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Public and Private Infrastructure Investment and Economic Growth in Pakistan: An Aggregate and Disaggregate Analysis †

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Abstract: This study investigates the relationship between infrastructure investment and economic growth at the aggregate and sectoral levels, namely, the industrial, agriculture, and services sectors for Pakistan over the period from 1972 to 2015. In contrast to earlier literature, we 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, roads, and telecommunication sectors. The long-run relationship is estimated using fully modified ordinary least squares (FMOLS) to address the problem of reverse causality. The main conclusion of this study is that both public and private infrastructure investments have positive but different effects on economic growth. In other words, the marginal productivities of private and public infrastructure investments differ across the different sectors of the economy. In most of the cases, public infrastructure investment has a larger impact on economic growth than private infrastructure investment. Two important policy implications emerge from this study, as follows: (1) The different elasticity estimates can be used by policy makers to quantify the impact of policies targeted at the specific sector and (2) the government should develop an enabled policy environment to attract private investment, with the consideration of structural characteristics of the various sectors. The involvement of the private sector in the provision of infrastructure would help to control the tight budgetary situation.

Keywords: infrastructure; public investment; private investment; FMOLS

1. Introduction

The economic impact of infrastructure has been at the center of the academic and policy debate for the last three decades. An adequate provision of infrastructure has been considered an essential feature of long-term economic growth and development. A well-functioning system of infrastructure reduces transaction costs and facilitates the mobility of goods and labor and the realization of economies of scale. Investment in public sector infrastructure affects the overall economic development through a number of channels [1]. These include, (1) that direct investment in economic infrastructure facilitates the production process and stimulates economic activities in the country, (2) it improves competitiveness by reducing transaction and trade costs, and (3) it generates employment opportunities to the poor [2]. However, the relationship between infrastructure investments and economic growth seems to vary across countries, as well as within different sectors of the economy.

As a service provider, infrastructure, directly and indirectly, enters into the production process. Therefore, it plays a critical role in the production process. Infrastructure influences growth directly, through capital accumulation, and indirectly, through total factor productivity gains. Infrastructure development enlarges production capacity by creating an investment-conducive environment for private investors. The cost of production for the private sector is reduced due to the intensive use of infrastructure services, hence enhancing the durability of private capital.

In the last three decades, a large body of empirical literature has focused on the quantitative assessment of the contribution of infrastructure investment for economic development; however, the results remain inconclusive. The previous literature concerning the causal relationship between infrastructure development and economic growth has two broad strands. The first strand argues that public investment in infrastructure has a positive and statistically significant impact on economic growth ([3–11]; however, countervailing evidence of ambiguous, insignificant, or negative impacts of infrastructure investment on economic growth prospects also continue to emerge [12]. The studies carried out by [13–15], based on more sophisticated econometric techniques and a broad range of countries, found much smaller and, in some cases, negative correlation between public investment in infrastructure and economic growth. A number of potential factors for the incongruous empirical findings on the growth impacts of infrastructure investment have been highlighted in the literature (see for example [16–21]. These include, the nonlinear relationship between infrastructure investment and growth, the presence of crowding-out effects in public investment, the source of financing for infrastructure investment, the accessibility of human capital as complementary inputs, the quality of institutions, political stability, and corruption, which hampers the association between infrastructure investment and economic growth.

Recently, the growth impact of infrastructure has become an omnipresent topic in many areas and dimensions of policy debate. For example, 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, from its dominant position in developing countries since the mid-1990s, from providing infrastructure under the increasing pressure of budgetary adjustment [22]. The second was the involvement of the private sector in infrastructure development. The financing of infrastructure to fast-track change is one of the key challenges for sustainable development, particularly for developing countries. Public investment continues to play a strategic role, but public budgets are often limited and governments may lack the necessary capacity. This has strengthened the role of public-private partnerships in the provision of infrastructures. Globally, public-private partnerships have become an increasingly popular means for the adequate provision of infrastructure services [23,24]. Due to the growing demand for infrastructure services on the one hand and the financial and budget constraints on the other hand, governments around the world now encourage the private sector to play a greater role in building and managing infrastructure projects. Some major reasons for the involvement of the private sector in infrastructure development are rising expenditures for the revamping, maintenance, and operation of public assets, increasing constraints on public budgets, the search for innovation through private sector acumen, and the goal of better risk management [25]. Roehrich et al. [25] and Kwak et al. [26] argue that public private partnerships ensure better quality infrastructures and services, at optimal cost, and risk sharing through the multiplicity of provision and contestability.

