Infrastructure, Economic Growth and Regional Connectivity: Spatial Econometric Analysis

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Abstract

While there is little consensus that infrastructure is an integral part of economic growth and development, much of the research on the relationship between infrastructure and economic growth has focused on describing access to various infrastructure services and reporting on the macroeconomic impact of infrastructure. The issue with the highly aggregated infrastructure-growth analysis is that, although it is useful to show the positive effects of infrastructure on economic growth, it has not exposed the specific underpinnings to connect infrastructure investment with an inter-sectoral component of economic growth and because of which infrastructure affects total economic growth. Impact of infrastructure varies significantly among different economic sectors; it is more crucial for some sectors of the economy than others.

This thesis adds to the literature on the contribution of infrastructure to aggregate and sectoral output, using an infrastructure augmented neoclassical production function approach. The study addresses several limitations of the earlier literature related to Pakistan. This research uses the multidimensional concept of infrastructure, combining power, road and telecommunication infrastructure into a synthetic index, constructed through a principal component analysis. The quality dimension of infrastructure has also been taken into account in the empirical analysis.

In this study, we also make a comparative analysis of the different composition of infrastructure investment, including public versus private investment and infrastructure investment in sub-sectors, such as power, road and telecommunication. This segregation aims to know the most productive form of infrastructure investment. The empirical approach involves estimation of production function, relating output per worker to non-infrastructure capital stock, labor, human capital and infrastructure input. Our empirical estimates are based on time series data from 1972-2016 for Pakistan.

Marginal contribution of road and electricity infrastructure to real GDP per worker is positive and statistically significant, while the marginal contribution of telecommunication infrastructure to real GDP per worker is negative. The marginal contribution of road infrastructure is highest in the agriculture sector (0.51) than in the industrial sector (0.36)

and in the service sector (0.20). Marginal contribution of electricity generation is positive and statistically significant for industrial and services sector, while it is negatively associated with the agriculture sector. The highest contribution of power generation infrastructure is in the industrial sector (0.50) than in the services sectors (0.25). Telecommunication infrastructure is positive only for the agriculture sector while it is negatively associated with industrial and services sectors.

Regarding the impacts of public and private infrastructure investments, positive and statistically significant effects are obtained in the case of public sector infrastructure investment both for aggregate as well as for subsector of the economy. In the case of private infrastructure investment, statistically significant and positive estimates are obtained for industrial and agricultural sectors, while it is negative for services sectors. The marginal contribution of investment in road & telecommunication is higher than the marginal contribution of investment in the energy sector in correspondence sector, except for the services sector. Impact of investment in electricity and gas distribution has the highest elasticity in the industrial sector (0.13) than in aggregate economy (0.09), while these elasticities are very small in agricultural (0.04) and services sector (0.05). Similarly, the elasticity of road and telecommunication investment is higher in the industry (0.22) than in agriculture (0.14) and in service sector (0.03).

Dynamic effects of public and private infrastructure investment on aggregate and sub-sector of the economy show that: (i) for aggregate as well as sub-sector of the economy, a shock to the public and private investment in infrastructure tends to have a significant positive impact on employment. (ii) In all different cases, public and private capitals are long-run complements. (iii) Shock to private sector investment in infrastructure tends to have a significant positive impact on output for all cases. However the same is not true for public sector investment in infrastructure.

Spatial econometric analysis confirms the positive spillovers effects of road infrastructure and supports the idea that the effects of investment in road infrastructure are not limited to the territory in which an infrastructure project is situated. Human capital has a prodigious effect on economic output because of direct and spillover effects, which endorse the nature of human capital intensity in the regional economy.

Chapter 1

Introduction

1.1 Background

Policy-makers have been intrigued with the role of infrastructure in promoting economic growth since long. The importance of infrastructure for economic growth and productivity is well documented in the literature[1]. Infrastructure affects the overall economic development through a number of channels (Agénor and Moreno-Dodson, 2006) , Anderson et al. 2006). For example, infrastructure investment facilitates the production process and stimulates economic activities in the country. Moreover, it improves the competitiveness by reducing transactions and trade costs. Furthermore, it also generates employment opportunities for the poor (Sahoo and Dash, 2009). Infrastructure development enlarges production capacity, by creating an investment-conducive environment for private investors. Cost of production for the private sector is reduced due to the intensive use of infrastructure services; hence enhancing the durability of private capital. Uninterrupted power supply (of gas and electricity), efficient transportation system (roads, railways, bridges) and telecommunication network directly reduce the cost for those firms and sectors which intensively use the services of such infrastructure (Anderson et al. 2006). Improved infrastructure may expand the productivity of private capital by reducing the adjustment cost of private capital (Canning and Pedroni, 2004). Infrastructure also plays an important role in economic growth by creating inter-sectoral linkages and

[1] (Agénor and Moreno-Dodson, 2006; Aschauer, 1989a, 1989b; World Bank, 1994; Cadot et al. , ; Calderón et al. 2015; Calderón and Servén, 2003; Canning, 1999a, 1999b; Canning and Pedroni, 2004; Demurger, 2001; Easterly and Rebelo, 1993; Esfahani and Ramírez, 2003; Kelejian and Robinson, 1997; Rioja, 2001; Straub, 2011)

facilitating resource allocation across regions. Infrastructure facilitates the allocation of factors of production across the region and the sector, by reducing transportation cost, increasing the spread of information and technology. Thus infrastructure development that connects various sectors and regions boosts interregional and intersectoral trade, which creates more spillover effects across the sector and the region (Cohen, 2010).

Infrastructure also contributes to the convergence of developing regions with the developed regions within a country, by creating interregional linkages through smooth mobility of factors of production, information and technology (Straub, 2008a). For example, transport infrastructure helps the reallocation of investment and mobility of labor across the regions. This expedites economic growth and structural transformation. Thus infrastructure development helps lagging regions of the country to catch up with the advanced regions. At the initial stage of development when economic activities are slow with poor investment climate, it requires a large amount of investment in infrastructure to provide a suitable environment that may attract domestic and foreign capital. Private investment starts to increase with the provision of an adequate supply of electricity, gas, road infrastructure and water. As a result, private capital has gradually been articulated (Calderón et al., 2015; Straub, 2008a)

Recently, the role of infrastructure has received more attention of the academician and policy-makers. From an academic perspective, the role of infrastructure has sought to quantify its impact on economic growth and development. From a policy point of view, the known concern of infrastructure can be traced back to two global developments that have taken place in the last two decades. The first was the withdrawal of the public sector since the mid-1990s in developing countries from its dominant position, in providing infrastructure under the increasing pressure of budgetary adjustment (Calderón and Servén, 2004). The second was the involvement of the private sector in infrastructure development.

Quantifying the impact of infrastructure has become an omnipresent topic in many areas and dimensions of policy debate. For example, there is evidence that adequate infrastructure supply is a crucial element of the "behind the border" agenda, needed for trade liberalization, in order to achieve the intended goal of efficient resource allocation and export growth (Calderon and Serven, 2004). Canning and Bennathan (2000) pointed out that transport infrastructure can have a profound impact on the size of the market and the ability of manufacturers to leverage economies of scale and specialization. Expanding the market through efficient transport infrastructure can increase competition and market contestability. The transport infrastructure also enables a greater diffusion of knowledge and technology. The geographical dimension is an essential characteristic of infrastructure which is less emphasized in the earlier literature. Agglomeration, transport costs and volume of trade are strands of infrastructure in the context of economic geography. Literature supports the view that infrastructure is a significant determinant of trade volume (Limao and Venables, 2001) and (Bougheas et al, 1999). Power generation capacity is another important component of infrastructure in a model of economic development, proposed by Murphy et al.(1989).

Lanau (2017) highlighted another important dimension of infrastructure: infrastructure is more important to some sectors than other sectors. The economic sector, which is more dependent on infrastructure, is more affected by poor infrastructure. Contribution of infrastructure at sectoral level is less emphasized in the literature.

A critical aspect of the empirical literature is to determine the suitable proxy of infrastructure variable. Earlier literature has used public capital (i.e., the amount of investment) in infrastructure and later on empirical literature has gradually shifted towards the use of a physical measure of infrastructure as a proxy variable. The relationship between infrastructure investment and growth remains inconclusive in the majority of the empirical studies (Straub 2008). One important reason for this inconclusive result is that the official amount of investment often does not represent the actual physical measure of infrastructure because of inefficient government or weak institutions in developing countries. Due to this shortcoming, literature shifted to the use of physical measure of infrastructure to quantify the impact of infrastructure on economic growth. However, physical measure of infrastructure also suffers from two main problems (Straub 2008). First, the physical infrastructure used in literature is considered relatively weak proxy for the services it supposed to provide. Second, the quality dimension of infrastructure services is almost absent from these indicators — few studies (for example (Calderón and Chong, 2004; Calderón and Servén, 2004); Lanau (2017); (Calderón and Servén, 2010); (Seneviratne and Sun, 2013) efforts to control the quality of infrastructure and find a significant and positive effect of the quality of the infrastructure on growth.

Potential endogeneity due to infrastructure variable is another critical problem with earlier studies, and it is believed that the endogeneity problem is responsible for inconclusive or unrealistic findings. There are three main reasons of endogeneity issue namely, measurement error, unobserved effects or omitted variables and reverse causation. Endogeneity issue has been addressed in previous literature, by taking lagged values of the independent variables as instruments. However, researchers agree that it is not a perfect solution, especially in the case of a small sample. According to Romp and De Haan (2007), when reverse causation issue was controlled, the magnitude of estimates was decreased to one-third of (Aschauer, 1989b)'s initial estimates.

Against this background, there are several critical macroeconomic dimensions of infrastructure, which need to be evaluated comprehensively in the perspective of developing countries. These dimensions and new areas of infrastructure include geographical dimension or spillover effect of infrastructure across the geographical location, quality versus quantity of infrastructure, role of specific infrastructure elements, such as transport, power and telecommunications and a dynamic contribution of public versus private infrastructure investment on economic growth at the aggregate and sectoral levels. For designing the growth promoting strategies, it is crucial to account for the variety of channels, both direct and indirect, through which various types of infrastructure indicators affect the economic growth at aggregate and sectoral levels. Therefore, we use various aspects of infrastructure indicators for empirical analysis in this thesis.

1.2 Motivation and contributions of the thesis

The geographical location of Pakistan is very important. Pakistan is located in South Asia and is at the junction of Central Asia and Middle East, bordering four countries namely, India, Afghanistan, Iran and China. The power potential of a country is the direct product of its geographical and geostrategic location, its human resources and its economic strength. Geography is a determining factor in topography, size, shape, infrastructure, weather and climate[2]. However, the geopolitical location has a direct impact on its foreign,

[2] Essay UK - http://www.essay.uk.com/free-essays/economics/economic-advantages-geographic-position-pakistan.php

economic and defense policies. The geo-strategic location of Pakistan also offers the region a number of economic benefits. Pakistan is close to the oil-rich Gulf States on one side while on the other side it touches the Central Asian Republics and China.

Pakistan can help strengthen Central Asian Economies and China by providing low-cost land routes. Through this connectivity, the economy of Pakistan will grow significantly. It can form a strategic bridge, connecting the Central Asian Republics and China with the Southeast Asia, Middle East and Japan. As Central Asian countries seek economic diversification, Pakistan has an exclusive opportunity to export goods, establish new industries and thus make a strategic contribution to the structural change in the region. In this respect, improvement and expansion of infrastructure is a prerequisite, not only to accelerate its own economic growth and social development but also to connect the regions.

Currently, Pakistan's infrastructure is relatively poor by international standards. According to the SBP[3] report, the estimated loss to Pakistan is about 4 to 6 percent of GDP due to insufficient infrastructure. Logistical bottlenecks increase the production costs of goods by about 30 percent (SBP, 2007). This has a significant impact as Pakistan faces tough competition from India and China in export markets. The suboptimal allocation and inefficient management of physical infrastructure are among the reasons for low development in Pakistan (Haque et al. 2011). Weak infrastructure is one of the main bottlenecks for doing business in Pakistan (Biller and Sanchez-Triana, 2013). Pakistan provides relatively low access to infrastructure services which in turn restrains domestic as well as foreign direct investment in the country. According to Global Competitive Index

[3] http://www.sbp.org.pk/departments/ihfd/InfrastructureTaskForceReport.pdf
The Pakistan Infrastructure Report

(GCI), Pakistan ranks 98 in 151 countries in terms of quality of overall infrastructure, compared to China, India and Sri Lanka, rank 51, 74 and 26 respectively for the years 2015-16. As far as transport infrastructure is concerned, Pakistan ranks 78 out of 151 countries while China, India and Sri Lanka rank 21, 32 and 43 respectively. Pakistan ranks 132 in electricity and telephone infrastructure compared to China, India and Sri Lanka which rank 70, 115 and 77 respectively. In order to improve and expand the infrastructure, Pakistan needs massive investment in infrastructure development.

The objective of Pakistan's vision 2025 is to establish an efficient and integrated system of communication and transportation corridors to connect with these four regional partners. Pakistan has placed considerable emphasis on infrastructure investment, particularly on transport, telecommunication and energy infrastructure, as means to bring about regional cohesion, reduce economic disparities and stimulate economic development. For the development of efficient infrastructure in the country, Pakistan has entered an agreement worth more than $64 billion, under the umbrella of China-Pakistan Economic Corridor (CPEC)[4]. CPEC is a collection of projects, including transport infrastructure (road and railway), energy projects and telecommunication. Pipeline for the transportation of natural gas and oil will also be laid as part of the project.

The choice of Pakistan for this thesis is motivated by the fact that the Government has spent a substantial amount on infrastructure development and up-gradation with the coordination of China. Infrastructure projects under the aegis of CPEC are expected to improve communication network and transportation infrastructure that may facilitate the geographic rationalization of economic activity and reduce transaction and coordination

[4] All information in this section are taken from website of Ministry of Planning Development & Reform

costs. CPEC project covers almost all provinces of Pakistan, including Gilgit-Baltistan through road and rail infrastructure. Improvement in infrastructure is likely to bring major countrywide transformation, not only by eliminating bottlenecks and disruptions in the transportation system and energy sector but also by increasing GDP, stimulating employment, smoothing and enhancing mobility. The massive investment in a wide range of energy generation projects that spread across the country will help to eradicate the energy crisis in the country too.

The critical policy question is whether a significant investment in infrastructure projects would be able to deliver greater economic development in the country. Theoretical and empirical analysis of the impact of infrastructure investment on economic development remains controversial. According to De Jong et al. (2017), the critical issue with public investment is their capacity to describe the true public capital satisfactorily. Literature provides inconclusive evidence on the economic impact of public capital[5]. Various specific research questions emerge, regarding massive infrastructure investment in Pakistan under the umbrella of CPEC. These are outlined as follows:

- Does massive infrastructure development matter for economic growth in Pakistan?
- What is sector wise (industry, agriculture, and service sector) contribution of infrastructure investment?
- Does the quality of infrastructure matter for economic growth in Pakistan?
- What is the most effective form of infrastructure investment in Pakistan; Public versus private infrastructure in Pakistan?
- How can geographical regions be integrated through spillover effects of infrastructure development in Pakistan?

[5] For in-depth reviews of the empirical literature on public capital and economic growth, see for example (Pereira & Andraz, 2013), (Romp and De Haan, 2007) and (Brons et al 2014)

The research questions are relevant in perspective of the recent substantial infrastructure investment in Pakistan. The role of quantity and quality of infrastructure, public versus private infrastructure, investment for economic growth and link between geographic and infrastructure development has not been studied in the context of Pakistan. In order to provide answers to the above mentioned questions, following objectives have been specified.

However, since CPEC is intended to modernize Pakistani infrastructure, thereby strengthening the country's economy, it is pertinent to ask, what is the possible quantitative impact of investment in infrastructure on the growth of the country? While the present thesis agrees that at present it is too early to quantify the impact of CPEC on the economic growth of Pakistan, nonetheless the analysis presented in the thesis can serve as a basis to the policy makers to evaluate the possible effects of such an investment on the economy.

1.3 Objective of the Study

There are four principal objectives of this thesis. The first is to develop an analytical framework to analyze the potential influence of infrastructure development on economic growth and to assess how the quantity and quality of physical infrastructure affect the growth. The second objective is to assess the role of monetary measure (infrastructure investment) in the economic growth of Pakistan. The final objective is to assess the spillover effect of infrastructure on regional economic performance, by using spatial econometric methodology.

To put it in other words, the specific objectives of the thesis are:

i. To develop a theoretical framework for the infrastructure growth relationship by integrating the quality of institutions.

ii. To empirically estimate the impact of infrastructure capital on economic growth at aggregate and sectoral level (Industry, Agriculture & Services sector)

a. By specific types of infrastructure such as Roads, Energy and telecommunication

b. Aggregate Infrastructure (a composite index of, Roads, Energy, and telecommunication)

c. Quantity vs. quality of infrastructure

iii. Estimates the impact of infrastructure investment on economic growth at aggregate and sectoral level

a. Aggregate infrastructure investment

b. Public versus private infrastructure investment

c. Disagreed Infrastructure investment by Energy and Roads & telecommunication

d. Dynamic effect of public and private infrastructure investment on economic growth and employment.

iv. To quantify the impact of infrastructure on the economic performance of the region, using spatial econometric analysis

1.4 Significance of the Study

The present thesis has several incremental contributions. In the context of Pakistan, most empirical studies use aggregate investment as proxy for infrastructure investment. The literature appears to be silent regarding the role of quality and quantity of physical infrastructure in case of Pakistan. The first contribution of the current thesis is that it introduces the role of quantity and quality of infrastructure for aggregate and subsector (industry, agriculture, and service sector) of the economy. The study also uses disaggregated infrastructure by type of infrastructure, i.e. transportation, communication and energy, to avoid potential aggregation misspecifications.

Likewise, the earlier literature for Pakistan also ignores the role of public versus private infrastructure investment and contribution of different composition of infrastructure investment such as the power sector, road and telecommunication for economic growth. Therefore, the second contribution of the present thesis is, in contrast to earlier literature, that we make a comparative analysis of the different composition of infrastructure investment, including public versus private investment and infrastructure investment in sub-sectors such as in power, road and telecommunication sector. This segregation aims to know the most productive form of infrastructure investment.

Thirdly, the present thesis is -to the best of the author's knowledge- the first to quantify the direct and indirect effect of infrastructure for economic growth across the country, and spillover effect of infrastructure in the region by using spatial econometrics technique. For regional connectivity, a spatial econometric technique is used to account for spillovers effects of infrastructure across the countries. Spatial econometric techniques are useful to take into account the spillovers and contiguity effects in the regional analysis (Del Bo and Florio 2012). This analysis is motivated by the fact that the CPEC has spillovers effects across the region. Project executed under the umbrella of CPEC is not the overall infrastructure, but the provision of specific investment types, like transportation, energy and telecommunication.

1.5 Methodology

The empirical investigation uses time series data for 1972-2015. Fully modified ordinary least squares (FMOLS) estimation methodology, developed by (Phillips and Hansen 1990) has been employed in this thesis to examine the contribution of infrastructure investment on aggregate and sub-sector of the economy. Spatial econometrics technique has been employed to quantify the spillover effects of infrastructure across the regions, over the period from 2006 to 2016.

1.6. Organization of Thesis

This thesis proceeds as follows:

In Chapter 2, the empirical and methodological debate on the growth impact of infrastructure is reviewed. Chapter 3 presents the state of infrastructure in Pakistan and its role in economic growth. A theoretical model is discussed in Chapter 4. Empirical strategy and data are presented in Chapter 5. Chapter 6 reports the empirical results of a physical and monetary measure of infrastructure. Results of spillover effect are presented in Chapter 7. In the end, Chapter 8 summarizes the results and draws some policy implications.

Chapter 2

Literature Review

2.1 Introduction

In this chapter, we provide a comprehensive review of existing literature explaining the impact of infrastructure development on economic growth. An ample literature is available that has developed theoretical framework to model the relationship between infrastructure and growth and as well as spillover effects of infrastructure development. This chapter has also included an integrated debate of the methodological developments that have successively led to the estimation of production functions, cost & profit functions and recently to autoregressive vector models. In this chapter we will shed light on the various channels through which infrastructure may exert a positive effect on economic growth. Literature divides the infrastructure into two major groups, economic infrastructure and social infrastructure. Social infrastructures consist of the provision of health, education, justice and community facilities. While the economic infrastructure includes power, transport, railways, telecommunications network and roads. Economic infrastructures are crucial components for the modern economy (Stewart 2010). In this study, our focus is on the effect of economic infrastructure on economic growth. More specifically our emphasis is to study the role of uninterrupted and persistent supply of power, roads, transport and telecommunications infrastructure for economic development. Infrastructure components such as, uninterrupted power supply system, efficient transport and communication system play a supporting role in the production and distribution of goods and services. Thus due to its supporting role, infrastructure enter directly and indirectly into production function and affect aggregate output.

This chapter is comprised of three sections: (1) Discussion of the theoretical foundation of economics of infrastructure and transmission channels through which various indicators of infrastructure effect economic growth. (2) Review of international empirical evidence on infrastructure-growth relationship (3) Critical assessment and discussion of available literature on Pakistan economy. The literature review on spillovers effect of infrastructure development, beyond the boundary of the country is presented in chapter 7.

2.2 Growth Impact of infrastructure

An adequate provision of infrastructure services has been considered an essential feature of the long-term persistent economic growth and development. Over the last three decades, the importance of infrastructure for economic development and welfare has attracted substantial attention of economists, researchers and policy makers. Numerous theoretical and empirical literatures have focused on the impact of quality and quantity of infrastructure on economic growth and welfare.

Infrastructure has a dual role between firms and household; it provides input services to the firm and producer and final services to the consumers (Shanks and Barnes, 2008). As a service provider, infrastructure directly and indirectly, enters into the production process; therefore it plays a critical role in the production process. The empirical and theoretical literature on the nexus between output and infrastructure suggests numerous transmission channels, through which infrastructure may affect growth. Theoretically, infrastructure development may contribute to economic growth, directly through productivity effect and indirectly through reducing transactions and other costs. The direct and indirect channels specified are explained as follows:

i. Direct Channel

Infrastructure as pure public good or intermediate input, directly contributes to economic growth through productivity effect. An increase in infrastructure stock would increase the productivity of other factors. Infrastructure can serve as a substitute or complement to other inputs in the production function; therefore it increases the productivity of other inputs in numerous ways. The first channel of infrastructure growth nexus was outlined by (Aschauer, 1989). He argues that investment in public infrastructure stimulates growth through private capital and is not subject to user charges. Therefore, an upsurge in capital stocks has a positive but decreasing effect on the marginal product of all factors, such as labor and capital. As a result, the cost of production decreases and the level of private production upsurges (Agénor and Moreno-Dodson, 2006). The second transmission mechanism through which infrastructure may affect economic growth is the private capital formation. According to Agenor and Moreno-Dodson (2006), investment in public infrastructure increases the marginal productivity of private inputs, thus increasing the rate of return on private capital. The influence of infrastructure on economic growth through private capital formation is well documented in the empirical literature for developing countries. For example, (Albala-Bertrand and Mamatzakis, 2004); (Agénor et al. 2005) find a positive and significant impact of investment in public infrastructure on private investment in Chile. Nadiri and Mamuneas (1996), argued that direct growth effect of infrastructure is based on the notion that the additional product of public investment is positive. This implies that surge in public capital services reduces the cost of production of the private sector which leads to an increase in output of the private sector.

Straub (2008), argued that private investment may increase in remote or excluded areas, when these areas are connected through roads, railways and giving access to services such as telecommunication and electricity. Investment in infrastructure network is essential for private investment. Shanks and Barnes (2008), point out that public investment in infrastructure is not subject to user charges and consequently offers an advantage to the producer that directly affects private sector output and productivity. This is also known as the free input effect.

Straub (2008) argue that source of financing of infrastructure is also crucial. He highlights the crowding out effect of public investment in infrastructure, especially if these investments are made through taxation or through borrowing from domestic financial institutions. However, Otto and Voss (1994), point out that the initial rise in infrastructure investment crowds out private investment, but potentially stimulates additional private investment, if additional public investment increases the marginal product of private capital. The long-term net effects of an increase in public investment, therefore, depend on the relative importance of these two effects.

ii. Indirect Channels

In addition to the direct effect of infrastructure on growth through the productivity of private inputs and rate of return on private capital, infrastructure exerts a positive effect on aggregate output through a variety of indirect transmission mechanisms. Potential indirect channels of economic infrastructure investment to growth include adjustment cost, labor productivity, the durability of private capital and economies of scale and scope (Straub, 2008; Agenor and Moreno-Dodson, 2006). Each of these is explained below:

a). Adjustment cost

Straub (2008) argues that there are two channels through which the enhancement of the stock of infrastructure capital reduces the adjustment cost of private capital. First, by reducing the logistic cost of private investment and second an improving public infrastructure allows for more flexible private investment in devices, such as electricity generators for more productive investments in machinery. (see for example (Reinikka & Svensson, 2002) for Uganda, (Alby et al. 2010), for Latin America, and (Lee et al. 1996) for Indonesia and Nigeria. Efficient and reliable services of stock of infrastructure reduce the firm's investment in substitution factor of production and thereby release the resources for productive investment.

b). Labor productivity:

Labor productivity is another potential channel through which improvement in infrastructure has a positive effect on aggregate output. An improvement in communication technology and road network reduces the time spent on traveling and also helps in organizing work time more efficiently. (Torvik, 2002), shows that improvement in public infrastructure spurs economic growth by reducing unit labor costs and enhancing labor productivity.

c). The durability of private capital

Maintaining the quality of public infrastructure, by improving the sustainability of private capital, leaves a positive impact on economic growth. Increasing the expenditure on the quality and maintenance of public infrastructure allows the private sector to spend less on the maintenance of its capital and enables them to allocate these resources to other uses. The negligence and inefficiency of government, spending on quality and maintenance of public infrastructure has been a persistence issue in most of the developing countries (Agenor and Moreno-Dodson, 2006). According to (World Bank, 1994) estimates for developing countries, technical inefficiency in public infrastructures such as roads, power supply, railways and water, has caused a loss of one-fourth of the annual investment in infrastructure in the early 1990s. Without regular maintenance, paved roads and railways deteriorate very fast. The inefficiency of transportation network causes repeated interruptions, raises the question on its reliability and creates severe damages for users. Increasing government spending for the maintenance of quality of transportation network, reduces power interruption and telecommunication fault, thus may positively affect private production. (Canning, 1999a) estimates show that reduction in roads roughness in Vietnam, from 14 International Roughness Index (IRI) to 6 IRI would save 12 to 22 percent vehicle operating costs. According to Gyamfi and Ruan (1996), due to poor road conditions in Latin America and the Caribbean, each dollar not spent on road maintenance leads to a three times increase in vehicle operating costs. Numerous studies (for instance Agénor and Moreno-Dodson, 2006; Calderón and Servén, 2004; Hulten, 1996) highlight the importance of quality of infrastructure for growth and argue that government's expenditure on maintenance of quality of infrastructure affects the durability and quality of private capital, which may generate additional impact on economic growth.

In addition to the role of direct input into production function, infrastructure may also have a spillover effect to non-infrastructure industries (Shanks and Barnes, 2008). Producer gains positive spillovers effects, when infrastructure services are used free of charge, leaving full benefits to the producer. If the producer charged for the use of infrastructure, the market-determined charge would not be able to capture all the advantages that producers generate, by using public infrastructure in the production process; so it is also a spillover effect (Shanks and Barnes, 2008). Different types of infrastructure such as power, transportation and telecommunication network have different nature of spillovers effects. Most commonly infrastructure may have an impact on transaction and coordination costs, diffusion of knowledge and information and geographic rationalization (Shanks and Barnes, 2008). Spillovers effect may also vary due to industry, using the infrastructure, for instance (Röller and Waverman, 2001) argue that spillover benefits from communication infrastructure can be enlarged with the information intensity.

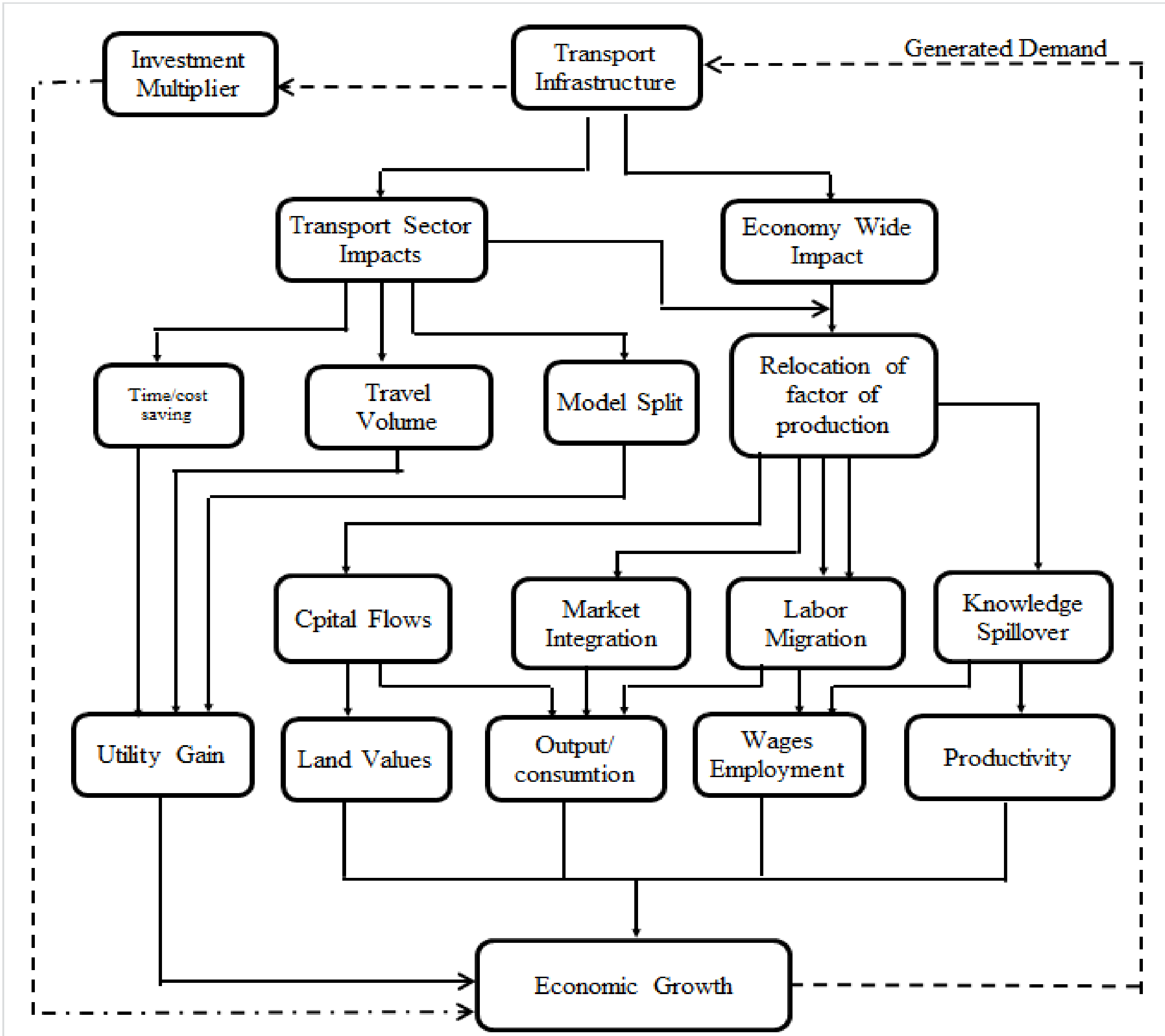
Different types of infrastructure like power, transportation and telecommunication network have different nature of spillovers effects. Most commonly, infrastructure may have an impact on transaction and coordination costs, diffusion of knowledge and information and geographic rationalization (Shanks and Barnes, 2008). Spillovers effect may also vary due to industry, using the infrastructure, for instance (Röller and Waverman, 2001) argue that spillover benefits from communications infrastructure can be enlarged with the information intensity. In the following section spillovers effects by type of infrastructure are provided.

2.2.1 Effects of transport Infrastructure on Economic Growth

Transport network plays its role in connecting people, businesses and resources. Investment in transportation network has a positive effect on economic development through increased income, property value, employment opportunity, business activity, tax revenues and competitiveness in international trade. Investment in transport infrastructure significantly affects economic growth by reducing transportation cost. Improved road network provides quick access to inputs, saves time and accomplishes speedy deliveries of products and raw material in less time, and there will be less wear and tear of transport. Reduction in transport operating cost will lead to lower the total unit cost of production; and thus will increase productivity. Efficient transportation network will also affect the local business supplying inputs. The most direct and significant impact of transport infrastructure investment is the reduction of transportation cost and labor mobility across the region. It provides the accessibility of market and resources, such as equipment, labor and material to the regional business. Construction of road network has a direct impact on wealth and job creation.

Banister and Berechman (2002) argue that the quality of transport infrastructure has the effect of reducing relocation costs and increasing factor mobility, which can facilitate industrial agglomeration with its advantages of the geographical proximity of other firms. Industrial agglomeration has improved operational efficiency, through information spillovers and access to common input pools. (Banister and Berechman, 2002; Prud'Homme, 2005) emphasize that better transport networks may enlarge labor market catchments. A larger effective size of labor market upsurges the possibility of both firms and workers, finding what they want and thus decreases qualification mismatch. Numerous studies have highlighted the link between economic growth and transportation network, by enabling firms to adopt just in time production. Figure 2.1 explain the various channels through which transport infrastructure may affect the growth.

Figure 2.1: Transport Infrastructure and Economic Growth



Source: Author own construction

2.2.2 Communication Infrastructure

According to Antonelli (1993) better quality of telecommunications infrastructure is the foundation for a variety of innovations. Antonelli (1993) suggests that the accessibility of advanced telecommunication infrastructure is crucial to provide worldwide reliable, high quality and low-cost information and communications services. Investment in advanced telecommunication technology is likely to spread technical externalities to other communication services. The most common spillovers effects of communications infrastructure include facilitation in product innovation, diffusion of technology, access to new consumers and low transaction cost. According to (Cronin et al. 1993) and (Globerman and Shapiro, 2002) telecommunication infrastructure, especially advancement in digital technology, has facilitated new communication services, such as computer communication services. Advancement in communication systems may raise the diffusion of knowledge and technology and thus will increase productivity (Canning and Pedroni, 1999; Madden and Savage, 1998) . According to (Nadiri* & Nandi, 2001) improvement in communication infrastructure play a facilitating role in economic growth and the number of economic activities, by raising the efficiency and size of the communication network which in turn augment the transfer of knowledge and information. Joint improvement in communication and transport infrastructure may allow timely and efficient product delivery to customers. (Madden and Savage, 2000) highlight the importance of communication infrastructure in the integration of domestic and international markets. Access to information and knowledge through advanced communication infrastructure allows the amalgamation of foreign and domestic markets, which in turn increases competition and market efficiency (Madden and Savage, 2000). Quality of communication infrastructure may facilitate dissemination of information and timely decision making within the firm. The updated communication network may increase the efficiency of a manager's communications, help coordination among different independent units and increase the diffusion of knowledge and information (Nadiri and Nandi 2001).

Investment in telecommunications infrastructure provides a range of benefits to the individual consumer, rural and urban society and overall economy. (Gabe and Abel, 2002) highlight the role of advanced telecommunications infrastructure for rural areas. According to Maleki (1996), infrastructure development helps to overcome the disadvantages associated with isolation and low density of economic activity in rural areas. Residents of the rural and isolated region can be benefited from advanced telecommunication networks, with greater access to educational opportunities through distance learning (Parker, 2000). The agricultural sector is a crucial sector in many rural areas, and investment in telecommunication infrastructure may also exert a positive effect on agriculture productivity.

2.3 Empirical Evidence

2.3.1 Production Function Approach

The work of (Aschauer, 1989b) led to an explosion in the literature on infrastructure and growth nexus. Aschauer approach was based on the production function, and this approach was extensively implemented in subsequent literature. A large body of subsequent literature employs the same methodology on international, regional and country-specific data. In empirical literature of infrastructure growth relationship, numerous estimation methodologies on a different data set, like panel, time series with different measures of infrastructure have been exercised in the successive body of literature. Numerous studies have used the production function method to find the impact of public capital on economic growth[6].

Most of the studies have found positive influence of different measures of infrastructure on output and productivity. However, the literature shows that findings are mostly influenced by a different measure of infrastructure employed in the empirical analysis.

[6] (Albala-Bertrand and Mamatzakis, 2004; Cadot et al. 1999, 2006; Calderón and Servén, 2003; Canning, 1999; Canning and Bennathan, 2000; Canning and Pedroni, 1999; Delgado and Alvarez 2000); Everaert and Heylen, 2004; Fernald, 1999; Holtz-Eakin and Schwartz, 1995a; Kamps, 2005; Kemmerling and Stephan, 2002; Ligthart, 2000; Shioji, 2001; Stephan, 2001, 2003; Vijverberg et al 1997).

