Infrastructure and Growth*

by
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Introduction

Physical infrastructure stock development has many important direct and indirect effects to an economy. These effects operate through various channels. For example, through labor productivity gains resulting from improved information and communication technologies, reductions in time wasted commuting to work and stress, improvements in health and education, and through improvements in economies of scale and scope throughout the economy. On the supply side, there is both a direct channel (infrastructure capital stock serves as a production factor), and an indirect one (improved infrastructure affects technological progress). From a demand side point of view, infrastructure provides people with services they need and want—water and sanitation; power for heat, cooking, and light; telephone and computer access; and transport.

In Pakistan, low infrastructure development in the past two decades has become binding constraints to production sector in the economy. It has also impacted to the direct consumption of the household sector and thereby reducing the overall welfare of the general public. Continuous underinvestment since the last few years has further aggravated the situation in Pakistan. These frequent cutbacks in the PSDP and the low levels in the allocations imply that there is a need for strategic selection of the projects/programs, specifically in the energy sector, to maximize the effectiveness of the development plans.

Table 1 gives the decadewise growth rates of different infrastructure indicators. The fastest growth in electricity generation is observed in the 80s, largely because of the commissioning of the Tarbela Dam. Per capita water availability for agriculture appears to have consistently declined over the last four decades. The 80s also saw relatively rapid expansion in the road network. This has visibly slowed down during the last decade. However, there has been a virtual explosion in the telephone network during the last ten years following the increased use of mobile phones. In 2010-11, we can see

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that most of the infrastructure variables have a negative growth rate. Only the mobile phones and water availability indicators have shown positive growth, although, the growth rate is very minor compare to early periods. Note that electricity generation has the largest negative growth in this year. Also from the Table 1, we can see that infrastructure appears to relate significantly to per capita GDP growth. This is particularly true in the decades of 70s and 80s mainly through accumulating infrastructure capital stock.

Table 1: Decadewise Growth Rate of Different Types of Infrastructure

(percentage)

	1970s*	**1980s**	**1990s**	**2000s**	**2010-11**
Per Capita GDP growth	2.7	2.9	1.8	2.8	0.3
Per Capita Electricity Generation (Gwh)**	6.1	7.4	2.3	1.9	-26.4
Per Capita Water Availability (MAF)	-1.5	-1.0	-1.2	-2.3	0.5
Length of Roads (Kilometers)	4.0	6.3	3.9	0.5	-0.5
Telecommunications					
- Number of Telephone Lines (per 1000 people)	7.8	11.1	11.3	0.2	-5.4
- Mobile Phones availability (per 1000 people)	-	-	45.7***	72.3	4.9

Source: World Development Indicators, World Bank.
Pakistan Economic Survey, Government of Pakistan.
* From 1975-76 to 1979-1980
**Adjusted for transmission losses.
*** From 1995-196 to 1999-2000.

The objective of this paper is, first, to find out the determinants of the total factor productivity (TFP). In this exercise our focus will mainly be on the public infrastructure stock as an important determinant of TFP. Second, to determine how infrastructure impacts on growth, specifically, to determine which types of infrastructure, that is, roads highways, power, telecommunications, irrigation, etc., are more effective from the viewpoint of raising the growth rate of the economy as a whole. Implications of the research on the allocation priorities within the PSDP will be derived.

The paper is organized as follows: Section 1 gives a brief introduction of the paper by describing and discussing the main objective of the paper. Section 2 reviews the literature relevant to the topic of the paper. Section 3 gives the framework of analysis of determinants of the TFP and the relationship between infrastructure and growth. This section also discusses the results of the two analyses. Final section concludes the paper and gives some policy recommendations.

Literature Review

Straub and Terada-Hagiwara (2011) in the paper presents the state of infrastructure in developing Asian countries. The paper applies two distinct approaches (growth regressions and growth accounting) to analyze the link between infrastructure, growth, and productivity. The importance of infrastructure development comes from the fact that it provides both the final consumption services to households and to key intermediate consumption items for production.