The standard growth models, which relate the output growth to the rate of capital formation, the labor force, and other factors, such as technological progress, make no distinction between the private and public components of investment [27]. Understanding the components of infrastructure investment that has a faster positive impact on economic growth has important policy implications for determining the most appropriate economic system. From a policy point of view, public investment is not only important to policymakers, as private sector investment in infrastructure also plays a crucial role in infrastructure development. It is generally accepted that private sector investment is more efficient and productive, but there is no empirical evidence for private sector investment in infrastructure. Therefore, the policies designed to promote private infrastructure investment should be based on proven facts and not on theoretical grounds.

Lanau [28] highlighted another important dimension of infrastructure. Empirical literature supports the hypothesis that the effect of infrastructure investment varies across different sectors of the economy [28–34]. Lanau [28] argues that 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. The contribution of infrastructure at sectoral level is less emphasized in the literature. Similarly, Rioja [33] argues that the use of an aggregate measure of infrastructure investment may hide the growth impact of infrastructure at a more disaggregate level.

This study revisits the question of the growth impact of infrastructure investment in the case of Pakistan. In particular, we investigate the questions of whether different forms of infrastructure investment have a differential impact on aggregate and sectoral components of GDP growth in Pakistan.

The choice of Pakistan for this paper is motivated by the fact that there is a substantial amount of government spending on infrastructure development and up-gradation, with the coordination of China. Infrastructure projects under the aegis of the China-Pakistan Economic Corridor (CPEC) will improve the communication network and transport infrastructure that can facilitate the rationalization of economic activity and reduce transaction and coordination costs.

Pakistan's infrastructure is relatively poor by international standards. According to the SBP [35] the estimated loss to Pakistan due to insufficient infrastructure is about 4% to 6% of the GDP. Logistical bottlenecks increase the production costs of goods by about 30 percent [35]. This has a significant impact as Pakistan faces tough competition from India and China in export markets. The suboptimal allocation and inefficient management of the physical infrastructure are among the reasons for low development in Pakistan [36]. The weak infrastructure is one of the main bottlenecks for doing business in Pakistan [37]. 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 (GCI), Pakistan ranks 98th out of 151 countries in terms of the quality of the overall infrastructure, compared to China, India, and Sri Lanka, ranked 51st, 74th, and 26th, respectively, for the years 2015–2016. As far as transport infrastructure is concerned, Pakistan ranks 78th out of 151 countries, while China, India and Sri Lanka rank 21st, 32nd, and 43rd respectively. Pakistan ranks 132nd in electricity and telephone infrastructure, compared to China, India and Sri Lanka, which rank 70th, 115th, and 77th, respectively. In order to improve and expand the infrastructure, Pakistan needs massive investment in infrastructure development.

Improvement in infrastructure are expected to bring major countrywide transformation, not only by moving bottlenecks and breaks in the transport and energy sector, but also in terms of improving the GDP, promoting employment, and facilitating 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.

The critical policy question is whether a massive investment in infrastructure projects would be able to deliver more significant economic development in the country. Theoretical and empirical analysis of the impact of infrastructure investment on economic development remains controversial. According to De Jong [38], a critical issue with public investment is their capacity to describe true public capital satisfactorily. Literature provides inconclusive evidence on the economic impact of public capital (For extensive reviews of empirical literature on public capital and economic growth, see for example [39–41]. Few empirical studies [42–50] examined the impact of infrastructure on economic growth in the context of Pakistan. The focus of earlier empirical studies of Pakistan, on the relationship between infrastructure and economic growth, is narrow in terms of the use of infrastructure measurements. Empirical results for the growth impact of infrastructure are less conclusive in the case of Pakistan.

The objective of this study is to assess the contribution of aggregate, public, and private infrastructure investment on aggregate and sub sectors of the economy. The motivation and justification for this study is threefold. In the context of Pakistan, most of the previous literature examines the impact of infrastructure investment on the aggregate economy. Although it is useful to show the positive effects of infrastructure on economic growth, the issue with the aggregated infrastructure-growth analysis is that it has not exposed the specific underpinnings that connect infrastructure investment with an inter-sectoral component of economic growth and through which infrastructure can affect economic growth. The impact of infrastructure varies significantly among different sectors of the economy; it is more crucial for some sectors of the economy than other sectors. Therefore, the first contribution of the current study is that it examines the contribution of infrastructure for the aggregate and sub-sectors (industry, agriculture, and service sector) of the economy. Previous studies have not made such a distinction and have only been focused on the effect of public investment on aggregate economic growth.