Regarding the measure of infrastructure capital, mostly two measure of infrastructure have been used in literature, (1) government investment as a percentage of GDP and (2) some physical measure or government capital stock, like the length of paved road in kilometers. Each measure has its own merits and demeritts. Empirical results are less conclusive, when infrastructure spending flow or infrastructure investment is employed as a proxy variable for infrastructure. For example, (Barro, 1990; Devarajan et al. 1996; Holtz-Eakin and Schwartz, 1995a) based on more sophisticated econometrics method and a broad range of countries, find much lesser and in some cases adverse correlation between public investment in infrastructure and economic growth. The IMF (2004) survey on public investment in infrastructure and growth relationship does not find a clear-cut correlation between these two variables. Similarly, literature survey conducted by (Straub, 2008a) has found that less than half of the studies show a positive relationship between public investment and growth. Literature highlights that the number of contextual factors, including a source of financing for infrastructure, accessibility of complementary inputs, such as human capital, quality of institutions, political stability and corruption impede the positive relationship between public investment and economic growth. Investment in infrastructure through excessive taxation, deficits or debt, tend to diminish economic growth by crowding out private investment or depress private investment (Adam and Bevan, 2005; Dessus and Herrera,2000; Gupta et al. 2005). The obtainability of complementary inputs plays a supporting role in the effectiveness of public spending on growth. The studies carried out by (Adam and Bevan, 2005; Bose et al. 2007; Haque and Kim, 2003; Solow, 1956) demonstrate that investment in infrastructure has the most significant impact on economic growth when combined with productive spending on education and health. The other contextual factors, such as quality of institution, political openness, transparency, perception of corruption, quality of governance and the risk of contract repudiation may also play critical role in mediating the long-run impact of infrastructure investment on economic growth (Esfahani and Ramírez, 2003; Haque and Kneller, 2008; Tanzi and Davoodi, 1998). Straub (2011), argue that due to the lack of efficiency in public investment and corruption, the exact mapping between actual values of infrastructure and investment in infrastructure is a foremost challenge. Pritchett (1996), demonstrate that investment flows in infrastructure are not good indicators for productive capital stocks because the cost of public investment in infrastructure is expected to fluctuate relative to its real value. The inefficiency of government or the departure of efficiency and possibility of corruption may be quite high in the infrastructure project, which are some serious concerns for the difference in infrastructure stocks and investment in infrastructure. Caselli (2005) and Pritchett (2000) discuss that inefficiency in public investment process, poor selection of infrastructure projects, inadequate monitoring and implementation can result in a fraction of public investment, translating into productive infrastructure and limiting long-term production gains.

On the other hand, there are studies[7]which argue that upsurge investment in public infrastructure increases economic growth in the short and long term. Abdul and Petia (2016) argue that increase in public investment in infrastructure, boosts economic growth in two ways: (1) in the short term, investment in infrastructure stimulates aggregate demand with the short-term investment multiplier (2) Infrastructure services are highly

[7] (for example, Abdul and Petia, 2016; Ansar et al. 2016); Demurger, 2001, 2001; Gupta et al. 2014) ;Magud and Sosa, 2015)

complementary, therefore crowding in private investment boosts economic growth. The empirical study of Abdul and Petia (2016), for a sample of 17 OECD economies, concludes that an increased public investment stimulates output, both in the short and long-term, crowds in private investment and reduces unemployment. The study further explores in countries where investment efficiency is low; increased public investment increases output by 2.2% in the long run, compared to 2.8% in countries where public investment is fully active. Komatsuzaki (2016) explores the macroeconomic of raising public investment in infrastructure for the economy of the Philippines and find that an increase in public infrastructure investment causes a statistically positive impact on output. The study of Lanau (2017) for six Latin American countries find that infrastructure raises growth and investment. Banerjee et al. (2012) and Demurger (2001) argue that investment in transport infrastructure has a positive impact on economic growth in Chinese province.

Pritchett (1996) highlights some severe drawbacks with the use of the monetary value of government investment (as a share of GDP), as a regressor in growth equation for infrastructure capital. Due to the public goods and nature of infrastructure capital, infrastructure investment projects usually are carried out by public sector institutions. As a result, there is a possibility of deviation of the actual and economic cost of infrastructure development. Therefore, the money value of infrastructure investment may not be an appropriate measure of infrastructure capital because of the inefficiency of government investment, particularly in developing countries (Pritchett, 1996). Pritchett's estimates show that just over half of the money invested in infrastructure schemes will have a constructive impact on the public capital stock. A large body of recent studies has used a physical measure of infrastructure capital, in investigating the impact of infrastructure on economic growth. For the stock of infrastructure capital, the number of telephones, the electricity generating capacity and the kilometers of paved roads were used (Canning and Pedroni, 1999;Esfahani and Ramírez, 2003; Sanchez-Robles, 1998). Straub (2008a) argues that inconclusive impact of infrastructure investment on economic growth might be due the fact that institutional and political factors often affect the level of infrastructure stock. According to Straub, it is the inefficiency of government, not the level of infrastructure investment which undermines the economic growth.

Aschhauer (1989a) and Munnell and Cook (1990) split total capital stock into public capital and core infrastructure and concludes that core infrastructure has a stronger effect on output than stock of public capital. Numerous other countries' specific studies[8] employ a production function approach and find positive effects of public capital on output. Bajo and Sosvilla (1993) employ the aggregate production function approach for Spain over the period from 1964-1988. The results of their study confirm the view that the public capital stock plays a significant role in private sector productivity. The study of Ligthart (2000) for Portugal examines the growth effects of public capital, by using annual time series data from 1965-1995 and conclude that public capital has a significant long-term impact on output growth in Portugal. The study of Ligthart (2002) further explores that investment related to roads, railways and airport is more productive than public investment in other major categories. Wylie (1996) find a high return to infrastructure investment in terms of goods sector productivity in Canada, over the period from 1946-1991 and reveal a complementarity between infrastructure and goods sector capital and labor inputs. (Cantos

[8] For example; Otto and Voss, 1994 for Australia; Sturm, 2001; Sturm and De Haan, 1995 for Netherlands and USA; Bajo and Sosvilla, 1993 for Spain; Ligthart, 2000 for Portugal and Wang, 2005 for Canada

et al. 2005) employ growth accounting and production function approach on Spanish data over the period from 1965-1995 and obtain similar elasticities with both methodologies for aggregate, concluded that the disaggregated results for the sector of production are inconclusive.

Few studies (for example (Calderón and Servén, 2004, 2010; Sanchez-Robles, 1998) construct a composite index of different infrastructure indicators, such as electricity generation, road and telecommunication. Calderon and Serven (2004, 2010) construct an aggregate index of infrastructure, by using different types of infrastructure and the quality of service in different infrastructure sectors. Calderon and Serven (2010) examine the impact of infrastructure development on economic growth and income inequality for Sub-Saharan Africa, using panel data over the period from 1960-2005. They used the standard set of control variables, along with infrastructure quality and quantity measure and the Generalized Method of Moments (GMM) approach has been used for growth regressions to control potential endogeneity. Their results suggest that both infrastructure stock and quality have a positive impact on long-term economic growth and a negative impact on income inequality.

Everaert and Heylen (2004) analyze the relationship between the individual as well as composite indices of infrastructure and income inequality. For an individual measure of infrastructure, roads, railways, telecommunication and energy have been used, and composite indices are constructed, using principal component analysis. Their findings confirm the negative relationship between income inequality and quantity and quality of infrastructure measure.

Calderón et al. (2015) evaluate the contribution of infrastructure on output for a large cross-country dataset. The study uses the aggregate infrastructure indices encompassing transport, power and telecommunication along with other standard determinants of growth. The long-run elasticity of output, relative to the aggregate infrastructure index, ranged from 0.07 to 0.10.

However, the methodological approach used by Aschauer was challenged on the econometric ground by a number of studies (Gramlich, 1994; Pereira and Andraz, 2013) . Aschauer's approach has been criticized for the simultaneity bias, the reverse causality of productivity to public capital, the fallacious regression because of the non-stationarity of the data. Pereira and Andraz (2013) argue that due to a single equation and static approach, the methodology of the production function is not able to take into account the simultaneity between different variables and for all non-contemporary effects. The most critical issue in Aschauer approach is the bidirectional causality between aggregate output and public capital. Economic growth may cause the demand for, and supply of public capital and public capital may affect output (Eisner, 1991; Romp and De Haan, 2007). Various studies for example (Eisner, 1991; Evans and Karras, 1994a, 1994b; Romp and De Haan, 2007; Sturm et al. 1999; Sturm and De Haan, 1995) criticize the Aschauer approach, for not taking into account the time series properties of data and ignoring the time series properties of data may cause spurious results.

Various methodological approaches have been used in the empirical literature to address reverse causality issue. The most prominent approaches are panel data estimation, reduced form equation or simultaneous equation models and instrumental variables approach (Canning and Pedroni, 1999, 2004). Another approach to deal with causality problem is to apply the appropriate econometric test to identify the direction of causality. A panel data estimation methodology may address the causality issue in infrastructure growth relationship (Canning and Bennathan, 2000). Similarly pooling the data across the countries may allow identification of long-run relationship. Canning and Pedroni 1999) employ a reduced form model to solve the problem of reverse causality. In reduce form model Canning and Pedroni used public and private capital which were financed out of the available savings. They found that the nature of the long-run relationship and the short-run dynamic between growth and capital vary across the countries. Their study further explores that the physical measure of infrastructure and GDP per capita are non-stationary, but have a long-term relationship, so that the series can be represented in the form of dynamic error correction model. Through testing the restriction, they find bidirectional causality between the physical stock of infrastructure and income. Canning and Pedroni find a long-run positive impact of investment in electricity generation capacity, in most of the countries.

Demetriades and Mamuneas (2000) employ a simultaneous equation model to address the problem of causality. Simultaneous equation model, developed by Demetriades and Mamuneas (2000) comprises of two equations. In the first equation, public capital is considered as an exogenous variable while in the second equation output is exogenous variable, and public capital is endogenous variable. A system of equation is estimated by Demetriades and Mamuneas (2000) for 12 OECD countries over the period from 1972-91. They find that in the short term, the impact of public capital on output varies from 0.36% in the United Kingdom to 2.06% in Norway.

Similarly, Esfahani and Ramirez (2003) estimate a simultaneous equation model for the cross-country growth analysis. In their analysis, Esfahani and Ramirez separate the reciprocal effects of infrastructure and rest of the economy through structural growth model. Esfahani and Ramirez (2003) establish the relationship between infrastructure and income as a recursive system that can be estimated simultaneously by solving the problem of identification. To take into account the simultaneous effect of infrastructure, an error correction mechanism is used by authors for the relationship between income and infrastructure to account. (Cadot et al., 1999;Cadot et al. (2006); Kemmerling and Stephan, 2002) use the simultaneous equation model for France and Germany, respectively to address the issue of causality between infrastructure and economic growth. Some studies (for example (Ai and Cassou, 1995); Calderón and Servén, 2003; Finn, 1993) have employed Generalized Method of moments (GMM) estimation methodology to avoid possible reverse causation between infrastructure and economic growth. Results of some selected studies, which use production function approach with the various definition of infrastructure, are summarized in Appendix A.

2.3.2 Vector Autoregressive (VAR) Approach

The criticism on Aschauer approach led to the use of Granger causality test, Vector Autoregressive (VAR) and VECM models. These econometrics techniques have become increasingly popular in infrastructure growth literature. These techniques are used extensively because they address the above mentioned econometrics issues, rigorously and comprehensively (Pereira and Andraz, 2013). The studies which used VAR and VECM approach to analyze the impact of infrastructure on economic performance include (Agénor et al., 2005; Batina, 1998; Belloc and Vertova, 2006; Crowder and Himarios, 1997; Everaert, 2003; Ghali, 1998; Kamps, 2005; Mamatzakis, 1999; Pereira, 2000; Sturm et al., 1999; Voss, 2002) among others. In most of these studies, mainly aggregate level studies, public investment and public capital stock have been used as proxies for public infrastructure. However, some studies use the road communication as explanatory variables. These studies are based on annual data, covering developed and developing countries, and majority of the above mentioned studies found a positive impact of infrastructure on output. Recently VAR methodology has become progressively popular to analyze the relationship between output and infrastructure capital. The extensive use of VAR models in infrastructure growth nexus is because the VAR approach addresses the most of econometric issues rigorously and comprehensively. The VAR methodology is based on the idea that it accounts dynamic feedbacks to understand the quantitative relationship between output and infrastructure capital.

Agénor et al. (2005) analyze the relationship between public infrastructure and private capital formation in Tunisia, Egypt and Jordan. Their results suggest that public infrastructure has both flow and stock impacts on private investment in Egypt, however in the case of Jordan and Tunisia, it is only stock effect. Impact of public infrastructure in these cases is minor and short-lived, imitating the hostile environment for private investment in these countries. Likewise, the study of Belloc and Vertova (2006) analyze the dynamic relationship between public investment, private investment and gross domestic product for the economies of heavily indebted developing countries (HIPCs). The results give empirical support, in six out of seven cases, to the existence of a complementary relationship between public and private investment and a positive effect of public investment on production. Findings of some selected studies, which have used the VAR approach with the various definition of infrastructure, are summarized in Appendix A.

2.3.3 Empirical Evidence from Pakistan

Few empirical studies (for example, Ghani and Din, 2006; Ahmed et al., 2013; Ahmed and Ali, 2014; Rehman et al. 2010) examined the impact of infrastructure on economic growth in Pakistan. The findings of these studies vary considerably regarding the magnitude of the impact. (Ghani and Din, 2006) explore the impact of public and private investment in the context of Pakistan and conclude that economic growth in Pakistan is primarily influenced by private investment. They further documented that public investment has a significant negative impact on economic growth in Pakistan, which calls into question the effectiveness of public investment.

Ahmed and Ali (2014) provides a comprehensive analysis of aggregate and sectoral public investment in private sectoral investment, output and employment. They used time series data from 1964 to 2011 and covered eight sectors of the economy and showed that fourteen out of sixteen cases exhibit a crowding in the impact of public investment on private investment. Ahmed et al (2013) employed a dynamic CGE model to estimate the macro-micro impact of public infrastructure investment. For empirical analysis, they used production taxes and foreign borrowing to finance additional public infrastructure investment. Their findings show that investments in public infrastructure have the same direction, whether they are financed by taxation or by international borrowing. They further explore short-term tax financing puts pressure on production in the industrial sector and thus reduces economic growth.

Faridi et al.(2011) examine the influence of transport and telecommunications infrastructure on Pakistan's economic growth, employing Solow's growth model. Roads in kilometers and number of telephone lines served as indicators for infrastructure. They find a positive and significant association between GDP growth and road infrastructure in Pakistan over the period studied. Results of the study indicate that a 1% increase in road infrastructure in Pakistan caused an average increase of 0.09% of GDP. On the other hand, the study demonstrates that the telecommunication infrastructure is adversely related to GDP. The findings indicate that a 1% upsurge in the number of telephone lines in the country caused a reduction of 0.08% of GDP. The authors claim that this is due to the misuse of telecommunication services.

Hashim et al. (2009) examine the impact of the various forms of infrastructure on economic growth in Pakistan, covering the period 1968-2007. For infrastructure indicators, they use a total number of landline and mobile phones over the population, investments in the telecommunication sector and transport infrastructure. The results indicate that the effects of telephone number and mobile phone on GDP are positive and significant.

Looney (1997) scrutinizes the impact of transport infrastructure and energy consumption on economic development in the case of Pakistan, by using an autoregressive vector (VAR) methodology. This study exposes that the expansion of public infrastructure has not played a significant role in the economy since 1973. The study further explores that only 1.5 % variations in GDP are explained by variation in infrastructure. Besides, infrastructure explained less than 5% variation in private investment in the large-scale manufacturing sector. He note that the extension of infrastructure is largely determined by the needs of private investment in the manufacturing sector rather than stimulating private capital formation.

Iqbal and Nadeem (2006) study the relationship between social, real, monetary and infrastructure expansion in Pakistan. Authors constructed a composite index using the principal component analysis approach. For the construction of an aggregate index of infrastructure, a number of variables related to road, rail, telephone, energy and a few other sectors are employed. The results of Granger causality test in a vector error-correction model show that infrastructure development causes social development in Pakistan. However, the study does not find any causal relationship between infrastructure development and growth.

In the context of Pakistan, empirical studies have tried to assess the impact of infrastructure investment on economic growth in Pakistan. Most of these studies use aggregate investment as a proxy for infrastructure investment and overlook the role of physical measures of infrastructure in case of Pakistan. The appropriate measure of infrastructure for empirical analysis is a critical question highlighted in the literature. Two proxies of infrastructure variable have been used in the literature; public capital (investment in infrastructure) and a physical measure of infrastructure. The focus of earlier empirical studies of Pakistan, on the relationship between infrastructure and economic growth is narrow in terms of use of infrastructure measure. Empirical results for the growth impact of infrastructure are less conclusive in the case of Pakistan. In order to fill this gap in the literature, we employ both measures of infrastructure, physical infrastructure and infrastructure investment.

Furthermore this study, in contrast to earlier literature, make a comparative analysis of the different composition of infrastructure investment including public versus private investment and infrastructure investment in sub-sectors, such as in power, road and telecommunication sector. The objective of this segregation is to know the most productive form of infrastructure investment. Using these insights, we have developed a theoretical framework for the analysis of the relationship between different dimensions of infrastructure and a sectorial component of GDP in Pakistan

2.4 Conclusion

This chapter gives a comprehensive overview of the methodological debate on the growth impact of infrastructure, and the empirical strategy used for quantification of infrastructure growth relationship over time. The analysis of the literature establishes the notion that infrastructure is a critical ingredient in economic growth. For a physical measure of infrastructure, the literature finds a positive relationship between infrastructure and economic growth; however little consensus emerges regarding the magnitudes of the effects of public infrastructure. Likewise, results are less irrefutable for infrastructure investment and economic growth. Earlier literature employs a production function approach, to investigate the relationship between infrastructure and economic growth; however, this approach is criticized as an inappropriate econometrics methodology used for estimation. The criticism on production single equation approach led to the use of Granger causality test, Vector Autoregressive (VAR) and VECM.

Chapter 3

State of Infrastructure Services in Pakistan and economic growth

3.1 Introduction

The emphasis of this chapter is limited to the current status of economic infrastructure services in Pakistan and its impact on economic development. In this chapter; we give particular attention to four aspects of major economic infrastructure, including road, electricity and telecommunication: (i) Public infrastructure's quality, trend and gaps in Pakistan, and compare the quality of infrastructure in Pakistan with infrastructure in selected countries in the region, (ii) trends in investment in infrastructure in Pakistan over the time , (iii) the extent to which infrastructure play its role in promoting economic activity, by industrial, agriculture, services sector and aggregate economy, (iv) infrastructure investment in Pakistan under CPEC

3.2 Comparative Perspective of Pakistan's Infrastructure Development

Infrastructure service is broadly acknowledged as key determinant of economic growth. In the accessibility of economic infrastructure, both in terms of quality and quantity, Pakistan lag considerably behind its neighboring countries. The provision of reliable and efficient infrastructure services enrich the competitiveness of an economy and create a business environment beneficial to industrial growth and development. Reliable infrastructure develops the link between firms and customers and suppliers and enables the use of modern technology in the production process. On the other hand deficiencies in infrastructure create obstacles to productive opportunities and enhance the cost of firms. In terms of quantity, quality and accessibility of economic infrastructure, Pakistan lag significantly behind those in South Asia and its neighboring economies like Bangladesh, China, India and Sri Lanka (See Table 3.1).

Table 3.1 Infrastructure Ranking in the region (2015-16)

	Bangladesh	China	India	Iran	Pakistan	Sri Lanka
Quality of overall infrastructure	124	51	74	76	98	26
Quality of roads	113	42	61	63	77	27
Quality of railroad infrastructure	75	16	29	45	60	37
Transport infrastructure	110	21	32	80	78	43
Quality of electricity supply	120	53	98	58	129	61
Fixed telephone lines/100 pop.	128	63	116	22	112	78
Mobile telephone subscriptions/100 pop.	119	107	121	110	124	91
Electricity and telephony infrastructure	122	70	115	56	132	77

Source: Global Competitiveness Report, 2015-16

Firm-level data of Enterprise Survey conducted by World Bank indicate that electrical outages, transportation infrastructure are the major constraints on economic activities in Pakistan (See Table 3.2). All other countries in the region have better performance in these indicators. In the case of Pakistan, 75.3 percent of firms identify that electricity is the major constraint for business activity and 25.5 percent of firms identify transportation as the major constraint for economic activity. The same constraints are 46 and 21 percent respectively for South Asia and Bangladesh; these percentages were 52 and 14.6 percent respectively.

Similarly, Pakistan performance is worse in all other indicators like electrical outages, and average losses due to electrical outages, relative to the South Asia and its neighboring countries. Regarding access to electricity, it is observed that 81% of firms in Pakistan experience electrical outages, compared to 59% in all countries, 66.2 % in South Asia, 55.4 percent in India and 33.7 percent in China. Furthermore, an average firm in Pakistan experiences 75.2 electrical outages in a typical month, which costs about 39 percent of the annual sale. In contrast, in South Asia, firm has to experience 25.4 power outages per month, which costs 11 percent of the annual sale.

Table 3.2 Infrastructures and Economic Activity

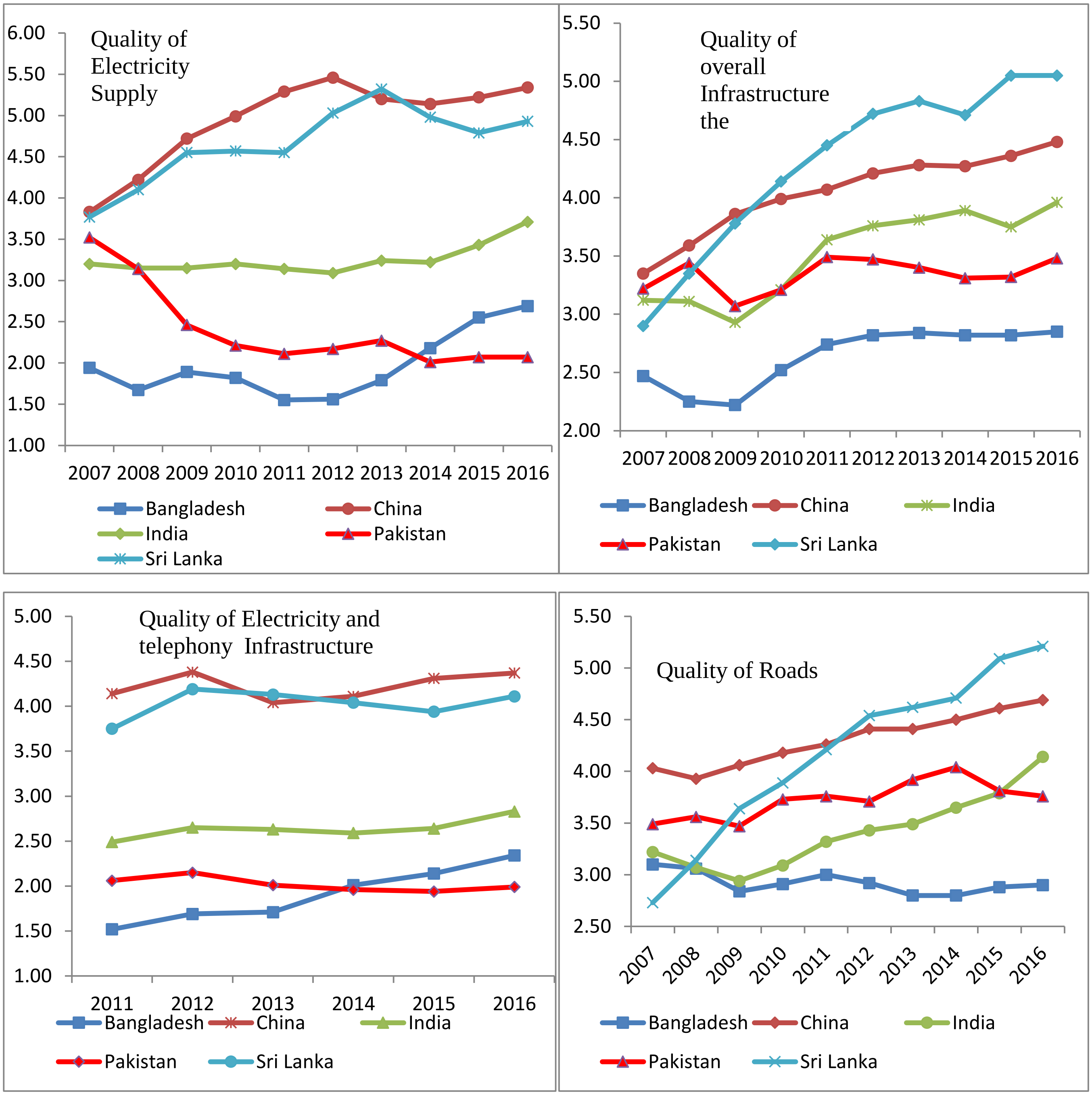
	All Countries	South Asia	Bangladesh	China	India	Pakistan	Sri Lanka
% of firms experiencing electrical outages	58.8	66.2	73.4	33.7	55.4	81.1	76.4
Number of electrical outages in a typical month	6.3	25.4	64.5	0.1	13.8	75.2	4.1
Average losses due to electrical outages (% of annual sales)	4.6	10.9	5.5	1.3	3.7	33.8	3.0
% of firms identifying electricity as a major constraint	31	46.1	52	1.8	21.3	75.3	25.6
% of firms identifying transportation as a major constraint	19.1	21.1	14.6	2.1	9.6	25.5	10.2

Source: World Bank Enterprise Survey

In Figure 3.1 below, we make a comparison of quality of major sectors of public infrastructure in Pakistan, including (a) Quality of overall Infrastructure, (b)Quality of Electricity Supply, (c) Quality of Roads infrastructure with other countries in the region. For comparison purpose, we used data compiled by the Global Competitiveness Report (GCR), rating the infrastructure indicators. Index range from 1 to 7 with larger value indicating improved quality.

Progress in the overall quality of infrastructure in Pakistan remains considerably lower than China, India and Sri Lanka. Some improvement is observed in the overall quality of infrastructure between 2009 and 2011, but no improvement was observed after 2011, indicating a large gap with China, India and Sri Lanka (Figure 3.1).

Figure 3.1 Quality of Overall Infrastructure, Electricity Supply and Road Infrastructure 1-7 (best)



Source: Global Competitiveness Report, 2015-16

In electricity supply, telecommunication and road infrastructure, Pakistan is also lagging behind. In the last ten years, a sharp improvement in transport infrastructure in China, Sri

Lanka and in India is observed, however in the case of Pakistan no considerable changes are noticed in road infrastructure during the same period. Growing evidence suggests that, in terms of the three infrastructure indicators, i.e. Road, electricity and telecommunication, Pakistan poorly performed by international standards and as well as at the regional level.

The performance indicators of major sectors of public infrastructure in Pakistan, compared to Bangladesh, China, India, and Sri Lanka, show a deteriorated trend, particularly in the quality of electricity supply. Pakistan has made some improvement in public infrastructure indicators over the last fifty years, but the rate of improvement for the majority of public infrastructure indicators is not impressive as compared to other similar countries. Other countries in a geographic location, such as India, China and Sri Lanka, even Bangladesh have mostly made good progress.

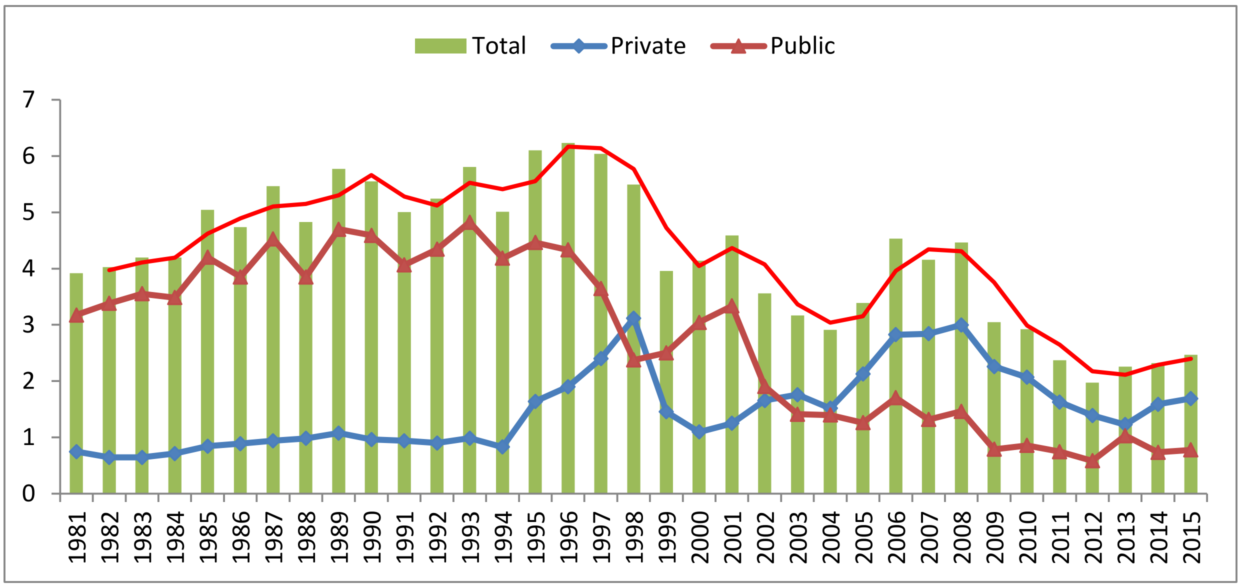
Concerning the power sector, Pakistan has the lowest electricity generation capacity and the highest energy losses compared to other countries. Due to institutional weaknesses, electricity production has remained below capacity in the recent years, leading to regular power outages and load shedding. Similarly, in the transportation sector, the quality of roads and railway is in miserable condition, with respect to other countries in the region — the telecommunications sector of Pakistan demonstrates relatively better outcomes. The landline density is relatively low; however, this is offset by an active mobile phone industry. According to (Loayza & Wada, 2012), if Pakistan improved its electricity, transport and telecommunications sectors to the corresponding levels of Malaysia, its per capita GDP growth rate would gradually increase by 3.7%, with variable contributions from each sector (1.9% electricity, 06% transport, and 1.2% telecommunications).

3.3 Trends in Infrastructure Investment in Pakistan

Infrastructure investment is generally acknowledged as a fundamental driver of economic growth. In recent years, scaling up of infrastructure investment is considered as a key pillar of national development strategy in many developing countries (Gurara et al., 2017). In most of the cases, public spending has been used for scaling up infrastructure investment; however, private sector participation in scaling up infrastructure investment is also growing over time. This section reviews the trends of infrastructure investment in Pakistan and highlights the role of public and private sectors in the evolution of infrastructure development in Pakistan. Figure 3.2 provides an overview of the level of public, private and total infrastructure investment as a percentage of GDP in Pakistan over the last two and half decades. The infrastructure investment trends comprise of investment in three infrastructure sectors, including transportation, electricity and telecommunication. Total infrastructure investment as a percentage of GDP has shown slightly improving trends till the 1990s but has been substantially declining over the time, except for the period between 2005 and 2008. Total infrastructure investment as a share of GDP was less than 4% in the early 1980s, but it gradually rose up around 6%, until 1997and then again started to fall.

The total infrastructure investment as a share of GDP slightly increased in the mid-2000s, however, it has dropped considerably in the last ten years and has reached the lowest level, i.e. 2.5% in 2015. During 1990s and particularly in the second half of the 1990s, series of challenges were faced by Pakistan's economy, including political instability, bad governance, failure to implement successive agreement, led to the loss of Pakistan's credibility in international community (Husain, 2000), economic sanction, followed by nuclear test in 1998, freezing of foreign currency account. According to Husain (2000), infrastructural investment was curtailed in the 1990s to alleviate the growing budgetary deficit. A sharp decline in the public infrastructure investment as a percentage of GDP was observed during 1996-1998. However, it gradually increased from 2.4% in 1998 to 3.3% in 2001. After 2001, Public infrastructure investment share in GDP continued to decline in the last 15 years to less than 1% of the GDP. The declining trend of public infrastructure investment as a percentage of GDP is reflected in the total infrastructure investment rates.

Figure 3.2 Public, Private and Total Infrastructure Investment as % of GPD (1981-2015)[9]



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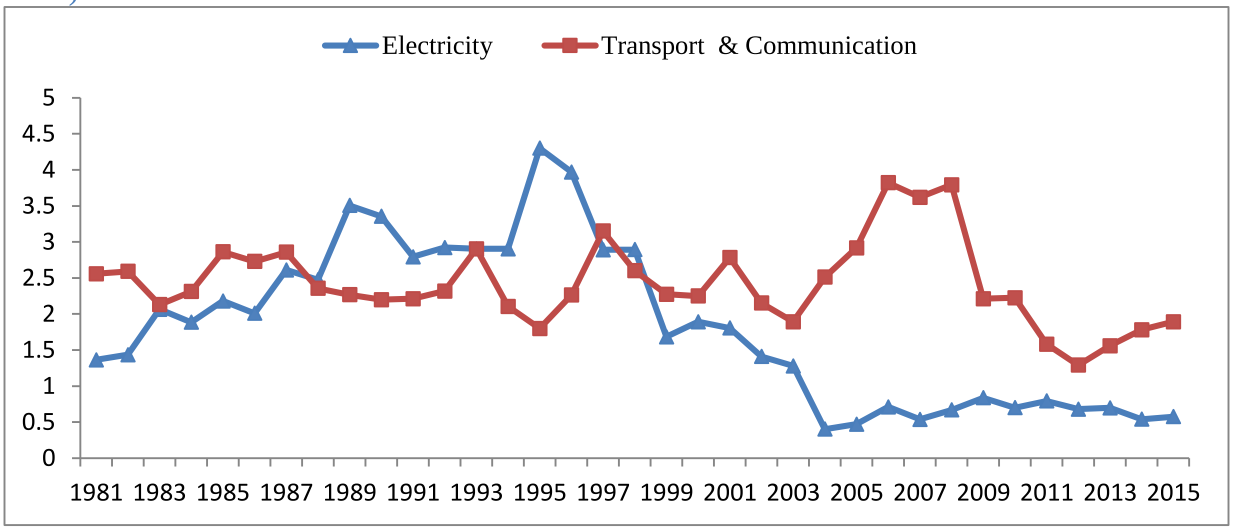
In contrast to public infrastructure investment, the private infrastructure investment, as a percentage of GDP in Pakistan, remains below 1% till 1994. However, it exhibited an upward trend during 1994-1998 and 2000-2008 and exceeded public infrastructure investment in the first half of the 2000. After 2008, private infrastructure investment share

[9] The data on infrastructure investment in public and private sector is the sum of gross fixed capital formation in transport, telecommunication and electricity by public and private sector, respectively. The disaggregated data on these variables are compiled from Handbook of Statistics on Pakistan Economy-2015, State Bank of Pakistan.

in GDP has declined but remained above the share of public infrastructure investment in GDP. To sum up, in the case of Pakistan, private infrastructure investment has become a substantial source of infrastructure investment in the country.

Infrastructure investment is further disaggregated by a component of infrastructure. Figure 3.3 depicts the investment in electricity generation as a percentage of GDP and investment in transport and communication as a percentage of GDP by public and private sectors. Since 1995, investment in power sector continued to decline from 4.3% of GDP in 1995 to less than 0.5% of GDP in 2004 (See Figure 3.3). From 2004 to 2006, it has been fluctuating around 0.5% of GDP.

Figure 3.3 Investments in Electricity, Transport and Communication as % of GDP (1981-2015)



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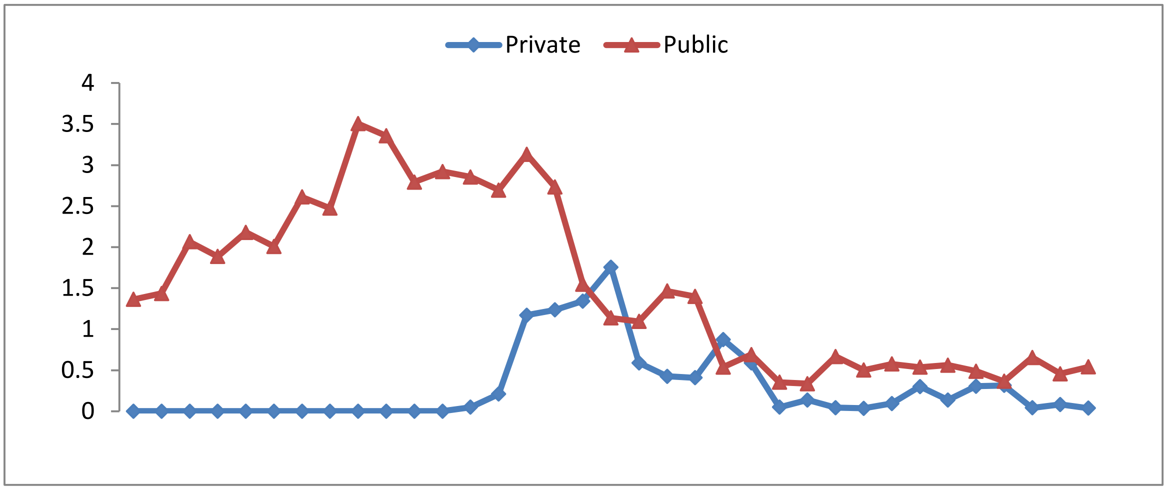
The GDP share in public and private investment in the transport and telecommunication sector was not remarkable over the period from 1981 to 2003. During this period 2.4% was the average investment in the transport and telecommunication sector. However, between 2003 and 2004, investment in transport and telecommunication sector sharply increased, mostly due to investment in the telecommunication sector.

Historical trend shows that public investment has been a dominated force over the last three decades and public sectors is still a primary source of investment in the power sector (See Figure 3.4). From 1980 to 1995, public investment was the only source of investment in the electricity sector, which gradually increased up to 3.5% of GDP in 1989. After 1995, the GDP share of public investment in electricity drastically dropped to less than 0.5% of GDP in 2004.

