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ROLE OF INFRASTRUCTURE

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Abstract

We examine the output elasticity of infrastructure for four South Asian countries viz., India, Pakistan, Bangladesh and Sri Lanka using Pedroni's panel cointegration technique for the period 1980-2005. In this context we develop an index of infrastructure stocks and estimate growth accounting equations to investigate the impact of infrastructure on output and per capita income. The study finds a long-run equilibrium relationship between output (and per capital income) and infrastructure along with other relevant variables such as gross domestic capital formation, labour force, exports, total international trade and human capital. The results reveal that fixed capital formation, labour force, export and expenditure on human capital exhibit a positive contribution to output. More importantly infrastructure development contributes significantly to output growth in South Asia. Further, the panel causality analysis shows that there is mutual feedback between total output and infrastructure development where as there is only one-way causality from infrastructure to per capita income.

Key words*: South Asia, Infrastructure, Output growth, Panel Cointegration, Panel Causality.*

JEL Classifications*: O1, H4, H54, L9.*

I. Introduction

South Asia has become one of the fastest growing regions in the world and accounts for nearly one quarter of world population and 40 percent of the world's poor. Further, South Asia needs to maintain the growth momentum in a sustainable manner to improve the overall standard of living and reduce poverty. Infrastructure development, both economic and social, is one of the major determinants of economic growth, particularly in developing countries. The role of infrastructure development in economic growth has been well recognized in literature (Aschauer 1989; Easterly and Rebelo 1993; Canning, Fay, and Perotti 1994; World Bank 1994; Roller and Waverman 2001; Calderón and Servén 2003; Canning and Pedroni 2004). Further, investment on physical and social infrastructure positively affects the poor directly and indirectly in multiple ways (Estache 2004; 2006 and Jones 2004). Infrastructure development is one of the major factors contributing to overall economic development through many ways for example: (i) direct investment on infrastructure creates production facilities and stimulates economic activities; (ii) reduces transaction costs and trade costs improving competitiveness and (iii) provides employment opportunities and physical and social infrastructure to the poor. In contrast, lack of infrastructure creates bottlenecks for sustainable growth and poverty reduction. Therefore, infrastructure development contributes to investment and growth through increase in productivity and efficiency as it links between resources to factories, people to jobs and products to markets.

Infrastructure constitutes the backbone of economic development in most developing economies and South Asia is no exception. The importance of infrastructure for overall economic development, enhancement of trade and business activities in South Asia need hardly be emphasized. Investment climate surveys repeatedly show that the limited and poor quality of infrastructure facilities act as a major impediment to business growth in South Asia. Moreover, infrastructure helps not just the domestic industry to compete effectively in the domestic market but also gives it an edge over foreign competitors. For the South Asian region to maintain the present growth momentum, it is essential to strengthen different kinds of infrastructure facilities such as transportation, energy, information, etc. across the South Asian countries. In this backdrop, the South Asian countries are making concerted efforts to improve infrastructure levels in their countries.

The People's Republic of China (PRC) and East/Southeast Asian countries have made rapid improvement in their macroeconomic situations, investment, exports and employment over the decade of 1980s and 1990s because of huge investments in infrastructure. South Asian policy makers realize that credible efforts for sustainable economic growth in South Asia must involve substantial upgradation of infrastructure investment and provision of quality infrastructure facilities. South Asian countries have many advantages to offer to potential investors, including high and steady economic growth, single-digit inflation, vast domestic markets, a growing number of skilled personnel, an increasing entrepreneurial class and constantly improving financial systems, including expanding capital markets. However, provision of quality infrastructure only would enable these countries to reap these benefits. In this context, an examination of the precise economic contribution of infrastructure to growth would be of great use to policy makers and researchers.

Most of the previous studies are either country-specific time series studies or cross-section studies of a large number of countries. Moreover, previous cross-section studies may not be appropriate to South Asian countries as each country in the analysis is not a representative sample and there may be extreme cases. A study focusing on South Asian countries with similar economic policies, factor endowments and process of production is a contribution to the literature. Moreover there is hardly any South Asia Pacific study covering a long period till 2005 to sufficiently explain the impact of infrastructure development on output. Most of the previous studies have taken public expenditure/infrastructure investment as a proxy for infrastructure which may not be right given the lack of governance and poor outcomes of infrastructure investment in under-developed or developing countries as those of South Asia. Unlike other studies where bi-variate causality analysis between infrastructure indicator/s and output has been used to show the link between output growth and infrastructure, the present study develops a composite index of leading physical infrastructure indicators to examine the impact of infrastructure development on output growth. Moreover, the analysis of the present study not only focuses on the stock of infrastructure facilities but also on the impact of human capital on economic growth on the basis of endogenous growth theories. Lastly, the present study uses panel coinegration technique which uses all information, both times series and cross section, which are not detectable in pure cross-sections or in pure time series[1]. Given the fact that we only have 26 observations for each country, panel cointegration estimation would provide reliable estimates.

II. MACROECONOMIC PERFORMANCE and INFRASTRUCTURE DEVELOPMENT IN SOUTH ASIA

Before examining the precise economic relationship between infrastructure development and economic growth in South Asian[2] countries, it is appropriate to review the macroeconomic performance and infrastructure facilities in these countries over the last two decades. All four South Asian countries viz., India, Pakistan, Bangladesh and Sri Lanka have been consistently implementing economic reforms while laying emphasis on a market economy and integrating their economies with the rest of the world[3]. Consequently, all the countries in the region except Pakistan have experienced higher economic growth and better macroeconomic performance during the nineties (Table-1A[4]).

The average growth rate of India increased to 7.6 percent during 2001-2005 from 5.7 percent during 1980-90. Similarly, Bangladesh and Sri Lanka had higher GDP growth rates in the 1991-2005 than the eighties (1980-1990). The higher growth rate in India, Bangladesh and Sri Lanka during post 1991 period was accompanied by substantial growth in the service and industrial sectors. But, GDP growth rate and macroeconomic performance in Pakistan slowed down substantially during the nineties compared to the eighties due to internal conflict, political instability, social insecurity, and an interrupted business climate. Per capita income growth also slowed down in Pakistan during the nineties, whereas it improved in India, Bangladesh, and Sri Lanka. However, both growth and per capita income have improved for Pakistan in recent years. Other important macro indicators like gross domestic savings, gross domestic capital formation and indicators on the external sector front such as the current account balance, foreign exchange reserves, foreign direct investment inflows and overall improvement in balance of payments was seen in all these countries except Pakistan during the post-reform

[1] See Baltagi and Kao (2000) for a detail discussion on the advantages of panel cointegration.
[2] South Asian countries include India, Pakistan, Sri Lanka and Bangladesh. Here we have excluded Nepal due to data unavailability.
[3] For details about economic reforms and performance in South Asia, see Sahoo (2006).
[4] All the tables mentioned in the text are given in the Appendix at the end.

period[5]. Overall, there has also been a positive movement in most of the macro indicators except the fiscal deficit, both on the domestic and external sector front. The above analysis suggests that with the exception of Pakistan which also has revived in recent years, the South Asian countries have registered a higher growth momentum during the period 1990-2005 than in the eighties. Indeed, the South Asian region has been one of the fastest growing regions in the world in recent years.

However, for the South Asian region to maintain the growth momentum in a sustainable manner, it is essential to strengthen infrastructure facilities such as transportation, transit and communication links across the South Asian countries. Table 2A reports the physical transport, telecommunication, information and energy infrastructure indicators for South Asian countries *vis-à-vis* other developing countries. All the South Asian countries lag behind other developing countries in almost all indicators. Overall, South Asia has a long way to go in improving infrastructure in the region. Similarly, the infrastructure and business indicators of South Asia *vis-à-vis* other East and South East Asia countries are presented in Table-3A. With the exception of Singapore, no country in the region is performing well in the overall infrastructure quality index. Singapore has a score of 6.6 out of 7, indicating a high level of infrastructure, followed by the Republic of Korea with a score of 5.1. PRC has a score of 3.4, which is higher than most of its counterparts in the region but is not as high as Singapore or the Republic of Korea. India has managed to receive a score of 3.3, Pakistan fares slightly better at 3.4 while Bangladesh has a score of 2.3. Further, if one compares the countries in the South Asian region, particularly in terms of the number of days required to start a business, there appear to be huge differences. In India, it takes about 80 days to start a business whereas in smaller economies such as Bangladesh and Pakistan it takes much lesser time.