It plays an important role to support growth and poverty reduction. From the supply point of view, there are both direct and indirect channel. The direct one deals with infrastructure capital stock which serves as a production factor. An increase in the stock of infrastructure is said to have a direct impact on the productivity of the other factors. The indirect one deals with the improvement in technology and its effects on infrastructure progress. These could operate through various channels like labour productivity gains which result in improved information and communication technologies that reduce time wasted in commuting to work and stress; better education and health facilities and through economies of scale and scope through out the economy. From a demand side point of view, infrastructure provides people with services they need and want like water and sanitation; power for heat, cooking, and light; telephone and computer access; and transport. The absence of some of the most basic infrastructure services is an important dimension of what we often mean when we talk about poverty. Increasing level of infrastructure stock, therefore, has direct implication for poverty reduction.

The paper concludes that the infrastructure stocks in developing Asia have been growing at a significant pace. However the findings show that their levels remain well below the corresponding world averages both in terms of quality and quantity. There seems to be a positive impact on the economic growth due to the accumulation of infrastructure stock (in electricity, telecommunications, transport, and water supply) as a massive build up of these stocks was needed but may be beyond the financial reach of many governments. The paper gives a cross country estimations which shows that for most infrastructure indicators, the growth rate of stocks has a positive and significant impact on per capita GDP average growth rate in the subgroups of EAP and SA countries. The growth accounting exercise, on the other hand, shows that positive and significant effects of infrastructure on TFP growth are only observed in a few countries like the PRC, the Republic of Korea, Thailand, for telecom and electricity indicators.

In another paper by Straub (2008) a survey was presented on recent research on the economics of infrastructure in developing countries in which energy, transport, telecommunication, water and sanitation are considered. There are two main set of issues that the survey covers. The first one shows the linkages between infrastructure and economic growth at the economy-wide, regional and sectoral level. The second deals with the composition, sequencing and efficiency of alternative infrastructure investments which include arbitrage between new investments and maintenance expenditures; OPEX and CAPEX, and public versus private investment.

The paper reviews the literature on infrastructure and development performed in this paper sustains a number of conclusions which lead to potential research areas and need for associated data development; which can be organized in three related parts, relating to macroeconomic, microeconomic and economic geography aspects. The paper conclude that in terms of data development, the main effort should be concentrated in the microeconomic part, through a strategy to gather data from both household and firm-level survey on aspects including access, quality and costs of services. Indicators, aggregated at different levels, could then be used both in macro-level and economic geography types of estimations.

Pierre-Richard Agénor and Blanca Moreno-Dodson (2006), in the paper on Public Infrastructure and Growth: New Channels and Policy Implications provide an overview of the various channels through which public infrastructure development may affect growth. In addition to the conventional productivity, complementarity and crowding out affects which is emphasized in the literature; the impact developing infrastructure on the investment adjustment cost like durability of private capital, and production of health and education services are also highlighted.

A number of microeconomic studies document the effects of health and education but recently the macroeconomists have begun to study their implications for growth. The endogenous growth model in the paper illustrates the link between health infrastructure and growth with transitional dynamics and optimal allocation of public expenditure is discussed. The paper concludes by drawing out the implications of the analysis for the design of strategies aimed at promoting growth and reducing poverty. It also reinforces the evidence provide by Straub and Terada-Hagiwara (2011) and Straub (2008).

Canning and Pedroni (2004), in the paper on the Effects of Infrastructure on Long Run Economic Growth, investigate the long run consequences of infrastructure provision on per capita in a panel data of countries from 1950 to 1992. The paper develops simple panel based tests which enable us to isolate the sign and direction of long run effect of infrastructure on income in a manner that is robust to the presence of unknown heterogeneous short run causal relationships. The results show clear evidence that in majority of the cases the development of infrastructure induces long run growth effects. But a great deal of variation has also been seen in the results across individual countries. When the countries are taken as a whole, the results demonstrate that telephones, electricity generating capacity and paved roads are provided at close to the growth maximizing level on average. But they are under-supplied in some countries and over-supplied in others. These results also help to explain why cross section and time series studies have in the past found contradictory results regarding a causal link between infrastructure provision and long run growth.