Figure 3.4 Public and Private Investments in Electricity Infrastructure % of GDP



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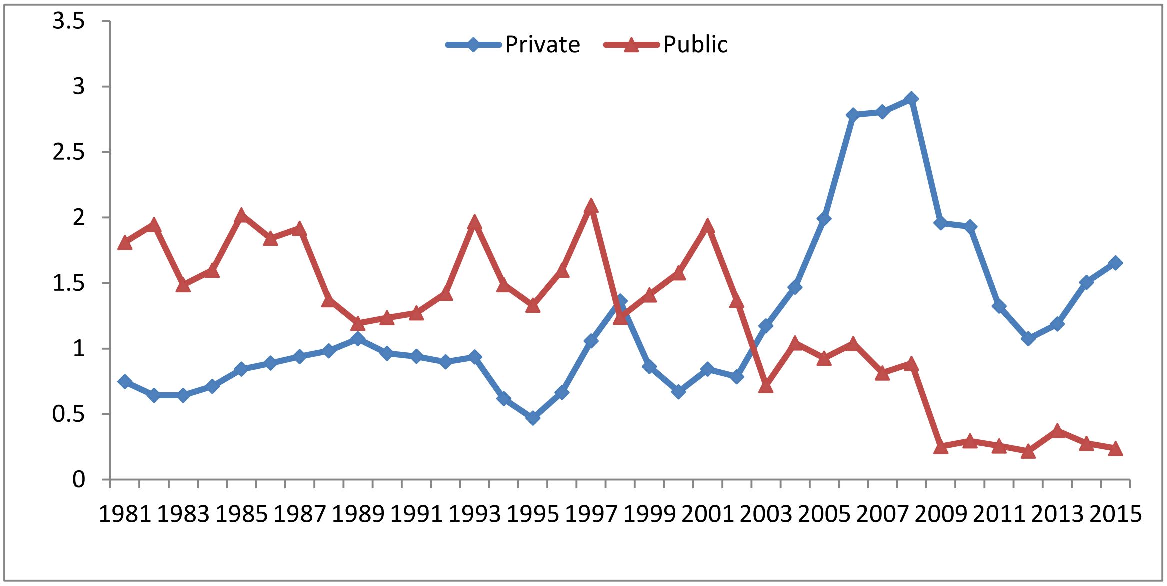
The private sector investment in the electricity sector started in the early 1990s, under the government strategic plan for restructuring the power sector in 1992. Consequently, private investment in the power sector sharply increased in 1995 and reached up to 1.7% of GDP in 1998. In the last decade, GDP share of private sector investment in the power sector continued to decline and reached about less than 0.1% of GDP.

The share of public and private investment in transport and telecommunication are depicted in Figure 3.5. It can be observed from the figure that public investment ratio to GDP in the transport and telecommunication sector fluctuated around 1.5% of GDP, over the period from 1981 to 2000. It showed a declining trend in the 1980s and stagnated during 1990s.

After slight recovery in 2004, public investment ratio to GDP in transport and telecommunication continued to decline and reached the lowest record of less than 0.3% of GDP in 2015.

Figure 3.5 Public and Private investment in Transport and Telecommunication sector % of GDP



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In contrast to the descending trend in public investment, private sector investment ratio to GDP in transportation and telecommunication sector raised substantially since 2000. In the decades of 1980s and 1990s, GDP share of private sector investment in transportation and telecommunication sectors amounted less than 1% of GDP. However, in the decade of 2000, GDP share of private investment in these two sectors continuously increased and jumped to 3% of GDP in 2008. This was most probably due to the increasing contribution of the private sector in the telecommunication services. However, it declined in 2008 and reached 1% of GDP in 2012.

To sum up, the evidence reported above shows that the GDP share of public sector investment in infrastructure has been falling over the past few years. Private sector investment ratio to GDP has been expanding in the telecommunication sector, while power sector seems to be neglected by the private sector. The public and private investment in the power sector seems to face severe sluggishness.

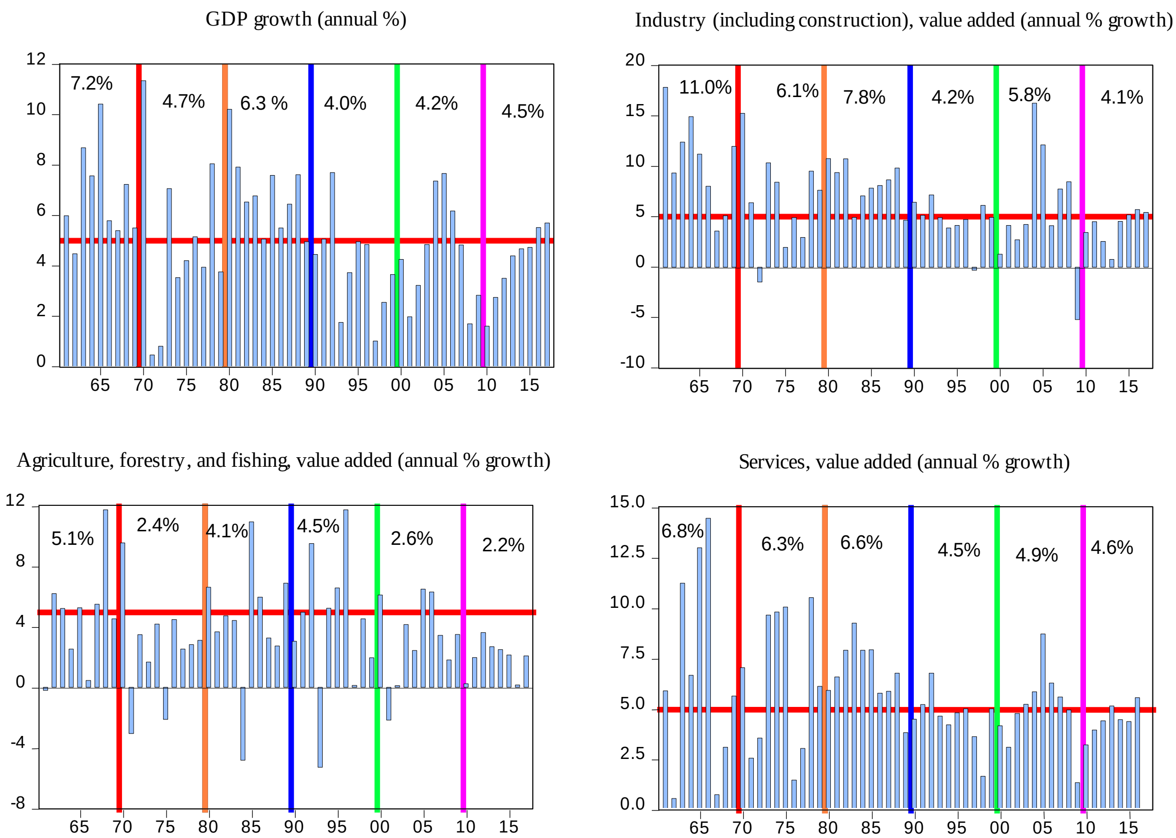
3.4 Infrastructure and Economic Growth in Pakistan

Literature supports the two-way causality between infrastructure and economic growth. On one side, availability of quality of infrastructure exhorts economic development through direct productivity effects and indirectly through complementarity effect. On the other side, resilient economic growth prompts extension of public infrastructure. In this section, we briefly discussed the role of power and transport infrastructure in the economic performance of aggregate GDP and components of GDP.

The stylized facts of Pakistan's economic growth are that the overall growth record has been satisfactory since 1960s; however high volatility is observed and growth accelerations tend to be short lived. On average the economy grew at an annual rate of slightly above 5 per cent from 1961 to 2017. Data presented in Fig 3.6 reveals that, since 1961 the country has witnessed three episode of rapid growth in which GDP growth was above 5 percent in successive years: 1963 to 1970, 1980 to 1988 and 2004 to 2006 (See figure 3.6). The long term structural growth shows a declining trend from an average of 70% in the 1960s to 4.5 % in the second half of 2010. According to World Bank (2013) one most important reason for declining the long term growth is that structural reform has been growth reducing rather than growth enhancing. The industrial growth rate has been quite impressive: the industrial GDP grew at an annual rate of 6.6 percent over the last 7 decades. However the long term trend of industrial GDP growth declined from an average of 11.0 percent in 1960s to 4.1

percent in 2017. The long term services sector growth declined from an average of 6.8 per cent to 4.6 per cent in the recent years.

Figure 3.6 Annual % growth rates of Aggregate and sub sector of the Economy (1961-2017)



Data Source: World Development Indicators, World Bank

Since 1990, the overall growth rate decreased from above 6 per cent to 4.1 percent, with episodes of boom and bust. Similarly industrial growth rate decreased from 8.4 per cent to 4.8 per cent and services sector growth declined from 6.6 per cent to 4.7 per cent. The major contributory factors of low or declining growth trend since 1990 are political instability, frequent changes of government in the 1990s, macroeconomic instability and volatility in external financing. Inadequate and insufficient provision of infrastructure also hurt the long term growth sustainability.

Pakistan's public infrastructure has improved over time, but has been sluggish, resulting in many gaps that put the country at a disadvantage compared to its competitors. Pakistan has low density of paved roads, bleak railways and inadequate airports. Pakistan has one of the lowest power generation capacities and the highest power losses of the analogue countries. Worse institutional shortages keep power generation below capacity, resulting in systematic power outages and load shedding. Improving and expanding infrastructure is a prerequisite for a sustainable high economic growth and development. Improving the quality and coverage of electricity, water and sanitation, transportation and logistics are crucial to the economy of Pakistan.

Resource constraints are the main reasons for the inadequate and inefficient infrastructure in Pakistan. Pakistan required substantial investment to improve and expand the infrastructure, but resources are limited. The persistently high budget, trade and current account deficits do not allow the country to conserve public sector resources for infrastructure development. The share of infrastructure investment has dropped significantly from almost 51 percent to below 33 percent (Pahsa, 2011). The infrastructure in Pakistan has traditionally been funded by public sector funding, many of which have actually been raised through foreign aid. However, given the rise in the input costs of the construction sector, it was almost impossible for the government to shoulder the rising unit costs of infrastructure financing. In the late 1990s, it became clear that Pakistan needed to deregulate, privatize and liberalize existing domestic infrastructure for domestic and foreign private investment. These measures have resulted in an absolute increase in capital formation in transport and communications sectors (Ahmed et al., 2013).

Corruption in infrastructure projects and the inability to complete infrastructure projects on time are main reasons for Pakistan, lagging behind other countries in the region. According to (Ahmed et al., 2013), corruption in infrastructure projects was estimated at 10-15 percent of the project value. An average project requires three times as long and twice as much of the originally planned costs (Pasha 2011).

3.4.1 Electricity and GDP growth in Pakistan

The significant components of GDP consist of industry, agriculture and services sectors. The following sectorial analysis sheds some light on the long-term development of Pakistan's economy and gives understanding to fluctuations, arising from the energy crisis and due to their infrastructure deficiencies. We start our analysis with the industrial sector. Industrial sector contribution in the national output was 19.2% while employing 22.2% of labor force[10]. The share of industrial sector in GDP increased gradually, from 13.2% in 1972 to 19.2% in 2015.

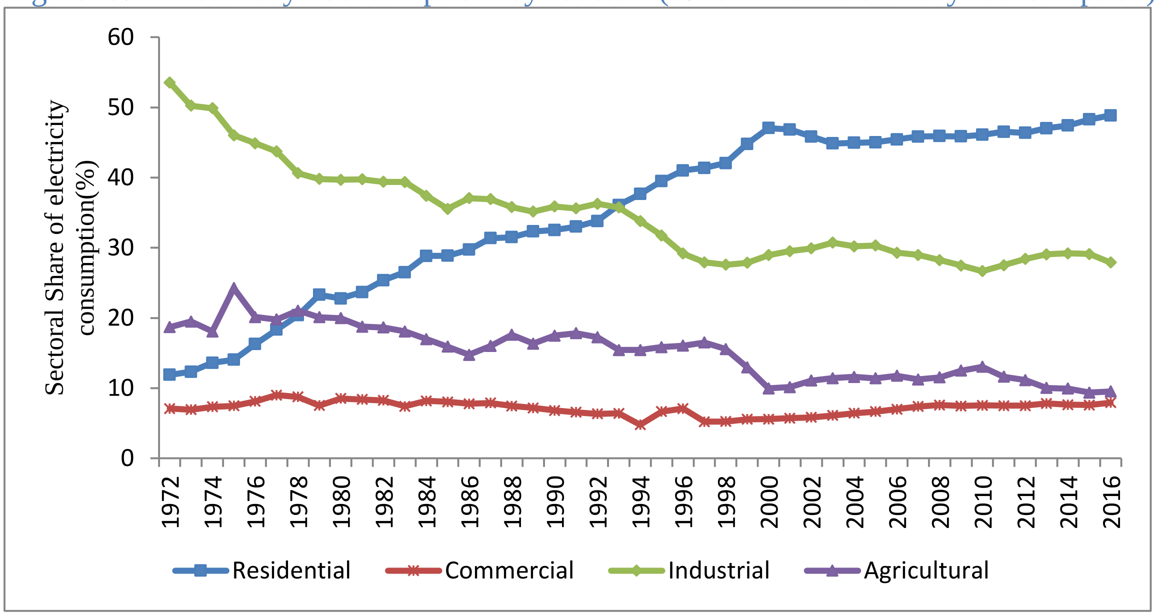
On the other hand, the agriculture sector share in GDP steadily declined from 40.1% in 1972 to 21.7% in 2015. Agriculture sector employed 40% labor force in 2015. The services sector has a major contribution in GDP in Pakistan; it contributed about 54% in GDP 2015 and employed 32% of labor force. The share of services sector in GDP amplified to an average of 12.9 % between 1973 and 2016 because the agriculture sector share in GDP shrunk more rapidly.

In recent literature, electricity consumption is well-thought-out, not only as an indicator of socio-economic development rather its role is also recognized in the production function.

[10] Sum of labor force employed in manufacturing, construction and electricity

Electricity is the highest quality energy component, and its share of energy consumption is increasing rapidly over time. In Pakistan, % share of electricity consumption by the industrial sector declined over time. Sector wise electricity consumption is presented in Figure 3.7.

Figure 3.7 Electricity Consumption by Sector (% of total electricity consumption)



Pakistan Economic Survey various issues

Electricity consumption share of industrial sector declined from 53.5% in 1972 to 27.9% in 2016. Likewise electricity consumption by agriculture sector has also gradually dropped over time. As the agriculture sector was consuming 24.3% of the total electricity consumption in 1975 and in 2016 this share was only 9.5%. Electricity consumption by services sector as a percentage of total electricity consumption remained within the range of 7% to 9%. Electricity consumption by the domestic sector sharply increased and in 2016 its share was 48.9% of the total electricity consumption.

Table 3.3 Growth Trend of Aggregate GDP, Sectoral GDP and Electricity Consumption

Components of GDP	Average Annual output Growth Rates					
	1973-2016	1973-79	1980-89	1990-99	2000-07	2008-16
Aggregate GDP	4.9	4.8	6.9	4.0	5.0	3.5
Industry GDP	5.8	5.9	8.2	4.7	6.6	3.3
Agriculture GDP	3.4	2.5	4.4	4.2	3.4	2.1
Services Sector GDP	5.6	6.8	6.8	4.5	5.5	4.1
Sector wise growth rates of electricity consumption						
Aggregate GDP	6.7	7.9	11.6	5.0	6.7	2.4
Industry GDP	5.2	3.3	10.2	2.6	7.2	2.0
Agriculture GDP	5.6	10.3	9.6	3.0	5.3	0.7
Services Sector GDP	7.5	8.9	11.3	3.9	10.6	3.3
Output elasticity with respect to electricity consumption						
Aggregate GDP	0.7	0.6	0.6	0.8	0.7	1.5
Industry GDP	1.1	1.8	0.8	1.8	0.9	1.7
Agriculture GDP	0.6	0.2	0.5	1.4	0.6	3.0
Services Sector GDP	0.7	0.8	0.6	1.2	0.5	1.2
Electricity Generation	6.3	9.2	9.4	6.6	5.3	1.1

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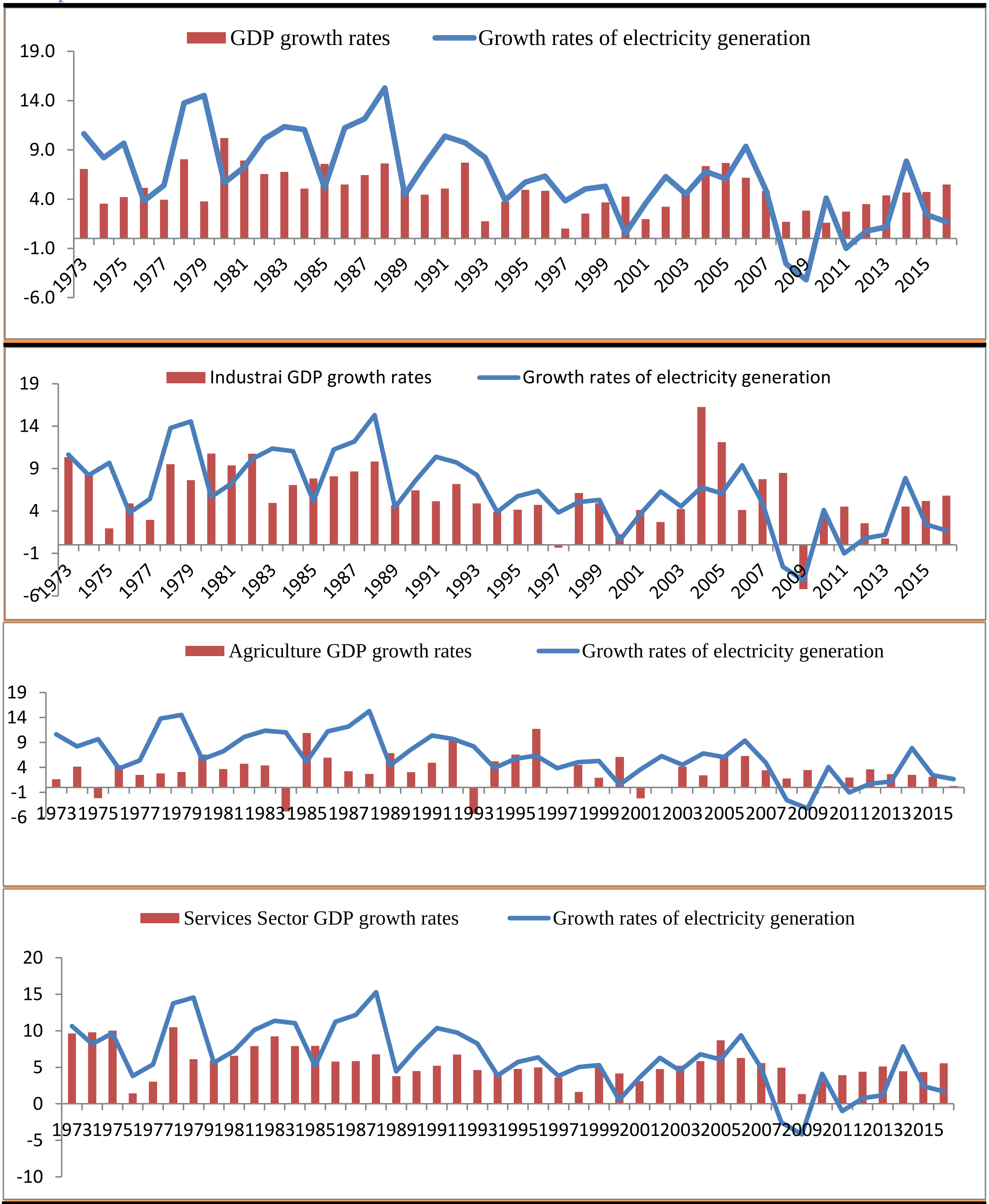
Real aggregate GDP growth rate averaged 4.9 percent annually during 1973-2016, while in industrial, agriculture and services sector GDP growth was growing annually at an average rate of 5.8 %, 3.4%, and 5.6% respectively, during the same period. Major economic activities of the industrial sector are manufacturing and construction which is more sensitive to the availability of electricity at an affordable price, law and order situation and governance. We observed a strong link between Industrial GDP growth and electricity (See Figure 3.7). The growth rate of industrial GDP was faster than the growth rate of electricity consumption by the industrial sector except for the 1980s. However in 1980s industrial GDP growth was extremely high. The declining trend in the growth rate of all the sectors in the last fifteen years, and particularly industrial sector can be an attributed largely to energy crisis, law and order situation and governance issues. The growth rate in electricity generation was fast in the 1970s and 1980s with an annual average growth rate of 9.2 % and 9.4% respectively (See Table 3.3). The high growth rate of electricity generation during the 70s and 80s can be contributed to commissioning of Mangla Dam in late 60s and Terbela Dam in the early 80s, allowed to significant jump in electricity supply at low cost. In the 1990s aggregate GDP grew at an average of 4 % and industrial GDP grew at an average of 4.7% compared to faster aggregate GDP growth of 6.9 percent and industrial GDP growth of 8.2 percent annually. Likewise, the services sector GDP growth was also declined from 6.8% in the 1980s to 4.5% in 1990s. Due to the slow growth rate in aggregate GDP and as well as in sectoral components of GDP in the 1990s, electricity demand was not so floating and the annual increase in electricity generation was 6.6% in 1990s, compared to the rapid growth of 9.4% per annum in 1980s. Since 2008, Pakistan was in the clutch of major infrastructural shortages, particularly in the available energy infrastructure, hindering output growth in all sectors, including industry, agriculture and services sector (See Table 3.3 and Figure 3.7). The industrial sector faces severe electricity and gas shortages. During that period significant increase in the frequency and intensity of power load shedding in Pakistan was witnessed. The growth rate in electricity generation grew at a rate of 1.1% annually.

Figure 3.8 Relationship between Electricity Generation and Growth Rate of GDP and its Components



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In the last few years, Pakistan's thermal power generation was shifted from gas to furnace oil. Consequently heavy dependence on imported furnace oil, instead of domestic low price gas, electricity generation cost increased sharply. In 2003, gas justified for 48.5 % of the total electricity production, while furnace oil accounted for 15.7% of the total electricity production. Over the gas, share in the generation of electricity shrank to 25% of the total production and oil share expanded and reached 40% of the total electricity generation.

3.5 Infrastructure investment in Pakistan under CPEC[11]

The CPEC is not only important for Pakistan, but it also has a significant impact on the countries of the region. It is expected that CPEC will drive trade and economic integration between China, Pakistan, India, Afghanistan, the Middle East and the Central Asian States. Under CPEP approximately 1000 KM will be constructed across Pakistan. The proposed project aims to expand and modernize Pakistan's infrastructure rapidly. CPEC infrastructure projects will connect the city of Gwadar in Baluchistan with northwest China's Xinjiang region via an extensive network of motorways and railways. According to the Ministry of Planning, Development & Reforms, CPEC has four major components, (1) Gwader, (2) Infrastructure (3) Energy and Others projects. Massive investment in energy and road infrastructure will help Pakistan to overcome energy crisis, deficiency in road infrastructure and stabilize the economy. A significant portion of investment under CPEC will be spent on electricity generation projects. With the completion of CPEC's energy projects, 13,000 MW of electricity will be added to the national grid. Under the

[11] Information in this section is taken from the website of Ministry of Planning Development and Reform, Pakistan and International Monetary Fund.

CPEC, $10 billion will be spent on developing road infrastructure, which will boost Pakistan's road infrastructure and communications sector. Infrastructure projects worth about $11 billion, 11000 kilometers highway will be built between Karachi and Lahore, and the Karakoram Highway between Rawalpindi and the Chinese border will be completely rebuilt and revised. The CPEC will open doors to enormous economic opportunities for Pakistan and China. It will physically connect China to its markets in Asia, and Europe will launch the port of Gwadar.

Pakistan has launched a major energy and infrastructure investment program under the auspices of the China-Pakistan Economic Corridor (CPEC). This section discusses the expected benefits of these investments and their potential macroeconomic impact. The planned investment in the energy sector under the CPEC projects is expected to reduce or eliminate the energy deficit, improve the fuel mix in power generation sector and reduce operating costs for the industrial sector in Pakistan (IMF 2017)[12]. The decline in Pakistan's energy deficit is expected to increase overall business activity and employment, as well as trade connectivity, leaving positive impact on production and exports. In the recent decade, Pakistan has faced chronic energy shortages and significant underinvestment in infrastructure. The estimated cost of inadequate and inefficient infrastructure for the economy is about 2 percent of GDP per year (IMF, 2017).

Heavy dependence on furnace oil in the face of rising oil prices, coupled with the administrative and operational inefficiencies and persistent losses in the energy sector, which in turn led to accumulation of backlogs in the energy sector, called circular debt. Country has faced substantial gap between demand and supply of electricity due to under-

[12] https://www.imf.org/en/Publications/CR/Issues/2017/07/13/Pakistan-Selected-Issues-45079

utilization of existing capacity and low investment in energy sector. The gap between energy demand and supply revealed itself in power outages averaging 10 to 12 hours per day in the 2012/13 financial year.

In addition, Pakistan has initiated a comprehensive project to increase and diversify its energy supply and improve infrastructure, to achieve the country's growth potential. The CPEC is a comprehensive package of investment projects for the next decade, aimed at developing infrastructure, strengthening and diversifying energy supply and improving regional trade connectivity, thereby stimulating investment. Investments in the energy sector comprise of a combination of coal and LNG production projects, hydropower plants, nuclear power plants and several solar and wind farms. According to IMF Pakistan's dependency on furnace oil is about 30 percent of the fuel mix in 2015 and it would reduce, making the energy sector more resilient to abrupt changes in international oil prices.

If these investment projects were implemented on time, it would surely have diminished Pakistan's power shortage, significantly improve energy costs and fuel mix, boost GDP growth in Pakistan. This push is likely to occur in three steps: construction, power generation, once the installed capacity is put into service and impact on the overall economic activity due to increased productivity, lower costs and improved trade connectivity due to improved infrastructure. The first two phases (direct contribution) are likely to occur over the next few years, while the effects of the second round are likely to increase more slowly and contribute significantly in the longer term, although the exact impact will depend on many other supporting factors.

3.6. Conclusion

Inefficiency and bottlenecks of infrastructure have been identified as major limitations to growth affecting productivity and market efficiency and obstacle in national integration and export performance. In this chapter, we assess the state of Pakistan's infrastructure, in the light of private and public infrastructure investment trends and various quality and quantity of infrastructure indicators. Pakistan's infrastructure stock and its quality, rank below comparators and in the region as well. Pakistan scores low on various qualitative indicators of infrastructure competence. Based on the quality of overall infrastructure, Pakistan ranked 124 among152 countries, surveyed by the World Economic Forum in 2015. Mainly the results of quality of roads, the quality of electricity supply and fixed telephone lines are inferior.

In case of the power sector, Pakistan ranked among the lowest electricity generation capacity with the highest power losses. Electricity generation, as well as the distribution of electricity, is fairly inadequate in the country. In the transport sector, Pakistan has a relatively low density of paved roads. Inefficient and low productivity of transport infrastructure leads to an annual loss of nearly 5% of GDP in Pakistan (Loayza & Wada, 2012). The telecommunications sector shows better results for Pakistan. The landline density is relatively low; however, this is offset by a very active mobile phone industry.

Infrastructure investment is an essential component for the provision of adequate infrastructure in the country. Evidence provided in this chapter reveals that infrastructure investment continued to decline over time. GDP share of public sector investment in infrastructure has been falling over the last few years. Private sector investment ratio to GDP has been expanding in the telecommunication sector, while power sector seems to be neglected by the private sector. The public and private investment in the power sector seems to be facing severe sluggishness.

Chapter 4

Economic Modeling of Infrastructure-Growth nexuses

4.1 Introduction

Policy-makers and economists agree that rapid and sustained economic growth is a prerequisite for the welfare of the general public. Governments around the world are always looking for new economic strategies to improve their economies and to provide their citizens with a better standard of living. In this regard, the economists have developed a more sophisticated model to assess the potential economic impact of various supply-side policies, aimed at increasing the productive capacity of the economy. In addition to traditional production factors, such as physical capital and human capital, economists have introduced non-traditional factors of production in macroeconomic modeling, as contributing factors to economic growth.

In this chapter, we develop a theoretical model of infrastructure growth nexuses in the light of recent literature. In order to see the role of quality of institution in a growth-enhancing effect of infrastructure, quality of institutions is added as an additional variable in the growth model. It is a widely accepted phenomenon that infrastructure development plays a vital role in connectivity across the boundaries. A spatial econometric model for spillovers effect of infrastructure across the region has also been discussed in chapter 7.

4.2 Infrastructure in the growth model

Academicians and policy makers have widely recognized that persistent and uninterrupted provision of infrastructure has fundamental determinants of economic growth. However various approaches have been discussed in the literature to study the transmission mechanism, through which infrastructure may affect economic growth. The critical studies (for example (Barro, 1990; Lucas Jr, 1988; Romer, 1986, 1990), considered infrastructure and human capital as essential determinants of aggregate production function in endogenous growth models. Barro (1990) endogenous growth model, in which government expenditure on infrastructure was incorporated as a factor of production, was criticized for ignoring the indirect effect of infrastructure on economic growth through total factor productivity (TFP). Literature also supports the positive effect of externalities prompted through public infrastructure investment. Infrastructure induced externality include regional and international trade, increase in profitability of investment project, expanded foreign direct investment, increased competitiveness and improved economic growth (Fedderke and Luiz, 2005; Fourie, 2006; Richaud et al 1999). So infrastructure has direct and indirect impact on economic growth.

Infrastructure as an additional factor of production was introduced for the first time by (Weitzman, 1970) and (Arrow and Kurz, 1970). Weitzman (1970) split the capital into two types, according to their role in the production function, The capital which directly influences the growth as a factor of production (K_α) and the capital which has indirect impact on economic performance (K_β). K_β type of infrastructure capital lays down the basic framework within which economic activities can function. According to Weitzman (1970), investment in capital, considered as a direct factor of production, is productive only if it has been preceded by sufficient investment in productive infrastructure development. K_β comprises of all social overhead capital such as health, education, drainage and irrigation system, transportation, communication, power and water supply. If K_β were plentiful at time t, then output (Y_t) depends only on the stock of $K\alpha$ capital and labor. The production function can be written as follows:

$$Y_t = F(k_\alpha(t)) \qquad (4.1)$$

When K_β is scarce, the production function would simply be

$$Y_t = F\big(k_\beta(t)\big) \qquad (4.2)$$

Latter on the empirical work of (David A Aschauer, 1989) on the influence of infrastructure on economic growth provided the new direction in this area. Before Aschauer's work, infrastructure was hardly considered as a potential factor of a slowdown in productivity. Aschauer's seminal work lays down the foundation of the literature on the impact of public sector investments in infrastructure on economic performance. To study the connection between infrastructure and economic growth, (Aschauer, 1989) integrates public expenditure as an additional explanatory variable in the production function. He disaggregates government spending into productive and unproductive and as well as in stock and flow variables in the production function. He, therefore, specifies the following form of production function within a standard neoclassical framework.

$$Y_t = A * f(L_t, K_{t,}, G_t) \qquad (4.3)$$

Where Y_t is output, L_t is labor, K_t private capital stock, and G_t aggregate public capital stock. In subsequent literature, public capital stock is introduced in production function as a direct factor of production and as well as the indirect factor of production through its effect on productivity (A).

$$Y_t = A\big(K_p\big)f(K_t, L_t, K_p) \qquad (4.4)$$

In Equation (4.4), K_t is non-infrastructure capital and K_p is stock of public capital (infrastructure). Although it is common in early literature to add public capital as an additional input in the production function, this approach is criticized because roads and other infrastructure do not produce anything (Romap and Haan, 2007). Services of public capital are generally considered as the non-rival public goods. On the other hand, Duggal et al.(1999) incorporated public capital into the growth equation, as a fragment of the technological restraint that defines total factor productivity. In this way, it is justified that public investment in infrastructure increases total factor productivity by lowering production cost. Increase in technology index, additional public capital shifts up production function, improving marginal products of factors of production. (Sturm et al., 1999) pointed out that when the Cobb-Douglas production function is estimated in logarithmic linear form, it does not matter whether public capital is considered as an additional factor of production or as influencing production by the factor representing technology. According to (Sturm et al., 1999), both approaches to modeling the impact of public capital provide the same estimable equations. Therefore, the direct and indirect impact of public capital cannot be unraveled.

Economies of scale in infrastructure, because of externalities are generally accepted limitations in infrastructure capital services (Bank, 1994). Therefore, infrastructure capital is differentiated from other categories of capital due to its market imperfections characteristics in the literature. Market imperfections lead to accumulation and operation of infrastructure capital disposed to widespread government interferences, and that signifies the importance of institutional characteristics (Roam and De Haan, 2007).

A number of theoretical justifications are put forward to demonstrate that infrastructure investment, promotes economic growth in literature. These channels are embodied in the following the generic framework of aggregate production function by Straub (2008a)

$$Y = A(\theta, K_I).F(K, L, G(K_I)) \qquad (4.5)$$

Where K_I represents the infrastructure capital stock, L is hours of labor work, and term $A(\theta, K_I)$ in equation (4.5) represents the productivity. This type of formulation is used for accumulation of infrastructure as an additional factor of production. Services provided by infrastructure are considered as non-excludable and non- rival because of good public characteristics of Infrastructure.

Straub at al. (2008) provided two justification for the introduction of infrastructure in the production function (see Equation 4.5) in two different ways; First, infrastructure is not always reflected as the pure public good characteristics. Second, when the private sector is involved, the level of unit costs and price of infrastructure services are not strictly determined by the market. Therefore K_I entered in the production function as a factor of production would be based on the theoretical hypothesis that firms are able to make decisions about the cost of the amount of infrastructure capital they employ Duggal et al. (1999).

Infrastructure K_I is added in the production function as intermediate inputs, such as $G(K_I)=I(K_I)$ rather than an additional factor of production. $I(K_I)$ is considered as an intermediary inputs. An escalation in K_I lowers the cost of associated intermediate inputs, such as transport, telecommunication and electricity that enter firms' production function. Hulten at al.(2006) called this a market-mediated effect of infrastructure and Straub (2008b) called it the direct effects of infrastructure.

Furthermore, production function specified in equation (4.5) differentiates two sources of augmented productivity parameters A. θ which represents generic efficiency-generating externalities and efficiency-enhancing externalities, specifically related to the accumulation of infrastructure capital. Straub et al. (2008) called it the indirect effects of infrastructure. Infrastructure has a dual role between firms and household; it provides the input services to firm and producer and final services to the consumers (Shanks and Barnes, 2008). As a services provider, infrastructure, directly and indirectly, enters into the production process; therefore it plays a critical role in the production process.

Following, Esfahani and Ramirez (2003), we specify the infrastructure growth model which enables us to capture the direct and indirect impact of investment in infrastructures on economic growth. Esfahani and Ramirez (2003) introduced the four factors in the production function, including Labor, infrastructure capital, non-infrastructure capital and all remaining factors which may affect the output. The analysis is built on the usual Cobb-Douglas production function with additional infrastructure capital $Q_{t,}$ entering the production function:

$$Y_t = K_t^{\alpha}\, Q_t^{\beta} H_t^{\gamma} (AL_t)^{1-\alpha-\beta-\gamma} \tag{4.6}$$

The production function exhibits a constant return to scale in its four factors: non-infrastructure capital (K), infrastructure capital (Q), human capital (H) and productivity augmented labor (AL). K (non-infrastructure capital) estimates according to the perpetual inventory method. H stands for human capital proxy in the empirical regressions by the percentage of the labor force with education. The exponents α, β and γ, in equation (4.1) represent the income shares for the factors of production and these parameters measure the income elasticity with respect to the respective variables. Production function exhibits a constant return to scale (CRS) for all inputs and decreasing return to scale for individual inputs.

Equation (4.6) can be transformed into intensive form, dividing both sides by AL:

$$y_t = k_t^{\alpha}\, q_t^{\beta} h_t^{\gamma} \tag{4.7}$$

where $y = \frac{Y}{AL}$, $k = \frac{K}{AL}$, $q = \frac{Q}{AL}$, $h = \frac{H}{AL}$

The equations of motion for labor (L) and the labor augmented productivity (A) are:

$$A_t = A_0 e^{gt}$$

$$L_t = L_0 e^{nt}$$

Where t represents the time over the year, g represents the exogenous growth rate of technological progress; n is the population growth rate. The public good nature of infrastructure capital gives a role to the government to ensure the provision of a sound and efficient infrastructure. As a result, political and institutional factors may potentially have an important influence on infrastructure provision. Therefore, to assess the impact of quality of institutions on growth, we include additional variables F that is a measure of the quality of the institution. According to Mankiw at al.(1992), A_0 reflect the impact of technology, climate, resource endowment, institutions and so many other variables. To identify the separate impact of quality of institution on growth, we enter an additional variable in the growth model. The institutions variable is assumed to have a positive impact on growth through better management and less corruption. The equation of motion for A (Labor augmented productivity) and L (Labor) is as follows:

$$\dot{A}_t = gA_t$$

$$\dot{L}_t = nL_t$$

We assume that all the three inputs, physical capital, infrastructure capital and human capital are accumulating factors. The representative agent saves the output to have more capital. The equations of motion of these inputs are represented by the following equations:

$$\dot{K}_t = s_k Y_t - \delta K_t \qquad (4.8)$$

$$\dot{H}_t = s_h Y_t - \delta H_t \qquad (4.9)$$

$$\dot{Q}_t = s_q Y_t - \delta Q_t \qquad (4.10)$$

$\dot{K}_t$, $\dot{H}_t$, $\dot{Q}_t$ represent the growth rate of physical capital, human capital and infrastructure capital respectively and $s_k, s_h, and\ s_q$ represent the investment share of respective inputs. Assume that δ is constant depreciation rate and is same for all the three types of capital. We transformed all the three variables into intensive form, dividing by AL

We assume that $k = \frac{K}{AL}$, $h = \frac{H}{AL}$ and $q = \frac{Q}{AL}$

In intensive form, the equation of motion for physical, human capital and infrastructure capital are presented in Appendix A, B and C.