Regional comparison of infrastructure facilities indicates that South Asia lags behind all the regions except Africa. In South Asia only 43 percent population have access to electricity, 84 percent population have access to improved water, and 35% of the population have access to sanitation. Similarly, teledensity (per 1000 population) is at 61 in South Asia lowest even compared to Africa which is at 62. South Asia is relatively at a better position in terms of road connectivity (65 percent of the rural population living within two km of an all-season road) compared to many other developed regions (see Table 4A). Further, a comparative

[5] After 1991.

infrastructure situation among the South Asian countries is presented in Table 5A. It is clear that there is unequal access to infrastructure facilities and levels of infrastructure development among South Asian countries. For example, Sri Lanka has the highest proportion of population connected to electricity, sanitation and telecom facilities, whereas Pakistan scores higher than any other country in relation to improved water resources. Bangladesh and India lag behind Sri Lanka and Pakistan in many facilities. A study by Fay and Yepes (2003) indicate that the South Asian region needs an annual investment of US$63 billion (US$ 28 billion new and US$ 35 billion on maintenance) on infrastructure facilities such as roads, railways, airways, ports, telecom and electricity. This is equal to 7 percent of their GDP (see Table 6A).

Infrastructure demands strong planning, coordination, decentralization, private participation and commercialization of service providers rather than a top-down approach. Since private participation in infrastructure is limited in developing countries, particularly in South Asia, cost recovery and measures to improve policy and institutional frameworks are important for a creating virtuous circle of investment and growth. Another important factor for accountable and cost effective provision of infrastructure is increasing competition though private participation and technological innovation. If the policy and institutional framework is clearly spelt out, international investors would like to invest in these countries where there is huge market for infrastructure projects. Though private participation, both domestic and international, is important, improving the capacity of the local financial markets is also very important. Some of the major issues for infrastructure development in South Asia include public-private partnership, budgetary allocation, infrastructure financing, fiscal incentives and tariff policy[6].

As there exists a huge infrastructure deficit in the region and a pressing need to increase infrastructure investment, a proper study of the exact and dynamic relationship between output growth and infrastructure development is useful for both academicians and policy makers.

III. BRIEF REVIEW OF LITERATRE

The empirical research on role of infrastructure in economic growth started after the seminal work by Aschauer (1989a; 1989b; 1989c; 1993) where he found that the output

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[6] Though these issues are very important for infrastructure development in south Asia, these are not subject matter of this study. For details on these issues, see Nataraj (2007).

elasticity of infrastructure spending is very high ranging from 0.38 to 0.56. Further, he suggests that lack of infrastructure spending leads to slow down of productivity growth in the United States (US). Supporting Aschauer, Munnell (1990a; 1990b; 1992) and Garcia-Mila and McGuire (1992) find high output elasticity, though comparatively lower than reported by Aschauer, of public investment on infrastructure.

Though high output elasticity of infrastructure by Aschauer has been criticized on methodological background i.e. reverse causation from productivity to public capital and a spurious correlation due to non-stationarity of the data (Holtz-Eakin 1994; Gramlich 1994; Holtz-Eakin and Schwartz 1995; and Garcia-Milà *et al*. 1996), a series of country-level studies support Aschauer's finding, though with lower elasticity, that infrastructure has a positive and significant impact on output growth. Some of the important studies are Uchimura and Gao (1993) for Korea, China and Taiwan; Bregman and Marom (1993) for Israel; Shah (1992) for Mexico and Wylie (1996) for Canada. Pereira (2000), using a multivariate time-series framework for the US over the period 1956-97, found that public investment on different types of physical infrastructure is a powerful means of promoting economic growth as it crowds in private investment in different sectors and increases the private output. Fedderke, Perkins and Luiz (2006) use the endogenous growth theory and show that investment in infrastructure to lead economic growth in South Africa directly and indirectly (the latter by raising the marginal productivity of capital). However, there is weak evidence of feedback from output to infrastructure; while the finding of an infrastructure growth impact is robust. Further, an industry-level panel study on South African manufacturing sectors by Fedderke and Bogeti (2006) reveal a significant positive impact of infrastructure on productivity growth even after controlling the endogeneity effect of infrastructure measures.

Similarly, there have been some cross-country studies on impact of infrastructure on economic growth in developing countries which show a positive and significant relationship between them (Canning and Fay 1993; Easterly and Rebelo 1993; Baffes and Shah 1993; Canning and Pedroni 1999; Roller and Waverman 2001; Calderón and Servén 2003a; 2004). Easterly and Rebelo (1993) find high output elasticity of infrastructure investment, particularly investment on transport and communication for a hundred countries. The study by Canning and Fay (1993) suggests normal to high rates of return on infrastructure investment for developed countries and moderate returns for underdeveloped countries. Further, Canning, Fay and Perotti

(1994) find a positive effect of telephones on economic growth, while Sanchez-Robles (1998) also find a positive impact of road length and electricity generating capacity in explaining subsequent economic growth.

More recent empirical literature, mostly in a cross-country panel data context, has confirmed the significant output contribution of infrastructure. Taking care of the reverse causality problem by using the structural model, Roller and Waverman (2001) find an output elasticity of 0.05 for main telephone lines per capita for OECD countries. Demetriades and Mamuneas (2000) find a positive but divergent rate of return of public capital for twelve OECD countries over the period 1972-91. Esfahani and Ramírez (2003) develop a structural growth model and use the simultaneous-equations system in their cross country study to distinguish the reciprocal effects of infrastructure and the rest of the economy on economic growth. The results reveal that the contribution of infrastructure services to GDP is substantial, and in general, exceeds the cost of providing these services.

Calderón and Servén (2003a), using GMM estimates of a Cobb-Douglas production technology for a panel of 101 countries for the period 1960-97, find positive and significant output contributions of three types of infrastructure assets: telecommunications, transport and power for Latin America countries. Further, the study suggests that the per-capita output gap between Latin America and East Asia over the 1980s and 1990s can be traced to the slowdown in Latin America's infrastructure accumulation in those years. Canning and Pedroni (2004) investigate the long-run consequences of infrastructure provision on per capita income in a panel of countries over the period 1950-1992. Though they find a positive contribution of infrastructure facilities till an equilibrium level, infrastructure provision above a growth maximizing level leads to diversion of resources from other productive uses and reduces long-run income. Calderón and Servén (2004) find that infrastructure stocks contribute positively to growth and reduce income inequality in their hundred-country study.

Though there is no present study thus examining the relationship between infrastructure development and output growth in South Asia, there have been a few studies examining different aspects of the role of infrastructure for economic growth. Barnes and Binswanger (1986) suggest that electricity and other rural infrastructures have a more direct impact on agricultural productivity and on private investment such as electric pumps and other electrical equipments. Binswanger *et al.* (1989) show the major effect of road infrastructure in rural

India leading to reduction in transportation costs and the increase in productivity. Elhance *et al.* (1988) using both physical and social infrastructures have shown that reductions in production costs in manufacturing mainly result from infrastructure investment in India. Dutt and Ravallion (1998) show that the Indian states with better infrastructure and human resources, among others, have seen significantly higher growth rates and poverty reduction. Sahoo and Saxena (1999) using the production function approach have concluded that transport, electricity, gas and water supply, and communication facilities have a significant positive effect on economic growth with increasing return to scale. Ghosh and De (2000c) using physical infrastructure facilities across the South Asian countries over last two decades have shown that differential endowments in physical infrastructure were responsible for rising regional disparity in South Asia. Mitra *et al*. (2002) find further confirmation of a substantial public capital effect at the state-level disparities.

