{t-k}$$

$$+ \sum_{t=1}^{2} \delta_{5l} LCOMN_{t-l} + \sum_{m=1}^{2} \phi_{5m} LEMP_{t-m} + u_{5t} \qquad \ldots (10)$$

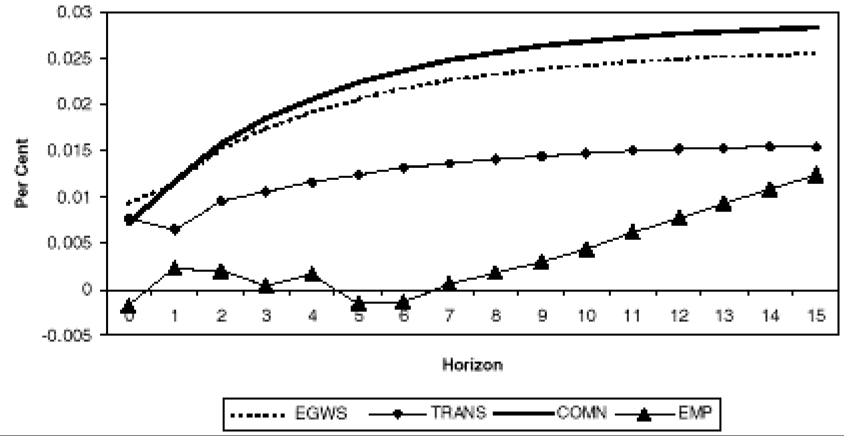
The original equation estimated here is a Cobb-Douglas production function without any structural model therein. Since there exists a cointegrating relationship among the infrastructural variables and GDPFC, the VAR model has been estimated at levels. In terms of methodological aspects, an unrestricted VAR model involves model estimation, impulse response function and variance decomposition for each of the system under consideration. The impulse response function computes the response of the system to particular initial shocks. The variance decompositions measure the percentage of forecast error variance in GDPFC that can be attributed to innovations in a particular stock of infrastructure under consideration. The extraction of variance decompositions from a VAR model typically requires orthogonalisation of the errors from the reduced form equations. It should be noted that coefficient estimates and their standard errors are in general not analysed in detail in an unrestricted VAR model for two reasons. First, with a highly parameterised model and a limited data set, the number of degrees of freedom is small and coefficient estimates are uninformative. Second, because of the highly parameterised nature of the model, near-collinearity of the regressors may lead to very imprecise estimates of the short-run relationship. For a more sophisticated data analysis, tests to examine the variance decomposition and impulse response of the system were conducted.

Impulse Responses

In each equation, iterations are made till 15 lag periods by imposing one-standard deviation shock to each variable in a generalised impulse response approach first developed by Koop *et al.* (1996). The main advantage of the generalised impulse response function is to circumvent the problem of the dependence of the orthogonalised impulse responses on the ordering of the variables in the VAR.

In the impulse response exercise, there had been positive effect on GDPFC for one-standard deviation shock in the various stock of infrastructure (Chart 2). In the shorter horizon, *i.e.,* up to three years, the output effect of one per cent shocks in TRANS was found to be declining marginally or less than one. This diminishing effect of shocks in TRANS infrastructure on output in the initial years could be due to the gestation period. Since most of the infrastructure projects are very long-term in nature, positive output may not be expected in the initial years. The shock to the employment variable, however, has a negative effect on the output in the initial years and positive in the long-run, which could be due to the large number of unskilled and abundant labour in India.

Chart 2 : Impulse Responses of GDPFC to Shocks in EGWS, TRANS, COMN & EMP



From the impulse response analysis, it could be seen that the percentage variation in the real output due to shocks in the communication sector is the highest, which is about double of the transportation sector and nearly close to the electricity, gas and water supply sector.

Variance Decompositions

The variance decomposition shows, for each variable, what proportion of the forecast error variance at different forecast horizons can be attributed to each shock in the model. More than two-thirds of the variance of the one-step forecast error in GDPFC were found to be due to the innovations in the electricity, gas, water supply (EGWS) and communications sectors, where EGWS has the highest share ranging from 0.03 to 0.65 per cent. In the EGWS sector, in the initial steps, a substantial amount in the decomposition pattern was explained by innovations in its own sector and GDPFC, however, in the successive steps the share of COMN increases. In the transport sector, much of the variance is explained by innovations in the GDPFC and in its own sector. Much of the variance in communications sector is explained by GDPFC followed by its own sector. On the whole, electricity, gas, water supply and communication sectors play a dominant role in explaining the variances not only in gross domestic product but also the variances in other sectors.

Section IV
Summary and Conclusions

This study estimates a vector autoregressive model to examine the relationship between gross domestic product and stocks of infrastructure using Indian data for the period 1970-71 to 2000-01.

The estimated model is also used for forecasting by measuring the impulse responses of gross domestic product to one per cent standard deviation shock in the stocks of infrastructure. In the shorter horizon, *i.e.*, up to three years, the output effect of one per cent shocks to infrastructure was found to be less than one. The diminishing effect of shocks in the case of a few stocks of infrastructure to output in the initial years could be due to the gestation period. Since most of the infrastructure projects are very long-term in nature, positive output may not be expected in the initial years. Among all the infrastructural sectors, electricity, gas, water supply and communication sectors were found to play a key role in explaining the movements in the gross domestic product.

Recognising the importance of infrastructure in fostering growth, the major concern for the policy makers is to remove the bottlenecks in supply. The success of delivering proper infrastructure in the country also depends on levying affordable and adequate user charges. For instance, in sectors like roads, telecommunications and ports, where Government has been able to identify and levy proper user charges, the growth in these sectors has been impressive. As the demand for infrastructure services continue to outpace supply, it warrants urgent new capacity buildup in almost all infrastructure sectors along with quality of services. While exploring the possibilities for revival of the economy, what is needed is to deploy the surfeit of liquidity in the financial system in 'supply-leading' strategy and that too for the badly needed railways development and other physical infrastructures in the new environment of administrative and financial reforms (Shetty 2001). In this context, a perceptive observation made by Dr. V.K.R.V. Rao (1981) two decades ago sounds valid, "The link between infrastructure and economic development is not a once for all affair. It is a continuous process; and progress in development has to be preceded, accompanied and followed by progress in infrastructure, if we have to fulfil our declared objectives of a self-accelerating process of economic development."

Notes

1.Development economists Rosenstein Rodan (1965), Ragnar Nurkse (1966) and Albert Hirschman (1965) have used this terminology.

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