The equations of motions for physical capital, infrastructure capital and human capital are given below:

$$\dot{k} = s_k y - (g + n + \delta)k \qquad (4.11)$$

$$\dot{q} = s_k y - (g + n + \delta)k \qquad (4.12)$$

$$\dot{h} = s_k y - (g + n + \delta)k \qquad (4.13)$$

In a steady state, physical capital, infrastructure capital and human capital per effective labor must be constant. This implies that we can solve them for the steady state by finding the values for k, q and h, which set the above equations of motion equal to zero. The steady state value for k is achieved when $\dot{k} = 0, \dot{q} = 0\ and\ \ \dot{h} = 0$, by using the equation (4.11), (4.12) and (4.13) we have ,

$$s_k y = (g+n+\delta)k \qquad (4.14)$$

$$s_q y = (g+n+\delta)q \qquad (4.15)$$

$$s_h y = (g+n+\delta)h \qquad (4.16)$$

By using production function $y_t = k_t^{\alpha} q_t^{\beta} h_t^{\gamma}$, given in equation (4.7), we can find the exact solution for k, q and h.

$$s_k k_t^{\alpha} q_t^{\beta} h_t^{\gamma} = (g+n+\delta)k \qquad (4.17)$$

$$s_q k_t^{\alpha} q_t^{\beta} h_t^{\gamma} = (g+n+\delta)q \qquad (4.18)$$

$$s_h k_t^{\alpha} q_t^{\beta} h_t^{\gamma} = (g+n+\delta)h \qquad (4.19)$$

By solving these three equations we obtain:

$$k = \left[\frac{s_k}{n+g+\delta}\right]^{\frac{1}{1-\alpha}} q^{\frac{\beta}{1-\alpha}}\, h^{\frac{\gamma}{1-\alpha}} \qquad (4.20)$$

$$q = \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1}{1-\beta}} k^{\frac{\alpha}{1-\beta}}\, h^{\frac{\gamma}{1-\beta}} \qquad (4.21)$$

$$h = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1}{1-\gamma}} q^{\frac{\beta}{1-\gamma}}\, k^{\frac{\alpha}{1-\gamma}} \qquad (4.22)$$

We substitute the value of k from equations (4.20) in (4.21) and in equation (4.22)

$$h = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1}{1-\gamma}} q^{\frac{\beta}{1-\gamma}} \left[\left[\frac{s_k}{n+g+\delta}\right]^{\frac{1}{1-\alpha}} q^{\frac{\beta}{1-\alpha}}\, h^{\frac{\gamma}{1-\alpha}}\right]^{\frac{\alpha}{1-\gamma}} \qquad (4.23)$$

$$q = \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1}{1-\beta}} \left[\left[\frac{s_k}{n+g+\delta}\right]^{\frac{1}{1-\alpha}} q^{\frac{\beta}{1-\alpha}}\, h^{\frac{\gamma}{1-\alpha}}\right]^{\frac{\alpha}{1-\beta}} h^{\frac{\gamma}{1-\beta}} \qquad (4.24)$$

From equation (4.23) we have:

$$h = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1}{1-\gamma}} q^{\frac{\beta}{1-\gamma}+\frac{\beta}{1-\alpha}\cdot\frac{\alpha}{1-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{1}{1-\alpha}\cdot\frac{\alpha}{1-\gamma}} h^{\frac{\gamma}{1-\alpha}\cdot\frac{\alpha}{1-\gamma}}$$

$$h^{1-\frac{\gamma}{(1-\alpha)}\cdot\frac{\alpha}{(1-\gamma)}} = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1}{1-\gamma}} q^{\frac{\beta}{1-\gamma}+\frac{\beta}{1-\alpha}\cdot\frac{\alpha}{1-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{1}{1-\alpha}\cdot\frac{\alpha}{1-\gamma}}$$

$$h^{\frac{1-\alpha-\gamma}{(1-\alpha)(1-\gamma)}} = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1}{1-\gamma}} q^{\frac{\beta}{(1-\alpha)(1-\gamma)}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{(1-\alpha)(1-\gamma)}}$$

$$h = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{1-\alpha-\gamma}} q^{\frac{\beta}{(1-\alpha-\gamma)}} \qquad (4.25)$$

From equation (4.24) we have:

$$q = \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1}{1-\beta}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{1}{1-\alpha}\cdot\frac{\alpha}{1-\beta}} q^{\frac{\beta}{1-\alpha}\cdot\frac{\alpha}{1-\beta}} \; h^{\frac{\gamma}{1-\alpha}\cdot\frac{\alpha}{1-\beta}+\frac{\gamma}{1-\beta}}$$

$$q^{1-\frac{\alpha\beta}{(1-\alpha)(1-\beta)}} = \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1}{1-\beta}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{1}{1-\alpha}\cdot\frac{\alpha}{1-\beta}} \; h^{\frac{\alpha\gamma}{(1-\alpha)(1-\beta)}+\frac{\gamma}{1-\beta}}$$

$$q^{\frac{1-\alpha-\beta}{(1-\alpha)(1-\beta)}} = \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1}{1-\beta}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{(1-\alpha)(1-\beta)}} \; h^{\frac{\gamma}{(1-\alpha)(1-\beta)}}$$

$$q = \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\beta}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{(1-\alpha-\beta)}} \; h^{\frac{\gamma}{(1-\alpha-\beta)}} \qquad (4.26)$$

By substituting the value of q from equation (4.26) into equation (4.25), we get:

$$h = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{1-\alpha-\gamma}} \left[\left[\frac{s_q}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\beta}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{(1-\alpha-\beta)}} h^{\frac{\gamma}{(1-\alpha-\beta)}}\right]^{\frac{\beta}{(1-\alpha-\gamma)}}$$

$$h = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{1-\alpha-\gamma}+\frac{\alpha}{(1-\alpha-\beta)}\cdot\frac{\beta}{(1-\alpha-\gamma)}} \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\beta}\cdot\frac{\beta}{(1-\alpha-\gamma)}} \; h^{\frac{\gamma}{(1-\alpha-\beta)}\frac{\beta}{(1-\alpha-\gamma)}}.$$

$$h^{1-\frac{\beta\gamma}{(1-\alpha-\beta)(1-\alpha-\gamma)}} = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha(1-\alpha)}{(1-\alpha-\beta)(1-\alpha-\gamma)}} \left[\frac{s_q}{n+g+\delta}\right]^{\frac{\beta(1-\alpha)}{(1-\alpha-\beta)(1-\alpha-\gamma)}}$$

$$h^{\frac{(1-\alpha)(1-\alpha-\beta-\gamma)}{(1-\alpha-\beta)(1-\alpha-\gamma)}} = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha(1-\alpha)}{(1-\alpha-\beta)(1-\alpha-\gamma)}} \left[\frac{s_q}{n+g+\delta}\right]^{\frac{\beta(1-\alpha)}{(1-\alpha-\beta)(1-\alpha-\gamma)}}$$

$$h = \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1-\alpha-\beta}{1-\alpha-\beta-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{(1-\alpha-\beta-\gamma)}} \left[\frac{s_q}{n+g+\delta}\right]^{\frac{\beta}{(1-\alpha-\beta-\gamma)}} \qquad (4.27)$$

$$h^* = \left(\frac{s_h^{1-\alpha-\beta} s_q^{\beta} s_k^{\alpha}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}} \qquad (4.27a)$$

To obtain the value of q, we substitute the value of h from equation (4.27) into equation (4.26):

$$q = \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\beta}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{(1-\alpha-\beta)}} \left[\left[\frac{s_h}{n+g+\delta}\right]^{\frac{1-\alpha-\beta}{1-\alpha-\beta-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{(1-\alpha-\beta-\gamma)}} \left[\frac{s_q}{n+g+\delta}\right]^{\frac{\beta}{(1-\alpha-\beta-\gamma)}}\right]^{\frac{\gamma}{(1-\alpha-\beta)}}$$

$$q = \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1-\alpha}{1-\alpha-\beta}+\frac{\beta}{(1-\alpha-\beta-\gamma)}\cdot\frac{\gamma}{(1-\alpha-\beta)}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{(1-\alpha-\beta)}+\frac{\alpha}{(1-\alpha-\beta-\gamma)}\cdot\frac{\gamma}{(1-\alpha-\beta)}} \left[\frac{s_h}{n+g+\delta}\right]^{\frac{1-\alpha-\beta}{1-\alpha-\beta-\gamma}\cdot\frac{\gamma}{(1-\alpha-\beta)}}$$

$$q = \left[\frac{s_q}{n+g+\delta}\right]^{\frac{1-\alpha-\gamma}{1-\alpha-\beta-\gamma}} \left[\frac{s_k}{n+g+\delta}\right]^{\frac{\alpha}{(1-\alpha-\beta-\gamma)}} \left[\frac{s_h}{n+g+\delta}\right]^{\frac{\gamma}{1-\alpha-\beta-\gamma}} \qquad (4.28)$$

$$q^* = \left(\frac{s_q^{1-\alpha-\gamma} s_k^{\alpha} s_h^{\gamma}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}} \qquad (4.28a)$$

By substituting the h* and q* from equation (4.27) and equation (4.28) into equation (4.20), we obtain the steady state value of k*.

$$k^* = \left(\frac{s_k^{1-\beta-\gamma} s_q^{\beta} s_h^{\gamma}}{g+n+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}} \qquad (4.29)$$

By substituting the equation (4.27a), (4.28a) and (4.29) in equation (4.7) we have,

$$y_t = \left[\left(\frac{s_k^{1-\beta-\gamma} s_q^{\beta} s_h^{\gamma}}{g+n+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}}\right]^{\alpha} \left[\left(\frac{s_q^{1-\alpha-\gamma} s_k^{\alpha} s_h^{\gamma}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}}\right]^{\beta} \left[\left(\frac{s_h^{1-\alpha-\beta} s_q^{\beta} s_k^{\alpha}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}}\right]^{\gamma}$$

$$y^* = \left[\frac{s_k^{\alpha} s_h^{\beta} s_q^{\gamma}}{(n+g+\delta)^{\alpha+\beta+\gamma}}\right]^{\frac{1}{(1-\alpha-\beta-\gamma)}} \qquad (4.30)$$

Where $y^* = \frac{Y^*}{AL}$

The standard Solow growth model results can be recovered from the above equation by imposing the restriction that β=0 and γ=0. The steady state level of output per effective labor in Solow growth model is:

$$y^*_{Solow} = \left(\frac{s_k}{n+g+\delta}\right)^{\frac{\alpha}{1-\alpha}} \qquad (4.31)$$

When $\beta \neq 0$ and $\gamma \neq 0$ the rate of human capital and infrastructure capital affect the steady state level of output per effective labor. The general message of this modeling approach is that the more investment in human and infrastructure capital through savings, the higher will be the level of output per effective labor. From empirical perspective, the addition of infrastructure capital to the model allows for another dimension to be invoked in explaining differences in output level across countries. Countries who invest in hard and soft infrastructure are predicted to have higher income levels than those who do not, for any given investment rate in physical infrastructure.

By taking natural log on both sides of equation (4.30) we have:

$$ln\widehat{y_t} = lnA_0 + gt + \left(\frac{\alpha}{1-\alpha-\beta-\gamma}\right) ln\frac{s_k}{(n+g+\delta)} + \left(\frac{\beta}{1-\alpha-\beta-\gamma}\right) ln\frac{s_h}{(n+g+\delta)} + \left(\frac{\gamma}{1-\alpha-\beta-\gamma}\right) ln\frac{s_q}{(n+g+\delta)} + \theta F_t \tag{4.32}$$

Where $\widehat{y_t} = \frac{Y}{L}$

In previous studies, two measure of infrastructure, government investment as percentage of GDP and some physical measure or government capital stock like number of kilometers of paved roads have been used. Each measure has its own merits and demerits. Pritchett (1996) highlighted some serious drawbacks of using monetary value of government investment (as share of GDP), as repressors in growth equation for infrastructure capital. Due to the public good nature of infrastructure capital, infrastructure investment projects are normally carried out by public sector institutions. As a result, there is a possibility of deviation of actual and economic cost of infrastructure development. Therefore, money value of infrastructure investment may not be appropriate measure of infrastructure capital because of inefficiency of government investment, particularly in developing countries (Pritchett, 1996). Pritchett estimates show that only slightly more than half the money invested in infrastructure projects will have a positive impact on public capital stock. Equation (4.32) is expressed in terms of level of investment; we can rewrite this equation in terms of level of capital instead of investment rate. In equation (4.32) s_h and s_q can be written as h_t and q_t which is the measure of human capital stock and infrastructure capital stock, respectively. Relationships are expressed in the following equation:

$$lns_q = ln\frac{Q_t}{L_t} - lnA_t = ln\frac{Q_t}{L_t} - (lnA_0 + gt + \theta lnF_t)$$
$$\ln S_g = \ln q_t \ - (lnA_0 + gt + \theta lnF_t)$$
(4.33a)

$$lns_h = ln\frac{H_t}{L_t} - lnA_t = ln\frac{H_t}{L_t} - (lnA_0 + gt + \theta lnF_t)$$
$$\ln S_h = \ln h_t \ - (lnA_0 + gt + \theta lnF_t)$$
(4.33b)

Substitute equation (4.33a) and (4.33b) in equation (4.32), we have:

$$ln\hat{y}_t = \left(\frac{\alpha}{1-\alpha-\beta-\gamma}\right) lns_k + \left(\frac{\beta}{1-\alpha-\beta-\gamma}\right) lnh_t + \left(\frac{\gamma}{1-\alpha-\beta-\gamma}\right) lnq_t - \left(\frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}\right) \ln(n + g + \theta) + \left(1 - \frac{\beta+\gamma}{1-\alpha-\beta-\gamma}\right)(lnA_0 + gt + \theta F_t)$$

(4.34)

Equation (4.33) describes the long run relationship between real GDP per worker and physical capital, human capital and infrastructure capital. Equation 4.34 can be rewritten as:

$$ln\hat{y}_t = \varphi_0 + \varphi_1 lnk_t + \varphi_2 lnh_t + \varphi_3 lnq_t + \varepsilon_t \quad (4.35)$$ [13]

Where $\varphi_0 = \left(\frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}\right) \ln(n + g + \theta) + \left(1 - \frac{\beta+\gamma}{1-\alpha-\beta-\gamma}\right)(lnA_0 + gt + \theta F_t)$

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[13] The main criticism on production function approach is that for not taking into account the potential endogeneity of public capital. In this study we address the issue of endogeneity by using FMOLS estimation technique. The main advantage of single equation production function approach is that in this approach, we can establish the long run relationship among variable of interest and elasticity estimates can be obtained directly.

$\varphi_1 = \left(\frac{\alpha}{1-\alpha-\beta-\gamma}\right),\ \varphi_2 = \left(\frac{\alpha}{1-\alpha-\beta-\gamma}\right), \varphi_3 = \left(\frac{\gamma}{1-\alpha-\beta-\gamma}\right)$

Where $\varphi_1, \varphi_2, \varphi_3$ reflects the elasticities of output per worker with respect to non-infrastructure capital, human capital and infrastructure capital. It is assumed that production function exhibits a constant return to scale (CRS) for all inputs and decreasing return to scale for individual inputs. In Eq. (4.35), we expect that $\varphi_1 > 0, \varphi_2 > 0, \varphi_3 > 0$ .The immediate effect of new infrastructure such as energy, transport, and communication boosts economic output. For example when electricity supply disruption are eliminated or available hours increased firms respond with greater supply. Removing infrastructure constraints, such as power outages, problematic access to the road network and communication, can facilitate the transfer of private resources to a more productive sector. Therefore we expect φ_3 to be positive in equation (4.35).

Chapter 5

Model Specification, Empirical Methodology and Data

5.1 Introduction

The significance of infrastructure for development and economic growth vary across countries and sectors of the economy. Two valuable lessons emerged from theoretical and empirical evidence on the role of infrastructure on economic growth, as discussed in the literature review chapter. First, at the local level, improvement in infrastructure generates externalities that may spread out across the different sectors of the economy. Second, infrastructure development has a spillover effect on the geographical distribution of the economic activities across the boundary. In this chapter our focus is to specify empirical models to test the contribution of a set of infrastructure variables on the aggregate economy and as well as on sub-sector of the economy. Infrastructure augmented production function has been employed in which output is a function of no-infrastructure capital, set of infrastructure variables and human capital.

Two broad measures of hard infrastructure have been used in empirical literature; public spending on infrastructure projects, i.e., a monetary measure of infrastructure and a physical measure of infrastructure (For example, roads in kilometer and number of telephone lines). Majority of the empirical literature on the economic impact of infrastructure supports the view of strongly positive and statistically significant contribution of physical measure of infrastructure on economic growth, in developed and in developing countries. However, the literature shows mix results, regarding the impact of public investment (a monetary measure of infrastructure) in infrastructure on economic growth. One distinguishing feature of this study is that we use both physical measures of infrastructure and a monetary measure of infrastructure for empirical analysis.

The remainder of this chapter is organized as follows: in section 5.2 we specified the empirical models for stock of infrastructure. Section 5.3 presents the model's specification for infrastructure investment. Section 5.4 discusses the econometric methodology applied in this research. Section 5.5 presents the data, definition of variables and source of data.

5.2 Empirical Models for stock of Infrastructure variables

Infrastructure augmented growth model in the previous chapter highlights the significance of various types of infrastructure variables for economic development, along with other determinants of economic growth. The traditional growth variables include human capital and physical capital. The estimable equation of the theoretical model framed in chapter 4 is:

$$ln\widehat{y_t} = \varphi_0 + \varphi_1 lnk_t + \varphi_2 lnh_t + \varphi_3 lnq_t + \varepsilon_t \quad (4.35)$$

Equation (4.35) describes the long-run relationship between real GDP, physical capital, human capital and infrastructure capital. All variables are expressed logs per workers term.

Infrastructure is more crucial for some sectors of the economy than other sectors. The economic sector that depends more on infrastructure would be more negatively affected by bad infrastructure (Lanau, 2017). Empirical literature supports the hypothesis that effect of public infrastructure investment varies across the different sectors of the economy (Cantos et al., 2005; Feltenstein and Ha, 1995; Lanau, 2017; Morrison and Schwartz, 1996; Nadiri and Mamuneas, 1994; Rioja, 2001; Sturm, 2001). Feltenstein and Ha, 1995 found that the effect of public infrastructure investment varies significantly among different sectors of the economy. Morrison and Schwartz (1996) and Nadiri and Mamuneas (1994) find positive effects on manufacturing in the US. The Sturm (2001) study for the Netherlands finds a higher positive impact of infrastructure in the service sector than in manufacturing and agriculture. Cantos et al. (2005) examine the impact of transport infrastructure on the private sector, agriculture, industry, construction and business services. The study of Cantos et al. (2005) conclude that a major sector of activity shows very different results with regards to the importance and magnitude of transport infrastructure. Among the four sectors, transport infrastructure has a statistically significant impact in the agriculture sector. Considering natural variation in the dependence of sectors on infrastructure, we examine the impact of infrastructure separately on economic sectors (aggregate, industry, agriculture and services). To investigate the relationship between GDP (aggregate, industry, agriculture, and services) and infrastructure variables, three different specifications have been employed. In the first specification we used all the three infrastructure variables separately:

$$y_{it} = \alpha_{oi} + \alpha_{1i}k_{it} + \alpha_{2i}h_{it} + \alpha_{3i}eng_t + \alpha_{4i}r_t + \alpha_{5i}tel_t + \varepsilon_t \quad (5.1)$$

Where subscript i stands for aggregate output, industrial sector output, agriculture sector output and services sector output, and t stands for periods. y_{it} is real output per worker of aggregate, industry, agriculture and services sector. k_{it} and h_{it} are respectively non-infrastructure capital per worker and human capital per workers in the aggregate economy and three subsectors of the economy. For infrastructure capital, we used electricity generation capacity proxy for energy infrastructure (eng_t), high type road infrastructure (r_t) and telecommunication infrastructure (tel_t).

In the second specification, we aggregated the three infrastructure variables (energy, roads, and telecommunication), by principal component analysis (PCA) to investigate the impact of aggregate infrastructure on economic performance:

$$y_{it} = \beta_{oi} + \beta_{1i}k_{it} + \beta_{2i}h_{it} + \beta_{3i}infra_t + \varepsilon_t \quad (5.2)$$

Where in equation (5.2) infra is the aggregate infrastructure variable.

Pakistan has lagged significantly in assessing infrastructure quality compared to other countries in the region. In developing countries context, new infrastructure is politically more eye-catching that economically, but infrastructure maintenance expenditure is less rewarding for politician. Therefore, in order to examine the role of quality of infrastructure for economic growth, quality of infrastructure variables have been included:

$$y_{it} = \gamma_{oi} + \gamma_{1i}k_{it} + \gamma_{2i}h_{it} + \gamma_{3i}qe_t + \gamma_{4i}qr_t + \varepsilon_t \quad (5.3)$$

Where qet and qrt are respectively quality of energy and road infrastructure variables.

The percentage of high type roads to low type roads in kilometers is uses as proxy of quality of road infrastructure, while transmission and distribution losses of electricity has been used as proxy of quality of energy. We expect that $\gamma_3 < 0 \; and \; \gamma_4 > 0$.

5.3 Empirical Models for Infrastructure Investment

Although a large body of empirical literature discovers a robust positive correlation between economic growth and a physical measure of infrastructure, however, the impact of public investment in infrastructure on economic growth is ambiguous. Ashauer (1989) found a positive and statistically significant impact of public investment on economic growth for the US and G7 countries. Latter on studies carried out by (Barro, 1991;

Devarajan et al., 1996; Holtz-Eakin and Schwartz, 1995a), based on more sophisticated econometrics method and a broad range of countries, found much smaller and in some cases negative correlation between public investment in infrastructure and economic growth. The IMF (2004) survey on public investment in infrastructure and growth relationship has not found a clear-cut correlation between these two variables. Similarly, literature survey conducted by Starub (2008), found that less than half of the studies confirm the positive influence of infrastructure investment on economic growth. Literature highlights the number contextual factors, including a source of financing for infrastructure, accessibility of human capital as complementary inputs, quality of institutions, political stability, corruption which hamper the association between infrastructure investment and economic growth. Public investment in infrastructure through excessive taxation, deficits or debt tend to diminish economic growth by crowding out private investment or depress private investment (Adam and Bevan, 2005; Dessus and Herrera, 2000; Gupta et al., 2005; Simone et al. 2006). The accessibility of complementary inputs plays a supporting role in the effectiveness of public investment for growth. The studies carried out by Adam and Bevan (2005), (Haque and Kim, 2003) and (Bose et al., 2007) demonstrated that investment in infrastructure has the leading effect on economic growth when it is combined with productive expenditure on education and health. The other contextual factors, such as quality of the institution, political openness, transparency, the perception of corruption, quality of governance and the risk of contract repudiation may also play a critical role in mediating the long-run impact of infrastructure investment on economic growth[14]. Straub

[14] See for example, (Esfahani and Ramírez, 2003; Baldacci et al. 2008; Bassanini et al., 2001); Tanzi and Davoodi, 1998; Haque and Kneller, 2008)

(2011) argue that due to the lack of efficiency in public investment, corruption, the exact mapping between actual values infrastructure and investment in infrastructure is the first challenge. Pritchett (1996) demonstrate that infrastructure investment flows are not a good proxy for the productive capital stocks because the cost of public investment in infrastructure is expected to fluctuate from its real value. Government inefficiency or departure from efficiency and potential corruption, which can be quite high in infrastructure project are significant concerns for the difference in infrastructure stocks and investment in infrastructure. Pritchett (2000) and Caselli (2005) discuss that inefficiency in public investment process, poor infrastructure project selection, inadequate monitoring and implantation issues may result in only a segment of public spending, transforming it into something fruitful, restraining the long-run output gains.

On the other hand, there are studies[15] which argue that an increased public infrastructure investment raises economic growth both in short and long run. Abdul and Petia (2016) argue that a rise in public investment in infrastructure stimulates the economic growth in two ways. (1) In the short run, infrastructure investment boosts aggregate demand through the short term investment multiplier, (2) through crowding in private investment, given the highly complementary nature of infrastructure services. The empirical study of (Abdul and Petia, 2016), for a sample of 17 OECD economies concluded that public investment has positive impact on output and private investment and negatively related with unemployment, both in the short and long-run.

[15] For example Gupta et al.,(2014); Abiad et al.(2015); Magud and Sosa(2015); Ansar et al.(2016); Banerjee et al.(2012); and Demurger (2001) among others)

The study further explores that in countries with a low degree of investment efficiency, an increase in public investment increases output by 2.2 percent in the long-run, compared with 2.8 percent in countries where public investment is sufficiently efficient. Komatsuzaki (2016) explore the macroeconomic of raising public investment in infrastructure for the Philippines economy and found that an increase in public infrastructure investment sustains a positive impact on output. The study of Lanau (2017), for six Latin American countries found that infrastructure raises growth and investment. Banerjee et al. (2012) and Demurger (2001) argued that investment in transport infrastructure has a positive impact on economic growth in Chinese province.

Earlier literature shows mix results, regarding the growth impact infrastructure investment. Country specific characteristics may be the reason behind inconclusive results, as most of the earlier studies use panel or cross-sectional data to investigate the impact of infrastructure investment. For Infrastructure growth relationship, we adopted a different approach from the previous literature. Our analysis is based on country specific time series data, and we separated infrastructure investment data by source of infrastructure investment and by type of infrastructure investment. By source infrastructure investment, we divided infrastructure investment into public investment in infrastructure and infrastructure investment. By type of infrastructure investment, we split infrastructure investment into energy sector investment and transport & telecommunication infrastructure. It is mentioned that public or private infrastructure is more crucial for some sector of the economy than other sectors. Keeping in mind this hypothesis, we are also focusing on the impact of public and private infrastructure investment on a sectoral component of GDP, such as industry, agriculture and services sector. Previous studies have not gone through such a peculiarity and have focused on the effect of public investment only on overall economic growth.

To consider the impact of infrastructure investment on the aggregate and sectoral component of GDP, we specified three different models from a different measure of infrastructure investment. In the first specification, we used aggregate infrastructure investment by the public and the private sector in electricity generation distribution, gas distribution and transport and communication.

$$y_{it} = \beta_{oi} + \beta_{1i}k_{it} + \beta_{2i}h_{it} + \beta_{3i}ai_t + \varepsilon_t \quad (5.4)$$

Where subscript i stands for aggregate output, industrial sector output, agriculture sector output and services sector output and t stands for periods. y_{it} is real output per worker of aggregate, industry, agriculture and services sector. k_{it} and h_{it} are respectively non-infrastructure capital per worker and human capital per worker in the aggregate economy and the three subsectors of the economy. a_{it} is used for aggregate investment in infrastructure capital.

In second specification we split the investment in infrastructure into public and private investment, in electricity generation distribution, gas distribution, and transport and communication

$$y_{it} = \theta_{oi} + \theta_{1i}k_{it} + \theta_{2i}h_{it} + \theta_{3i}gi_t + \theta_{4i}pi_t + \varepsilon_t \quad (5.5)$$

Where g_{it} and p_{it} represent the public and private component of infrastructure investment respectively.

In the third specification, we divided the infrastructure investment by type of infrastructure investment.

$$y_{it} = \pi_{oi} + \pi_{1i}k_{it} + \mu_{2i}h_{it} + \pi_{3i}eng_t + \pi_{4i}tr_t + \varepsilon_t \quad (5.6)$$

Where eng_t and tr_t represent the infrastructure investment in the energy sector and transport & telecommunication sector respectively.

5.4 Econometric Methodology

5.4.1 Unit Root Testing

Empirical findings based on time series data often produce spurious results when variables included in the analysis are non-stationary. To deal with spurious regression, unit root tests and cointegration test are employed on time series data. In the first stage, Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1981) and (Phillips and Perron, 1988) and (Kwiatkowski, Phillips, Schmidt, & Shin, 1992) (KPSS) tests have been used, without considering the structural break tests. (Phillips and Perron, 1988) test has been used to control serial correlation and heteroscedasticity problem in error term. However, both the ADF and PP tests are having low power against the alternative hypothesis that the series is stationary (DeJong et al. 1992). ADF and PP test of the unit root is upward biased in rejecting the null hypothesis of a unit root. One possible solution of these problems is proposed by KPSS to use the stationarity test under the null hypothesis. As opposed to other, KPSS (1992) test assumed that the series is stationary under null hypothesis. The KPSS test is residuals based test and residuals are obtained from the OLS regression. KPSS unit root test has its own limitations; it inclines to reject the null hypothesis too frequently. There is high probability of type I errors in KPSS test. Literature suggests that to address the potential possibility of high type I error is to combine the ADF test and KPSS test. If the results from both tests suggest that the time series is stationarity, then there is a chance that series is stationary.

5.4.2 Unit Root Testing with Structural Break

However, literature criticized the standard unit-root tests for ignoring the possible existence of structural breaks in the series and low power of the tests (Ferreira and León-Ledesma, 2007). Perron (1989) shows that because of the existence of structural breaks in the series, results of The ADF unit root test by Dickey and Fuller and p-p test by Philips and Perron may be biased towards the non-rejection of a unit root.

For structural break unit root test, four distinct specifications of the Dickey-Fuller regression proposed by (Agnolucci et al. 2017; Perron, 1989; Perron and Vogelsang, 1992; Vogelsang and Perron, 1998) has been considered in this study. We define the dummy variable to specified break date Tb.

An intercept break variable.

$$DU_t(T_b) = 1 \; if \; t \geq \; T_b$$

That will take value 0 for all dates prior to the break and 1 thereafter

A trend break variable

$$DU_t(T_b) = 1 \; if \; (t \geq \; T_b). \text{ (t - } T_b\text{+1)}$$

Which takes the value 0 for all dates prior to the break and is a break date rebased trend for all subsequent dates.

One time break dummy varaible

$$D_t(T_b) = 1 \; if \; (t = \; T_b$$

Which takes the value 1 only on the break date and 0 other wise

Model (A) non-trend data with intercept break

$$y_t = \alpha_0 + \alpha_1 DU_t(T_b) + \omega D_t(T_b) + \rho y_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta y_{t-i} + e_t \quad (5.7)$$

Setting trend and trend break coefficient β and γ equal to zero in model A. This is a random walk model against a stationary model with intercept break.

Model B: Trend data with intercept break:

$$y_t = \alpha_0 + \beta t + \alpha_1 DU_t(T_b) + \omega D_t(T_b) + \rho y_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta y_{t-i} + e_t \quad (5.8)$$

Setting trend break coefficient γ equal to zero in model B. This is a random walk with drift model, against a trend stationary model with intercept break.

Model C: Trending data with intercept and trend break:

$$y_t = \alpha_0 + \beta t + \alpha_1 DU_t(T_b) + \gamma DT_b(T_b) + \omega D_t(T_b) + \rho y_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta y_{t-i} + e_t \quad (5.9)$$

Model c random walk model with drift against a trend stationary with intercept and trend break.

Model C: Trending data with trend break:

$$y_t = \alpha_0 + \beta t + \gamma DT_b(T_b) + \beta D_t(T_b) + \rho y_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta y_{t-i} + e_t \quad (5.10)$$

Set the intercept break and break dummy coefficients α_1 and ω zero. This is a random walk with drift against a trend stationary with trend break.

5.4.3 Testing for cointegration

Macroeconomic time series data may contain a unit root and this property of time series data has spurred the development of the theory of non-stationary time series analysis. When the null hypothesis of unit root test is rejected, we advance to test for cointegration among the variable included in our analysis. Several tests for cointegration relationship have been suggested in the literature for time series data. In our analysis, to perform cointegration test, we employ two types of cointegration tests; (1) VAR based cointegration test developed in Johansen (Johansen, 1988, 1991) and cointegration tests for a single equation.

5.4.4 Johansen Cointegration Test

Consider a VAR of order p:

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + Bx_t + \varepsilon_t \qquad (5.11)$$

Where yt is a k vector of non-stationary I (1) variables, x_t is a d vector of deterministic variables and ε_t is a vector of innovations. The above equation can be rewritten as:

$$\Delta y_t = \pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + Bx_t + \varepsilon_t \qquad (5.12)$$

Where $\pi = \sum_{i=1}^{P} A_i - i, \qquad \Gamma_i = -\sum_{j=i+1}^{p} A_j$

Granger's representation theorem states that if the coefficient matric π has reduced rank r<k., then there exist kxr matrices α and β, each with rank r such that $\pi = \alpha\beta'$ and $\beta' y$ is I(0). R is the number of cointegrating relations. Johansen's method estimates the π matrix from an unrestricted VAR.

Trace and Maximum Eigenvalue has been used to determine the number of cointegrating vector r. According to the null hypothesis of trace statistics, r is the number of co-integration of relations and alternative hypothesis is K number of cointegrating relations. K denotes the number of explanatory variables in the system. The trace statistic for null hypothesis of r cointegrating relations can be computed as follows:

$$LR_{tr}\left(\frac{r}{k}\right) = -T \sum_{i=r+1}^{k} \log(1 - \lambda_i) \quad (5.13)$$

Where λi is the i-th largest Eigen value of the Π matrix.

The null hypothesis of the maximum eigenvalue test statistic is that there are r cointegrating relations against the alternative of r+1 cointegrating relations. The test statistics is computed as:

$$LR_{max}\left(\frac{r}{r+1}\right) = -Tlog(1-\lambda_{r+1}) \quad (5.14)$$

$$= LR_t\left(\frac{r}{k}\right) - LR_t(r+\frac{1}{k})$$

5.4.5 Single Equation Cointegration Tests

In the case of a single equation, literature proposed, Engle-Granger and Phillips-Ouliaris residual-based test of cointegration to identify the long run relationship among the variable of interest and Hansen's instability test to check parameter stability.

The Engle-Granger and Phillips-Qaliaries are residual-based cointegration tests. Residual is obtained through FMOLS estimation and then unit root test is applied on the residuals. The null hypothesis that there is no cointegration against the alternative that series is cointegrated. The key difference in both cointegration tests is in the treatment of serial correlation in the residuals. The Engel-Granger test is a parametric approach that uses augmented Dickey-Fuller test while the Phillips-Quliaris test is a nonparametric approach and uses Phillips-Perron methodology. The asymptotic distributions of the Engle-Granger and Phillips Quliaris are non-standard and depend on the deterministic regressors specification. So the critical values of the tests statistics are gained from simulation results.

5.5 Fully Modified Ordinary Least Squares (FMOLS)

Regarding the macroeconomic impact of public infrastructure, most of the earlier literature found a positive relationship between infrastructure and economic growth.

Infrastructure development generates positive externality to the private sector and reduces transaction costs; facilitates the mobility of goods within the country and across the country; facilitates labor mobility and realization of economies of scale. Despite a strong theoretical linkage of infrastructure development and growth through numerous channels, the impact of infrastructure on economic growth was attributed to empirical weakness. For example, seminal work of Achauer (1989a, b) and a large body of subsequent literature used a production function approach to assess the impact of infrastructure capital on growth. Achauer's estimation methodology was used extensively in subsequent literature for international, regional and sector-specific analysis and failed to produce the same effect of infrastructure capital on output (Pereira and Andraz, 2013). However, the methodological approach used by Aschauer was challenged on the econometric ground (Gramlich, 1994; Pereira and Andraz, 2013). Aschauer's approach was criticized for simultaneity biased, endogeneity and spurious regression because of non-stationarity of data. Pereira and Andraz, (2013) argued that due to a single equation and static approach, the methodology of the production function is not able to take into account the simultaneity between different variables and non-contemporary effects. The most critical issue in Aschauer approach is the bidirectional causality between aggregate output and public capital. Empirical literature supports the bidirectional causality between indicators of infrastructure and output growth. For example, (Kumo 2012) confirmed strong bidirectional causality between infrastructure investment and economic growth for South Africa.

In order to address this criticism, different approaches like multivariate static cost function approach, vector autoregressive(VAR), panel data estimation, reduced form equation or simultaneous equation models and instrumental variables approach have been used in the subsequent empirical literature. To identify the direction of causality, the literature suggests applying the appropriate econometric test. In this regard, (Canning & Bennathan, 2000) pointed out that a panel data estimation methodology may address the causality issue in infrastructure growth relationship. Canning and Bennathan argued that pooling the data across the countries may allow identification of long-run relationship. Canning and Pedroni (1999) employed a reduced form model to solve the problem of reverse causality. The vector autoregressive (VAR) methodology is the most prominent approach to quantify the macroeconomic impact of infrastructure.