However, the exact economic relationship between infrastructure and economic growth and output elasticity of infrastructure has been debatable (see Table 7A). An interesting study by Devarajan *et al*. (1996) finds a negative relationship between infrastructure expenditure and economic growth for a sample of 43 developing countries. They argue that this result may be due to the fact that excessive amounts of transportation and communication expenditures in those countries make such expenditures unproductive. Further they find that increase in the share of consumption expenditure have a significant positive impact on economic growth whereas increases in the share of public investment expenditure have a significant negative effect. Another cross country study by Sanchez-Robles (1998) using the public investment share of GDP as regressor report a negative growth impact of infrastructure expenditure in a sample of 76 countries. Similarly, Prichett (1996) suggested that public investment in developing countries is often used for unproductive projects. As a consequence, the share of public investment in GDP can be a poor measure of the actual increase in economically productive public capital. Therefore, the impact of infrastructure on growth can vary from negligible to negative (Eberts 1986; 1990; Caning and Fay 1993; Shah 1992; Holtz-Eakin 1994, Evan and Karras 1994; Holtz-Eakin and Schwartz 1995; Garcia-Milà *et al* 1996; and Devarajan, Swaroop and Zou 1996; and Ghali 1998).

Overall, it is clear from previous findings that the effect of public capital or infrastructure investment is growth-enhancing in general. However, the impact is much lower than that found by Aschauer (1989) and Munnell (1990), which is generally considered to be the starting point of this line of research. Further, the effect of public investment differs across countries, regions, and sectors depending upon the quantity and quality of the capital stock and infrastructure development.

IV. THEORITICAL FRAMEWORK, INFRASTRUCTURE INDEX AND DATA SOURCES

Since the objective of the paper is to examine the effect of infrastructure stocks on growth, we use a general production function framework with infrastructure stock as an additional variable along with capital and labour,

$$Y_t = f\,(K_t, L_t, I_t)\ . \ . \ ., \qquad (1)$$

Where Y_t is gross output produced in an economy using inputs such as capital (K_t) and labour (L_t) and supporting infrastructure (I_t).

However, trade theories suggest that (Krueger 1975; Srinivasan 1985; Bhagawati 1988; Awokuse 2003) free trade enriches the nations in various ways. Subsequently economic growth literature triggered by the endogenous growth theory (Grossman and Helpman 1990; Rebelo 1991; Barro and Sala-i-Martin 1995) emphasizes on international trade in achieving a sustainable rate of economic growth by increasing labour productivity, generating greater capacity utilization, bringing more technological progress and opening up more employment opportunities. Following these studies, we include variables like trade openness and exports alternatively in the production function. Besides, social infrastructure such as education, health and water and sanitation are also important for economic growth (Barro 1991). In order to assess the impact of human capital on growth, we consider public expenditure on health and education[7]. Higher public expenditure on social infrastructures induces more literacy, better

[7] Since it is difficult to get compatible and reliable time series data on social indicators, we have considered public expenditure on health and education.

health and manpower skill, which lead to higher productivity and growth. Thus the new production function is as follows,

$$Y_t = f\,(K_t, L_t, I_t, Tt_t, EXPhe_t)\ .\ .\ , \qquad (2)$$

Where Tt_t implies total trade and $EXPhe_t$ is public expenditure on health and education. Thus the output variables we consider in this study are real GDP and GDP per capita. Trade variables are real total trade (export + import) and real total exports. The present study uses gross domestic capital formation[8] (GFCF) as a proxy for capital. Here, the Labour force stands for the total active labour force available. The empirical approaches to examine the impact of infrastructure on growth use a variety of definitions of infrastructure development such as infrastructure investment or some indicators of physical infrastructures. However, we have made a composite index of major infrastructure indicators to examine the impact of infrastructure on growth.

Infrastructure Indicators: The Infrastructure index has been made by using the Principal Component Analysis (see Appendix). We include major infrastructure indicators as follows:

1. Per capita electricity power consumption
2. Per capita energy use (kg of oil equivalent)
3. Telephone line (both fixed and mobiles) per 1000 population
4. Rail Density per 1000 population
5. Air Transport, freight million tons per kilometer
6. Paved road as per centage of total road.

The Eigen values and respective variance of these factors are as given in Table 8A. The first factor or principal component has an Eigen value larger than one and explains over two thirds of the total variance. There is a large difference between the Eigen values and variance explained by the first and the next principal component. Hence, we choose the first principal component for making a composite index representing the combined variance of different

[8] It is important to note that this strategy has been widely used by researchers as it is difficult to estimate the total stock of capital. Investment is the addition to capital stock, thus we have taken investment as the proxy for capital.

aspects of infrastructure captured by the six variables. The factor loadings for each of the five original variables are given in Table 9A.

Finally, we estimate the following equations (3) and (4):

$$ln\ Rgdp_{it} = \alpha_i + \delta_i t + \beta_{1i}\ ln\ Rgdcf_{it} + \beta_{2i}\ ln\ Lf_{it} + \beta_{3i}\ ln\ Iindex_{it} + \beta_{4i}\ ln\ (RTt_{it}/REexp_{it}) + \beta_{5i}\ ln\ Rexhe_{it} + \varepsilon_{it} \ldots, \quad (3)$$

$$ln\ Rpgdp_{it} = \alpha_i + \delta_i t + \beta_{1i}\ ln\ Rgdcf_{it} + \beta_{2i}\ ln\ Lf_{it} + \beta_{3i}\ ln\ Iindex_{it} + \beta_{4i}\ ln\ (RTt_{it}/REexp_{it}) + \beta_{5i}\ ln\ Rexhe_{it} + \varepsilon_{it} \ldots. \quad (4)$$

(The expected sign of (β_{1i}, $\beta_{2i,}$ $\beta_{3i,}$ β4i and β_{5i}) is > 0).

Where *Rgdp* and *Rpgdp* are gross domestic product and per capita gross domestic product respectively. *Rgdcf is* gross domestic capital formation; *Iindex* is infrastructure index*, RTt* implies total international trade; *Rexp* is real exports*; Reaped* is real expenditure on health and education.

Data source: Annual data on total exports, total imports, Gross Domestic Product (GDP), per capita GDP, gross domestic capital formation, expenditure on health and education and labour force are taken from World Development Indicators CD-ROM, World Bank, 2007. Real GDP, real per capita income, real export, real domestic capital formation public expenditure on health and education are calculated by dividing the respective GDP deflator (2000=100). All variables are in real terms. Labour force is taken according to the ILO definition of the economically active population that includes both the employed and the unemployed. Infrastructure variables considered in this study are: air freight transport (million tons per K.M.), electric power consumption (kwh per capita), energy use (kg of oil equivalent per capita), and total telephones lines (main line plus cellular phones) per 1000 population, rail density (per 1000 population) and paved road as percentage of total road are taken from World Development Indicators, various years.

V. ECONOMETRIC ANALYSIS

We use panel data techniques to estimate the growth equations {Eqns 3 and 4} because of its advantages over cross-section and time series in using all the information available, which is not detectable in pure cross-sections or in pure time series[9]. In addition, panel data estimation provides improved estimates over time series techniques by increasing the power of the tests if the data span is short, given the fact that we only have 26 observations for each country. The first step of panel cointegration is to ascertain the stationary properties of the relevant variables. In this context, we use the panel unit root test developed by Im, Pesaran and Shin (2003) techniques to test the stationary properties of the variables.

Testing for stationarity in panel data: The traditional Augmented Dickey-Fuller (ADF)-type of unit root test suffers from the problem of low power in rejecting the null of stationarity of the series, especially for short-spanned data. Recent literature suggests (Levin, Lin and Chu, 2002; Im, Pesaran and Shin 2003; Maddala and Wu 1999; Choi 2001; and Hadri 2000) that the panel-based unit root tests have higher power than unit root tests based on individual time series. We use the IPS panel unit root test as it allows for heterogeneity in choosing the lag length in ADF tests when imposing a uniform lag length is not appropriate. In addition, slope heterogeneity is more reasonable in the case of cross-country studies because of differences in economic conditions and degree of development of each country.