Theoretical Framework and Empirical Results

Most of the literature on economic growth measures the impact of the infrastructure through the standard production function where factors are gross complements, an increase in the stock of infrastructure capital would have a direct, increasing effect on the productivity of the other factors. These approaches measure the impact of infrastructure capital in terms of some estimates of output elasticity. However, recent studies point out a number of weaknesses in the methodology and estimation of these approaches on measuring the impact of infrastructure capital on economic growth. See for example Straub (2011); Romp and de Haan (2005); and Bom and Ligthart (2008). The authors point out a number of weaknesses in the econometric analysis by the earlier studies. These weaknesses include the presence of likely potential reverse causality between output and infrastructure investment, which can generate an upward bias in the estimated coefficients. For example, taking these concerns into account, these authors find out that the output elasticities of public capital are between 0.1 and 0.2. Similarly, in a paper, Calderón et al. (2009) estimate the output elasticity of public infrastructure to be between 0.07 and 0.10.

This paper uses a different methodology to measure the impact of the physical infrastructure development on economic growth, as developed by the Straub and Terada-Hagiwara (2011). In this approach, the relationship between the infrastructure and growth is quantified by indicators of physical availability of infrastructure rather than the total public capital stock (in constant prices) in infrastructure. This approach also has the merit that it enables identification of the differential impact of various types of infrastructure on growth.

The analysis of the paper is divided into two parts. In the first part, we present the determinants of TFP using the growth accounting framework. In the second part, we present the growth regression analysis to measure the impact of individual infrastructure variables on economic growth.

A. Determinants of Total Factor Productivity

In this section, we used growth accounting analysis to find out the determinants of TFP. Specifically, in this part, we try to find out the impact of public capital stock on TFP along with other exogenous variable. For this, we ran a regression of the form

$$GTFP_t = \alpha_{0t} + \alpha_{1t} GPKS_t + \alpha_{it} Z_{it} + e_t; \qquad i = 2,3,\dots,n$$

where *GTFP* is the growth rate of total factor productivity, *GPKS* is the growth rate of the public capital stock and Z_{it} is the vector of other exogenous variables. Three most important determinants of the total factor productivity, other than public capital stock, that can be identified from the literature are the human capital stock, foreign direct investment and the trade openness of a country. The growth rate of the TFP is calculated by taking the elasticities of the labour, capital stock and the land from the paper of Ahmed and Bukhari (2007)[†]. The analysis period of their paper is almost same as the analysis period of this paper. Data for the GPKS construction requires long term series data and is a time-consuming task. Fortunately, the data base of the Social Policy and Development Centre (SPDC) Integrated Social Policy and Macroeconomic Planning Model for Pakistan contains such an index, which has been constructed from 1972-73 to 2007-08 at constant prices of 1999-2000. This index has been made available to us by SPDC. From 2007-08 onwards, the series has been extended using the methodology of the SPDC's model. For other variables data is collected from the Annual Reports of the State Bank of Pakistan and Annuals Reports of the SPDC.

The results of the regression on determinants of TFP are given below:

$$GTFP = -1.0525 + 0.785GMYS + 0.317GPKS + 0.012GFDI + 0.048GOPENNESS$$

(-2.391)** (4.328)* (3.665)* (2.783)* (1.689)***

Adjusted-R^2 = 0.636, DW-Stat = 2.539

F-statistic = 11.490 (0.000)

In this regression, *GMYS* is the growth rate of the mean years of schooling taken as a proxy for human capital stock, *GFDI* is the growth rate of foreign direct investment and *GOPENNESS* is the growth rate of the trade openness. The results of the regression are very much according to the expectations. As can be seen from the results, the human capital development has the largest impact on the *TFP* growth. After it growth in the public capital stock has the largest impact on growth of *TFP*. Other two variables, *GFDI* and *GOPENNESS*, also impact growth in *TFP* positively and significantly but their magnitude is relatively small compare to *GMYS* and *GPKS*. Overall, the regression is a good fit and gives reasonable results.