The extensive use of VAR approach in infrastructure – growth nexus is because VAR adequately addresses the above mentioned econometric issue comprehensively. Pereira and Andraz (2013) pointed out that static nature of production approach and the multivariate cost function approach disregard the existence of feedbacks between private inputs and public capital as well as dynamic feedbacks between all inputs. Exclusion of these variables may cause model miss-specification. The VAR approach to infrastructure – growth nexus is based on the notion that considering the dynamic feedbacks is crucial to realize the connection between private sector performance and public capital. The VAR approach has its limitations and shortcomings. Identification of exogenous shocks in the VAR approach is an imminent issue, as the effects of exogenous variables generated through cumulative impulse response are sensitive to the ordering of variable in VAR methodology. The restriction imposes in the VAR model must be based on the assumption of exogeneity for innovations that can only be inferred from theoretical considerations. In the context of VAR, elasticities are not based on ceteris paribus assumption; the VAR results indicate the accumulated long-term variations in each explanatory variable because of an initial shock in public capital.

Some previous studies (for example (Ai & Cassou, 1995; Calderón & Servén, 2003; Finn, 1993) have employed Generalized Method of moments (GMM) estimation methodology, to avoid possible reverse causation between infrastructure and economic growth. However, the GMM methodology is applicable when data is stationary. Fully modified least squares estimation methodology, developed by (Phillips & Hansen, 1990) is appropriate to take into account the endogeneity problem in the regressors and serial correlation problem. According to (Phillips, 1995), FMOLS provides an approach to unrestricted regression for time series that takes advantages of data nonstationarity, without being explicit to the presence or number of any unit roots and cointegration relations. Fully Modified OLS (FMOLS) methodology, proposed by Phillips and Hansen (1990) is semi-parametric approach which addresses the problems, triggered by the long-term association between the cointegration equation and the innovations of stochastic regressors. FMOLS estimators are asymptotically unbiased and have a full-strength usual asymptotic mixture, allowing standard Wald tests using Chi-square asymptotic statistical inference.

Following (Christopoulos and Tsionas, 2004); and (Di Iorio and Fachin, 2012), we specify the following data generation process

$$y_t = \alpha + x_t'\beta + \mu_t \qquad (5.15)$$

$$x_t = x_{t-1} + \varepsilon_t$$

Where y_t is a scalar time series and x_t is a kx1 vector of time series. Intercept term α is included as deterministic component in the model.

Where stochastic error term is defined as $\omega_t = [\mu_t, \varepsilon_t']'$ and it is assumed that ω_t is a vector of integration of order zero i.e I(0). x_t is a vector of integration of order one, i.e I(1) process and there exists a long run relationship among $[y_t, x_t']'$ with cointegrating vector $[1, -\beta']'$

It is assumed that vector of stochastic error term ω_t satisfies the functional central limit theorem of the form,

$$\frac{1}{\sqrt{T}} \sum_{t=1}^{Tr} \omega_t \to B(r) = \sqrt{\Omega}\, W(r) \quad (5.16)$$

Where [Tr] is the integer part of Tr and $W(r)$ is a K+1 vector of independent standard Brownian motions. The covariance matrix of $B(r)$ is

$$\Omega = \sum_{i=-\infty}^{\infty} E\left[\omega_{i\,,}\omega_{t-i}'\right]$$

One side long run covariance matrix is

$$\chi = \sum_{i=-\infty}^{\infty} E\left[\omega_{i\,,}\omega_{t-i}'\right]$$

Both Ω and χ can be rewritten as follows:

$$\Omega = \begin{pmatrix} \Omega_{\mu\mu} & \Omega_{\mu\varepsilon} \\ \Omega_{\epsilon\mu} & \Omega_{\varepsilon\varepsilon} \end{pmatrix}, \qquad \chi = \begin{pmatrix} \chi_{\mu\mu} & \chi_{\mu\varepsilon} \\ \chi_{\epsilon\mu} & \chi_{\varepsilon\varepsilon} \end{pmatrix}$$

Let's denote $X_t = diag(x_{1t}, \ldots, x_{Nt})$ and $Y_t = (= (y_{1t}, \ldots, y_{Nt})'$, $\Omega_{\mu\varepsilon} = (\Omega_{\mu\mu} - \Omega_{\mu\varepsilon}\Omega_{\mu\mu}^{-1}\Omega_{\mu\varepsilon})$

Denoting by an hat a consistent estimate, then

$$\hat{y_t}^{+} = y_t - \hat{\Omega}_{\mu\varepsilon}\hat{\Omega}_{\varepsilon\varepsilon}^{-1} \Delta x_t \ , \ \tilde{y}_t^{+} = (\tilde{y}_{1t}^{+}, \ \dots, \tilde{y}_{Nt}^{+})' \quad (5.17)$$

$$\tilde{y}_{it}^{+} = y_{it} - \hat{\Omega}_{\mu\varepsilon}^{ii} (\hat{\Omega}_{\varepsilon\varepsilon}^{ii})^{-1} \Delta x_{it} \quad i=1,2,\dots,N$$

$$\hat{\psi} = (\hat{\psi}_1', \dots, \hat{\psi}_n')' \ , \hat{\psi}_i = \hat{\chi}_{\varepsilon\mu}^{ii} - \hat{\Omega}_{\mu\varepsilon}^{ii} (\hat{\Omega}_{\varepsilon\varepsilon}^{ii})^{-1} \hat{\chi}_{\varepsilon\varepsilon}^{ii}$$

FMOLS estimator can be defined as follows:

$$\hat{\beta} = \left(\sum_{t=1}^{T} X_t X_t'\right)^{-1} \left(\sum_{t=1}^{T} X_t \tilde{Y}_t^{+} - T\hat{\psi}_i\right) \quad (5.18)$$

5.6 Structural Vector Autoregressive (SVAR)

The vector autoregressive (VAR) methodology is the most prominent approaches to quantify the macroeconomic impact of infrastructure. The widespread use of VAR approach in infrastructure growth nexus is because VAR methodology adequately and comprehensively addresses the econometric issues, such as endogeneity and reverse causality. Pereira and Andraz (2013) pointed out that static nature of production approach and the multivariate cost function approach do not take into account the existence of feedback between private inputs and public capital and dynamic feedbacks between all inputs. Exclusion of these variables may cause model miss-specification. The VAR approach to infrastructure growth nexus is based on the notion that considering the dynamic feedbacks is crucial to establishing the link between private sector performance and public capital.

Recently the SVAR method, we applied here is a preferred method to study the dynamic impact of infrastructure investment on production and employment. In contrast to the production function approach, the SVAR approach does not require a causal relationship between regressors and regression measures, to address the endogeneity issue related to infrastructure growth (Kamps, 2005). In the SVAR technique, the long-term impact of the infrastructure on growth is achieved, by taking into account the interaction of the various variables included in the model. Following (Cecchetti and Rich, 2001), we assume that the economy is described as follows:

$$B_0 x_t = B_1 x_{t-1} + B_2 x_{t-2} + \cdots + B_k x_{t-k} + \varepsilon_t \quad (5.19)$$

where $\mathrm{E}\left[\varepsilon_t \varepsilon_t^{'}\right] = \Omega$

The reduced form of the model can be written as:

$$x_t = B_0^{-1} B_{\ 1} x_{t-1} + B_0^{-1} B_2 x_{t-2} + \cdots + B_0^{-1} B_k x_{t-k} + B_0^{-1} \varepsilon_t$$

$$= D_1 x_{t-1} + D_2 x_{t-2} + \cdots + D_k x_{t-k} + \mu_t \qquad (5.20)$$

where μt is the vector of reduced form innovations. The structural disturbances and reduced form residuals are related by:

$$\varepsilon_t = B_0 \mu_t \qquad (5.21)$$

The equation (5.20) can be written as:

$$[1 - D_1 L - D_2 L^2 - \cdots] x_t = \mu_t$$

$$D(L) x_t = \mu_t, \qquad E[\mu_t \mu_t'] = \Sigma$$

Equation (5.20) can be inverted to vector moving average (VMA) form:

$$x_t = [1 - D_1 L - D_2 L^2 - \cdots]^{-1} \mu_t$$

$$x_t = [1 - D_1 L - D_2 L^2 - \cdots]^{-1} B_0^{-1} \varepsilon_t \quad (5.22)$$

From equation (5.22) we can write as:

$$x_t = [1 + C_1 L + C_2 L^2 - \cdots]^{-1} \mu_t$$

$$x_t = \mu_t + C_1\mu_{t-1} + C_2\mu_{t-2} \dots$$

$$x_t = B_0^{-1}\varepsilon_t + C_1\mu_{t-1} + C_2\mu_{t-2} + \cdots = C(L)\mu_t \qquad (5.33)$$

The Cj matrices correspond to Aj matrices in the original formulation, can be written as:

$$x_t = A_0\varepsilon_t + A_1\varepsilon_{t-1} + A_2\varepsilon_{t-2} + \cdots = A(L)\varepsilon_t \quad (5.34)$$

Which implies that:

$$E[(A_0\varepsilon)(A_0\varepsilon)'] = A_0\Omega A_0' = \Sigma = E[(\mu)(\mu)']$$

$$\Sigma = B_0^{-1}\Omega B_0^{-1}$$

We imposed (n2-n)/2 restrictions on the structural model, in order to detect the structural model from estimated VAR. Maximum likelihood estimates of Ω and B_0 can be obtained only through sample estimates of Σ.

The SVAR model is based on the MA representation of the structural model, and the empirical analysis is employed to estimate the impulse response function. The impulse response function (IRF) is usually calculated to show the model's response to one standard deviation shock on the structural innovations. Therefore, the SVAR model is normalised by setting the variance matrix to zero, since the standard deviation shocks in the normalization correspond to unity innovation in ε_t. Thus it is assumed that the variance-covariance matrix of structural innovation has the form $\Sigma_\varepsilon = I$. The interpretation of matrix B in the SVAR model refers to the simultaneous relationship between disturbances of the reduced form. The goal of the SVAR model is to identify the structural innovation ε_t to determine the dynamic response of the model to the shock that provides the IRF. Therefore, the SVAR model focuses on the relationship $B\Gamma\mu_t = \varepsilon_t$ and identifies the structural innovations by imposing constraint B. In the SVAR model, the dynamic relationship in the economy is modeled as a relationship between shocks

5.6.1 Identification scheme

Following Kamps (2005), for the economy as a whole and the subsector of the economy, we include four variables: public infrastructure investment (K^g), private investment in infrastructure (K^p), labor force (N) and real GDP (Y). All variables are expressed in natural logarithms, and transformed variables are displayed in lowercase letters. The data vector is expressed as:

$$X_t = \left[k_t^g, k_t^p, n_t, y_t\right] \qquad (5.35)$$

To identify the relationship between the reduced form disturbances ε_t and the structural disturbance μ_t take the following form. The identification scheme characterized by the following non-recursive structure of the kind $\varepsilon_t = B_0\mu_t$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 \\ a_{41} & a_{42} & a_{43} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{kg} \\ \varepsilon_{kp} \\ \varepsilon_n \\ \varepsilon_y \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \mu_{kg} \\ \mu_{kp} \\ \mu_n \\ \mu_y \end{bmatrix} \qquad (5.36)$$

There are 6 zero restrictions on the a_{ij} parameters, the system is exactly identified, exact identification requires only $(4^2-4)/2=6$ restrictions for four variables of VAR model. There are six unknown a_{ij} parameters and against diagonal covariance matrix of the structural disturbance. The system is exactly identified. Where $\varepsilon_{kg}, \varepsilon_{kp}, \varepsilon_n, \varepsilon_y$ are the reduced form disturbances, which are public investment shocks, private investment shocks, labor force shocks and output shocks respectively, and $\mu_{kg}, \mu_{kp}, \mu_n, \mu_y$ are the structural disturbances that represent unexpected movements of each variable.

Following Kamps (2005), we define the restriction of the structure parameter B_0. It is assumed that public investment does not contemporaneously respond to shocks to other variables included in the model. The restriction is justified because the change in public infrastructure spending is fundamentally separate from the business cycle. In this regard, a government decision on public investment involves delays in implementation. It, therefore, seems reasonable to assume that public investment is simultaneously affected by private sector shocks (Kamps, 2005). In the private investment equation, it is assumed that real GDP shocks and employment have no concomitant impact on private investment in infrastructure. As with public investment, private investment does not depend on the business cycle (see, for example, (King and Rebelo, 1990). The employment equation assumes that employment does not simultaneously respond to shocks in real GDP, however, shocks on public and private investment Employment is highly pro-cyclical, and it is reasonable to assume that production shocks have no simultaneous impact on employment. We assume that the actual production is simultaneously affected by shocks on all other variables of the model. Due to the production function, it is justified that three inputs simultaneously influence the real GDP.

5.7 Data Description and Sources

The empirical analysis is based on time series data over the period from 1972-2015.This study is based on two types of empirical investigations. One is country specific, in which we employ both quantity and quality related measure of infrastructure stock for empirical estimation, by following the work of (Canning and Pedroni, 1999) and (Calderón and Chong, 2004). A qualitative measure of infrastructure is typically related to the efficiency of the stock of infrastructure. We also use public and private investment in infrastructure to assess the impact of these investments on output in Pakistan. The second type of empirical investigation is for spillover effects of infrastructure development in Pakistan across the region. Three broad categories of infrastructure at aggregate and disaggregate level have been used in this study: (i) road infrastructure (ii) energy (iii) telecommunication. For quantity of road infrastructure category, the total length of road (high type road and low type road) is used, while for quality indicators of the road, the percentage of low type (non-paved) road network is used. For energy infrastructure, electricity generation capacity and transmission and distribution losses of electricity have been used for quantity and quality indicators of energy category respectively. Fixed telephone per 100 people has been used for telecommunication indicator of infrastructure. Definition of variables and source of data are presented below:

Gross Domestic Product (GDP)

Data on aggregate and sectoral GDP at the constant prices are taken from Hand Book of Statistics, State Bank of Pakistan. Industrial sector GDP includes Mining & Quarrying, Manufacturing, Construction and Electricity and Gas Distribution. Agriculture sector GDP includes Major Crops, Minor Crops, Livestock, Fishing and Forestry. Service sector GDP include Transport, Storage and Communication, Wholesale and Retail Trade, Finance and Insurance, Ownership of Dwellings, Public Administration & Defense and Community Services

Investment:

Gross Fixed Capital Formation (GFCF) has been used as a proxy for investment and data on GFCF constant prices is taken from Hand Book of Statistics, State Bank of Pakistan.

Human Capital:

For human capital, we use secondary school enrollment. It is defined as the total number of students enrolled at secondary level in public and private schools. This variable is taken from World Development Indicators.

Labor Force

Labor force data is taken from, Pakistan Economic Survey various issues. For the labor force used in the Industrial sector, we sum the labor force data of Mining & manufacturing, construction and electricity and Gas Distribution. For Services sector, we sum the labor force data of Transport sector & communication, wholesales & retail trade and others. For the Agriculture sector, agriculture labor force is used.

The stock of Infrastructure variables:

Roads: Data source for road infrastructure is Pakistan Economic Survey various issues

Quantity: High type (Paved roads) roads length in kilometers,

Quality: Percentage of high type roads to low type roads in kilometers

Energy

Quantity: Electricity generation capacity (in megawatts), the data source is Pakistan Energy Year Book

Quality: Electric power transmission and distribution losses (% of output) data source is World Development Indicators

Telecommunication: Fixed telephone subscriptions (per 1000 people), the data source is World Development Indicators

Aggregate Index of Infrastructure:

Physical infrastructure is a multidimensional concept that refers to the combined availability of several individual components, for example, energy, road telecommunication. To construct the synthetic index of infrastructure, we use Principal component analysis. The variables included in the index are Electricity generation capacity, telecommunication (phone line per 1000 peoples) and length of paved roads in kilometers. All the three variables are used in per worker terms and expressed in logs. The first principal component accounts for 94% of the overall variance of the three variables. All variables included in the infrastructure index have similar weights. Weights obtained through principal component analysis have been rescaled to add up to one.

$$Index = 0.33 * \ln\left(\frac{eng}{l}\right) + 0.34 * \ln\left(\frac{hr}{l}\right) + 0.33 * \ln(\frac{tel}{l})$$

Where (eng/l) represent electricity generation capacity per workers, $\left(\frac{hr}{l}\right)$ represent the total length of road network per workers

Infrastructure Investment variables:

Gross fixed capital formation, at a constant price, has been used as a proxy for investment and data is taken from the Hand Book of statistics, State Bank of Pakistan. Aggregate Investment in infrastructure is the sum of gross fixed capital formation of public and private sector in electricity generation distribution, gas distribution and transport and communication.

Public Capital Investment is the sum of gross fixed capital formation of the public sector in electricity generation distribution, gas distribution and transport and communication.

Private capital investment is the sum of gross fixed capital formation of the private sector in electricity generation distribution, gas distribution and transport and communication.

Disaggregated Infrastructure investment by type of infrastructure includes investment in the energy sector and investment in transport and telecommunication sectors. Investment in the Energy sector is the sum of public and private investment in electricity generation distribution, gas distribution and investment in transport and telecommunication is the sum of public and private investments in transport and communication.

5.8 Conclusion

In this chapter, we specified the empirical models based on the theoretical framework developed in chapter 3. Empirical models have been specified in this chapter to assess the marginal contribution of type of stock of infrastructure on aggregate output and across the different sectors of the economy. Three different specification stocks of infrastructure have been used for empirical analysis, Quantity of infrastructure, quality of infrastructure and a composite index of infrastructure. We also specified the empirical model to capture the link between infrastructure investment and sectoral GDP. An empirical model of infrastructure investment is further split into public and private investment and investment by type of infrastructure. These models will be used in chapter 6 for empirical analysis. Different tests for time series properties of data and cointegration tests have also been explained. Various econometric methodologies have been explained in this chapter which have been used in earlier literature for empirical analysis of the macroeconomic impact of infrastructure. In the last section, we discussed the data source and variables definitions.

Chapter 6

Infrastructure and Economic Growth: An Empirical Analysis

6.1 Introduction

The theoretical and empirical literature presented in Chapter 2 argues that infrastructure stock promotes economic growth with varying contribution across different sectors of the economy. Empirical literature does not precisely determine the linkages between the set of infrastructure variables and a sectoral component of GDP. Likewise, the literature shows inconclusive results about the impact of investment in infrastructure on economic growth. This shows a room for further investigation of the growth effects of infrastructure stock and infrastructure investment. The objective of this chapter is to empirically explore the association between a different measure of infrastructure variables and aggregate and a sectoral component of GDP. The objective of disaggregate analysis is to capture the structural and behavioral relationship between infrastructure investments and sectoral output. Infrastructure investments affect economic growth by changing the relative prices, structure of inputs and outputs, changes in market patterns and factor allocation, such as labor allocation and land usage. The analysis of infrastructure investment at the aggregate level overlooked most of these connections and hence did not guide for policy intervention at the disaggregate level. Therefore, we analyze the contribution of public and private infrastructure investment at sectoral level, namely industry, agriculture and services sector. Both physical measures of infrastructure and infrastructure investment are used in this study. To allow for a systematic and comprehensive measure of overall physical infrastructure, aggregate infrastructure index is constructed by using PCA (Principal

Component Analysis). Moreover, the infrastructure is also disaggregated by its type, i.e. transportation, communication and energy. This is done to avoid potential aggregation misspecifications.

Previous literature on infrastructure investment and growth focus on the effect of only public investment or aggregate infrastructure investment on growth. These studies do not distinguish between private and public infrastructure investments for the effectiveness of economic growth.

One of the contributions of this study is that, in contrast to earlier literature, it makes a comparative analysis of different compositions of infrastructure investment, including public versus private investment and infrastructure investment in sub-sectors, such as in power, road and telecommunication sectors. The objective of this segregation is to know the most productive form of infrastructure investment at aggregate and sectoral level. Public or private infrastructure is more crucial for some sectors of the economy than other sectors. Therefore, the present chapter focuses on the impact of public and private infrastructure investment on aggregate and sectoral component (such as industry, agriculture and services sector) of GDP. Lastly, the present section also employs SVAR methodology to examine the dynamic effects of public and private infrastructure investment on economic growth and employment in Pakistan.

This chapter consists of three sections. In Section 6.2, the effect of quality and measures (aggregated and disaggregated) of infrastructure on the economic performance of the whole economy and its sectors (industrial, agriculture and services sectors) are examined. Section 6.3 examines the impact of aggregate investment in infrastructure, public and private infrastructure investment on the economic performance of the aggregate economy, and sub-sector of the economy. Lastly, Section 6.4 examines the dynamic effects of public and private infrastructure investment on economic growth and employment in Pakistan.

6.2 Physical measure of Infrastructure and Economic Growth

We have estimated the impact of disaggregated and aggregated infrastructure on aggregate economic activity and as well as on sub sector (industry, agriculture, and services), using empirical model described in Chapter 5.

6.2.1 Unit root test and structural breaks

Time series properties of the variables are of great importance for econometric modeling, as well as for the associated statistical analysis. Granger and Newbold (1974) suggested that ignoring the time-series properties of the variables under study, may lead to misleading conclusions, when modeling relationships between variables. Therefore, unit root tests and cointegration relationships of the variables of interest become an important concern for econometricians.

Following standard practice in time series econometrics, we start our empirical analysis with stationarity test of the data. Augmented Dickey-Fuller (ADF), Phillip-Parron (PP) and Kwiatkowski-Phillips-Schmid-Shin (KPSS) tests have been employed to test the time series properties of the data. Results of all the three unit root tests are reported in Table 6.1 (showing a physical measure of infrastructure) and Table 6.2 (showing results of unit root test for infrastructure investment). Results reveal that all the series included in the analysis are first difference stationary. The null hypothesis of non-stationarity or unit root for all variables cannot be rejected, even at 10% level of significance and at first difference null hypothesis of unit root is rejected at 1 % level of significance. However, the null hypothesis of a unit root for energy generation capacity variable is rejected at 10% level of significance. These results are also established by the Kwiatkowski-Phillips-Schmid-Shin (KPSS) test in which the null hypothesis is stationary.

Table 6.1 Unit Root Test of Infrastructure Capital

Variables Name	Level			First Difference		
	ADF	PP	KPSS	ADF	PP	KPSS
Aggregate Economy						
GDP	-1.64	-1.48	0.77	-10.4^{a}	-9.61^{a}	0.23^{a}
Capital Stock	-1.99	-1.99	0.39	-6.98^{a}	-6.97^{a}	0.21^{a}
Human Capital	-2.0	-2.26	0.77	-6.56^{a}	-6.57^{a}	0.06^{a}
Energy	-2.69^{c}	-2.75^{c}	0.74	-6.48^{a}	-6.62^{a}	0.07^{a}
Roads	-1.60	-1.54	0.69	-7.74^{a}	-7.63^{a}	0.15^{b}
Telel	2.02	1.83	0.77	-3.73^{b}	-3.66^{b}	0.48^{a}
Industrial Sector						
GDP	-1.43	-1.45	0.19	-6.95^{a}	-6.95^{a}	0.08^{a}
Capital Stock	-151	-1.47	0.38	-6.28^{a}	-6.29^{a}	0.31^{a}
Human Capital	-0.87	-1.02	0.69	-5.27^{a}	-5.37^{a}	0.08^{a}
Energy	-2.25	-1.97	0.70	-7.04^{a}	-6.27^{a}	0.52^{b}
Roads	-2.43	-1.25	0.61^{b}	-6.06^{a}	-6.42^{a}	0.34^{b}
Telel	-1.44	-1.42	0.74	-3.52^{b}	-3.39^{b}	0.45^{b}
Agriculture Sector						
GDP	1.93	1.94	0.15	-6.92^{a}	-7.37^{a}	0.27^{a}
Capital Stock	2.41	-2.41	0.77	-6.14^{a}	-7.61^{a}	0.17^{a}
Human Capital	-1.94	-1.94	0.81	-5.47^{a}	-5.41^{a}	0.06^{a}
Energy	-2.92^{c}	-2.82^{c}	0.76	-5.08^{a}	-5.07^{a}	0.61^{b}
Roads	-1.88	-1.73	0.74	-5.69^{a}	-5.82^{a}	0.44^{b}
Telel	-1.81	-1.70	0.77	-4.14^{b}	-4.10^{b}	0.48^{b}
Service Sector						
GDP	-2.69	-2.55	0.16	-8.57^{a}	-8.69^{a}	0.27^{a}
Capital Stock	-3.37	-1.82	0.69	-5.60^{a}	-5.27^{a}	0.18^{a}
Human Capital	-2.13	-2.23	0.72	-6.22^{a}	-6.22^{a}	0.06^{a}
Energy	-3.05^{b}	-2.96^{c}	0.74	-7.43^{a}	-7.36^{a}	014^{b}
Roads	-1.35	-1.59	0.68^{a}	-3.68^{a}	-8.43^{a}	0.33^{a}
Telel						

Note a, b, c indicate reject the non-stationarity of the series at 1 , 5 and 10percent level of significance.

Table 6.2 Unit Root Test Infrastructure Investment

	Level			First Difference		
	ADF	PP	KPSS	ADF	PP	KPSS
Aggregate Economy						
Aggregate Investment	-2.46	-2.38	0.23	-7.03[a]	-7.34[a]	0.12[a]
Public Investment	-2.4	-4.15[c]	0.2	-6.67[a]	-6.77[a]	0.05[a]
Private Investment	-2.58	-2.59	0.11	-7.1[a]	-7.09[a]	0.06[a]
Electricity	-2.41	-2.3	0.19	-7.8[a]	-7.82[a]	0.06[a]
Roads & Telecommunication	-2.31	-2.42	0.12	-5.62[a]	-6.55[a]	0.22[a]
Industry						
Aggregate Investment	-1.87	-1.83	0.19	-6.36[a]	-6.44[a]	0.30[a]
Public Investment	-2.11	-2.03	0.21	-6.39[a]	-6.44[a]	0.31[a]
Private Investment	-2.33	-2.41	0.12	-6.35[a]	-6.36[a]	0.13[a]
Electricity	-2.12	-2.03	0.19	-7.36[a]	-7.37[a]	0.06[a]
Roads & Telecommunication	-1.54	-1.39	0.13	-5.8[a]	-5.76[a]	0.20[a]
Agriculture						
Aggregate Investment	-2.03	-2.15	0.19	-6.73[a]	-6.94[a]	0.33[a]
Public Investment	-2.55	-2.52	0.21	-6.72$_{a}$	-6.82[a]	0.35[a]
Private Investment	-2.45	-2.51	0.11	-6.31[a]	-6.31[a]	0.11[a]
Electricity	-2.44	-2.43	0.19	-7.39[a]	-7.4[a]	0.23[a]
Roads & Telecommunication	-2.25	-2.36	0.74	-5.82[a]	-7.01[a]	0.23[a]
Services						
Aggregate Investment	-2.29	-2.22	0.22	-6.55[a]	-7.12[a]	0.32[a]
Public Investment	-2.4	-2.32	0.21	-6.46[a]	-6.53[a]	0.30[a]
Private Investment	-2.67	-2.68	0.12	-6.49[a]	-6.49[a]	0.11[a]
Electricity	-2.41	-2.36	0.19	-7.41[a]	-7.42[a]	
Roads & Telecommunication	-3.46[b]	-2.62	0.69	-6.35[a]	-8.81[a]	0.31[a]

*. Used in investment model, is calculated by subtracting the capital stock of power, transport, and road from total capital stock. Note a, b, c denotes significance at 1%, 10% and 5% level of significance.

A noticeable feature of macroeconomic time series data is the presence of structural breaks in the data and these breaks in data often play a decisive role in economic policy analysis. Literature criticizes the standard unit-root tests to disregard the possible existence of structural breaks in the series and low power of the tests (Ferreira and León-Ledesma, 2007). Perron(1989) showed that the results of standard unit root test may be biased towards the non-rejection of a unit root due to the presence of breaks in the data. To deal with the problem of existence of a structural break in the data, the present study uses a structural break unit root test that identifies the breaks in data endogenously. Results of structural break unit root tests are presented in Table 6.3. These tests indicate that the most significant structural breaks in different series occurred in 1994, 1996, 1998, 2002, 2003, 2004 and 2005.

The structural breaks are observed during 1990s and reflect national and international factors which affect the economic performance of the country. National factors include poor governance, political instability and frequent changes in political regimes with two to three years of average lifespan. The first structural break of 1994 in the data reflects the impact of pest attacks on the agriculture sector, political instability, and viral attacks on crops, electricity crisis and a devastating flood in the country. During this period economy of Pakistan performed below its potential: its GDP growth declined sharply and balance of payment crisis up surged due to the widened current account balance. At that time the country failed to attract foreign investment to boost the economy. Since early 1990s, the gap between demand and supply of electricity widened, resulting in prolong load shedding. To combat the electricity shortage, in 1994, the government encouraged private sector to invest in energy infrastructure, and as a result, the Private Power and Infrastructure Board (PPIB) was established. Government articulated a long-term energy development plan through the involvement of a public-private partnership, to enhance the power generation capacity.

Table 6.3 Structural Break Unit Root Test: Infrastructure Capital

Variables Name	Level		First Difference	
	ADF-Stat	Break Year	ADF-Stat	Break Year
Aggregate Economy				
GDP	-4.76	1994	-11.3[a]	1993
Capital Stock	-4.98[c]	1998	-8.30[a]	2009
Human Capital	-3.55	1998	-7.39[a]	1992
Electricity	-4.19	1996	-8.72[a]	1998
Roads	-4.53	1998	-10.77	1990
Telec	-4.79	2003	-6.54	2012
Industry Sector				
GDP	-3.59	1990	-7.94[a]	1994
Capital Stock	-4.15	2001	-6.96[a]	2009
Human Capital	-4.65	1990	-6.12[a]	1994
Electricity	-4.02	1990	9.61[a]	1994
Roads	-4.56	2002	-6.45[a]	1996
Telec	-1.32	2006	-5.45[a]	2012
Agriculture Sector				
GDP	-4.48	1990	-7.67[a]	1996
Capital Stock	-3.28	1991	-6.81[a]	2000
Human Capital	-7.55[a]	1990	-	-
Electricity	-3.87	1990	-6.97[a]	2007
Roads	-3.14	1990	-8.22[a]	1991
Telec	-1.65	2001	-6.44[a]	2012
Service Sector				
GDP	-4.23	1996	-9.17[a]	2002
Capital Stock	-4.41	1985	-6.64[a]	2008
Human Capital	-3.27	1996	-7.40[a]	1992
Electricity	-4.53	1991	-9.09[a]	2014
Roads	-4.46	2002	12.3[a]	1986
Telec	-1.39	2011	-6.70[a]	2012

Note a, b, c indicate reject the null hypothesis of unit root at 1 %, 5% and 10% level of significance

Hydropower was also opened to the private sector in 2003. In 1998, as an aftermath of a nuclear test, economic sanctions were imposed, and the government froze foreign currency account. This caused a substantial decrease in workers' remittances, exports earning, aid and other capital inflows.

As a consequence, GDP growth, private investment and external sector were severely affected. Structural breaks unit root test, reported in Table 6.3, reveals that all variables except human capital in the agriculture sector are first difference stationary. The null hypothesis of unit root with structural break cannot be rejected at the level and can be rejected at first difference, even at 1 % level of significance. However, the null hypothesis of a unit root for human capital in agriculture sector is not rejected at level.

Structural breaks unit root test of infrastructure investment variables, reported in Table 6.4, reveals that all series are non-stationary at the level and stationary at first difference. The null hypothesis of unit root with structural break cannot be rejected at the level and can be rejected at first difference, even at 1 % level of significance. However, the null hypothesis of a unit root for human capital in agriculture sector is not rejected at level.

Table 6.4 Structural Break Unit Root Test of Infrastructure Investment

	Aggregate Eco		Industry		Agriculture		Services	
	ADF-Stat	Break Year	ADF-Stat	Break Year	ADF-Stat	Break Year	ADF-Stat	Break Year
	Level							
Aggregate Inv.	-4.88	1998	-3.74	1999	-3.91	1999	-3.98	1994
Public Inv.	-4.10	1999	-5.77[a]	1994	-4.36	1990	-6.29[a]	1999
Private Inv.	-3.92	1994	-3.23	2004	-3.99	2004	-4.49	2007
Electricity	-4.21	1994	-4.43	1994	-4.15	1994	-3.84	1996
Tele	-5.68[b]	2003	-6.02[a]	2005	-5.26[c]	2005	-5.68[c]	2003
	First Difference							
Aggregate Inv.	-7.93[a]	1998	-6.83[a]	2005	-7.31[a]	1999	-6.82[a]	2008
Public Inv.	-7.35[a]	2003	--	--	-7.41[a]	2000	--	--
Private Inv.	-8.62[a]	1999	-7.94[a]	1999	-7.86[a]	1999	-7.98[a]	1999
Electricity*	-9.14[a]	2004	-8.65[a]	2004	-8.76[a]	2004	-8.68[a]	2004
Telec**	--	--	--	--	--	--	--	--

a, b, c denotes significance at 1%, 5% and 10% level of significance. * Public and private sector investment in electricity generation distribution, gas distribution, ** Public and Private sector investment in road transport and telecommunication

6.2.2 Physical Measure of Infrastructure: Cointegration Relationship

To establish that the dependent variable is structurally related to infrastructure and other explanatory variables, FMOLS methodology is employed. FMOLS technique is appropriate to deal with the problem of non-stationary regressors and the problem of simultaneity bias, due to endogeneity of infrastructure variable on the right-hand side of the equation. After estimation of FMOLS, we employ, Engle-Granger and Phillips-Ouliaris residual-based test of cointegration to identify the long run relationship among the variable of interest and Hansen's instability test to check parameter stability. We also employ Johansen maximum likelihood cointegration test, and the results are reported in Table 6.5 and 6.6.

Table 6.5 Co-integration Tests; Infrastructure Capital

	Whole Economy	Industrial Sector	Agriculture Sector	Services Sector
Engel Granger Tau stat	-5.6 [0.035]	-5.7 [0.015]	-4.9 [0.076]	5.6 [0.0353]
Engle Granger Z stat	-37.4 [0.0296]	-37.1 [0.014]	-33.1 [0.045]	37.3 [0.0296]
Phillips and Ouliaris Tau	-5.7 [0.0292]	-5.7 [0.0139]	-4.84[0.085]	5.7 [0.0292]
Phillips and Ouliaris Z test	-38.7 [0.0202]	-34.7 [0.028]	-29.7[0.092]	38.7 [0.0202]
Hansen Parameter Instability	1.2 [0.0125]	0.58 [0.200]	0.98 [0.0688]	1.2 [0.0125]

Note: p values are given in [ ]

Results of Engle-Granger and Phillips-Ouliaris residual-based tests, reported in Table 6.5, show that the null hypothesis (stating that series are not cointegrated) is rejected in all cases. We also use Johansen maximum likelihood cointegration test to identify the cointegration relations among the variables under investigation and the results are reported in Table 6.6. The trace statistic and maximum eigenvalue statistics reject the null hypotheses of no cointegration for aggregate economy and as well as for the three sub sectors. The results of trace statistic and maximum eigenvalue statistic show that cointegration relations existed in all the cases and we found two significant coingrating relations for the aggregate economy and one for all the sub-sectors.

Table 6.6 Johansen Co-integration Tests; Infrastructure Capital

	Trace Statistic					
	r=0 (107.3)	r≤1 (79.34)	r≤2 (55.24)	r≤ 3 (35.0)	r≤4 (18.4)	r ≤5 (3.8)
Whole Economy	135.6*	88.04*	53.44	26.41	10.54	0.28
Industrial	151.5*	95.9*	58.1	28.8	10.9	3.1
Agriculture	136.2*	87.8*	51.7	21.7	11.9	2.7
Service	150.6*	98.5*	53.2	28.7	9.3	0.04
Maximum Eigenvalue Statistic						
	r=0 (43.4)	r≤1 (37.2)	r≤2 (30.8)	r≤ 3 (24.2)	r ≤4 (17.1)	r≤5 (3.8)
Whole Economy	47.5*	34.6	27	15.9	10.3	0.28
Industrial	55.5*	37.9*	29.2	17.8	7.8	3.1
Agriculture	48.3*	36.1	30.1	9.8	7.2	2.6
Service	52.1*	45.3*	24.5	19.2	9.2	0.04

Note: r represents the number of co-integrating vectors. Schwarz criterion has been used to select optimal lag lengths. Numbers in the brackets denote the critical values at 5% level of significance. * indicates rejection of the null hypothesis of no co-integration at 5% level of significance.