The IPS test is based on the following equation:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \sum_{j=1}^{p_i} \rho_{i,j} \Delta y_{i,t-j} + \gamma_i t + \varepsilon_{i,t} \qquad (5)$$

where $y_{i,t}$ (i=1, 2,…..,N; t=1,2,…….,T) is the series for panel member (country) i over period t, p_i is the number of lags in the ADF regression, and the error terms $\varepsilon_{i,t}$ are assumed to be independently and normally distributed random variables for all i's and t's with zero means and finite heterogeneous variances σ_i^2. Both β_i and the lag order ρ are allowed to vary across sections (countries). The null hypothesis is $\beta_i = 0$, while the alternative hypothesis is $\beta_i < 0$. IPS developed two test statistics and called them the LM-bar and the t-bar tests. The t-bar statistics

[9] See Baltagi and Kao (2000) for a detail discussion on the advantage of panel cointegration.

are calculated using the average t-statistics for β_i from the separate ADF regressions in the following fashion:

$$\tilde{t} - bar_{NT} = \frac{\sum_{i=1}^{N} t_{i,T}(p_i)}{N} \tag{6}$$

Where $t_{i,T}$ is the calculated ADF statistics from individual panel members. Using Monte Carlo simulations, IPS show that the t-bar is normally distributed under the null hypothesis, and it outperforms M-bar in small samples. They then use estimates of its mean and variance to convert t-bar into a standard normal 'z-bar' statistic so that conventional critical values can be used to evaluate its significance.

Panel Cointegration Test: We use the panel cointegration test developed by Pedroni (1999) which extends the residual based Engle and Granger (1987) cointegration strategy. This formulation allows one to investigate heterogeneous panels, in which heterogeneous slope coefficients, fixed effects and individual specific deterministic trends are permitted. In its most simple form, this consists of taking no cointegration as the null hypothesis and using the residuals derived from the panel analogue of an Engle and Granger (1987) static regression to construct the test statistic and tabulate the distributions. Pedroni's method includes a number of different statistics for the test of the null of no-cointegration in heterogeneous panels. The first group of tests is termed "within dimension". This includes the panel-v, panel rho (r), which is similar to the Phillips, and Perron (1988) test and panel non-parametric (pp) and, panel parametric (adf) statistics. The panel non-parametric statistic and the panel parametric statistic are analogous to the single-equation ADF-test. The other group of tests is called 'between dimension' which is comparable to the group mean panel tests of Im *et al*. (2003). The 'between dimension' tests include tests such as group-rho, group-pp, and group-adf statistics. The seven of Pedroni's tests are based on the estimated residuals from the following long-run model:

$$Y_{it} = \alpha_i + \delta_i t + \beta_{1i} X_{1it} + \ldots + \beta_{mi} X_{mit} + \varepsilon_{it} \tag{7}$$

$$i = 1, 2, \ldots, N, \; t = 1, 2, \ldots\ldots, T, \; m = 1, 2, \ldots M,$$

where T is the number of observations over time, N is the total number of individual units in the panel and M is the number of regression variables.

To test for cointegration, the residuals are pooled either within or between the dimension of the panel, giving rise to the panel and group mean statistics (Pedroni, 1999). In the former, the statistics are constructed by summing both numerator and denominator terms over the individuals separately, while in the latter, the numerator is divided by the denominator prior to the summation. Consequently, in the case of the panel statistics the autoregressive parameter is restricted to be the same for all cross sections. If the null is rejected, the variables in question are cointegrated for all panel members. In the group statistics, the autoregressive parameter is allowed to vary over the cross section, as the statistics amount to the average of individual statistics. If the null is rejected, cointegration holds at least for one individual. Therefore, group test offers an additional source of heterogeneity among the panel members. Both panel and group statistics are based on the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) method. Under an appropriate standardization, based on the moments of the vector of Brownian motion function, these statistics are distributed as standard normal. The standardization is given by:

$$\kappa = [k_{NT} - \mu \sqrt{(N)} \; / \; \sqrt{\nu} \qquad (8)$$

Pedroni (1999) gives critical values for μ and *v* with and without intercepts and deterministic trends to determine the existence of cointegration among the relevant variables. The small sample size and power properties of all seven tests are discussed in Pedroni (1997). He finds that size distortions are minor, and power is high for all statistics when the time span is long. For shorter panels, the evidence is more varied. However, in the presence of a conflict in the evidence provided by each of the statistics, Pedroni shows that the *group-adf statistic* and *panel-adf statistic* generally perform best.

Panel FMOLS: In case of the existence of panel cointegration, Pedroni (2001) suggests fully modified ordinary least square (FMOLS) to obtain long-run cointegrating vectors. In the presence of unit root variables, the effect of super consistency may not dominate the endogeneity effect of the regressors if OLS is employed. Pedroni (2001) shows that OLS can be modified to make an inference in being cointegrated with the heterogeneous dynamic panel. In the FMOLS setting, non-parametric techniques are exploited to transform the residuals from the cointegration regression and can get rid of nuisance parameters. Therefore, the problem of endogeneity of the regressors and serial correlation in the error term are avoided by using FMOLS.

***Panel causality test*:** If all the variables are found to be integrated of the same order, the panel causality test based on Engle and Granger (1987) line can be used to see the direction of causality between output and infrastructure development. Following Banerjee *et al.* (1993) and Shiu and Lam (2004), a general dynamic regression model in the form of error correction model (ECM) is equal to:

$$\Delta Y_{i,\,t-1} = \alpha_i + \lambda ECM_{,\,t-1} + \sum_{j=1} \beta_1(j)\Delta y_{i,\,t-j} + \sum_{j=1} \beta_2(j)\Delta x_{i,\,t-j} + \gamma I + \varepsilon_{i,\,t}\,, \qquad (9)$$

where index j is equal to the number of lags. ECM, the error correction term (ECT) is obtained from the fixed effect model. If β2's are jointly significantly different from zero, X Granger causes Y in the short run. The long-run Granger causality can be found by testing the significance of the ECT. As we are using panel data, a fixed effect model will be used to account for idiosyncratic country effects (variable I in equation Eqn. 5). This is indeed important as mentioned by Holtz-Eakin (1994).

VI. EMPIRICAL RESULTS

The results of the panel unit root tests suggest that all the relevant variables are integrated of order one as we reject the null of unit root at first difference (see Table 10A). Once ascertained that all the variables are I (1), we turn to the question of possible cointegration among the variables. We have estimated panel cointegration for two time periods i.e. 1980-2005 and 1991-2005. The reasons for grouping the estimation period into two are (i) the infrastructure index for the period 1991-2005 includes paved road which was not available for all the countries in question before 1991, and (ii) all the four South Asian countries followed economic reforms with a greater emphasis on globalization and liberalization during nineties and also achieved better macroeconomic performance (except Pakistan during the nineties). The result of the cointegration tests with time trend and without time trend (and also with exports and total trade alternatively) is presented in Tables 1 (1980-2005) and 2 (1991-2005). Out of seven tests, four test statistics are significant rejecting the null of no-cointegration and suggesting the existence of a long-run equilibrium relationship among the relevant variables for both the periods. But three other panel cointegration tests (panel v-stat, panel rho-stat and group rho-stat) do not reject the null of no cointegration. However, the most important statistics *group-adf* and *panel-adf statistics* reject the null of no cointegration and suggest that there exists a cointegrating relationship.

Table 1: Panel Cointegration Test (1980-2005)

	Without Trend		With Trend	
	Export	Total Trade	Export	Total Trade
Panel v-stat	0.466	0.432	0.748	0.532
Panel rho-stat	-0.154	-0.038	0.105	0.591
Panel pp-stat	-3.066*	-2.456*	-3.417*	-2.559*
Panel adf-stat	-2.293*	-2.036*	-2.558*	-2.384*
Group rho-stat	0.557	0.687	0.578	0.81
Group pp-stat	-3.273*	-2.656*	-3.959*	-3.551*
Group Adf-stat	-1.883*	-2.362*	-2.87*	-3.248*

Table 2: Panel Cointegration Test (1991-2005)

	Without Trend		With Trend	
	Export	Total Trade	Export	Total Trade
Panel v-stat	-0.484	-0.68	0.20	-0.91
Panel rho-stat	0.783	1.31	1.43	1.16
Panel pp-stat	-3.53*	-1.14	-4.05*	-2.63*
Panel adf-stat	-3.92*	-1.93*	-3.01*	-1.998*
Group rho-stat	1.48	2.05	2.19	2.01
Group pp-stat	-5.551*	-1.84*	-4.03*	-3.08*
Group Adf-stat	-3.935*	-1.75*	-2.31*	-1.71*