B. GROWTH REGRESSION ANALYSIS

As we saw in the last section that public capital stock has a significant positive impact on TFP. In this section, we will see how the individual physical infrastructure

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[†] The growth accounting framework is based on a standard Cobb-Douglass production function with constant return to scale of the type $Y = AK^{\alpha}N^{\beta}L^{1-\alpha-\beta}$, in which Y is the gross domestic product, A is a measure of total factor productivity, K is the capital stock, N is the total labour force and L is the land. From this production function, we calculated TFP by the Solow's residual equation, as

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \alpha\frac{\Delta K}{K} - \beta\frac{\Delta N}{N} - (1-\alpha-\beta)\frac{\Delta L}{L}$$

For more details on the methodology, see the paper of Ahmed and Bukhari (2007).

stock has an impact on economic growth. For this we used the following growth regression technique:

$$g_t = \beta_{0t} + \beta_{it}Z_{it} + \beta_{jt}K_{jt} + e_t$$

$$\text{while } i = 1,2, \ldots, m \;\&\; j = 1,2, \ldots, n$$

where g_t is the growth rate of real per capita GDP, Z_t is a vector of control variables and K_t is a vector of physical infrastructure variables. To control the structure of the economy we used the following variables: agriculture growth rate, nominal interest rate, and the mean years of schooling. On the other hand, following indicators of physical availability of infrastructure have been used in the analysis:

- per capita electricity generation, adjusted for transmission losses (in Gwh)
- per capita availability of water for agriculture (in MAF), including water from tubewells
- length of roads (in Kms)
- telephone lines (including mobile phones) per 100 people

Data on the above indicators has been obtained for the period, 1975-76 to 2010-11, from the Pakistan Economic Survey and the World Bank Development Indicators data base.

Results of the econometric analysis of the impact of growth of different types of infrastructure on the growth rate of real per capita GDP are given in Table 2. Initially, we ran regression only on the exogenous variables, like agricultural growth, nominal interest rate and mean years of schooling. Then along with these exogenous variables each infrastructure indicator is introduced separately in the OLS regressions, in equations (2) to (5) respectively. Thereafter, different infrastructure indicators are added sequentially in equations (6) to (8).

The results of the regressions with separate indicators indicate the high level of significance of the electricity generation indicator. The telecommunications and water availability indicators are also significant at the 5 and 10 percent level of significance. The surprising result is the complete lack of significance of the indicator of access to roads and highways. This is the first indication that the country has perhaps been overinvesting in the development of the road network, especially highways.[‡] As expected, the exogenous variables, especially agricultural growth, are significant in most regressions. The other two exogenous variables are also significant at highly significant.

[‡] According to the *Global Competitiveness Report, 2010-11*, Pakistan has a higher ranking in Quality of Roads than countries like Iran, Egypt, Indonesia, India and Bangladesh, although Pakistan still has not reached desirable levels of road density.

Table 2: RESULTS OF REGRESSIONS ANALYSIS ON INFRASTRUCTURE AND GROWTH[a]

(Dependent variable is Growth Rate of Real Per Capita GDP)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	4.024* (2.720)	2.603*** (1.879)	4.214* (2.971)	1.871 (1.328)	3.938* (2.602)	2.946** (2.447)	**1.543** **(1.274)**	1.403 (1.124)
Agriculture Growth Rate	0.294* (4.630)	0.284* (4.933)	0.303* (4.971)	0.235* (4.227)	0.294* (4.554)	0.320* (6.357)	**0.287*** **(6.088)**	0.286* (5.993)
Nominal Interest Rate (%)	-0.325* (-2.876)	-0.240*** (-2.275)	-0.326* (-3.018)	-0.192*** (-1.856)	-0.327* (-2.854)	-0.252* (-2.746)	**-0.163***** **(-1.816)**	-0.164*** (-1.811)
Growth Rate of Mean Years of Schooling	0.437* (2.607)	0.413* (2.796)	0.431* (2.685)	0.554* (3.887)	0.440* (2.588)	0.304** (2.530)	**0.352*** **(3.183)**	0.358* (3.185)
Growth Rate of Electricity Generation Per Capita	-	0.120* (3.283)	-	-	-	0.161* (5.193)	**0.160*** **(5.716)**	0.157* (5.456)
Growth Rate of Per Capita Water Availability	-	-	0.174*** (1.954)	-	-	0.325* (4.592)	**0.327*** **(5.099)**	0.327* (5.030)
Growth Rate of Per Capita Availability of Telephones and Mobiles	-	-	-	0.020** (2.314)	-	-	**0.019*** **(2.684)**	0.020* (2.686)
Growth Rate of Length of Roads	-	-	-	-	0.032 (0.427)	-	**-**	0.035 (0.589)
Adjusted-R^2	0.514	0.624	0.556	0.664	0.501	0.726	**0.774**	0.769
F-statistics	12.650*	11.971*	11.333*	14.099*	9.275*	16.426*	**18.122***	15.530*
DW-Stat	2.297	2.372	2.449	2.032	2.292	2.067	**2.646**	2.552
SC-Value	3.709	3.591	3.689	3.476	3.807	3.367	**3.238**	3.325
Wu-Hausman test, p-value						0.185	**0.587**	0.529