6.2.3 Infrastructure capital and Aggregate Economy

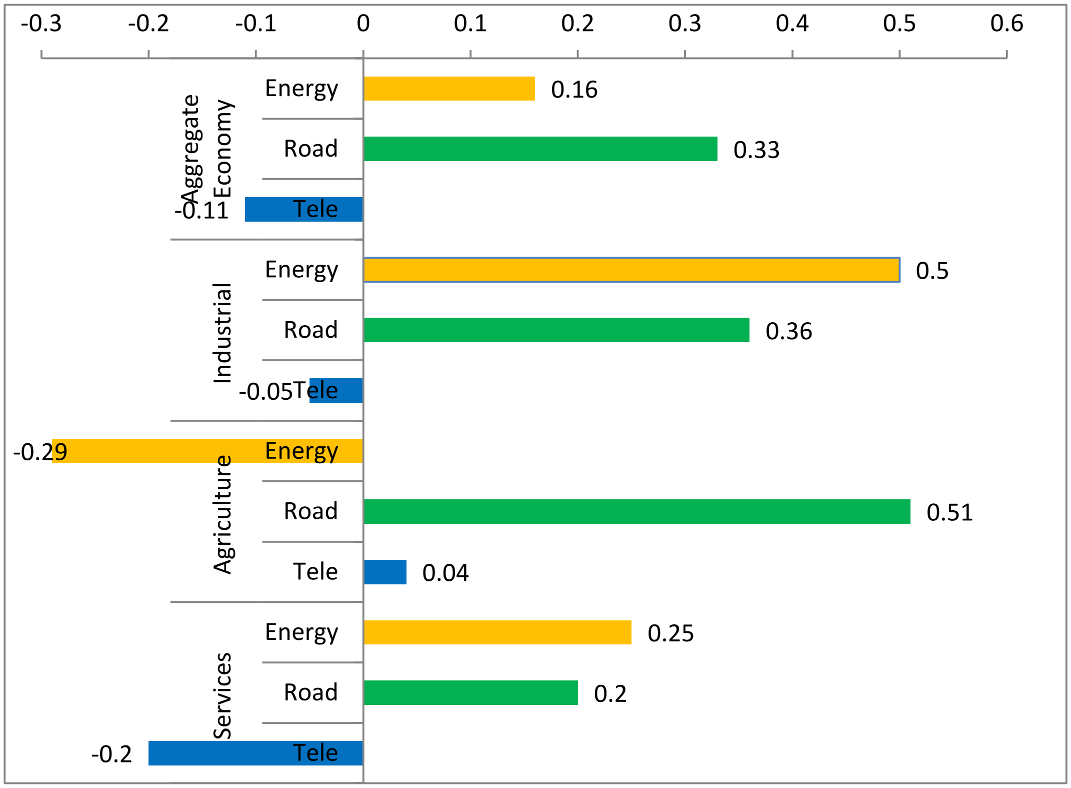
The aggregate analysis is an important step as it is consider as benchmark for overall effects of public and private infrastructure investment. After establishing a cointegration relationship between output per worker and infrastructure variables, we now turn to estimate the impact of infrastructure on output per worker. Three different estimations have been performed for the whole economy as well as for sectoral analysis, (1) for individual infrastructure by types, to avoid potential aggregation misspecification (2) composite index of infrastructure, using data of transportation, communication and the power sector to allow for a systematic and comprehensive measurement of overall infrastructure and (3) quality of infrastructure. The structural breaks are also introduced in the estimation to capture the changes observed in time series data of infrastructure variables and output per workers. Empirical results for the whole economy are reported in Table 6.7.

Table 6.7 Individual Infrastructure stock: Dependent Variable GDP per Worker

	Whole Economy		Industrial		Agriculture		Services	
	WOSB	WSB	WOSB	WSB	WOSB	WSB	WOSB	WSB
Capital Stock	0.19[a]	0.18[c]	-0.07[a]	-0.08[a]	0.04[a]	0.05[a]	0.04	0.08[a]
	(4.38)	(4.72)	(-2.80)	(-7.58)	(1.90)	(3.63)	(0.58)	(4.30)
Human Capital	0.08[a]	0.09[a]	0.17[a]	0.23[a]	0.15[a]	0.19[a]	0.15[b]	0.18[a]
	(2.62)	(3.03)	(2.63)	(9.43)	(2.75)	(5.96)	(1.98)	(7.38)
Energy	0.15[a]	0.16[a]	0.50[a]	0.50	-0.29[a]	-0.29[a]	0.27[b]	0.25[a]
	(3.48)	(4.14)	(13.1)	(33.1)	(-3.41)	(-5.86)	(2.37)	(6.63)
Roads	0.33[a]	0.33[a]	0.34[a]	0.36	0.53[a]	0.51[a]	0.17	0.20[a]
	(8.20)	(9.35)	(4.87)	(13.4)	(5.91)	(9.64)	(1.45)	(5.21)
Tele	-0.11[a]	-0.11[a]	-0.03[a]	-0.05	0.05[a]	0.04[a]	-0.21[a]	-0.20[a]
	(-6.06)	(-7.00)	(-1.17)	(-4.93)	(1.88)	(2.91)	(-5.40)	(-14.9)
Constant	6.35[a]	6.39[a]	4.67[a]	3.88	5.37[a]	5.14[a]	9.03[a]	7.88[a]
	(21.5)	(22.7)	(7.81)	(16.6)	(9.97)	(16.6)	(6.71)	(17.7)
Trend	0.01[a]	0.01[a]					0.01[a]	
	(7.41)	(8.23)					(5.53)	
Structural Break		0.13[a]		-0.02		-0.02[a]		-0.03
		(2.04)		(-3.57)		(-2.12)		(-1.43)
R^2	0.99	0.99	0.99	0.99	0.97	0.97	0.97	0.97
Adj R^2	0.99	0.99	0.99	0.99	0.97	0.97	0.97	0.97

Note: t values are given in brackets and , WOSB stands for without structural break and WSB stand for with structural break, a, b, c denotes significance at 1%, 5% and 10% level of significance

Figure 6.1 Summary of Estimated Coefficients of Energy, Road and telecommunication



Results show that the marginal contribution of infrastructure varies with different types of infrastructure. The traditional variables, such as capital stock and human capital have positive and statistically significant parameters values. The elasticity of capital stock is 0.18 for estimation with structural breaks and is 0.19 for equation without structural breaks. In both cases, coefficients are statistically significant at 1% level of significance. According to (Bom & Ligthart, 2008) output elasticity of public capital is 0.15 for meta-analysis of 67 studies. The coefficient of human capital is 0.09, and it is statistically different from zero. The results obtained for the human capital, measured by secondary school enrolment ratio to the total labor force, are in line with earlier estimates in the literature. For example, (Topel, 1999) found the coefficient of human capital measure by average years of secondary schooling, ranges from 0.092 to 0.276 for panel data of 111 countries over 30 years. (Calderón et al., 2015) found the coefficient of human capital measure by secondary education is 0.10 for the Spanish economy.

Marginal contribution of road infrastructure and energy generation to GDP is positive and significant at 1% level of significance, while telecommunication infrastructure is negatively associated with GDP per worker. One percent increase in the paved road will increase the real GDP per workers by 0.33 percent and one percent increase in electricity production will increase real GDP per workers by 0.16 percent. Similarly, one percent increase in telecommunication infrastructure will reduce the real GDP by 11 percent, and this negative relationship is statistically significant. Since 2000, the usage of the cell phone has increased even faster than that of telephone, and this is the main cause of the negative association between telecommunication and real GDP. Electricity and road infrastructure seem to be strongly correlated to economic performance in the country. It is observed that the impact of roads infrastructure on real GDP per worker is larger than the impact of electricity production. The immediate effect of new infrastructure such as energy, transport, and communication boosts economic output. The direct effect of infrastructure is raising the productivity of lad, labour, and other physical capital. For example when electricity supply disruption are eliminated or available hours increased firms respond with greater supply. Removing infrastructure constraints, such as power outages, problematic access to the road network and communication, can facilitate the transfer of private resources to a more productive sector. Our results align with other literature on the subject. A growing body of empirical and theoretical literature predicts a positive relationship between physical networks of infrastructure and economic activities. According to endogenous growth theory, the stock of infrastructure can escalate long-term rate of economic growth, enduringly through spillover effects of other factors of production (Barro and Sala-i-Martin, 1995). The survey of the empirical literature on the subject carried out by (Straub, 2008b) also supported the positive and significant association of infrastructure with economic growth. Electricity network, road, telecommunication infrastructure have sturdiest growth influence (Canning and Pedroni 2004, Calderon and Serven 2004).

6.2.4 Infrastructure capital and sub-sector of the economy

In this section, we present the empirical analysis of the impact of disaggregated infrastructure by type of infrastructure, including road, energy and telecommunication on sub-sector of the economy. The objective is to see whether the growth impact of disaggregated infrastructure is uniform across the sub-sector of the economy or not. Mainly our focus is to examine the marginal contribution of each type of infrastructure (roads, energy, and telecommunication) on output growth of industrial, agriculture and services sector. The elasticity of the human capital variable is positive and statistically different from zero, at 1% level of significance for all the three sectors of the economy. The highest elasticity is recorded in the industrial sector (0.23) than in the agriculture (0.19) and services sector (0.18), when the structural break is introduced in our regression model. The coefficients of the human capital, variable with structural break, are slightly higher for all the three sectors of the economy than those of corresponding coefficients without structural breaks (See Table 6.7).

The magnitude of the type of infrastructure varies across different sectors of the economy. Results of sectoral analysis reveal that the stock of road infrastructure is positively associated with the output of all the three sectors of the economy. The marginal contribution of road infrastructure is highest in the agriculture sector (0.51) than in the industrial sector (0.36) and in the service sector (0.20). The results obtained in this study, with respect to the type's infrastructure are consistent with those of (Cantos et al., 2005), for the Spanish economy. In Cantos et al. (2005), the elasticity of agriculture output with respect to stock of road is 0.124, the elasticity of industry with respect to stock of road infrastructure is 0.067 and elasticity for services sector is 0.013. The high size of the elasticity in our case can be justified on the basis that at the initial stage of development, when infrastructures stock is relatively small, the impacts of an increase in infrastructure are relatively high (Hulten and Schwab, 1993). Marginal contribution of electricity generation is positive and statistically significant for industrial and services sector, while it is negatively associated with the agriculture sector. The highest contribution of power generation infrastructure is in the industrial sector (0.50) than in services sectors (0.25). Telecommunication infrastructure is favorable only for the agriculture sector while it is negatively associated with industrial and services sector.

6.2.5 Aggregate Infrastructure and Economic Growth

Results of the aggregate index of infrastructure are placed at lower panel of Table 6.8. The signs of the standard growth variables, i.e. non-infrastructure capital and human capital are positive and significant. When the aggregate index of infrastructure is introduced, the magnitude of the coefficient of capital stock increases from 0.18 to 0.32 and the coefficient of human capital increases from 0.09 to 0.40.

The estimated coefficient of capital stock is 0.32, close to those reported in the previous empirical macroeconomic literature. For example, a study by Calderon et al. (2014) on the Spanish economy found the coefficient of capital stock 0.34. Mankiw et al.(1992)

estimated the elasticity of capital stock as 0.31 for non-oil countries, and 0.29 for intermediate countries and 0.14 for OECD countries. The elasticity of human capital is 0.40 which is slightly higher than that estimated by Mankiw et al. (1992). Their estimates of human capital are 0.23 for non-oil countries, 0.27 for intermediate countries and 0.22 for OECD countries.

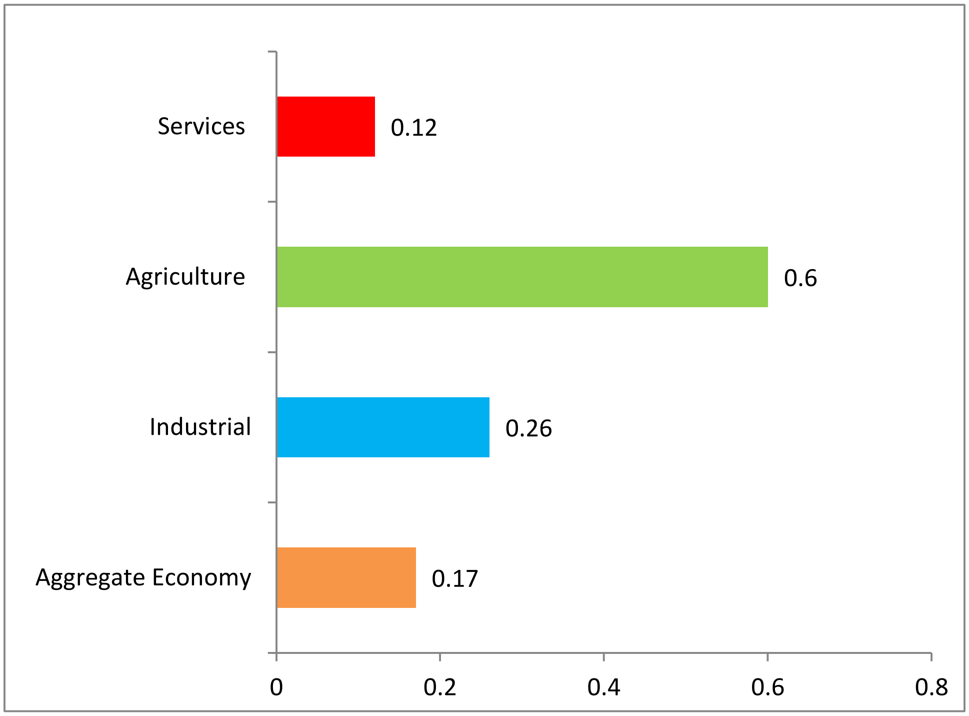
Table 6.8 Aggregate Measure of Infrastructure Variables

	Whole Economy		Industrial		Agriculture		Services	
	WOSB	WSB	WOSB	WSB	WOSB	WSB	WOSB	WSB
Capital Stock	0.34[a]	0.33[a]	0.05	0.05 [c]	-0.04	-0.04	0.46 [a]	0.28[a]
	(5.85)	(5.42)	(0.76)	(1.72)	(-1.66)	(-1.56)	(4.17)	(5.29)
Human Capital	0.28[a]	0.29[a]	0.45[b]	0.51[a]	0.25[b]	0.25[b]	0.44[b]	0.36[a]
	(3.73)	(3.74)	(2.36)	(6.23)	(2.71)	(2.71)	(2.42)	(4.15)
Infrastructure	0.17[a]	0.17[a]	0.27a	0.26[a]	0.17[a]	0.16[c]	0.03	0.12[a]
	(6.98)	(6.96)	(4.22)	(9.61)	(5.61)	(5.03)	(0.53)	(4.16)
Constant	3.35[a]	3.25[a]	1.95	1.42[c]	6.59[a]	6.67[a]	1.49	3.42[a]
	(4.49)	(4.27)	(0.97)	(1.68)	(8.13)	(8.35)	(0.76)	(3.62)
Structural Break		-0.05[b]		0.10[b]		-0.02		-0.01
		(-2.54)		(5.22)		(-0.73)		(-0.42)
R^2	0.95	0.96	0.95	0.93	0.96	0.95	0.91	0.95
Adj R^2	0.95	0.95	0.94	0.92	0.95	0.95	0.91	0.95

Note: t values are given in brackets and WOSB stands for without structural break and WSB stand for with structural break. a, b, c denotes significance at 1%, 5% and 10% level of significance

Aggregate index of infrastructure and real GDP are positively associated. An increase in the aggregate index of infrastructure is associated with a 0.14 percent increase in the real GDP per worker. Our estimate of infrastructure index is slightly higher than that of Calderon et al. (2015) estimates (0.08). They construct the infrastructure index by using the same variables, roads, electricity generation and telecommunication.

Figure 6.2 Summary of Estimated Coefficient of Aggregate Infrastructure



6.2.6 Empirical Estimates of Quality of Infrastructure

The results of quality of infrastructure services are reported in Table 6.9. Paved roads and electricity power transmission and distribution loss are used as quality of road infrastructure and electricity provision, respectively. According to these results, the quality of roads infrastructure has positive while the quality of electricity generation has a negative association with real GDP per worker. One percent increase in quality of road infrastructure would increase the real GDP by 0.36 percent for our preferable model. The findings of sub-sector of the economy show that paved road infrastructure has a higher positive impact in the industrial sector (0.38) than in the service sector (0.19) and agriculture sector (0.11). One percent increase in paved roads increases industrial output by 0.38%, the services sector GDP by 0.19% and 0.11% agricultural GDP. An electric power transmission and distribution loss has negative and statistically significant relation with industrial and services sector GDP, while it has a positive and statistically significant impact on agriculture GDP. Reducing power transmission and distribution loss by 1%, increases the industrial GDP by 8%, services sector GDP by 16 % and aggregate economy by 6 %.

Interestingly power transmission and distribution loss has a positive impact on agriculture GDP. This may be due to electricity theft in the agriculture sector. These results are in line with the findings of (Ismail & Mahyideen, 2015) and (Calderón et al., 2015).

Table 6.9 Quality of Infrastructure stock: Dependent Variable GDP per Worker

	Aggregate Economy		Industrial		Agriculture		Services	
	WOSB	WSB	WOSB	WSB	WOSB	WSB	WOSB	WSB
Capital Stock	0.56[a]	0.51[a]	0.28[a]	0.23[a]	0.12	0.12	0.34[a]	0.29[a]
	(6.15)	(16.6)	(4.5)	(20.5)	(1.35)	(1.33)	(5.04)	(10.8)
Human Capital	0.13	0.17[a]	0.45[a]	0.48[a]	0.42a	0.45[a]	0.22	0.24[a]
	(0.92)	(3.69)	(3.09)	(18.6)	(3.18)	(3.47)	(1.45)	(3.95)
Energy	0.05	-0.06[b]	-0.08	-0.08[a]	0.35[a]	0.29[a]	-0.21[b]	-0.16[a]
	(0.65)	(-2.04)	(-0.50)	(-2.95)	(4.22)	(3.40)	(-1.98)	(-4.02)
Roads	0.38[a]	0.36[a]	0.36[a]	0.38[a]	0.15[c]	0.11	0.16[b]	0.19[a]
	(5.29)	(15.2)	(4.59)	(26.9)	(1.75)	(1.31)	(2.39)	(7.37)
Constant	4.37[a]	4.4[a]	2.73	2.79[a]	3.47[b]	3.25[b]	0.38[b]	6.59[a]
	(3.47)	(10.2)	(1.6)	(9.21)	(2.84)	(2.63)	(2.89)	(7.58)
Structural Break		0.006		0.08[a]		-0.04		0.01
		(0.625)		(12.2)		(-1.44)		(1.01)
R^2	0.97	0.97	0.96	0.95	0.95	0.95	0.95	0.95
Adj R^2	0.97	0.96	0.95	0.94	0.94	0.94	0.94	0.94

Note: t values are given in brackets and WOSB stands for without structural break and WSB stand for with structural break. a, b, c denote significance at 1%, 5% and 10% level of significance

In summary, infrastructure provision is considered as an essential input in the production process. As power supply is an essential input for production and consumption, road and transport networks link the producers and consumers to markets, and telecommunication linkages help in exchange of information and dissemination of knowledge. On the other hand, insufficient availability of infrastructure in any economy, such as power outages, nonexistence or dilapidated of road networks may adversely affect output in the economy and cause a significant barrier in the development process.

6.3 Investment and Economic Growth

The earlier empirical literature on growth impact of infrastructure investment show mixed results. In this section we examine the impact of public spending on infrastructure on economic growth at the aggregate and sectoral levels, namely industrial, agricultural and services sector, using empirical model described in Chapter 5.

The public infrastructure investment is further split into private and public investment, in order to see the separate impact of this investment on the whole economy and as well as on sectoral components of GDP. First, we investigate the impact of aggregate infrastructure investment on aggregate and sub-sector of the economy. From aggregate investment in infrastructure, we mean sum of the investments in roads, telecommunication and power sector. In the second stage, we split the investment in infrastructure capital into public sector investment and private sector investment. In the third stage we analyze the separate impacts of investment in roads, telecommunication, and power.

6.3.1 Infrastructure investment: Cointegration Relationship

Johansen maximum likelihood cointegration test, reported in Table 6.10, rejects the null hypothesis of no cointegration for aggregate economy and as well as for the three sub-sectors of the economy in all cases.

Table 6.10 Johansen Co-integration Tests; Infrastructure Investmnet

	Trace Statistic				
	r=0 (63.8)	r≤1 (42.9)	r≤2 (25.8)	r≤ 3 (12.5)	
Aggregate Investment in Infrastructure					
Aggregate Economy	76.4*	33.5	16.5	6.5	
Industrial	63.97*	31.9	16.8	6.2	
Agriculture	64.2*	23.6	11.1	2.9	
Service	65.2*	31.2*	15.5	3.7	
	r=0 (88.8)	r≤1 (63.9)	r≤2 (42.9)	r≤ 3 (25.9)	r≤ 3 (12.5)
Public – Private Investment in Infrastructure					
Aggregate Economy	103.6*	58.5	25.9	10.4	4.2
Industrial	97.3*	46.3	26.3	14.6	4.7
Agriculture	92.3*	54.1	32.6	18.6	5.9
Service	98.4*	66.2*	35.7	15.9	4.8
Disaggregated Investment in Infrastructure by type of Infrastructure					
Whole Economy	120.5*	73.6*	43.2	16.8	4.2
Industrial	107.1*	53.7	27.1	13.6	5.2
Agriculture	104.1*	51.6	29.6	15.4	5.8
Service	107.2*	64.2*	36.1	17.3	4.3
Maximum Eigenvalue Statistic					
	r=0 (32.1)	r≤1 (25.8)	r≤2 (19.4)	r≤ 3 (12.5)	
Aggregate Investment in Infrastructure					
Aggregate Economy	42.9*	16.9*	9.9	6.5	
Industrial	33.2*	15.1	10.7	6.2	
Agriculture	36.6*	12.6	8.2	2.9	
Service	30.9	15.7*	11.8	3.7	
	r=0 (38.3)	r≤1 (32.1)	r≤2 (25.8)	r≤ 3 (19.4)	r≤ 3 (12.5)
Public – Private Investment in Infrastructure					
Aggregate Economy	45.2*	32.5*	15.5	6.2	4.2
Industrial	51.3*	19.9	11.6	9.95	4.7
Agriculture	38.2	21.4	14.0	12.6	5.9
Service	32.2	30.5	19.7	11.1	4.8
Disaggregated Investment in Infrastructure by type of Infrastructure					
Aggregate Economy	46.9*	30.4	26.5	12.6	4.2
Industrial	53.4*	26.6	13.4	8.4	5.2
Agriculture	52.5*	22.04	14.2	9.5	5.8
Service	43.02*	28.1	18.8	13	4.3

Note: r represents the number of co-integrating vectors. Schwarz criterion has been used to select optimal lag lengths. Numbers in the brackets denote the critical values at 5% level of significance. * indicates rejection of the null hypothesis of no co-integration at 5% level of significance

6.3.2 Growth Impacts of Aggregate Infrastructure Investment

We estimate the impact of public and private infrastructure investment on aggregate economy and sectoral output over the period from 1972 to 2015, using fully modified ordinary least squares (FOLS) methodology. We also incorporate the dummy for structural breaks in the data. Empirical results, reported in Table 6.11, show the effect of infrastructure investment on aggregate economy, industrial, agriculture and services sector economy. Marginal contribution of aggregate investment in infrastructure to real GDP per worker is positive and statistically significant for aggregate as well as for sub-sector, i.e., industrial, agriculture and services sectors. Almost in all models, estimated coefficients of investment in infrastructure are significant at 1 percent level of significance. However, the impact of aggregate infrastructure investment on aggregate and sub-sector of the economy shows very different estimates in terms of magnitude. The estimated elasticity of public infrastructure investment for the industrial sector (0.32) is higher than the agricultural sector (0.11) and in the services sector (0.06). Cantos et al., (2005), for Spanish economy, examined the impact of transport and road infrastructure on four different sectors of the economy, namely industry; agriculture, business services and construction and found larger elasticity in agriculture (0.124) than in industry (0.067) and the services sector (0.013).

6.3.3 Growth impacts of Public versus Private Infrastructure Investment

When total investment in infrastructure is disaggregated into the public, and private sector, positive and statistically substantial effects are attained in the case of public sector infrastructure investment for aggregate as well as for subsector of the economy. In the case of private infrastructure investment, statistically significant and positive estimates are obtained for industrial and agricultural sectors, while it is harmful for services sectors.

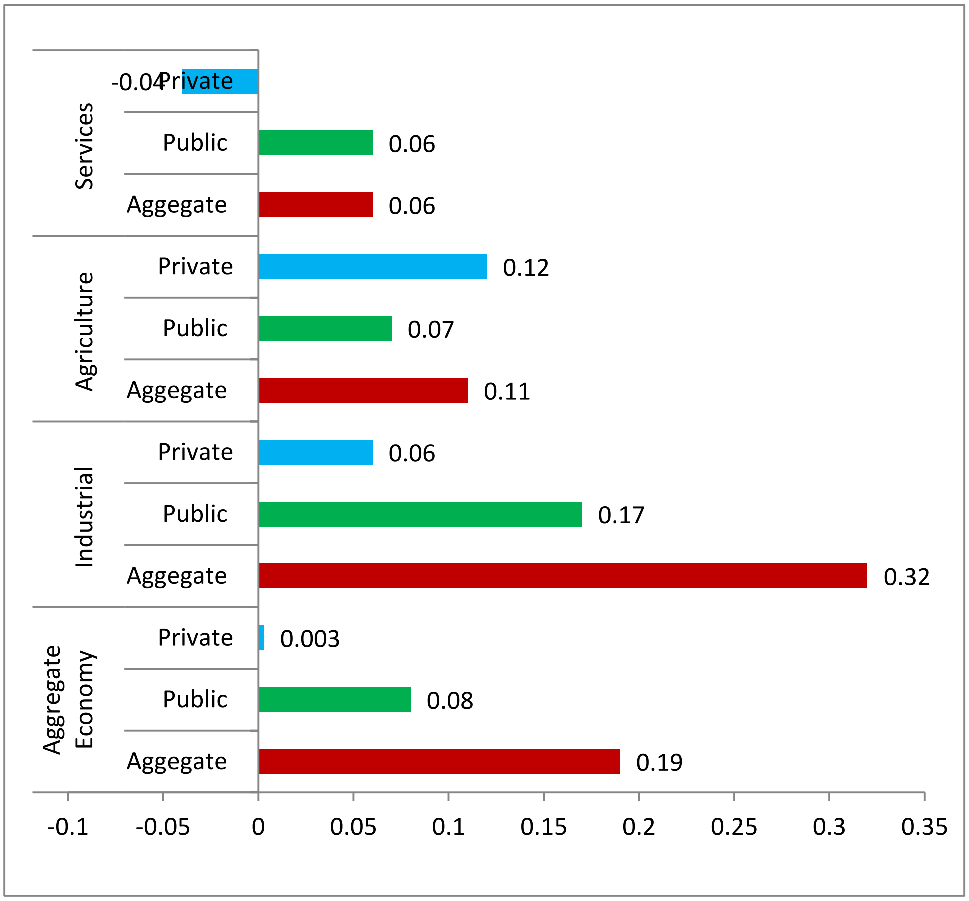
Impact of private infrastructure investment on the aggregate economy is statistically insignificant. Estimated elasticities of non-infrastructure capital stock are statistically insignificant for industrial and agriculture sector, while this is positive and significant for the services sector. The elasticity of human capital for aggregate and for all the three sub-sectors of the economy is positive and statistically different from zero for both specifications. In the case of aggregate investment in infrastructure, the magnitude of the elasticity of human capital is higher in agriculture sector (0.49) than industrial and services sector (0.28). When public and private investment is separately introduced in the regression equation, the highest elasticity of human capital is observed for industry (0.34) than in agriculture (0.29) and in the services sector (0.25).

Table 6.11 Aggregate Investment in Infrastructure: Public vs. Private
Dependent Variable GDP

	Aggregate Eco		Industrial		Agricultural		Services	
Capital Stock	0.03	0.08[b]	-0.02	-0.01	-0.03	-0.01	0.21[a]	0.12[a]
	(0.67)	(2.30)	(-0.28)	(-0.13)	(-1.20)	(-1.42)	(5.70)	(3.42)
Human Capital	0.21[a]	0.45[a]	0.28[b]	0.34[a]	0.49[a]	0.29[a]	0.28[a]	0.25[a]
	(3.01)	(9.63)	(2.47)	(3.47)	(6.91)	(10.1)	(4.15)	(4.98)
Aggregate Inv	0.19[a]		0.32[a]		0.11[a]		0.06 [a]	
	(6.97)		(4.83)		(2.96)		(2.58)	
Public		0.08[a]		0.17[a]		0.07[a]		0.06[a]
		(9.87)		(5.06)		(10.8)		(5.0)
Private		0.003		0.06[a]		0.12[a]		-0.04[b]
		(0.45)		(2.09)		(13.4)		(-2.84)
Constant	6.95[a]	4.89[a]	4.48[a]	4.51[a]	4.20[a]	5.92 [a]	5.62 [a]	7.30[a]
	(7.99)	(9.49)	(3.54)	(4.02)	(7.58)	(4.78)	(6.32)	(9.55)
Trend	-0.01[a]		0.01[a]	0.02[a]			0.01[a]	0.01[a]
	(-3.09)		(7.76)	(8.67)			(8.27)	(10.1)
Structural Break	0.05[a]	0.09[a]	0.07[a]	0.07[b]	-0.11[a]	-0.01	0.06[a]	0.02[c]
	(3.02)	(6.53)	(2.29)	(2.48)	(-4.43)	(-1.38)	(3.65)	(1.88)
R2	0.97	0.96	0.97	0.97	0.89	0.96	0.96	0.97
Adj R2	0.96	0.96	0.97	0.97	0.88	0.95	0.96	0.96

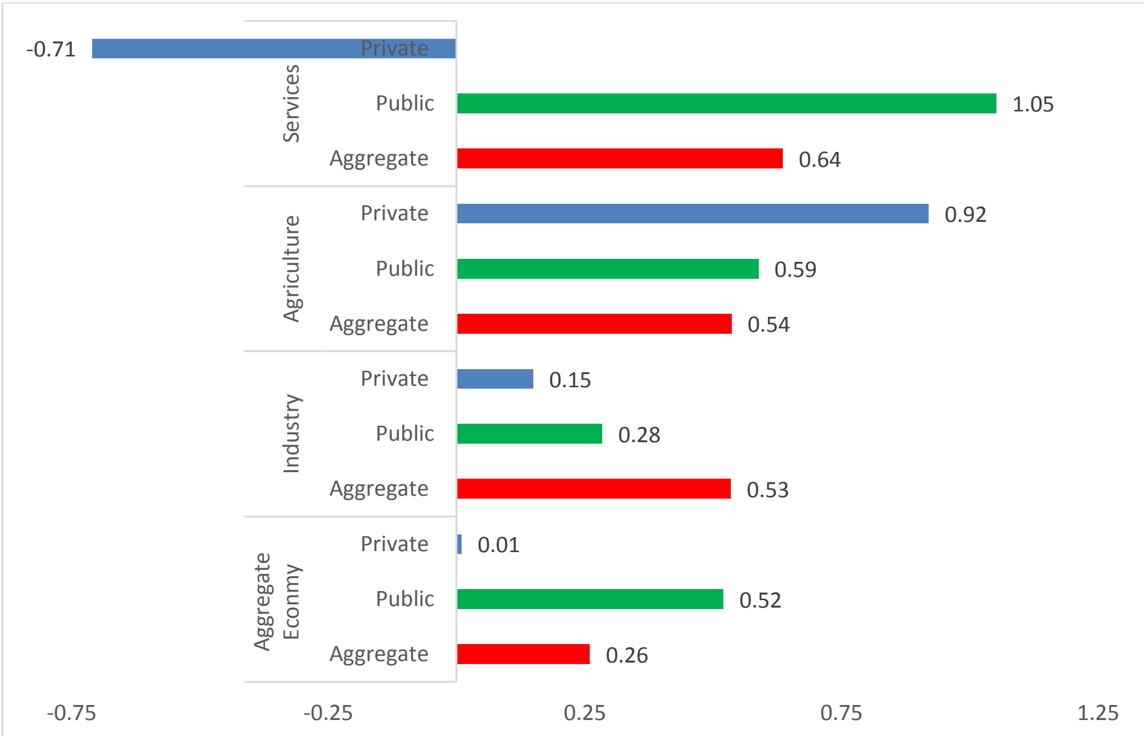
Note: t values are given in brackets a. a, b, c denotes significance at 1%, 5% and 10% level of significance

Figure 6.3 Summary of Estimated Coefficients of Aggregate, Public and Private Infrastructure Investments



The estimated coefficient of public sector infrastructure investment is higher than private sector infrastructure investment for aggregate economy and industrial sector, while it is less in the case of the agriculture sector. Both public and private infrastructure investments contribute to economic growth in Pakistan. However, public infrastructure investment seems to play a much important role in the industrial sector, while private infrastructure investment role is more significant in the agriculture sector. Our findings contradict with that of (Zou, 2006), who found that private investment contributes more to economic growth than making public investment in case of the USA.

Figure 6.4 Summary of Marginal Coefficients of Aggregate, Public and Private Infrastructure Investments



6.3.4 Growth impacts of a component of Infrastructure Investment

To examine the role of investment in infrastructure, by type of infrastructure, we disaggregate infrastructure investment into investment in electricity generation distribution, gas distribution and transport communication (results are reported in Table 6.12). By types of infrastructure investment, although the estimated elasticities of energy and road infrastructure are positive and statistically significant for aggregate economy and as well as for sub-sector of the economy, the results are very heterogeneous in terms of the magnitude of elasticity across the sectors. The marginal contribution of investment in road and telecommunication is higher than the marginal contribution of investment in the energy sector in correspondence to the sector, except for the services sector. The findings indicate that the infrastructure related energy, road and telecommunication have positive significant coefficients at 1 % significance level for different specifications. Impact of investment in electricity and gas distribution has the highest elasticity in the industrial sector (0.13) than in aggregate economy (0.09), while these elasticities are very small in agricultural (0.04) and services sectors (0.05).

Similarly, the elasticity of road and telecommunication investment is higher in the industry (0.22) than in agriculture (0.14) and in the service sector (0.03). The sectoral analysis reveals that investment in electricity and gas distribution, road and telecommunication network is highly crucial for the industrial sector in Pakistan. The empirical findings of this study are in line with many other studies that emphasize the role of infrastructures, such as the adequate provision of electricity, roads and telecommunication network. Our results for disaggregated infrastructure investment are in line with that of (Pereira, 2000). Pereira (2000) established that various forms of infrastructure investment have a positive and significant impact on economic growth. The high return was found in public, spending on gas, electricity, transportation systems, water supply and sanitation systems.

Telecommunication infrastructure assists producers, consumers, business and another stakeholder, to obtain relevant information and knowledge which can be referred to as growth enhancement. Provisions of road infrastructure enhance the economic growth, by reducing the traveling cost, time cost and by increasing labor mobility. Electricity is considered an essential input and the importance of electricity for economic growth is extensively discussed in the literature. Outage or deficiency of electricity can significantly reduce output.

Table 6.12 Investment in Infrastructure: Dependent Variable GDP per Worker

	Whole Economy	Industrial	Agricultural	Services
Capital Stock	0.20[b] (2.82)	0.02 (0.06)	0.12[a] (17.4)	0.20[a] (9.59)
Human Capital	0.40[a] (4.28)	0.28[a] (3.14)	0.18[a] (7.74)	0.26[a] (6.94)
Energy	0.09[a] (3.91)	0.13[a] (5.27)	0.04[a] (10.8)	0.05[a] (6.04)
Roads & Tele	0.12[b] (2.70)	0.22[a] (5.44)	0.14[a] (19.8)	0.03[b] (2.16)
Constant	4.39[a] (5.52)	5.78[a] (4.99)	19.9[a] (32.1)	6.43[a] (12.4)
Trend		0.01[a] (7.73)	0.01[a] (15.5)	0.01[a] (14.3)
Structural Break	0.02 (0.44)	0.06 (1.24)	0.03[a] (6.24)	0.04[a] (4.21)
R^2	0.96	0.97	0.98	0.96
Adj R^2	0.95	0.97	0.98	0.95

Note: t values are given in brackets a. a, b, c denote significance at 1%, 5% and 10% level of significance

Agénor and Moreno-Dodson (2006) argued that public investment in infrastructure may stimulate the productivity of labor and capital. Because of the reduction in the costs of inputs, the level of private production may rise. This scale effect may lead to higher private investment and thereby enhancing the production capacity. This implies that public investment in infrastructure is complementary to other investments and inadequate or insufficient infrastructure investments are constraints to other investments, particularly for private investors. Therefore, it restraints economic growth. The theoretical literature on infrastructure investment and economic growth pinpoints five significant channels through which investment in infrastructure boosts economic growth. These channels include (1) direct input in the production function (2) complementary to the other inputs (3) infrastructure investment may stimulate human capital accumulation (4) infrastructure investment may boost aggregate demand in the economy, through expansionary spending

(5) investment in infrastructure can also assist a tool to provide guidance for industrial policy; the government should try to initiate this channel by developing specific infrastructure projects, to boost industrial production in the country (Fedderke and Garlick, 2008).