Since the variables in questions are co-integrated, the FMOLS estimation technique has been used to obtain the long-run coefficients of individual variables. In particular we are interested in whether innovations to infrastructure stocks have a long-run effect on GDP and GDP per capita. The results are given in Tables 3 and 4. As noted earlier, our strategy involves estimation of an infrastructure-augmented income regression. Following Loayza *et al.* (2003) we include the following control variables: gross domestic capital formation, labour force, expenditure on health and education, export and trade. Given the importance of contribution of exports and trade in empirical growth literature, we have taken both exports and total trade alternatively in our growth estimations. As expected (see Table 3) the coefficients of investment, export, labour and expenditure on health and education are positive and significant, indicating statistically significant positive impact on GDP. More importantly the long-run coefficient of infrastructure is 0.26 and is statistically significant at one per cent. The results are almost similar with the infrastructure index having a positive and significant coefficient of 0.24 when exports are replaced by total trade. Repeating the same estimation for the dependent variable per capita GDP, we also find a positive and significant coefficient for the infrastructure index. However, the coefficient is small in magnitude at around 0.16. Therefore it is clear from these results that the output elasticity of infrastructure varies between 0.16 to 0.26 percent for South Asian countries.

Table 3: Fully Modified OLS result (1980-2005)

Dependent Variables: Log GDP and Log Per capita GDP

Variables	Dependent Variable: LGDP		Dependent Variable: Per capita GDP (Lpgdp)	
	Eqn 1	Eqn 2	Eqn 3	Eqn 4
LEexp (Export)	0.13** (5.56)	-	0.08** (3.69)	-
LTt (Total Trade)	-	0.07* (2.70)	-	0.04* (2.17)
Lgdcf (Investment)	0.26** (7.46)	0.26** (7.59)	0.22** (5.77)	0.20** (5.39)
LLf (Labour)	0.63** (12.15)	0.72** (13.59)	0.26* (2.82)	0.32** (3.40)
Lexhe (Exp. on Health and Education)	0.15** (2.93)	0.21** (3.65)	0.08 (1.63)	0.12* (2.54)
Lindex (Infrastructure Index)	0.26* (2.51)	0.24* (2.46)	0.16# (1.88)	0.16* (1.96)

Notes: # significance at 10% level, * significance at 5% level, ** significance at 1% level. All the variables are in real and log (L) values.

The results for the period 1991-2005 reveal that the output elasticity of export, investment, labour and expenditure on health and education are positive. The impact of trade on GDP is also positive and significant which is presented. However, the interesting point to note is that the output elasticity of the infrastructure index is positive and statistically significant at 0.18 and 0.21, respectively. Similarly, the elasticity of infrastructural investment with respect to per capita income is 0.20 in equation 4 and 0.25 for equation 5. Among the infrastructure facilities, energy use, electricity use and paved roads are the most important infrastructure that contributes the maximum to growth (see Table 11A).

Table 4: FMOLS result (1991-2005)

Dependent Variables: Log GDP and Log Per capita GDP

Variables	Dependent Variable: LGDP		Dependent Variable: Per capita GDP (Lpgdp)	
	Eqn. 1	Eqn. 3	Eqn. 4	Eqn.5
LEexp (Export)	0.15** (3.91)	-	0.07** (3.43)	-
LTt (Total Trade)	-	0.21** (3.61)	-	0.06 (1.48)
Lgdcf (Investment)	0.15** (3.10)	0.20* (2.58)	0.14* (2.47)	0.14# (1.92)
LLf (Labour)	0.73** (13.24)	0.74** (13.81)	0.12** (3.47)	0.16** (3.22)
Lexhe (Exp. on Health and Education)	0.19* (2.86)	-	0.15** (3.63)	0.13* (2.07)
Lindex (Infrastructure Index)	0.18* (2.00)	0.21** (4.25)	0.20** (3.64)	0.25** (3.12)

Notes: # significance at 10% level, * significance at 5% level, ** significance at 1% level. All the variables are in real and log (L) values.

Table 5: Panel causality Test between Infrastructure and Growth

Direction of Causality	No. of Lags	$\Theta=0$: t-statistic (P-value)	$\Sigma\beta_i=0$: F-statistic (P-value)
Infrastructure→GDP	1	-4.01** (0.00)	4.07* (0.05)
GDP→ Infrastructure	1	-2.30* (0.04)	1.14 (0.28)
Infrastructure →Per capita GDP	2	-3.18** (0.002)	0.71 (0.43)
Per capita GDP →INFRA	1	-1.64 (0.11)	3.16** (0.05)

Notes: * denotes significant at 5% level and ** significance at 1% level.

Overall, the results reveal that labour force, investment, infrastructure stock, export and expenditure on health and education play an important role in economic growth in South Asia. Some of the important results of the study are: (i) Infrastructure development in South Asia has a significant positive contribution to growth; (ii) Like physical infrastructure, expenditure on social infrastructure such as health and education also contributes to economic growth in South Asia.

Since the empirical literature on the nexus between growth and infrastructure development has been debatable, we look at the direction of feedback by using the panel causality methodology. The results indicate that there is a two-way causality between infrastructure and GDP. However, there is a one way causality from infrastructure to level of per capita income (table 5).

VII. CONCLUDING REMARKS AND POLICY IMPLICATIONS

In this study, we investigate the role of infrastructure in economic growth for four South Asian countries after controlling other important variables such as investment, labour force and trade by using the panel cointegration techniques for the period 1980 to 2005. In contrast to the earlier studies, the present analysis develops a composite index for infrastructure stocks to examine the impact of physical infrastructure on growth and includes human capital proxied by expenditure on health and education. Overall, the results reveal that labour force, investment, infrastructure stock, export and expenditure on health and education play an important role in economic growth in South Asia. Some of the important results of the study are: (i) Infrastructure development in South Asia has a significant positive contribution to growth; (ii) like physical infrastructure, expenditure on social infrastructure such as health and education also contributes to the economic growth in South Asia.

From the policy perspective, the study suggests that infrastructure development contributes positively to economic growth and also to per capita income in four South Asian countries. Hence these countries should place a greater emphasis on infrastructure development, both on physical infrastructure and also human capital such as health and education. In addition the study also emphasizes the role of investment, labour force and trade openness for sustaining the high growth momentum in South Asian countries. The development of physical and human capital needs attention to improve the ability of workmanship and productivity in these economies.

References

Aschauer, D.A. 1989a. "Is public expenditure productive?" *Journal of Monetary Economics*, 23 (2): pp.177-200.

_________,1989b. "Public Investment and Productivity Growth in the Group of Seven." *Economic Perspectives*, 13, pp. 17-25.

_________, 1989c. "Does Public Capital Crowd out Private Capital?" *Journal of Monetary Economics*, 24(2): pp. 171-88.

________ ,1993. "Infrastructure and Productive Efficiency: A Literature Review." mimeo

Awokuse, O Titus., 2003; "Is the export-led growth hypothesis valid for Canada?," *Canadian Journal of Economics,* Canadian Economics Association, 36 (1): 126-136, February

Baffes, J. and A. Shah, 1993. "Productivity of public spending, sectoral allocation choices, and economic growth." Policy Research Working Paper Series, No. 1178, Washington D.C.: The World Bank.

Baltagi, B. H. and C. Kao, 2000. "Nonstationary Panels, Cointegration in Panels and Dynamic Panels: A Survey." *Center for Policy Research,* Working Paper, No. 16, Syracuse University.

Banerjee, A., J. J., Dolado, J.W., Galbraith, and D. F. Hendry, 1993. *Co-integration, error-correction, and the econometric analysis of non-stationary data.* New York: Oxford University Press Inc.

Barnes, D. F. and H. P. Binswanger, 1986. "Impact of Rural Electrification and Infrastructure on Agricultural Changes, 1966-1980." *Economic Political Weekly*, Vol. 21.

Barro, R. 1991. "Economic Growth in a Cross Section of Countries." *Quarterly Journal of Economics* 106(2): pp. 407-43.

Barro, R. and X. Sala-i-Martin, 1995. *Economic Growt*h. New York, McGraw-Hill.