Likewise, the earlier literature for Pakistan uses aggregate investment as a proxy for infrastructure investment and ignores the role of public versus private infrastructure investment and the contribution of different compositions of infrastructure investment, such as the power sector, roads, and telecommunications for economic growth. Therefore, in contrast to earlier literature, the second contribution of the present study is that the current study disentangles infrastructure investment into public and private components and examines the relative importance of each component of infrastructure investment to economic growth. This addresses the shortcomings of most previous studies on this topic, which only focused on the impact of the public investment component on economic growth.

In time series analysis, the detection and adjustment of structural changes in the data are crucial for reliable estimates. The third contribution of this study is that we use a structural break unit root test to address the issue of structural breaks in the data and fully modified ordinary least squares (FMOLS) estimation methodology is employed to address the problem of reverse causality.

The remainder of the paper is structured along the following lines: In Section 2, we present a theoretical relationship between infrastructure and economic growth. The econometric technique and results are provided in Section 3. In Section 4, the results are presented. The conclusion and policy implications are presented in Section 5.

2. Overview of Economic Growth and Infrastructure in Pakistan

The stylized facts of Pakistan's economic growth are that the overall growth record has been satisfactory since 1960s; however high volatility has been observed and growth accelerations tend to be short lived. On average, the economy grew at an annual rate of slightly above 5%% from 1961 to 2017. Data presented in Figure 1 reveals that, since 1961, the country has witnessed three episodes of rapid growth in which GDP growth was above 5 percent in successive years, 1963 to 1970, 1980 to 1988, and 2004 to 2006 (Figure 1). The long-term growth rates show a declining trend from an average of 7% in the 1960s to 4.5 % in the second half of 2010. One most important reason for the declining long-term growth is that structural reform has been reducing growth rather than enhancing growth. The major contributory factors of the 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 a 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. 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.

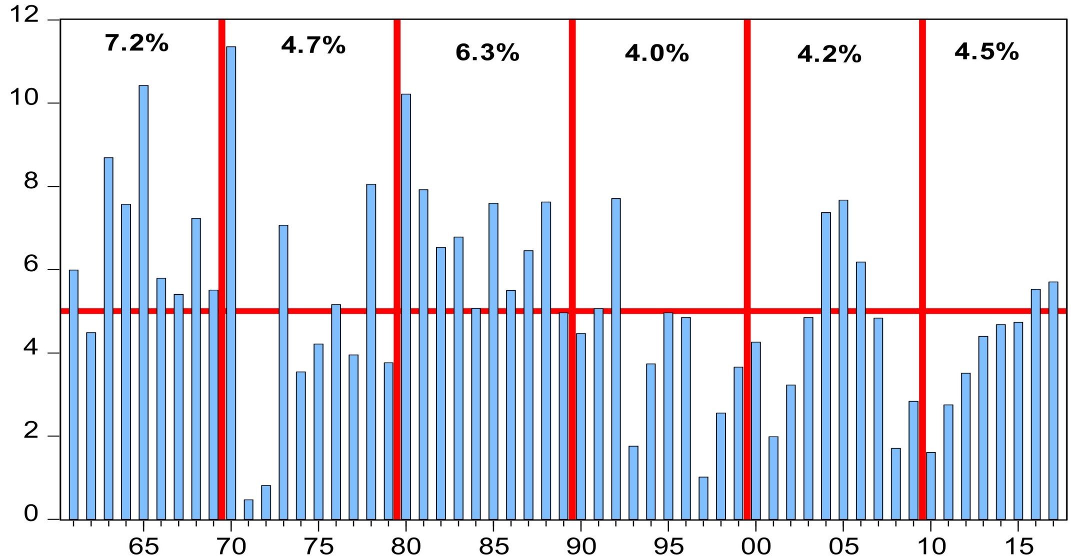

Figure 1. GDP growth (annual %). Handbook of Statistics on Pakistan Economy-2015, State Bank of Pakistan.