6.4 Dynamic impacts of Private and Public and Private Infrastructure on output and employment

Structural Vector Autoregressive (SVAR)

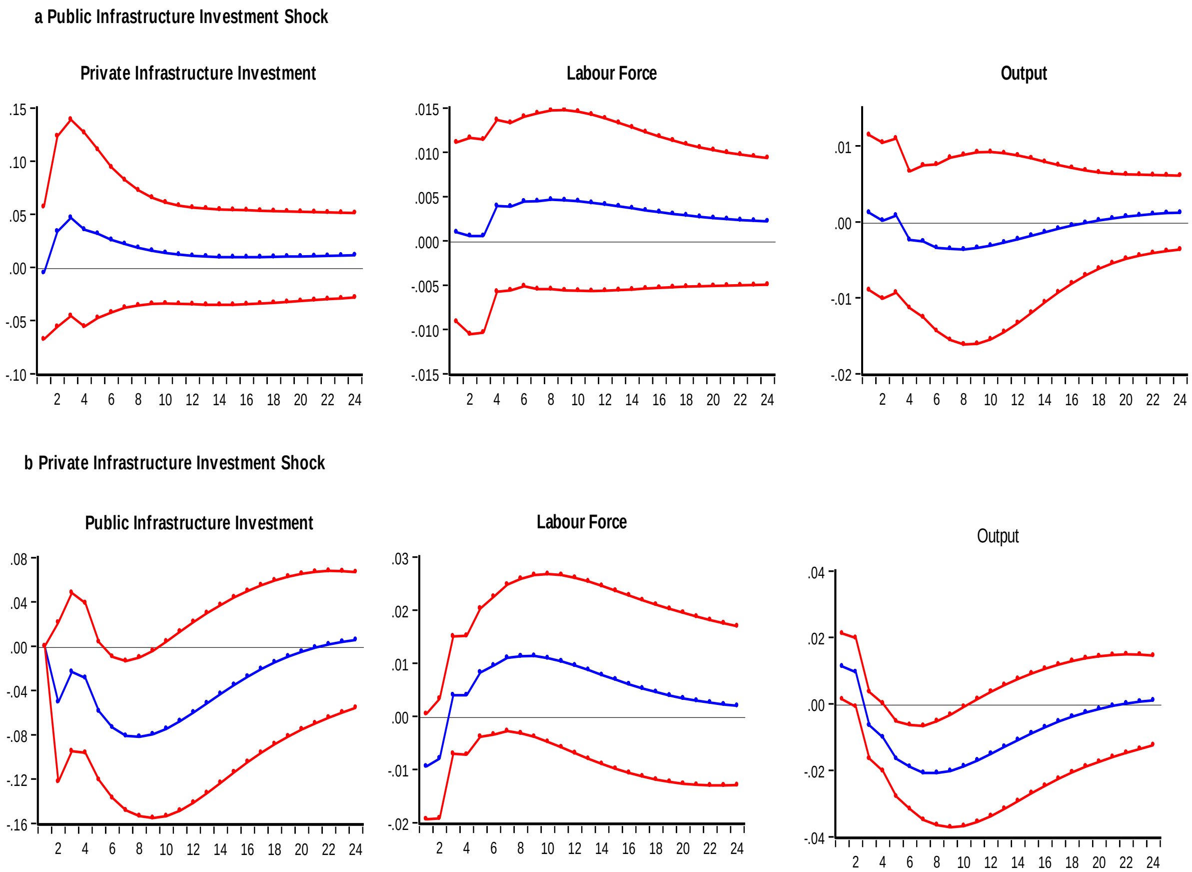
SVAR methodology that we adopt here remains a favorite technique for investigation of the dynamic effect of infrastructure investment on output and employment. Unlike the production function approach, the SVAR approach does not require imposition of any causal link between regressors and regressand, to tackle endogeneity issue in infrastructure growth nexus (Kamps, 2005). The long-term growth impact of infrastructure investment in the production function method is obtained by estimating the output elasticity with respect to infrastructure capital. In contrast, in the SVAR technique, the long run growth impact of infrastructure is obtained by considering the interaction of the different variables included in the model. Kamps (2005) argues that it is likely that public infrastructure investment may affect output through its impact on individual factors of production. In the SVAR technique, economic theory is used to develop the link between forecast errors and fundamental shocks. Equation 5.10, given in chapter 5, is estimated through the SVAR technique.

6.4.1 Dynamic Effects of Public and Private Infrastructure investment on aggregate Economy

Results for aggregate economy are obtained from impulse response functions, associated with SVAR model relating output, employment, public and private infrastructure investments. The impulse responses are shown in Figure 6.5.

In Figure 6.5 (Panel a), we display the estimated impulse responses of private sector investment in infrastructure, GDP and employment shock to public infrastructure investment. In response to public infrastructure investment shock, the private infrastructure investment initially rises smoothly over a period of three years horizon and then gradually falls for up to seven years. Afterwards, the response remains positive and constant over the entire forecast horizon. This implies that public investment complement in the short run, in case of Pakistan as private capital react positively to a one standard unit shock to public capital. Our results align with those of Erden and Holcombe (2005) and Serven (1999). Serven (1999) related the public and private capital for India, and reported crowding-out effect in the short- run and crowding-in effect of private capital due to infrastructure investment in the long-run. Erden and Holcombe (2005) results also support the hypothesis that public and private investments are complementary in case of emerging economies. The response of employment to public infrastructure investment is negative in the short run but positive and significant in the medium run. Following a positive unit shock to public investment, employment starts rising drastically after second year, but after the 6th year the response follows a declining trend and remains positive by the end of the 24th year. The response of real output to positive shocks to public investment in infrastructure is negative in the short run; however, medium term response is positive and significant. These findings are aligning with the findings of Kamps (2005) for Canada, Iceland, Norway, Spain and UK.

Figure 6.5. Structural Impulse Responses of Infrastructure Investment (Public and Private), Employment and Real GDP: Aggregate Economy

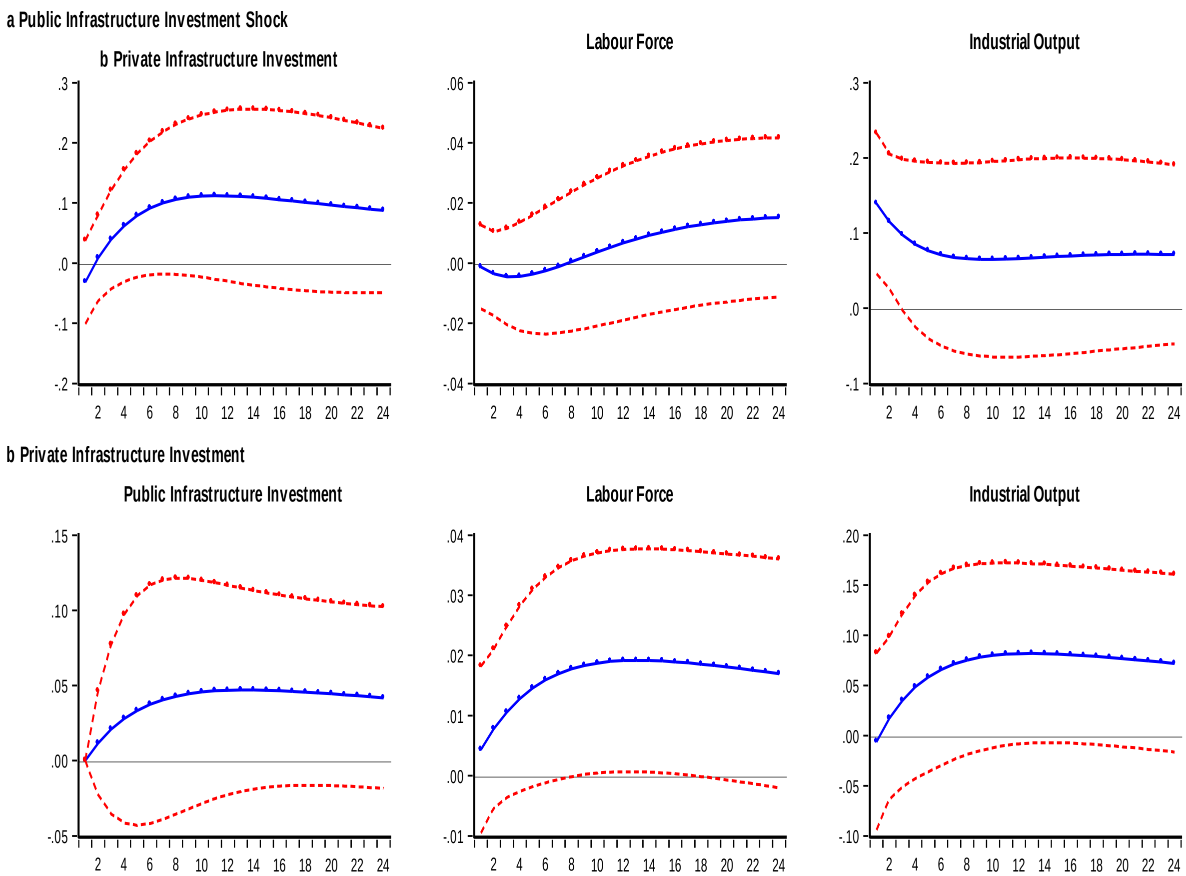


The estimated impulse responses of public infrastructure investment, employment and real GDP to one standard unit positive shock, to private infrastructure investment are presented in Figure 6.5 (Panel b). In response to a positive shock to private infrastructure investment, one average the public infrastructure investment initially declines for up to eight and half years, and afterwards the response reverts and increase steadily, crossing zero line in the twenty first year and then remains positive over the remaining horizon. The response of employment to private infrastructure investment is observed to be positive and statistically significant. Initially, employment starts rising but after 8th year it follows a declining trend and remains positive over the entire forecast horizon. The response of employment to private infrastructure investment seems to be more prominent as compared to employment response of public infrastructure investment. The impact effect of positive shock to private infrastructure investment is positive, afterwards the response gradually decreases and reaches its minimum level around 8^{th} year. Thereafter, the response reverts and increases steadily and crosses zero line in the 22^{nd} year and remains positive over the remaining horizon. This implies that output responds negatively to a positive shock to private infrastructure in the short-run, but in medium to long run output responds positively to private infrastructure investment. The analysis of aggregate economy with respect to infrastructure investment reveals that short-run output response is negative, while the medium to long-run output response is positive. Response of employment to both, public and private infrastructure investment is positive, however, the response of employment response to private infrastructure investment is dominant as compared to other responses.

6.4.2 Dynamic Effects of Public and Private Infrastructure investment on Industrial Sector

The impulse response functions, based on the sector-specific SVAR model, are reported in Figure(s) 3-5 (panel a-b). Figure 6.6 (Panel a) shows the estimated impulse responses of private infrastructure investment, employment and real GDP of industrial sector to shock to public infrastructure investment. The response of private infrastructure investment to a positive shock in public infrastructure investment is positive and statistically significant. This result is in line with the existing literature which suggests that public infrastructure investment, such as investment in roads, energy and telecommunication may boot private investment. This implies that public infrastructure investment and private infrastructure are complementary (crowding in) from short to long-run in industrial sector in Pakistan. Public investment in infrastructure may provide necessary infrastructure, boosting private infrastructure investment.

Figure 6.6 Response of Infrastructure Investment, Employment and Industrial Output; Industrial GDP



Public investment in infrastructure exerts positive and significant impact on employment in the industrial sector. This finding is consistent with the Keynesian models that public spending in infrastructure plays a key role to sustain private sector employment. Di Giacinto et al. (2010) also found positive impact of infrastructure investment on employment for Italy. Demetriades and Mamuneas (2000) also concluded that investment in public infrastructure has significant employment induced effects. However, this study does not find a significant positive response of industrial output to a shock in public infrastructure investment.

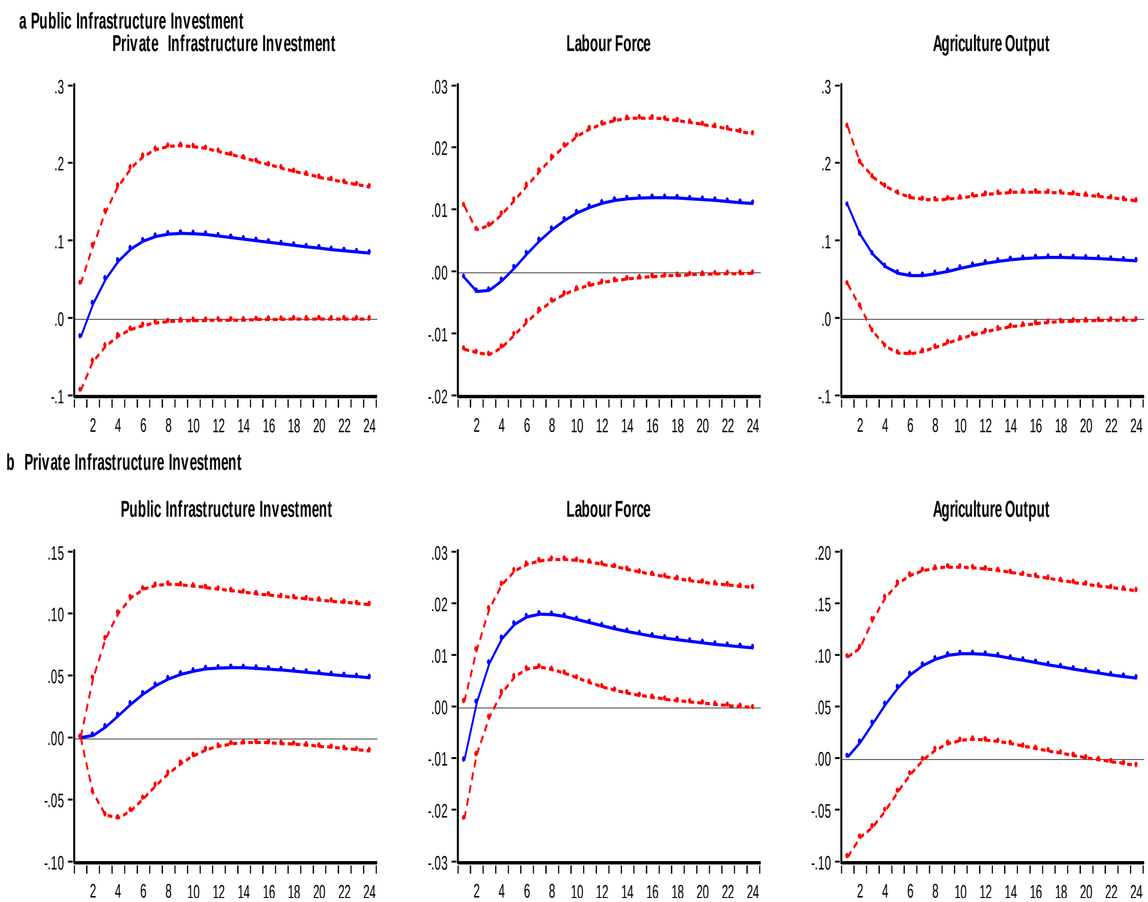
Figure 6.6 (Panel b) shows the dynamic effects of private investment in infrastructure on industrial sector investment, labour force and output. In response to private infrastructure investment shock, we find positive and statistically significant response of public infrastructure investment; employment and industrial output (see Figure 6.6 b). Positive responses of public infrastructure investment to shock to private capital infrastructure show that private and public capital are complementing each other in the short-run. Positive and long lasting effect of private infrastructure investment on employment and industrial output shows a significant role of private sector, in reducing unemployment and increasing output in the country.

6.4.3 Dynamic Effects of Public and Private Infrastructure investment on Agriculture Sector

Figure 6.7 (Panel a & b) illustrates the impulse response of employment and output to a one-standard-deviation shock to public and private investment in infrastructure, respectively in agriculture sector. The response of private infrastructure investment and employment to a shock in public infrastructure investment is positive and statistically significant (see Figure 6.7a). However, in response to public infrastructure investment shock, agriculture value added declines in the short run. Our finding, regarding response of agriculture output to public infrastructure investment aligns with the finding of Ahmed and Ali (2014). They find that the response of agriculture output to aggregate public investment is negative for Pakistan.

The response of private infrastructure investment in agriculture sector to a shock in public infrastructure investment and employment is positive and statistically significant. Public infrastructure investment and private infrastructure are complementary (crowding in) from short to long-run in agriculture sector of Pakistan. The response of employment and agriculture GDP is positive and statistically significant to one standard deviation shock to private infrastructure investment (see Figure 6.7b). Dynamic effect of private infrastructure investment on employment and real output in sub-sector of the economy is more dominant as compared to public infrastructure investment on employment and output.

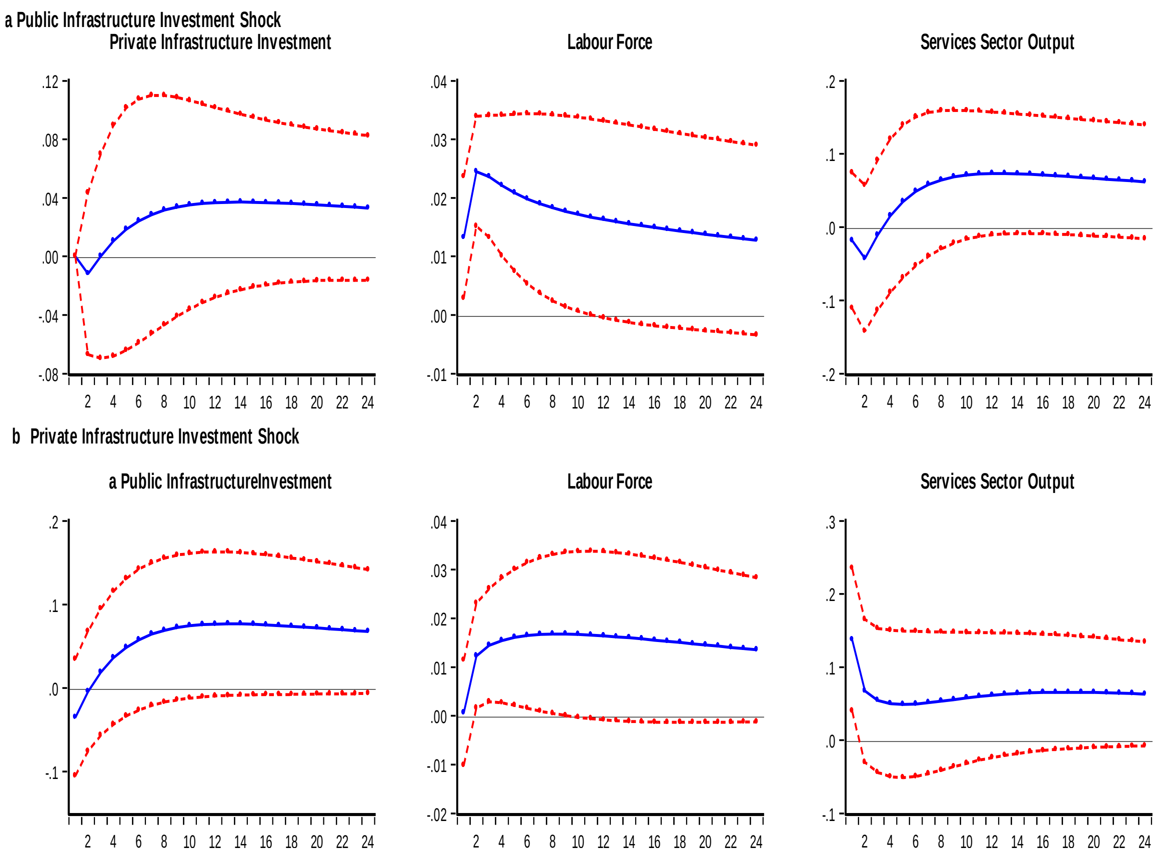
Figure 6.7 Response of Infrastructure Investment, Employment and Agriculture Output: Agriculture GDP



6.4.4 Dynamic Effects of Public and Private Infrastructure investment on Service sector

Figure 6.8 (a & b) illustrates the impulse responses of employment and output to a one-standard-deviation shock to public and private investment in infrastructure investment in services sector. The response of private infrastructure investment to a positive shock in public infrastructure investment is positive and statistically significant in service sector, which implies that there is complementary relationship between public and private infrastructure investment. The response of employment to a shock in public infrastructure investment is positive and statistically significant (see Figure 6.8a).

Figure 6.8 Response of Infrastructure Investment, Employment and Service Sector Output



In response to public infrastructure investment shock, services sector value added declines in the short run. The response of employment and services sector GDP is positive and statistically significant to one standard deviation shock to private infrastructure investment (See Figure 6.8b).

6.5. Conclusions

In this chapter, we examined the contribution of infrastructure on aggregate output and sub-sector of the economy empirically, by employing production function approach. Various specifications of growth model, augmented with infrastructure variable are estimated, by taking into account the limitations of past studies on infrastructure growth relationship. Fully modified ordinary least squares (FOLS) technique has been employed to address the issue of endogeneity due to unobservable factors. The empirical analysis encompasses the estimation of a production function, connecting GDP per worker to capital per worker, human capital and a set of infrastructure variables. To analyze the impact of infrastructure capital investment on economic activity in Pakistan, three different specifications have been used for estimation: (1) aggregate investment in infrastructure, (2) public and private investment separately and (3) In the third stage we analyze the separate impact of investment in roads, telecommunication and power. Improvement in infrastructure indicators generates externalities that may spread across different sectors of the economy. Therefore, in this chapter, we also estimated the contribution of infrastructure on different sub-sectors of the economy.

We find that marginal contribution of aggregate investment in infrastructure to real GDP per worker is positive and statistically significant for aggregate as well as for sub-sector of the economy. The estimated elasticity of public infrastructure investment for the industrial sector (0.34) is higher than the agricultural sector (0.16) and in the services sector (0.06). In the case of private infrastructure investment, statistically significant and positive estimates are obtained for industrial and agricultural sectors, while it is negative for services sectors. The marginal contribution of investment in road & telecommunication is higher than the marginal contribution of investment in the energy sector, in corresponding sector except for the services sector. Impact of investment in electricity and gas distribution has the highest elasticity in the industrial sector (0.13) than in aggregate economy (0.09), while these elasticities are very small in agricultural (0.04) and services sector (0.05). Similarly, the elasticity of road and telecommunication investment is higher in the industry (0.22) than in agriculture (0.14) and in the service sector (0.03).

This chapter also provides dynamic effects of public and private infrastructure investment on aggregate and sub-sector of the economy by using SVAR methodology. The main findings of the SVAR methodology analysis can be summarized as follows:

(i) For aggregate as well as sub-sector of the economy, a shock to the public and private investment in infrastructure tends to have a significant positive impact on employment. (ii) In all different cases, public and private capitals are long-run complements. (iii) Shock to private sector investment in infrastructure tends to have a significant positive impact on output for all cases. However the same is not true for public sector investment in infrastructure.

Results obtained through the production function approach and SVAR methodology show that the economic impact of infrastructure investment is positive in most of the cases.

Besides, our estimates of the influence of human capital and non-infrastructure physical capital on real GDP are also significant and broadly consistent with the previous literature.

Chapter 7

Infrastructure, Spatial Spillover Effects and Regional Growth

7.1 Introduction

Asia is one of the fastest growing economic regions in the world and comprises of more than half of the world's population. The significant economic growth of Asian economies in the recent years owes much to the expansion of international trade. Both economic and social Infrastructure development has played a signification role in the expansion of trade and economic growth in the region (Brooks and Menon, 2008). The importance of infrastructure for economic growth and productivity is well documented in the literature (Aschauer 1989; Easterly and Rebelo (1993); World Bank 1994; (Röller and Waverman, 2001); (Calderón and Servén, 2003); Canning and Pedroni 2004; (Agénor and Moreno-Dodson, 2006) , among others.

Developing countries, especially the emerging Asian economies, have placed emphasis on infrastructure development, where trade is expanding at its fastest pace (Brooks and Menon, 2008). Asian economies have rapidly improved their economic situation, investment, trade and employment over the past two decades, due to massive investment in infrastructure (Chatterjee, 2005; Sahoo and Dash, 2012; Straub et al., 2008).

Most of the early literature has attempted to investigate the impact of public infrastructure on productivity and economic growth at national and regional level. Previous studies on the infrastructure-growth relationship are either country-specific time series studies or cross-section studies. However, the role of the spatial spillover effect of public infrastructure on economic growth across the geographic location has been overlooked.

The potential impact of transport infrastructure on growth is not limited to the region in which the infrastructure is placed, but its influence also extends to the neighboring regions (Cohen and Paul, 2004). (Holl, 2011) argues that the expansion of transport infrastructure networks plays a significant role in the development of the region. Through traditional econometric methodology, the spatial dimension of data cannot be captured. (LeSage and Pace, 2009) argue that when the data is geographically distributed, the problem of spatial dependence between observations may interrupt the Gauss-Markov theorem.

Infrastructure has played a vital role in trade facilitation, particularly in the context of recent trade liberalization in Asia, which has caused significant tariff reductions. Infrastructure services not only have an impact on the region's economy in which they are placed but also have an impact on the neighboring countries. The focus of this study is to assess the economic contribution of aggregated and disaggregated infrastructure to GDP, of 22 countries in Asian region in a spatial framework. The attractive feature of the spatial econometrics approach is to permit the spatial spillover effects of infrastructure across the region. The spillover effect suggests that input from one region or sector influences the economic output of a neighboring country or region through trade and market linkages (Del Bo et al. 2010).

The motivation and justification for this study are twofold: First, the spatial econometrics approach has been used to analyze the spillover effect of infrastructure on economic growth across the geographic location. Second, aggregate and disaggregate measure of economic infrastructure has been used in this study to know the most productive form of infrastructure investment in terms of its effect on economic growth and to avoid potential aggregation problem.

The remainder of this chapter is structured as follows. Section 2 discusses the role of infrastructure spillover effects on regional GDP. Section 3 presents the methodology and data. Results and discussions on output elasticity of aggregate infrastructure index and disaggregation of infrastructure are analyzed in section 4. Section 5 provides summary and the conclusion.

7.2 Spillovers Effects of Infrastructure

Amplifications in infrastructure services are expected to lessen transportation costs, reduce travel time and congestion (Forkenbrock and Foster, 1990). In addition to plummet traveling and logistic costs, improvements in infrastructure services may expand the market potential of businesses, by allowing them to serve broader markets more economically. Efficient and well-functioning transportation infrastructure systems can provide firms with a greater diversity of specialized skilled labor and input products that can make firms more productive. Recently, literature on economic growth and infrastructure has considered the spillover effect of infrastructure investment across geographic boundaries. Through several channels, such as technological diffusion, capital flow, trade, economic and social policies, countries have the potential to interact with each other. (Cohen, 2010) argues that development in the field of spatial econometrics helps researchers explore the role of infrastructure investment across the region. Transportation infrastructure investment reshapes the geographic location and helps in the agglomeration of economic activity. The debate on spatial spillover effect of infrastructure investment in new economic geography models is established on the notion that infrastructure lessens trade costs and accelerates trade flows between countries (Straub, 2008). It is generally believed that investment in infrastructure reduces fixed costs, attracts investors and factors of production and thereby, positively affects output (Egger and Falkinger, 2003; Haughwout, 2002). In recent years, numerous studies have found positive spillover effects of transport infrastructure (see for example, (Cantos et al., 2005; Cohen and Paul, 2004; Dundon-Smith & Gibb, 1994; Gutiérrez et al. 2010; Pereira et al., 2006; Pereira and Andraz, 2004). In addition, some studies have found positive spillover effects of infrastructure investment on growth (see for (Boarnet, 1998; Cohen and Monaco, 2008; Sloboda and Yao, 2008). Some studies have also found mixed or no spillover effects of transportation infrastructure on economies (see for example (Jiwattanakulpaisarn et al. 2010; Kelejian and Robinson, 1997).

The theory of new economic geography suggests that public infrastructure may positively affect economic growth, as transportation costs are crucial factors of the location and scale of economic activity (Fujita et al., 2001; Holtz-Eakin and Schwartz, 1995b; Krugman, 1991; Limao and Venables, 2001; Venables, 1996). Limao and Venables (2001) investigate the dependence of transport costs on infrastructure and geography. Their research conclude that infrastructure is a crucial determinant of transport costs, and that distance explains approximately 10 percent of the transport costs.

By using spatial econometric analysis, (Del Bo and Florio, 2012) investigate the growth spillover effects of infrastructure in the regions within the European Union. Estimates of the spatial Durbin model confirms the positive role of infrastructure in the regions within the European Union, and studies identify the highest rate of return of telecommunications and transport network accessibility.

The spatial econometrics approach has been extensively used in the recent empirical literature to explore the spillover effects of transport infrastructure investment across the region. (Hu and Liu, 2010; Xueliang, 2008; Yu et al. 2013) found positive spillover effects of transportation infrastructure on the economic performance in China. (Chen and Haynes, 2015; J. P. Cohen, 2010; Tong, Yu, Cho, Jensen, & Ugarte, 2013) found positive spillover effects of infrastructure investment for different states in the U.S. (Cantos et al., 2005) and (Arbués, Baños, & Mayor, 2015), incorporated disaggregated information on transport infrastructure for Spain, and obtained positive direct and spillover effects of transports infrastructure. Some selected studies of the impact of the spillover effect of infrastructure are summarized in Table 7.1.

Regional economic activities and provisions of efficient infrastructure services and the spillover to other regions are well documented in the literature. Cohen (2010) argue that infrastructure development has an influence beyond the geographic region, state, or country in which infrastructure investments are undertaken. Numerous recent studies (see for example Arbués, Banos, & Mayor, 2015; Boarnet, 1998; Cantos et al., 2005; Cohen, 2010; Hu & Liu, 2010; Kelejian & Robinson, 1997; Xueliang, 2008; Yu et al., 2013) have employed spatial econometric techniques to assess the spillover impact of public infrastructure, beyond the region where infrastructure investments have taken place. Cohen (2010) argues that the advancement in the area of spatial econometrics facilities the spillover strand of infrastructure in the literature.

Table 7.1 Some Selected Studies of Spillover Infrastructure

Study	Countries Sample	Public Capital Measure	Model Specification	Conclusion
Arbués et al (2015)	Spain 47 Province	Roads Infrastructure	Spatial Durbin Model (SDM) GMM	Road Infrastructure has positive effects on the output of region in which infrastructure is located and its neighboring provinces
Yu et al. (2013)	China Region 1978 2009	transport infrastructure	SDM	positive spillovers exist due to the connectivity characteristic of transport infrastructure at the national level
Chen and Haynes (2013)	U.S. States 1991 2009	transport infrastructure	SDM Panel with FE	Transportation infrastructure have a significant impact on regional output, most of which is from spillover effect
Del Bo and Florio (2012)	European Union	transport infrastructure	SDM	Highest rates of return as associated with telecommunication, quality and accessibility of transportation networks a positive impact of roads and railways.
Zhang and Yi (2012)	China Region 1993-2009	transport infrastructure	SDM	Transport infrastructure has spatial spillover effects on regional economic growth
Hu and Liu (2010)	China provinces 1985-2006	Transportation	ML SDM	Spillover effects to the economic growth is on average 13.8% every year
Tong et al. (2013)	U.S. 44 States 1981 2004	Transport Infrastructure	SDM panel data	Spillover effect of road infrastructure on agricultural output in neighboring states varies w.r.t spatial weight matrix used in the model
Xueliang (2008)	China 1993-2004	Transport Infrastructure		Spatial output spillovers from transport infrastructure are largely positive, but evidences of negative spatial spillovers are also found

The objective of this study is to assess the influence of aggregated and disaggregated infrastructure in regional economic performance by taking into account spillover effects.

The inspiration for this study is to employ spatial econometrics in the context of the new theory of economic geography, for testing the spillover effects of public infrastructure in selected Asian countries. Del Bo and Florio (2012) suggest that to find a comprehensive measurement of the return of infrastructure on economic growth, a departure from output elasticity approach is needed, as indicated by (Aschauer, 1989). Therefore it is crucial to examine the regional and spatial dimensions of the connection between aggregated and disaggregated infrastructures and output. The Cobb- Douglas production function has been employed to test the spillovers effect of public infrastructure on regional economic activities. For aggregate infrastructure indicator, a composite index of quality road infrastructure, telecommunication and energy consumption have been constructed by using principal component analysis (PCA). For disaggregated infrastructure indicators, roads and energy consumption have been used. The use of individual indicators permits to distinguish the relative significance of public infrastructure by mode and by their impact on regional economic activity. Hausman test is used to address the problem of endogeneity in the model. Lastly, a systematic approach to the selection of the spatial model is introduced to carry out a rigorous estimation procedure.

7.3 Methodology and Data

Spillover effects restrict to be zero in standard econometric models; however, an essential feature of the spatial econometric approach is that the significance and magnitude of spatial spillover can be empirically evaluated (Elhorst and Vega, 2013)[16]. Recently, the spatial econometric technique has been widely used in infrastructure related studies. In the last few years, the econometric models that include both a spatially lagged dependent

[16] http://www.regroningen.nl/elhorst/doc/Spatialspillovers.pdf

variable and a spatial auto-correlated error term have attracted the attention of researchers and policymakers. In this respect, the spatial Durbin model (SDM) has been widely used which comprises of both spatially lagged dependent variable and spatially lagged explanatory variables (LeSage & Pace, 2009), and (Yu et al., 2013). Spatial autocorrelation implies interdependencies among different localities. Cohen (2010) explain that spatial autocorrelation arises when error term in a regression equation of one geographic location correlates with neighboring localities shocks or innovation. In this situation, we cannot assume that the error term is normally distributed with zero mean, constant variance and zero covariance between observations over time and space. Ignoring spatial autocorrelation can lead to parameter estimates with higher standard errors that if spatial autocorrelation had not been present. Higher standard error, due to negligence of spatial autocorrelation, may lead to accepting fall hypothesis erroneously. Overlooking spatial autocorrelation may cause parameter estimates, with high standard errors that may increase the probability of accepting the fall null hypothesis.

For empirical analysis, Cobb-Douglas production function is extended with spatial interaction effect (Arbués et al., 2015; Cohen, 2010; Del Bo et al., 2010; Elhorst and Vega, 2013; Yu et al., 2013). The baseline empirical model is as followed:

$$Y_t = K_t^{\beta_1} L_t^{\beta_2} I_t^{\beta_3} H_t^{\beta_4} e^{\mu} \quad (7.1)$$

Where Y is a gross domestic product, K is non-infrastructure capital, L is labor force, I is infrastructure capital, and H is human capital. Non-infrastructure capital (K) is estimated by using the perpetual inventory method[17]. Secondary school enrollment has been used as a proxy for Human capital (H). The parameters β_1, β_2, β_3 and β_4 in equation (1) represent the income shares for the factors of production, and these parameters measure the income elasticities with respect to the respective variable. Equation (7.1) can be transformed into a log-linearized reduced version:

$$lnY = \beta_0 + \beta_1 lnK_t + \beta_2 lnL_t + \beta_3 lnI_t + \beta_1 lnH_t + \mu_t \quad (7.2)$$

For the assessment of spillovers effects, the selection of an appropriate spatial econometric model is essential among various specification of the spatial econometric model (Anselin, 2013). The Spatial Durbin Model (SDM) in its limited form can be interpreted as a Spatial Error Model (SEM) or Spatial Autoregressive (SAR) model. Elhorst and Vega (2013) developed a systematic procedure for the identification of the appropriate spatial panel model. Elhorst's methodology has been adopted to identify the technically preferred model. Both robust and non-robust LM (Lagrange multiplier) tests are built on the residuals of simple OLS estimation and the LR (likelihood ratio) test. Following LeSage and Pace (2009), we consider the Spatial Durbin Model (SDM) for empirical analysis:

$$y = \rho W y + Z\beta + \theta W Z + \alpha I_n + \varepsilon \quad (7.3)$$

where spatial autocorrelation coefficient is represented by ρ in equation (7.3), w represents the spatial weight matrix and Z is the set of control variables (including labor, physical

[17] Following IMF the initial capital stock is set to 0 for all countries in 2006 and depreciation rate is assumed 8% percent: see, https://www.imf.org/external/np/fad/publicinvestment/data/info.pdf

capital, human capital, and infrastructure). Whereas α, θ, and β are coefficients and ε is the error term. The SDM specification of spatial econometric analysis comprises of a spatial lag of both independent variables (WZ) and dependent (WY) variable. A key feature of this approach is that this methodology enables us to capture the network effect. A variation in the variable for a single country may affect the variable in all other regions by the network effect. A change in the explanatory variable for a single observation can potentially affect the dependent variable in all the observations. From equation (7.2) and (7.3) we can specify the following estimable equation:

$$lnY_{i,t} = \rho \sum_{j=1}^{N} W_{ij} lnY_{j,t} + \beta_0 + \beta_1 lnK_{i,t} + \beta_2 lnL_{i,t} + \beta_3 lnI_{i,t} + \beta_4 lnH_{i,t} + \theta_1 \sum_{j=1}^{N} W_{ij}\, lnK_{j,t} + \theta_2 \sum_{j=1}^{N} W_{ij}\, lnL_{j,t} + \theta_1 \sum_{j=1}^{N} W_{ij}\, lnI_{j,t} + \theta_1 \sum_{j=1}^{N} W_{ij}\, lnH_{j,t} + \varepsilon_{i.t} \qquad (7.4)$$

where Y is real GDP, subscript i and t represent the country of the region and time respectively. W_{ij} represents each of the elements in the spatial weight matrix W that describe the spatial arrangement of the different regions. In an SDM context, the regional variation in GDP levels is modeled to depend on the GDP level from neighboring country, captured by the spatial lag vector Wy as well as the factor input (including K, L, I and H) of the neighboring country represented by WX.

Before testing for spatial autocorrelation and incorporating a spatial lag, it is essential to choose the specification for the spatial weights W_{ij}. One common approach is contiguity weight, where all jurisdictions that are contiguous geographic neighbors to a particular jurisdiction, are weighted equally. However spillover effects are proportional to the inverse of the distance between counties, so weight matrix W is a row standardize contiguity matrix based on the inverse of geographical distance.

One of the essential objectives of spatial analysis is to explore the spatial effects of a different measure of infrastructure on regional economic growth. The spatial information regarding the neighboring countries is added in the shape of spatial weight matrix. According to LeSage and Pace (2009), the SDM has the capacity to distinct spatial effects from total effects. Therefore spatial model helps to estimate the three different forms of the impact of infrastructure variables. These include (i) average direct impact; (ii) average indirect impact and (iii) average total impacts. The average direct impact measures the influence of the explanatory variables that come from the same geographic unit as the dependent variable. The average indirect impact measures the influence of explanatory variables that come from different geographical units. The average total impact consists of both direct and indirect impacts. These measures capture the cumulative effect of changes in the independent variables, including the infrastructures that allow a change in the long-run. LeSage and Pace (2009) offer a theoretical framework for the elucidation of feedback effect, through the transformation of the spatial weight matrix and correlating the role of diagonal elements.