Bhagawati, J. N.1988. "Export-Promoting Trade Strategies: Issues and Evidence", *The World Bank Research Observer.*

Binswanger, H. P., S.R. Khandkur, and M. R. Rosenzweig. 1989. "How Infrastructure and Financial Institutions affect Agriculture Output and Investment in India." Policy Planning and Research Working Paper No. 163, Washington D.C.: The World Bank.

Bregman, A and A. Marom, 1993. "Growth Factor in Israel's Business Sector, 1958-1988." Bank of Israel, Tel Aviv.

Calderón, C. and L. Servén, 2003a. "The Output Cost of Latin America's Infrastructure Gap." In Easterly, W., Servén, L., (ed.), *The Limits of Stabilization: Infrastructure, Public Deficits, and Growth in Latin America*. Stanford University Press and the World Bank, pp. 95-118.

_________, 2004. **"**The Effects of Infrastructure Development on Growth and Income Distribution." *World Bank, Policy Research Working Paper*, No. 3400.

Canning, D. and P. Pedroni, 1999. "Infrastructure and Long-run economic Growth." Mimeo:. Harvard *University*

_________, 2004. "The Effect of Infrastructure on Long-Run Economic Growth." mimeo: *Harvard* University, November 2004.

Canning, D., and M. Fay, 1993. "The Effect of Transportation Networks on Economic Growth." Columbia University, mimeo.

Canning, David, Fay, M. and R. Perotti, 1994. "Infrastructure and Growth." In Baldassarri, M., Paganaetto, M., and Phelps, E.S., (ed.), *International Differences in Growth Rates,* New York: St. Martin's Press.

Choi, I. 2001. "Unit root tests for panel data." *Journal of International Money and Finance* 20, pp. 249-272.

Demetriades, P.O. and T. P. Mamuneas, 2000. "Intertemporal output and employment effects of public infrastructure capital: Evidence from 12 OECD economies." *Economic Journal* (110): pp. 687–712.
Devarajan, S. V. Swaroop, and H. F. Zou, 1996. "The Composition of Public Expenditure and Economic Growth." *Journal of Monetary Economics* 37, pp 313-344.
Dutt, G. and M. Ravallion, 1998. "Why Have Some Indian States Done Better than Others at Reducing Rural Poverty." *Economica*, 65, pp. 17-38.
Easterly, W. and S. Rebelo, 1993. "Fiscal Policy and Economic Growth." *Journal of Monetary Economics*, 32, pp. 417-458.
Eberts, R.W. 1986. "Estimating the Contribution of Urban Public Infrastructure to Regional Growth." Federal Reserve Bank of Cleveland, Working Paper No. 8610.
_________, 1990. "Public Infrastructure and Regional Economic Development." *Economic Review*, Federal Reserve Bank of Cleveland, 26 (1): 15-27.
Elhance, A. P. and T. R. Lakshamanan. 1988. "Infrastructure- Production System Dynamics in National and Regional Systems: An Economic Study of the Indian Economy." *Regional Science and Urban Economics*, 18.
Engle, R. and C. Granger, 1987. "Co-integration and Error Correction: Representation, Estimation and Testing," *Econometrica,* 55, pp. 251-76.
Esfahani, H.S., and M. T. Ramirez, 2003. "Institutions, Infrastructure and Economic Growth." *Journal of Development Economics* 70: 443-477.
Estache, A. 2004. "Emerging Infrastructure Policy Issues in Developing Countries: A Survey of the Recent Economic Literature." Background paper for the October 2004 Berlin meeting of the POVNET Infrastructure Working Group. The World Bank, Washington, DC. Processed.
_________, 2006. *Infrastructure: A survey of recent and upcoming issues*. Washington D.C.: The World Bank.
Evans, P., and Karras, G. 1994. "Is government capital productive? Evidence from a panel of seven countries." *Journal of Macroeconomics,*(16, pp. 271–279.
Fay, M. and T. Yepes, 2003. "Investing in Infrastructure: What is needed from 2000 to 2010?" World Bank Policy Research Working Paper, No. 3102, Washington D.C.: The World Bank.
Fedderke, J. W. and Z. Bogeti, 2006. "Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of 19 Infrastructure Measures, Policy Research Working Paper, No. 3989, Washington D.C.: The World Bank.
Fedderke, J.W., P. Perkins, and J.M. Luiz, 2006, Infrastructural Investment in Long-run Economic Growth: South Africa 1875-2001." *World Development*, 34, pp. 1037-59.
Garcia-Mila, T., T. J. McGuire, and R.H. Porter, 1996. "The Effect of Public Capital in State Level Production Functions Reconsidered." *Review of Economics and Statistics*, pp 177-180.
Garcia-Mila, T., and T. J. McGuire, 1992. "The contribution of publicly provided inputs to states economies." *Regional Science and Urban Economics*, 22, pp. 229-41.
Ghali, K.H. 1998. "Public investment and private capital formation in a vector error-correction model of growth." *Applied Economics*, 30, pp. 837–844.
Ghosh, B and P. De. 2000c. "Infrastructure, Economic Growth and Trade in SAARC." Research and Information System, Discussion Paper, No. 66.
Global Competitiveness Report, Various Years, World Economic Forum, Switzerland.
Gramlich, E., 1994. "Infrastructure Investment: A Review Essay." *Journal of Economic Literature*, pp. 1176-1196.

Grossman, G. M. and E. Helpman, 1990. "Comparative Advantage and Long-Run Growth." *American Economic Review*, 80, pp. 796-815.
Hardi, K. 2000. "Testing for Stationarity in Heterogeneous Panel Data." *Econometric Journal,* 3, pp. 148-161.
Holtz-Eakin, D. 1994. "Public Sector Capital and the Productivity Puzzle." *Review of Economics and Statistics*, 76, pp.12-21.
Holtz-Eakin, Douglas, and A. E. Schwartz, 1995. "Infrastructure in a Structural Model of Economic Growth." *Regional Science and Urban Economics*, 25, pp. 131-151.
Im, K.S. M. H. Pesaran, and Y. Shin, 2003. "Testing for Unit Roots in Heterogeneous Panels." *Journal of Econometrics*, 115, pp. 53-74.
Jones, S. 2004. "Contribution of Infrastructure to Growth and Poverty Reduction in East Asia and the Pacific." Background paper, Oxford Policy Management, October.
________, 2006. "Infrastructure Challenges in East and South Asia", Promoting Growth, Ending Poverty Asia 2015 conference, Institute of Development Studies, Sussex, UK.
Krueger, A.O., 1975. "The Benefits and Costs of Import Substitution in India: A Microeconomic Study, Minneapolis: University of Minnesota Press.
Levine, A., C. F. Lin, and C. S. Chu, 2002. "Unit root tests in panel data: Asymptotic and finite-sample properties." *Journal of Econometrics,* 108, pp. 1-24.
Loayza, N., P. Fajnzylber, and C. Calderón, 2003. "Economic Growth in Latin America and the Caribbean: Stylized Facts, Explanations and Forecasts." Washington, DC: The World Bank, Mimeo.
Maddala, G.S. and S. W. Wu, 1999. "Comparative study of unit root tests with panel data and a new simple test." *Oxford Bulletin of Economics and Statistics* 61, pp. 631-652.
Mitra, A., A. Varoudakis, and M. Véganzonès-Varoudkis, 2002. "Productivity and technical efficiency in Indian states' manufacturing: the role of infrastructure." *Economic Development and Cultural Change*, 50, 395-426.
Munnell, A. H., 1990a. "Why has productivity growth declined? Productivity and public investment. *New England Economic Review*, January/February, 3-22.
_________, 1990b. "How does public infrastructure affect regional economic performance?" *New England Economic Review*, September/October , pp.11-32.
_________, 1992. "Infrastructure investment and economic growth.". *Journal of Economic Perspectives*, 6(4): 189-198.
Nataraj, G. 2007. **"**Infrastructure Challenges in South Asia: The Role of Public-Private Partnerships**"** ADBI Discussion paper No. 80. Tokyo.
Pedroni, P. 1997. "Panel Cointegration, Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis, New Results." *Indiana University,* Mimo.
________, 1999. "Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors." *Oxford Bulletin of Economics and Statistics,* 61, pp. 653–678.
________, 2000. "Fully modified OLS for heterogeneous cointegrated Panels." *Advances in Econometrics*, 15, pp. 93–130.
________, 2001. "Purchasing power parity in cointegrated panels." *Review of Economics and Statistics*, 83, pp. 727-731.
Pereira, A. M. 2000. "Is all public capital created equal?" *The Review of Economics and* Statistics*,* 82 (3): 513-518.