Resource constraints are the main reasons for the inadequate and inefficient infrastructure in Pakistan. Pakistan requires 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 infrastructure in Pakistan has traditionally been funded by public sector funding, much which has 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 the transport and communications sectors [38]. Corruption in infrastructure projects and the inability to complete infrastructure projects on time are main issues for Pakistan, which is lagging behind other countries in the region. According to De Jong [38], corruption in infrastructure projects was estimated at 10%–15% of the project values.

3. Infrastructure and Economic Growth

Infrastructure as an additional factor of production was introduced the first time by Weitzman [51] and Arrow and Kurz [52]. Later on, the seminal work by Aschauer [3] laid 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 [3] integrates public expenditure as an additional explanatory variable in the production function. He disaggregates government spending into productive and unproductive categories, as well as in stock and flow variables in the production function. 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 [40]. Services of public capital are generally considered as non-rival public goods.

On the other hand, Duggal et al. [53] 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 the total factor productivity by lowering production costs. With an increase in the technology index, additional public capital shifts up production function, improving the marginal products of factors of production. Sturm et al. [54] points 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. [55], 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.

As a consequence of externalities, economies of scale in infrastructure are generally accepted limitations in infrastructure capital services [56]. Therefore, infrastructure capital is differentiated from other categories of capital due to its market imperfections characteristic 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 [49].

A number of theoretical justifications are put forward in literature to demonstrate that infrastructure investment promotes economic growth. These channels are embodied following the generic framework of aggregate production function by Straub [12].

$$Y = A(\theta,\ K_I).F(K, L, G(K_I)), \tag{1}$$

where K_I represents the infrastructure capital stock, L is hours of labor work, and the term $A(\theta,\ K_I)$ in Equation (1) represents the productivity. This type of formulation is used for accumulation of infrastructure as an additional factor of production. Romp and Haan [40] assumes that $G(K_I) = K_I$. Services provided by infrastructure are considered as non-excludable and non-rival because of the public good characteristics of infrastructure. Straub [12] provides two justifications for the introduction of infrastructure in the production function 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 the price of infrastructure services are not strictly determined by the market. Therefore K_I, entered into the production function as a factor of production, would be based on the theoretical hypothesis that firms can make decisions about the cost of the amount of infrastructure capital they employ [53].

Infrastructure K_I is added in the production function as an intermediate input, such as G (KI) = I(KI), rather than an additional factor of production. $I(K_I)$ is considered as an intermediary input. An escalation in K_I lowers the cost of associated intermediate inputs, such as transport, telecommunication, and electricity, which enter firm's production function. Hulten et al. [57] calls this a market-mediated effect of infrastructure and Banerjee [10] call it the direct effects of infrastructure.

Furthermore, the production function specified in Equation (1) differentiates two sources of augmented productivity parameters A. The value θ, which represents generic efficiency-generating externalities and efficiency-enhancing externalities specifically related to the accumulation of infrastructure capital. Straub et al. [58] calls it the indirect effect of infrastructure. Infrastructure has a dual role between firms and households; it provides the input services to the firm and producer and final services to the consumers [59]. 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 effects, and indirectly, through reducing transactions and other costs. The direct and indirect channels specified in Equation (1) are explained as follows:

3.1. Direct Channel

Infrastructure as the pure public good or an intermediate input directly contributes to economic growth through the 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 the infrastructure growth nexus was outlined by Aschauer [60] and Baro [61]. They argue 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 [1]. The second transmission mechanism through which infrastructure may affect economic growth is the private capital formation. According to Agénor [1] 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 [62] and Agénor [63] found a positive and significant impact of investment in public infrastructure on private investment in Chile. Nadiri and Mamuneas [64] argue that the direct growth effect of infrastructure is based on the notion that the additional product of public investment is positive. This implies that a surge in public capital services reduces the cost of production in the private sector, which leads to an increase in the output of the private sector.

Straub [12] argues that private investment may increase in remote or excluded areas when these areas are connected through roads and railways and given access to services such as telecommunication and electricity. Investment in the infrastructure network is essential for private investment. Shanks and Barnes [59] point out that public investment in infrastructure is not subject to user charges and consequently offers an advantage to a producer that directly affects private sector output and productivity. This is also known as the free input effect.

Straub [12] also notes that the 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 [65] point out the initial rise in infrastructure investment crowds out private investment, but could potentially stimulate 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.