The SDM model can be rewritten as:

$$(I_n - \rho W)y = Z\beta + WZ\theta + I_n\alpha + \varepsilon \quad (7.5)$$

$$y = \sum_{r=1}^{k} S_r(W)x_r + V(W)I_n\alpha + V(W)\varepsilon \quad (7.6)$$

where $S_r(W) = V(W)(I_n\beta_r + W\theta_r)$ and $V(W) = (I_n - \rho W)^{-1}$

If we expand equation (6) from one country to n country, we have:

$$\begin{matrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{matrix} = \sum_{r=1}^{k} \begin{bmatrix} S_{r\,(W)_{11}} & S_{r\,(W)_{12}} & \cdots & S_{r\,(W)_{1n}} \\ S_{r\,(W)_{21}} & S_{r\,(W)_{22}} & \cdots & S_{r\,(W)_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ S_{r\,(W)_{n1}} & S_{r\,(W)_{n2}} & \cdots & S_{r\,(W)_{nn}} \end{bmatrix} \begin{bmatrix} x_{1r} \\ x_{2r} \\ \vdots \\ x_{nr} \end{bmatrix} + v(w)\varepsilon \quad (7.7)$$

In equation (7.7), an average of the diagonal elements of matrix Sr(W) can be represented as the average direct impact. The average total impact can be obtained by taking the average of sum of the rows (or column) of matrix Sr(W), and average indirect impacts (Spillover effects) are obtained as a difference between the total and direct impacts.

$$\bar{M}(r)total = n^{-1}I_nS_r(W)$$
$$\bar{M}(r)direct = n^{-1}tr(S_r(W))$$
$$\bar{M}(r)indirect = \bar{M}(r)total - \bar{M}(r)direct$$

The sign and magnitude of the direct and indirect impacts of the explanatory variables can be calculated. Methodology proposed in this study is different from earlier studies in two ways: First, our proposed model considered the spillovers from all the countries, not limited to the first round neighbors as opposed to the previous literature (Berechman et al ,2006; Moreno and López-Bazo, 2007; Ozbay et al., 2007). Second, by following (Yu et al., 2013) study at hand, we used more general spatial specifications, developed recently , both considering the spatial autoregressive model and spatial error model, which can provide a more complete and accurate picture of the spillover effects than the existing literature (Hu and Liu, 2010; Zhang and Yi, 2012)

7.3.1 Data

The analysis is based on panel data of 22 countries during the period from 2006 to 2016. List of countries included in analysis is provided in Appendix E. Data on GDP (constant 2010 US$), Gross fixed capital formation (constant 2010 US$), Labor force, Human capital (Secondary school enrollment), Fixed telephone subscriptions (per 100 people) and

Electric power consumption (kWh per capita) are taken from World development indicator. Data on the quality of road infrastructure has been collected from the Quality of Government Institute (QOGI). Principal component analysis (PCA) has been used to construct aggregate infrastructure index, by using quality of road, telephone and electricity consumption. Summary statistics of data are provided in Table 7.2. Descriptive statistics provided in table 7.2 show that mean and standard deviation telecommunication and aggregate infrastructure is very high, while mean and standard deviation of road infrastructure is very low.

Table 7.2: Descriptive Statistics of Data

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	242	11.57	2.11	6.98	16.07
Capital Stock	242	3.50	0.90	0.42	5.97
Labor Force	242	2.23	1.98	-1.15	6.67
Human Capital	242	14.47	2.04	10.72	18.73
Road	242	1.33	0.30	0.64	1.85
Tele	242	121.50	70.00	1.00	242.00
Energy	242	3.98	1.82	1.00	8.68
Infrastructure	242	97.54	251.19	1.89	1565.04

All variables are presented in natural log

7.4 Results

In order to test the existence of spatial autocorrelations among the variables, global Moran's I test has been employed to all variables included in our analysis. The universal global Moran's I is defined as:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \cdot \frac{\sum_{i=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \overline{x})}{\sum_{i=1}^{n} w_{ij}\ (x_i - \bar{x})^2}$$

Where w_{ij} represents the spatial weight matrix, it shows the relationships between countries i and country j. The spatial weight matrix is generated, using inverse distance measure. n is the number of countries, which is 22 in our case. Moran's I results are displayed in Table

7.3. The results of the Moran's I test for all variables are highly significant which implies that spatial autocorrelations exist across all variables except labor force.

Table 7.3 Diagnostics

Moran'S and LM tests		
	Statistics	P- values
Spatial Error Model		
Moran'S I	24.462	0.00
LM tests	161.36	0.00
Robust LM	160.553	0.00
Spatial Lag		
LM tests	3.803	0.05
Robust LM	2.997	0.08
Hausman Test: Test Value	18.16	0.001

The results of aggregated and disaggregated infrastructure, obtained through the estimation process of SDM with fixed spatial effect are presented in table 7.4. The results reported in Table 7.4 start by considering road infrastructure measure presented in column 2, the result of telecommunication infrastructure is presented in column 3 and estimates of energy consumption is reported in column 4. In the last column (6) the results of aggregate infrastructure indicator, obtained through a principal component analysis (PCA), is reported. Direct, indirect and total effects of an explanatory variable on explanatory variables are presented for SDM in Table 7.5. Mostly the empirical findings associated with the dependent variables are consistent with the other studies. The estimated coefficients of the spatial lag variables endorse the existence of significant spatial process, working through the dependent variables.

The estimated coefficient of spatial autocorrelation coefficient ρ is positive and statistically different from zero across various specifications of the regions under consideration, which are associated with positive and significant level of spatial correlation. The estimated value of spatial autocorrelation coefficient ρ ranges from 0.37 to 0.51.

The estimated coefficients associated with other explanatory variables in a spatial setting, are statistically significant for capital stock, human capital, labor force and infrastructure variables except for telecommunication. The aggregate infrastructure coefficients are 0.04 (column 6), and it is highly significant. The road infrastructure variable (column 2) has an associated coefficient of 0.40 and seems to be exceptionally relevant. The literature on economic growth and infrastructure development alludes to the existence of spillovers effects of infrastructure between the regions because of trade flow between countries, on the basis that technology is transmitted by the use of goods produced in one region but consumed in another region. Cantos et al (2005) argue that trade flows between countries measure not only the value of the trade between countries , but also the fact that a greater amount of goods sold implies that greater amount of goods transported and therefore greater use of the infrastructure between the countries. Calderon and Serven(2004) pointed out that adequate infrastructure supply is a crucial element of the "behind the border" agenda, needed for trade liberalization, in order to achieve the intended goal of efficient resource allocation and export growth. Our results are similar to that obtained by Cantos et al. (2005) and Del Bo and Flori 2012).

Table 7.4 Estimates of Infrastructure impact on Regional Growth: Spatial Durbin Model with Fixed Effect

	1	2	3	4	5	6
Capital Stock	0.17*	0.18*	0.17*	0.17*	0.17*	0.17*
	(5.96)	(7.23)	(5.99)	(5.95)	(7.17)	(6.28)
Labor Force	0.16***	0.23*	0.17***	0.16***	0.23**	0.18**
	(1.83)	(2.93)	(1.88)	(1.79)	(2.80)	(2.17)
Human Capital	0.16**	0.14**	0.16**	0.16**	0.14**	0.18*
	(2.75)	(2.56)	(2.72)	(2.74)	(2.62)	(3.15)
Road		0.40*			0.41*	
		(6.87)			(7.19)	
Tele			0.03		0.06**	
			(0.96)		(2.04)	
Energy				0.06**	0.09**	
				(2.18)	(2.32)	
Infrastructure						0.04*
						(4.87)
Spatial Variables						
W* Capital Stock	-0.54*	-0.24	-0.51*	-0.54*	-0.25***	-0.49*
	(-3.69)	(-1.64)	(-3.41)	(-3.71)	(-1.75)	(-3.48)
W* Labor Force	-0.81*	-0.87*	-0.81*	-0.79*	-0.85*	-0.70*
	(-4.20)	(-5.38)	(-4.23)	(-4.08)	(-5.16)	(-3.64)
W* Human Capital	2.05*	1.82*	2.11*	2.03*	1.84*	1.78*
	(5.75)	(6.53)	(5.81)	(5.64)	(6.39)	(4.97)
w*Road		0.89*			0.86*	
		(3.58)			(3.33)	
w*Tele			0.001		0.006	
			(-0.72)		(-0.45)	
w*Energy				0.04**	0.04*	
				(2.42)	(2.47)	
w*infrastructure						0.20**
						(2.49)
P	0.51*	0.38**	0.51*	0.52*	0.37*	0.46*
	(3.82)	(2.45)	(3.72)	(3.88)	(2.32)	(3.18)
e*yk	0.43*	0.02	0.44*	0.43*	0.05	0.48*
	(3.19)	(-0.07)	(3.31)	(3.14)	(0.23)	(3.57)
ML	222.35	253.6	223.5	222.4	256.04	234.15
Sigma2	0.0858	0.003	0.004	0.004	0.075	0.003
R^2	0.96	96	0.97	98	0.94	0.93

Note: t values are given in parenthesis and *, **, and *** indicate rejection of the null hypotheses at the 1%, 5% and 10% significance levels respectively.

These results are similar to those obtained by (Cantos et al., 2005) for the Spanish region, and (Del Bo and Florio, 2012) for EU countries. The magnitude of estimated coefficients of telecommunication and energy is very small, and telecommunication coefficient is statistically insignificant.

Considering the spatial lagged explanatory variable, regional output is positive function of road infrastructure, human capital, energy and aggregate infrastructure while the regional output is negatively associated with labor (w*labour) and capital stock (w*capital stock) in the neighboring region.

To examine the role of the spatial spillover effect of infrastructure, direct, indirect and total effects are computed. Spatial lagged regressors give an idea of the interactions between regions, the sign and magnitude of MDS impacts (direct and indirect) can be more accurately estimated, that may provide a more complete and accurate picture of spillover effects, particularly in infrastructure. Increasing investment in infrastructure in a country can lead to improve the accessibility of the region's network and thus expanding its market scale (Banister and Berechman, 2001). Enlargement in infrastructure could fuel the economy both in the area where the infrastructure investment takes place and in the neighboring region due to a growing market. Therefore the positive spillover effect of infrastructure investment in one country can be beneficial for the people from other regions through network facilities (Munnell and Cook, 1990).

The direct, indirect (Spillover) and total effects of aggregated and disaggregated infrastructure along with other explanatory variables on output are presented in Table 7.5. According to results presented in Table 7.5, the direct effects of capital stock, labor, human capital and road infrastructure on output are positive and statistically significant.

The direct elasticity of capital stock is between 0.14 and 0.17, and direct elasticity of labor is varied between 0.11 and 0.30 and, human capital lies in the range of 0.22 to 0.30 for various specifications. These findings are similar to those obtained by (C. F. Del Bo & Florio, 2012) and for EU region and Arbués et al. (2015) for Spanish. Moreover, the direct elasticity of road infrastructure is 0.44 which is positive and highly significant. Similarly, the direct effect of aggregate infrastructure (last column in Table 7.4) has a positive and statistically significant impact on output, but the magnitude of the estimated coefficient is minimal. Estimation of the direct effect of telecommunication and energy is insignificant.

Feedback effects of infrastructure indicators and other explanatory variables are calculated. The feedback effect is the difference between the SDM estimated coefficients and the estimated direct impact and represented the spillover to the neighboring regions or country and returning to the region itself (LeSage and Pace, 2009). There is some evidence of positive feedback effect of aggregate infrastructure on the regional GDP, feedback effect of 0.03 indicating importance of direct infrastructure network. Feedback loop works through the neighboring regions and back to the region.

7.4.1 Direct, Indirect (Spillover) and total effect

Indirect effects of aggregated and disaggregated infrastructure on regional GDP are analyzed, in order to examine the spillover effect across the region. In the Spatial Durbin Model (SDM), indirect affects stimulus the existence and size of effect across boundaries. Findings of this study confirm the positive spatial spillover effects of road infrastructure with an estimated effect of 1.21

Table 7.5 Direct, Indirect (Spillover) and total effect

Direct effects	**1**	**2**	**3**	**4**	**5**
Capital Stock	0.169*	0.141*	0.137*	0.167*	0.146 *
	(6.42)	(4.10)	(3.91)	(6.30)	(4.56)
Labor Force	0.199**	0.116	0.108	0.192*	0.146
	(2.43)	(1.25)	(1.17)	(2.33)	(1.67)
Human Capital	0.223*	0.309*	0.313*	0.220*	0.290*
	(3.72)	(3.92)	(3.95)	(3.70)	(3.98)
Road	0.44*			0.456*	
	(7.88)			(8.13)	
Tele		0.0003		0.001***	
		(0.67)		(1.87)	
Energy			0.009	0.008	
			(0.26)	(0.26)	
Infrastructure					0.0056*
					(4.32)
Indirect effects					
Capital Stock	-0.196	-0.584**	-0.643**	-0.213	-0.531**
	(-1.17)	(-2.49)	(-2.66)	(-1.29)	(-2.57)
Labor Force	-0.894*	-1.007**	-1.004**	-0.862*	-0.796**
	(-3.27)	(-2.68)	(-2.62)	(-3.21)	(-2.41)
Human Capital	2.152 *	3.023*	2.998*	2.126 *	2.405*
	(4.93)	(4.24)	(4.13)	(4.95)	(3.84)
Road	1.201*			1.138*	
	(3.38)			(3.28)	
Tele		0.001		0.0004	
		(-0.58)		(-0.26)	
Energy			0.067	0.038	
			(0.42)	(0.42)	
Infrastructure					0.003***
					(1.70)
Total effects					
Capital Stock	-0.0272	-0.443***	-0.506*	-0.0462	-0.385***
	(-0.15)	(-1.72)	(-1.90)	(-0.26)	(-1.69)
Labor Force	-0.695**	-0.891**	-0.895**	-0.669**	-0.649***
	(-2.36)	(-2.17)	(-2.13)	(-2.32)	(-1.79)
Human Capital	2.374*	3.332*	3.312*	2.347*	2.694*
	(5.12)	(4.34)	(4.24)	(5.13)	(4.00)
Road	1.645*			1.594*	
	(4.49)			(4.45)	
Tele		0.001		0.0002	
		(-0.39)		(0.13)	
Energy			0.076	0.030	
			(0.42)	(0.31)	
Infrastructure					0.003**
					(1.91)

Note: t values are given in parenthesis and *, **, and *** indicate rejection of the null hypotheses at the 1%, 5% and 10% significance levels respectively.

This finding indicates that an increase in road infrastructure in a country would yield positive effects on the real GDP of its neighboring country. The estimated coefficient of the indirect effect of aggregate infrastructure (Column 5 Table 7.5) is small in magnitude and weakly significant. As a result of the interpretations of the indirect effects presented above, the development of road infrastructure in one country would have a positive spillover impact on GDP of the neighboring country, by improving the quality of the overall road transportation system. For telecommunication and energy variables, study does not find clear evidence of spillovers effects.

The labor and capital stock were found to have an adverse and statistically significant total effect on regional output. The significant and positive direct effects of labor and capital stock indicate that both variables are positively associated with the local economic output, but the same is not true for regional output. The adverse spillover effect of capital stock implies the competitive nature of capital stock in the regional economy. Human capital was found to have a positive and statistically significant direct and indirect effect. The direct effect elasticity of human capital is 0.22, indicating that one percent rise of human capital is associated with a 0.22 percent increase in local economic output. Similarly, the indirect (spillover) effect elasticity of human capital is 2.4, which indicates that a one percent increase in human capital in one country is associated with a 2.4 percent increase of regional economic output.

Lastly, the total effects of the variables included in the analysis are obtained by adding direct and indirect effects (see table 7.5). It is found that the average total effect of human capital, road infrastructure and aggregate infrastructure are positive and statistically significant. The average total effect of road infrastructure is 1.64, indicating the importance of quality of road infrastructure, in terms of creating a network that would enhance the regional accessibility and attractiveness. Aggregate infrastructure has an estimated total effect, which is 0.003. This estimated coefficient can be interpreted as an elasticity, meaning a 10 percent increase in the aggregate infrastructure will correspond to a significant increase in regional economic output of around 0.03 percent, accounting for both direct, own regional effects. The average total effect of telecommunication and energy appears to have no impact on the economic output in the region.

7.5 Conclusion

This paper has offered a new assessment of the economic contribution of aggregated and disaggregated infrastructure to GDP, of 22 countries of Asian region in a spatial framework. The important contribution of this study is to introduce spatial lags of dependent and independent variables in the empirical analysis. The introduction of spatial lag as an explanatory variable has been justified empirically and theoretically.

The main findings of the study indicate a significant and positive role of quality of road infrastructure and aggregate infrastructure on regional GDP. The road infrastructure exhibits a significant impact (1.65) that consists of 0.44 from direct effect and 1.2 from spillover effects. The results of the current study indicates that the positive spillovers effects of road infrastructure support the idea that the effects of investment in road infrastructure are not limited to the territory in which an infrastructure project is situated. Human capital has a prodigious effect on economic output through both direct and spillover effects, which endorses that the nature of human capital intensity in the regional economy. Positive direct effect and an adverse spillover effect of capital stock are found in this study indicating the competitive nature of capital stock in the regional economic output.

Chapter 8

Conclusions and Policy Implications

The development of infrastructure is widely recognized as a key driver of economic growth. The relationship between infrastructure capital and economic growth has been controversial. A number of empirical studies have yielded a high return on infrastructure investment. However, the robustness of the results has been questioned in other empirical studies (for instance; Munnell, 1992; Tatom, 1993; Gramlich, 1994). Provisions of infrastructure can affect economic growth through direct and indirect channels. Through direct channel, infrastructure can increase output by shifting the production function or by increasing the rate of return of private investment. The improvement in infrastructure can increase productivity, stimulate private investment and facilitate domestic and international trade, thereby promoting sustainable growth. Thorough indirect channel, infrastructure may affect economic growth by changing the relative price structure of inputs and outputs. This connection between infrastructure and growth may ensue at the market level, through lower transaction costs, higher market integrations and changes in relative price. Infrastructure development and economic growth can be related to changes in the market patterns and factor allocation, such as labor allocation, and land usage. All these channels through which infrastructure development influence economic growth, may ultimately have an impact on the welfare of the general public and income distribution, in the areas where infrastructure is built.

From policy perspective, recent analytical and empirical research has highlighted many new areas and dimensions of infrastructure-growth relationship, which has been overlooked in the context of developing countries, particularly in the case of Pakistan.

These dimensions include, public versus private sector role in provision of infrastructure, New Economic Geography, Quality versus Quantity of Infrastructure and Aggregate versus sectoral contribution of infrastructure. This thesis adds to the literature on the contribution of infrastructure to aggregate and sectoral output, using an infrastructure augmented neoclassical production function approach. The study addresses several limitations of the earlier literature related to Pakistan. This thesis uses the multidimensional concept of infrastructure, combining power, road and telecommunication infrastructure into a synthetic index, constructed through a principal component analysis. The quality dimension of infrastructure has also been taken into account in the empirical analysis.

In this thesis, we also make a comparative analysis of the different composition of infrastructure investments, including public versus private investment and infrastructure investment in sub-sectors, such as in power, road and telecommunication sectors. This segregation aims to know the most productive form of infrastructure investment. Geographical dimension is another important dimension of infrastructure which is completely ignored in the context of Pakistan. The impact of infrastructure on growth is not limited to the region in which the infrastructure is placed, but its influence also extends to the neighboring regions.

The empirical approach involves the estimation of a production function, relating output per worker to non-infrastructure capital stock, labor, human capital and infrastructure input. Our empirical estimates are based on time series data from 1972-2016 for Pakistan. The empirical results are obtained in a framework that controls for reverse causation, and survive a variety of statistical tests that fail to show any evidence of misspecification. From this we conclude that the empirical results reflect causal, and not merely coincidental effects of infrastructure on growth.

Our main findings can be summarized in the following points: First, the overall results reveal significant positive impact of infrastructure stocks on aggregate economic growth. At disaggregate level, the electricity infrastructure exerts negative impact on agriculture sector, while telecommunication infrastructure has negative association with industrial and service sectors. The findings regarding quality of infrastructure and growth reveal that quality of road infrastructure has positive impact on economic growth, while quality of electricity infrastructure has negative impact on growth as expected. Second, public and private infrastructure investment exerted significant positive impact on aggregate and as well as on sub-sectors of the economy. Third, based on the SVAR model, the study finds dynamic interactions between output, employment, public infrastructure investment and private infrastructure investment. (i) Aggregate versus sectoral analysis show that the crowding-in effect of public investment in infrastructure is more substantial at sectoral level than at the aggregate level. (ii) Private infrastructure investment plays a dominant role in the short to medium run to generate employment opportunity, both at the aggregate and the sectoral level. (iii) The output contribution of public and private infrastructure varies across the sub-sectors of the economy.

Policy Recommendations

The following policy implications emerge from the empirical analysis.

The elasticity estimates of quantity and quality of infrastructure, and elasticity estimates of public and private investment in infrastructure at sectoral level enable us to draw a number of interesting insights into the economics of infrastructure.

First, the significant differences in the elasticity of different types of infrastructures have important implications for infrastructure modeling and for policy design. From a policy point of view, the different elasticity estimates can be used by policymakers to quantify the impact of policies targeted at the sector.

Second, the statistically and economically significant coefficients of quality of road and energy infrastructure emphasize the importance of the quality of infrastructure services for economic growth, both at aggregate and sectoral levels. The quality of the infrastructure often deteriorates over time and therefore requires constant maintenance and updating. The Government should put more emphasis on the maintenance, rehabilitation and up gradation of existing infrastructure.

Third, it is evident from the findings that there are high positive complementary effects between public and private infrastructure investment. The complementary role of public infrastructure investment suggests that policymakers should develop an enabled policy environment to attract private investment, with the consideration of structural characteristics of various sectors. This study identifies infrastructure investment opportunities for policy makers and private investors that generate a multiplier effect by attracting additional public and private infrastructure investment in the economy.

Fourth, Spatial econometric analysis confirms the positive spillovers effects of road infrastructure and supports the idea that the effects of investment in road infrastructure are not limited to the territory in which an infrastructure project is situated. Human capital has a prodigious effect on economic output through both direct and spillover effects, which endorse the nature of human capital intensity in the regional economy. Our results show that road infrastructure and overall infrastructure are crucial for regional growth. Transport infrastructure links between countries are becoming increasingly important, as they generate many positive externalities, from which countries benefited more than being independent. In this respect, the CPEC infrastructure between China and Pakistan is crucial. The government should involve more countries in this project.

Fifth, although government of Pakistan has mainly focused on large-scale infrastructure projects, such as motorways, highways, railways and bridges, there is also a need to invest in rural roads network and micro hydroelectric power plants. Rural road network will not only help in reducing transport and transaction costs but will also improve the market relationships, by connecting people with their communities, building social capital and paving the way of rural development.

The intersectoral analysis of this study suggests that the infrastructure network must be comprehensive and must be connected with the remote and backward regions of the country where the most miserable people live. Providing good quality infrastructure in remote and backward areas will provide health and education infrastructure for the poor. In general, for infrastructure spending, priority has often been given to urban and politically visible areas. Growth-enhancing infrastructure strategies should assess what the poor people might need to access health and education services.

Appendix A. Selective study of production function approach

Study	Countries Sample	Public Capital Measure	Model Specification	Conclusion
David Alan Aschauer (1989b)	U.S. 1949-1985	Public capital Stock	C-D; Δlog	Positive effects of public capital on output. Output elasticity w.r.t total public capital is 0.39 Output elasticity w.r.t infrastructure is 0.24
David Alan Aschauer (1989a)	G-7 Panel data 1966-1985	Public capital Stock	C-D; Δlog	Positive effects of public capital on output. Elasticity between 0.33 and 0.55
Calderón and Servén (2003)	101 countries Panel data 1960-1997	Infrastructure capital stock	C-D; log	Positive effects of public capital on output. Elasticity is 0.16
Canning and Pedroni (1999)	Panel data 1950-1992	Telephone Electricity Road	ECM	Telephones and paved roads are provided at the growth maximizing level on average electricity generating capacity is under provided on average
Canning and Bennathan (2000)	62 countries Panel data 1960-1990	Public capital Stock	C-D Trans log	Elasticity of output w.r.t public capital varies from 0.04 to 0.144
Duggal et al. (1999)	U.S. 1960-1989	Public capital Stock	C-D; log	Output is positively affected by public capital Elasticity is 0.27
Eisner (1991)	U.S 1961-1991	Public capital Stock	C-D; log	Positive effect of public capital on output
Evans and Karras (1994)	7 OECD Panel data 1963-1988	Public capital Stock	C-D; Δlog	Insignificant effects of public capital on output
Fernald (1999)	U.S 1953-1989	Stock of roads	TFP growth	Roads contribute 1.4% per year to growth before 1973 and about 0.4 % after 1973

Appendix A. continue

Study	countries' Sample	Public Capital Measure	Model Specification	Conclusion
Otto and Voss (1994)	Australia 1966-1990	Construction and Equipment	C-D; log	Elasticity's varies from 0.38 to 0.45
Strurm and De Haan (1995)	U.S. 1949-1985	Public Capital stock	C-D; log; Δlog	Positive but statistically insignificant effect of public capital on output
Sahoo et al. (2012)	China 1975-2007	Composite index of infrastructure	C-D; Δlog	Infrastructure has positive effect on growth
Strurm and De Haan (1995)	Netherlands 1960-1990	Public capital stock	C-D; log; Δlog	Elasticity are 1.15, 0.98 and 0.80. No evidence of cointegration
Canning and Pedroni (2004)	Panel of countries 1950-1992	Tel, EGC, Road	Panel cointegration	In the vast majority of cases infrastructure does induce long run growth effects
Rioja (2001)	Brazil, Mexico and Peru	Infrastructure investment	General Equilibrium Model	Infrastructure can have positive effects on output, private investment and welfare
Sharma and Sehgal (2010)	India 1994-2006	Transportation Infrastructure	FMOLS	Infrastructure has positive effect on output and TFP Effect of infrastructure on the labor productivity is negligible
Ismail and Mahyideen (2015)	Asian Economies	Physical Indicators of Infrastructure	PGME	Quantity as well as quality of infrastructure is important to enhance economic growth
Calderon Calderón et al. (2015)	large cross country data set	Synthetic measure of infrastructure	pooled mean group (PMG)	The long run output elasticity w.r.t. infrastructure index is ranging from 0.07 to 0.10

Appendix A. continue

Study	Countries Sample	Public Capital Measure	Model Specification	Conclusion
Everaert and Heylen (2004)	43 Belgian regions 1965-1996	Public Investment	Trans log ; general equilibrium	Positive effects of public capital on private output and capital formation Public capital and private employment are found to be substitute Negative effect of public capital on employment
Finn (1993)	U.S. 1950-1989	Highways	C-D; Δlog	Positive effects of public capital on output. Elasticity is 0.16
La Ferrara and Marcellino (2000)	Italy 1970-1994	Public Capital Stock	C-D	Negative output elasticity in 70s and positive in 80s and 90s
Ford and Poret (1991)	11 OECD 1960-1989	Narrow and broad definition	C-D; Δlog	Significant positive effects in some of countries Elasticities are 0.29 and 0.33 for narrow and broad definition respectively
Holtz-Eakin and Schwartz (1995)	U.S 1971-1986	Public capital stock	C-D	Infrastructure has a negligible effect on output
Hulten and Schwab (1993)	U.S. 1949-1985	Public capital Stock	C-D; Δlog, log	Insignificant effects of public capital on output Elasticity is 0.03
Kamps (2005)	22 OECD 1960-2001	Public capital Stock	C-D; Δlog, log	Positive effects of public capital on output Elasticity is 0.22 in panel data
Ligthart (2002)	Purtugal 1965-1995	Public capital Stock	C-D; Δlog	Positive effects of public capital on output Roads, railways and airports are more productive
Munnell and Cook (1990)	7 OECD 1963-1988	Public Investment	C-D; log	Positive effects of public investment on output Elasticity of output w.r.t public investment is 0.31 Elasticity of output w.r.t. infrastructure is 0.49
Nourzad and Vrieze (1995)	U.S. 1949-1987	Public capital Stock,	C-D; log	Positive effects of public capital on output. Elasticity between 0.31 and 0.39

Appendix A.Selective study of VAR approach

Study	countries' Sample	Public Capital Measure	Model Specification	Conclusion
Agenor et al (2005)	Egypt, Jordan Tunisia 1965 – 2002	Public capital stock	VAR log	Insignificant effect of public capital on private capital
Batina (1998)	U.S. 1948-1993	Public capital stock	VAR Δlog	Positive effects of public capital on output and vice versa
Belloe and Vertova (2006)	7 Countries 1970-1999	Public Investment	VECM	in 6 cases out of 7, there is positive effect of public investment on output
Flores et al. (1998)	Spain 1964-1992	Transport communications	VARMA , Δlog	Positive effects on output, private capital, and employment. LR output elasticity w.r.t public capital is 0.21
Ghali (1998)	Tunisia 1963-1993	Public capital stock	VECM	Public investment has negative effects on growth
Ligthar (2002)	Potugal 1965-1995	Public Capital stock	VAR, log	Positive output effects of public capital on output Elasticity varies from 0.20 to 0.35
Mamatzakis (1999)	Greece (1959-1997)	Public Capital stock (core infrastructure)	VECM	Positive effects of public capital on industrial output Elasticity is 0.14
Pereira (2000)	U.S 1956-1997	Public Investment	VAR, Δlog	All types of investment positively affect private output Crowding in effects on private investment
Pereira (2000a)	U.S 1956-1997	Core infrastructure	VAR, Δlog	Positive effects of public capital on output Elasticity is 0.257

Appendix A. continue

Study	countries' Sample	Public Capital Measure	Model Specification	Conclusion
Pereira and Andraz (2005)	Portugal 1976-1998	Transportation	VAR, Δlog	Public investment positively affect private investment, employment and output
Pereira and Roca i Sagalés (2006)	Spain 1970-1995	Transport communications	VAR, Δlog	Significant positive long run effects on output, employment and private capital
Sturm et al. (1999)	Netherlands (1853-1913	Public Investment	VAR, log	Significant positive effects in the short run No long run effects
Voss (2002)	U.S & Canada	Public Investment	VAR, log	Public investment crowd out private investment
Cadot et al. (1999)	France, 21 region (1985-1991	Transportation	Simultaneous equation	Elasticity is 0.10
Everaert (2003)	Belgium 1953-1996	Public capital stock	VECM	Elasticity of output w.r.t. public capital is 0.14 Elasticity of output w.r.t. public capita is lower than elasticity of output w.r.t. private capital
Pereira and Andraz (2011)	Pourtugal (1977-1998)	Road infrastructure	VAR, Δlog	Road infrastructure investment promote long term growth in all region
Pradhan and Bagchi (2013)	India 1970-2010	Transportation Road Rail	VECM	Bidirectional causality between Transportation and capital formation GCF and economic growth Unidirectional causality between rail transportation economic growths

Appendix A. continue

Study	countries' Sample	Public Capital Measure	Model Specification	Conclusion
Komatsuzaki (2016	Philippines	public investment	DSGE	Public infrastructure investment positively effects output
Abdul and Petia (2016)	17 OECD 1985-2014	Public Investment	VAR	Increased public investment raises output, both in the short term and in the long term, crowds in private investment, reduces unemployment
Bahal, Raissi, and Tulin (2018)	India 1996Q2-2015Q1	Public and Private Investment	SVECM	Public-capital accumulation crowds out private investment in India
Lanau (2017)	Latin America cross-section	quality of infrastructure	OLS	infrastructure raises growth and investment
Ahmed and Ali (2014)	Pakistan 1964-2011	aggregate and sectoral public investments	VAR	fourteen out of sixteen cases confirm a crowding-in of private investment in the Pakistan economy
Seneviratne and Sun (2013)	76 advanced & emerging economies 1980-2010	Communication Power, Road Composite Index	Pooled OLS	Better infrastructure, both quality quantity, promotes income equality link between investment and income distribution is weak
Paniagua, Hernández, and Hewings (2011)	Spanish Regions 1972-2000	public infrastructures	SVAR	public capital has positive effects on output and employment In the short-run, private capital and public

				capital could act as both complements and substitutes
(Kodongo and Ojah (2016))	5 Sub-Saharan African 2000-2011	public infrastructures	System GMM	Positive effects of spending in infrastructure on output

Most of the studies in this table are taken from Pereira and Andraz (2013) and Romp and de Haan, 2007)

Appendix B

First, we take the time derivative of k_t:

$$\dot{k} = \frac{\dot{K}\,(\dot{AL}) - K(\dot{A}L + A\dot{L})}{(AL)^2}$$

(B1)

$$\dot{k} = \frac{\dot{K}}{AL} - \left(\frac{\dot{A}}{A} + \frac{\dot{L}}{L}\right)k$$

$$\dot{k} = \frac{\dot{K}}{AL} - (g+n)k$$

(B2)

The movement of capital can be written as $\dot{K} = I_t - \delta K$ we have:

$$\dot{K} = s_k Y - \delta K$$

$$\frac{\dot{K}}{AL} = s_k \frac{Y}{AL} - \delta \frac{K}{AL}$$

$$\frac{\dot{K}}{AL} = s_k y - \delta k$$

(B3)

From equation (2) $y_t = k_t^{\alpha}\, q_t^{\beta} h_t^{\gamma}$ and in equation (a3)

$$\frac{\dot{K}}{AL} = s_k k_t^{\alpha}\, q_t^{\beta} h_t^{\gamma} - \delta k$$

(B4)

Substitute equation (a4) in equation (a2)

$$\dot{k} = s_k k_t^{\alpha}\, q_t^{\beta} h_t^{\gamma} - \delta k - (g+n)k$$

By rearranging we law of motion for k:

$$\dot{k} = s_k k_t^{\alpha}\, q_t^{\beta} h_t^{\gamma} - (g+n+\delta)k$$

(B5)

Appendix C

Second, we take the time derivative of h_t: $h = \frac{H}{AL}$

$$\dot{h} = \frac{\dot{H}(AL) - H(\dot{A}L + A\dot{L})}{(AL)^2}$$

(C1)

$$\dot{h} = \frac{\dot{H}}{AL} - \left(\frac{\dot{A}}{A} + \frac{\dot{L}}{L}\right)h$$

$$\dot{h} = \frac{\dot{H}}{AL} - (g+n)h$$

(C2)

The movement of capital can be written as $\dot{H} = I_t - \delta H$ we have:

$$\dot{H} = s_h Y - \delta H$$

$$\frac{\dot{H}}{AL} = s_h \frac{Y}{AL} - \delta \frac{H}{AL}$$

$$\frac{\dot{H}}{AL} = s_h y - \delta h$$

(C3)

From equation (2) $y_t = k_t^{\alpha} q_t^{\beta} h_t^{\gamma}$ and in equation (b3)

$$\frac{\dot{H}}{AL} = s_h k_t^{\alpha} q_t^{\beta} h_t^{\gamma} - \delta h$$

(C4)

Substitute equation (b4) in equation (b2)

$$\dot{h} = s_h k_t^{\alpha} q_t^{\beta} h_t^{\gamma} - \delta h - (g+n)h$$

By rearranging we law of motion for k:

$$\dot{h} = s_h k_t^{\alpha} q_t^{\beta} h_t^{\gamma} - (g+n+\delta)h$$

(C5)

Appendix D

Second, we take the time derivative of q_t: $q= \frac{Q}{AL}$

$$\dot{q} = \frac{Q(\dot{AL}) - Q(\dot{A}L + A\dot{L})}{(AL)^2}$$

(D1)

$$\dot{q} = \frac{\dot{Q}}{AL} - \left(\frac{\dot{A}}{A} + \frac{\dot{L}}{L}\right) q$$

$$\dot{q} = \frac{\dot{Q}}{AL} - (g+n)q$$

(D2)

The movement of capital can be written as $\dot{Q} = I_t - \delta Q$ we have:

$$\dot{Q} = s_q Y - \delta Q$$

$$\frac{\dot{Q}}{AL} = s_q \frac{Y}{AL} - \delta \frac{Q}{AL}$$

$$\frac{\dot{Q}}{AL} = s_q y - \delta q$$

(D3)

From equation (2) $y_t = k_t^{\alpha} \, q_t^{\beta} h_t^{\gamma}$ and in equation (c3)

$$\frac{\dot{Q}}{AL} = s_q k_t^{\alpha} \, q_t^{\beta} h_t^{\gamma} - \delta q$$

(D4)

Substitute equation (c4) in equation (c2)

$$\dot{q} = s_q k_t^{\alpha} \, q_t^{\beta} h_t^{\gamma} - \delta q - (g+n)q$$

By rearranging we law of motion for k:

$$\dot{q} = s_q k_t^{\alpha} \, q_t^{\beta} h_t^{\gamma} - (g+n+\delta)q$$

(D5)

Appendix E List of Countries

	Country		Country		Country
1	Azerbaijan	8	Japan	16	Pakistan
2	Bahrain	9	Jordan	17	Saudi Arabia
3	Bangladesh	10	Kazakhstan	18	Sri Lanka
4	China	11	Kyrgyz Republic	19	Tajikistan
5	Egypt, Arab Rep.	12	Kuwait	20	Turkey
6	India	13	Lebanon	21	United Arab Emirates
7	Iran, Islamic Rep.	14	Nepal	22	Yemn
		15	Oman		

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