Phillips, P.C.B. and P. Perron, 1988. “Testing for a Unit Root in Time Series Regressions.” *Biometrika,* 75, pp Varoudakis,. 335-346.

Pritchett, L. 1996. “Mind your P’s and Q’s”. *World Bank Policy Research Paper* No. 1660, Washington D.C.: The World Bank.

Rebelo, S. 1991. "Long-Run Policy Analysis and Long-Run Growth," *Journal of Political Econom*y, 99, 500-521.

Roller, L.H. and L. Waverman. 2001. “Telecommunications infrastructure and economic development: A simultaneous approach.” *American Economic Review,* 91 (4): 909-923.

Sahoo, Pravakar, 2006. “FDI in South Asia: Trends, Policy, Impact and Determinants*” ADBI Discussion Paper Series*, No.56, Tokyo.

Sahoo, S. and K. K. Saxena, 1999. “Infrastructure and Economic Development: Some Empirical Evidence.” *The Indian Economic Journal*, 47, pp. 39-57.

Sanchez-Robles, B., 1998. “Infrastructure Investment and Growth: Some Empirical Evidence.” *Contemporary Economic Policy*, 16, pp. 98-108.

Shah, A. 1992. “Dynamics of Public Infrastructure and Private Sector Profitability.” *Review of Economics and Statistics,* 74(1).

Shiu, A., and P. L. Lam, 2004. “Electricity consumption and economic growth in China.” *Energy Policy*, 32, pp. 47–54.

Srinivasan, T.N. 1985. “Neoclassical Political Economy, the State and Economic Development.” Asian Development Review, 3(4): 38-58.

Uchimura, K. and H .Gao, 1993. “The Importance of Infrastructure on Economic Development.” Latin America and Caribbean Regional Office, World Bank, Washington DC.

World Bank. 1994. *World Development Report 1994: Infrastructure for development*. New York: Oxford University Press.

Wylie, Peter J. 1996. “Infrastructure and Canadian Economic Growth 1946-1991.” *The Canadian Journal of Economics,* 29, pp. S350-S355.

Appendix

Infrastructure Index:

The Infrastructure index has been made by using the Principal Component Analysis (PCA). The PCA is a multivariate choice method. This approach develops a composite index by defining a real valued function over the relevant variables objectively. The principle of this method lies in the fact that when different characteristics are observed about a set of events, the characteristic with more variation explains more of the variation in the dependent variable compared to a variable with lesser variation in it. Therefore, the issue is one of finding weights to be given to each of the concerned variables. The weight to be given to each of the variables is determined on the principle that the variation in the linear composite of these variables should be the maximum. Therefore, the composite index is defined as

$$C_i = W_1X_{11} + W_2X_{12} + W_3X_{13} + \ldots\ldots\ldots\ldots + W_nX_{1n}$$

Or $$C_1 = \sum W_iX_{ij} ,$$

Where C_i is the composite index for the i^{th} observation, W_j is the weight assigned to j^{th} indicator and X_{ij} is the observation value after elimination of the scale bias.

Since the variables chosen for analysis are measured in a different scale, it is required to covert them into some standard comparable unit by using following method

$$x_{ij} = ((X_{ij} - X_m)/\sigma),$$

where, x_{ij} is the scale free observation, X_{ij} is the original observation and X_m is the mean of the series and σ is the standard deviation.

Table 1A
Trend of Exports and Major Macroeconomic Indicators of Four South Asian Countries

Major Macro Indicators	Bangladesh			India			Sri Lanka			Pakistan		
	(Average annual growth)											
	1980-90	1991-00	2001-05	1980-90	1991-00	2001-05	1980-90	1991-00	2001-05	1980-90	1991-00	2001-05
GDP	3.67	4.89	5.55	5.7	6.2	7.6	4.00	5.26	5.30	6.32	3.56	5.58
GDP per capita	1.25	2.69	3.54	3.49	4.39	6.02	2.51	3.94	4.04	3.52	1.06	3.07
Agriculture	2.10	3.03	2.60	3.12	3.05	2.45	2.24	1.82	1.26	4.04	4.40	3.40
Industry	5.97	7.37	7.41	6.89	6.65	8.45	4.60	6.98	4.58	7.74	3.93	7.50
Manufacturing	5.18	7.13	6.88	7.44	7.48	7.78	6.25	8.01	4.38	8.11	3.66	9.60
Services	3.78	4.55	5.70	6.87	8.31	8.9	4.72	5.66	6.87	6.81	4.24	5.88
Exports of goods and services	5.40	13.57	8.29	4.92	11.05	17.03	4.64	7.38	6.71	8.39	9.98	10.95
Imports of goods and services	3.15	11.15	6.47	6.07	12.62	22.64	3.47	8.57	9.85	2.14	1.91	8.77
Gross domestic capital formation	7.24	9.77	8.87	6.21	6.79	18.03	0.68	6.83	11.78	5.77	1.38	1.00

Major Macro Indicators	Bangladesh				India				Sri Lanka				Pakistan			
	(% Of GDP)															
	1980	1990	2000	2005	1980	1990	2000	2005	1980	1990	2000	2005	1980	1990	2000	2005
Gross capital formation	14.43	17.05	23.02	24.52	18.68	24.06	24.77	33.35	33.70	22.57	28.03	26.21	18.48	18.93	17.37	16.83
Gross domestic savings	2.05	9.64	17.77	18.06	15.51	22.64	24.02	29.71	11.87	13.75	17.43	14.61	6.86	11.10	16.11	12.20
Current account balance	-3.87	-1.32	-0.64	-0.21	-0.98	-2.21	-0.99	1.42	-16.28	-3.71	-6.38	-2.75	-3.65	-4.14	-0.11	-3.12
FDI		0.01	0.59	1.33	0.04	0.07	0.77	0.81	1.06	0.53	1.05	1.16	0.26	0.61	0.42	1.97

Source: World Development Indicators, 2007 CD-ROM, World Bank.

Table 2A
Infrastructure Facilities in South Asia *vis-a-vis* other Developing Countries

	Electric power consum. (kwh per capita)	Energy use (kg of oil equi. per capita)	Paved Roads (% of Total Roads)	Total Rail route '000 sq. k.m.)	Air freight trans.(Milli. for K.M.)	Air pass. transport ('000 Pop.)	Total Telphones (Per' 000 persons)
Countries	2003	2003	2003	2004	2004	2004	2004
India	435.3	519.9	62.6*	21.26	689.43	22.03	84.5
Bangladesh	127.66	158.7	9.5	20.22*	179.61	11.82	37
Sri Lanka	325.14	421.23	81	---	300	124.4	164.9
Pakistan	407.78	466.91	60	10.1	402	33.52	62.64
Nepal	67.90	3352.89	53.9	0.41	7.01	16.88	21.78
China	1378.52	1089.9	79.9	6.54	8188	92.41	499.37
Korea	7018.33	4290.5	76.75	31.69	7969.4	694.4	1302.85
Singapore	7977.15	5358.6	100.00	----	7192.8	4178.4	1350.04
Indonesia	440.11	752.54	58.00	2.99*	434.1	123.10	183.78
Malayasia	3060.54	2318.42	77.9*	5.07	2599.22	773.98	765.55
Thailand	1751.75	1405.69	99.17*	7.89*	1868.57	323.82	536.56
Japan	7818.36	4053.38	77.7*	55.03	8937.6	807.08	1176.08

Source: World Development Indicators, Various Years and Centre for Monitoring Indian Economy (CMIE).