[a] Note that the asterisks *, **, *** indicate that the coefficients are significant at the 1%, 5% and 10% level of significance. Values in parentheses are the t-ratios. SC-value is the Schwarz criterion value. SC-Value is the Schwartz Criterion value. We perform the Wu-Hausman test of endogeneity and each equation passed the test. The analysis period is from 1975-76 to 2010-11.

The results do not alter when all infrastructure indicators are introduced simultaneously into the regression analysis. The significance of the electricity generation indicator remains unchanged, highlighting the robustness of the relationship between availability of power and growth. The elasticity of per capita income growth with respect to growth in electricity is about 0.16. This is close to the elasticity of 0.20 estimated by Straub and Hagiwara (2010) for a cross-section of Asian countries. Part of the reason for the decline in GDP growth rate in the last few years is clearly due to the failure in expanding power generation capacity.

The water availability and telecommunications variables also remain significant, although at a high level of significance. The access to roads variable remains insignificant when all infrastructure variables are introduced simultaneously in the growth regressions. Overall, the results clearly demonstrate a clear positive and highly significant differential impact of various types of infrastructure on growth. The table also presents the results of the Wu-Hausman test of endogeneity. Its p-value indicates that there is no problem of endogeneity in the regression models.

We have estimated the capital cost of electricity generation per 100 MW from a sample of the recent vintages of plants. The cost is approximately $ 950 million per 100 MW. Given the coefficient of electricity generation capacity in the growth regressions the implied incremental capital-output ratio is only 0.57. This indicates the high returns today to investment in the power sector.

Conclusion and Policy Recommendations

Physical Infrastructure stocks in Pakistan since the last two decades have been growing at a low pace. After reviewing the state of infrastructure development in Pakistan we performed two types of analyses in the study. In the first analysis, we tried to find out the impact of different indicators on TFP, specifically that of the public infrastructure stock and, in second analysis, we tried to find out the impact of the physical infrastructure stock (electricity generation, telecommunications, water availability and access to roads and highways) on real per capita GDP. Both these analyses clearly demonstrate that infrastructure matters from the viewpoint of growth and TFP. Individual and combined results, from the growth regression, show that investments in power generation, telecommunications and in enhancing the availability of water for agriculture have significant effects on growth. However, in the Pakistani setting, development outlays on expanding/upgrading the road network do not seem to confer significant visible benefits. Within the PSDP, the sector actually receiving the largest allocation currently in the area of infrastructure development is communications (mostly highways). There is a case for changing this priority and diverting resources away from communications to water and power to achieve a bigger impact on GDP growth, within a given size of PSDP. Also, results of the analysis do not have implications on priorities within the communications sector. For example, it may be that investment in railways sector and expansion of the road network may have higher returns than development outlays on Motorways and Exressways.

Further, as can be seen from results of both analyses, infrastructure stock accumulation has a positive impact on economic growth, a massive buildup of infrastructure stock in electricity, telecommunication, transport, and water supply is needed for it to have a positive impact on economic growth. Moreover, demand for infrastructure services is expected to soar in cities due to rapid urbanization. In order to keep cities competitive, investments in infrastructure need to be designed to take account of congestion, environmental degradation, and other impediments to productivity that are associated with urban agglomeration. Another key question refers to sequencing. Which type of infrastructure is more effective in supporting growth and should be prioritized? Clearly, the results show that investment in electricity generation capacity should be the most important priority of the Public Sector Development Programme (PSDP). Currently, the total outlay through the budgetary PSDP and self-financing of power investments adds up to 0.65 percent of the GDP. This will have to be increased to above 1.5 percent of the GDP if the problems of shortage of electricity is to be addressed on a priority basis so as to raise the growth rate of the economy.

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