Table 3 A

Infrastructure and Business Indictors in South, East and Southeast Asia (2006)

	Overall Infrastructure Quality	Rail Road Infrastructure Development	Port Infrastructure Development	Air Transport Infrastructure Development	Time Required To Start a Business*	Hiring and Firing Practices
India	3.3	4.7	3.5	5.1	71	3
Bangladesh	2.3	2.3	2.4	2.5	35	4.6
Sri Lanka	3	2.5	3.7	4.1	50	3
Pakistan	3.4	3.6	3.8	4.6	24	4.6
Nepal	1.9	1.2	1.3	3.3	21	3.1
PRC	3.4	3.8	3.7	3.7	48	4.2
Republic of Korea	5.1	5.2	5.2	5.5	22	3.8
Singapore	6.6	5.7	6.9	6.9	6	5.9
Malaysia	5.7	5	5.8	6	30	4
Thailand	5	3.6	4.7	5.5	33	3.8
Philippines	2.7	1.7	2.7	4	48	3.6

Note: Overall Infrastructure Quality is (1= poorly developed and inefficient and 7= among the best in the world). The same applies to rail, port and air transport infrastructure.

Hiring and Firing Practices (1= impeded by regulations, 7= flexibility determined by employers)
* No of days required to register a business
Source: Global Competitiveness Report, 2006-07

Table 4 A
Summary of Comparative Indicators of Infrastructure across Developing Regions

Region	AFR	EAP	ECA	LCR	MNA	SAR
Population (in millions)	674	1823	474	518	300	1378
Percentage living on less than US$1-a-day	46	15	4	10	2	31
Percentage of Urban Population	36	43	65	77	59	28
Major Access Indicators	51	62	70	85	70	42
Electricity (% of population access to network)	24	88	99	89	92	43
Water (% of population access to improved sources)	58	78	91	89	88	84
Sanitation (% of population access to improved sanitation)	36	49	82	74	75	35
Roads (% of rural population living within 2 km of an all-season road)	34	95	77	54	51	65
Teledensity (fixed line and mobile subscribers per 1,000 people)	62	357	438	416	237	61

Source: Jones 2006.
Note: AFR: Sub-Saharan Africa; EAP: East Asia and Pacific; ECA: Eastern Europe and Central Asia; LCR: Latin America and Caribbean; Middle East and North Africa; SAR: South Asia.

Table 5 A
Summary of Infrastructure Access Indicators in South and South East Asia, 2005

	Electricity	Water	Sanitation	Teledensity	Road Density (by population)	Road Density (by area)
Afghanistan	5	13	8	12		32
Bangladesh	25	75	48	16	1.6	1594
Cambodia	10	34	16	38	1	70
PRC	97	77	44	424	1.4	189
India	40	86	30	71	3.2	1115
Indonesia	80	78	52	127	1.7	203
Myanmar	5	80	73	8		
Nepal	15	84	27	18	0.6	107
Pakistan	55	90	54	44	1.8	334
Sri Lanka	75	78	91	122		
Viet Nam	60	73	41	88	1.2	287

Source: Jones 2006.
Note: Electricity (% of population access to network), Water (% of population access to improved sources), Sanitation (% of population access to improved sanitation), Teledensity (fixed line and mobile subscribers per 1,000 people), Roads (% of rural population living within 2 km of an all-season road).

Table 6 A
Expected Annual Investment Needs, 2005–2010

	New		Maintenance		Total	
By Income Group	US$M	% GDP	US$M	% GDP	US$M	% GDP
Low Income	49,988	3.18	58619	3.73	108607	6.92
Middle Income	183,151	2.64	173,035	2.50	356,187	5.14
High Income	135,956	0.42	247,970	0.76	383,926	1.18
Developing Countries by Region						
East Asia and Pacific	99,906	3.67	78986	2.90	178892	6.57
South Asia	28,069	3.06	35,033	3.82	63,101	6.87
Europe & Central Asia	39,069	2.76	58, 849	4.16	98,918	6.92
Middle East & N.Africa	14,884	2.37	13, 264	2.11	28.148	4.48
Sub-Saharan Africa	13,628	2.84	12,644	2.71	25,912	5.55
Latin American & Caribbean	37,944	1.62	32,878	1.40	70,822	3.02
All developing countries	233,139	2.74	231,654	2.73	464,793	5.47
World	369,095	0.90	479.624	1.17	848.719	2.07

Source: Fay Marainne and Tito Yepes (2003), "Investing in Infrastructure: What is needed from 2000 to 2010," World Bank Policy Research Working Paper 3102, July 2003.

Table 7A

Estimates of Output Elasticity of Infrastructure Indicators

Country/ Region	**Author**	**Output elasticity of Infrastructure**	**Infrastructure Measure**
USA	Aschauer (1989)	0.39	Public Capital
USA	Munnell (1990)	0.34	Public Capital
Mexico	Shah (1992)	0.05	Transport, Power and communication
Taiwan	Uchimura and Gao (1993)	0.24	Transport, Water and communication
Korea	Uchimura and Gao (1993)	0.19	Transport, Water and communication
DCs	Easterly and Rabelo (1993)	0.16	Transport and communication
USA	Holtz-Eakin (1994)	0	Public Capital
USA	Gracia Milla *et al.* (1996)	0	Public Capital
LDCs	Devarajan *et al.* (1996)	negative	Transport and communication
Canada	Wylie (1996)	0.31	Public Capital
Cross Country	Canning (1999)	-0.23 to 0.22	Road, Telephone, and Electricity
Cross country	Calderón & Servén (2002)	0.16	Transportation, Communication, general purpose
Cross country	Esfahani and Ramíres (2003)	0.12	Power and Telephones
South Africa	Fedderke, Perkins and Luiz (2006)	-0.06 to 0.20	Physical capital stock

Source: Authors compilation.

Table 8A
Eigen values and Variance Explained by Principal Components

Principal Components	1980-2005			1991-2005		
	Eigen Values	% of Variance	Cumulative Variance	Eigen Values	% of Variance	Cumulative Variance
1	3.092	61.98	61.92	4.273	71.33	71.33
2	1.005	20.12	82.04	0.863	14.40	85.73
3	0.7197	14.39	96.43	0.725	12.09	97.82
4	0.1701	3.040	99.84	0.095	1.590	99.41
5	0.0081	0.001	100.00	0.303	0.059	99.92
6				0.0051	0.008	100

Table 9A
Factor Loadings of Original Values

Infrastructure Variables	Factor Loadings **(1980-2005)**	Factor Loadings **(1991-2005)**
Electricity Power consumption (per capita)	0.538	0.463
Energy use (kg of oil equivalent per capita)	0.556	0.477
Telephone	0.318	0.274
Rail Density (Population)	0.294	0.357
Air Transport, freight	0.460	0.369
Paved road as% of total road		0.467

Table 10A
The Im, Pesarn and Shin (IPS) Panel Unit root test

Variables	With Time Dummy		Without Time Dummy		Order of Integration
	At level	Ist Diff.	At level	Ist Diff.	
LRYpc	5.10	-6.22*	1.41	-4.61*	I(1)
LTrade	6.01	-6.17*	0.08	-6.55*	I(1)
LGDP	3.82	-5.72*	3.54	-5.54*	I(1)
LInvestment	3.04	-6.36*	1.53	-5.21*	I(1)
Lexport	4.22	-5.64*	0.11	-6.37*	I(1)
LLabour	2.13	-5.27*	-1.39	-6.59*	I(1)
LInfrastructure	7.64	-5.79*	5.12	-6.12*	I(1)
LHealth and Education Exp.	3.53	-6.45*	0.78	-6.35*	I(1)

Notes: the critical values for the panel unit root test at the 1%, 5% and 10% levels of significance are -2.326, -1.645 and -1.282 respectively. * denotes significance at the 5% level

Table 11A
Long-run coefficients individual infrastructure indicators

	1980-2005		***1991-2005***	
Infrastructure Indicators	***GDP***	***PER capita GDP***	***GDP***	***PER capita GDP***
Electricity Power consumption (per capita)	0.14	0.09	0.08	0.09
Energy use (kg of oil equivalent per capita)	0.14	0.09	0.09	0.10
Telephone	0.08	0.05	0.05	0.05
Rail Density (Population)	0.08	0.05	0.06	0.07
Air Transport, freight	0.12	0.07	0.07	0.07
Paved road as % of total road			0.08	0.09

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