3.2. Indirect Channels

In addition to the direct effect of infrastructure on growth through the productivity of private inputs and the 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, economies of scale, and scope [1,12]. Each of these is explained below.

3.2.1. Adjustment Cost

Straub [12] 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 and Svensson [66] for Uganda, Alby et al. [67], for Latin America, and Lee et al. [68], for Indonesia and Nigeria). Efficient and reliable services of stock of infrastructure reduce the firm's investment in substitution factors of production and thereby release the resources for productive investment.

3.2.2. 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 the road network reduces the time spent on traveling and helps in organizing work time more efficiently. Torvik [69] shows that improvement in public infrastructure spurs economic growth by reducing unit labor costs and enhancing labor productivity.

3.2.3. The Durability of Private Capital

Maintaining the quality of public infrastructure has a positive impact on economic growth by improving the sustainability of private capital. 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 others uses. The absence of government spending on quality and maintenance of public infrastructure has been a persistence issue in most of the developing countries [1]. According to World Bank [56] estimates for developing countries, technical inefficiency in public infrastructures such as roads, the power supply, railways, and water, causes losses of equal to 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 the transportation network causes repeated interruptions, raises the question of its reliability, and creates severe damages for users. By increasing government spending for maintenance and the quality of the transportation network, reducing power interruption and telecommunication faults may positively affect private production. Canning and Bennathan [70] estimates show that, in Vietnam, a reduction in the roads' roughness from a 14 on the International Roughness Index (IRI) to 6 IRI would save 12% to 22% of vehicle operating costs. According to [71], 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 [1,22,57]) highlight the importance of the quality of infrastructure for growth and argue that government expenditure on maintenance and 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 [59]. Producers gain positive spillovers effects when infrastructure services are used free of charge, leaving the full benefits to the producer. If the producer charged for the use of the 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 [59]. Different types of infrastructure, such as power, transportation, and telecommunication networks, have different natures of spillover effects. Most commonly, infrastructure may have an impact on transaction and coordination costs, diffusion of knowledge, and information and geographic rationalization [59]. Spillover effects may also vary due to industry use of the infrastructure, for instance Röller and Waverman [72] argue that spillover benefits from the communications infrastructure can be enlarged with the information intensity.

3.2.4. Public versus Private Investment and Economic Growth

The debate on the relative impact of public and private investment on economic growth largely depends on whether public investment is crowd out or crowd in private investment in the economic growth process. Public sector investment can expedite the new private capital formation, thereby promoting economic growth through its impact on private sector economic activity [73–75].

On the one hand, literature highlights two channels through which public investment crowd out private investment, as follows: Public investment can delay private investment and, ultimately, economic growth when public investment is financed through borrowing from the external and internal financial market. Debt financing of public investment increases the cost of capital and reduces the expected return on private capital after tax. This slows down the new capital growth rate of the private sector and the economic growth [14,76]. Public investment can also displace private investment if it produces goods and services that compete with the private sector [76].

4. Model and Econometric Technique

To quantify the impact of infrastructure investment on an aggregate and sectoral component of GDP, we specified three different models on the basis of the different compositions of infrastructure investment. In the first specification, we use aggregate infrastructure investment, i.e., the sum of public and private sectors investment in electricity generation distribution, gas distribution, and transport and communication.

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

where y_{it} is real output per worker of aggregate industry, agriculture, and service sectors; k_{it} and h_{it} are respectively non-infrastructure capital per worker and human capital per worker in the aggregate economy and three subsectors of the economy. The value ai_t is used for aggregate investment in infrastructure capital.

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

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

where gi_t and pi_t represent the public and private component of infrastructure investment, respectively.

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

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

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

Empirical Strategy

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 externalities to the private sector and reduces transaction costs, facilitates the mobility of goods within the country and across the country, and facilitates labor mobility and the realization of economies of scale. Despite a strong theoretical linkage from infrastructure development to growth through numerous channels, the impact of infrastructure on economic growth was attributed to empirical weakness. For example, the seminal work of Aschauer [3] and the large body of subsequent literature used a production function approach to assess the impact of infrastructure capital on growth. Aschauer [3] 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 [39]. However, the methodological approach used by Aschauer was challenged on the econometric ground [39,77]. Aschauer's approach was criticized for simultaneity bias, endogeneity, and spurious regression because of non-stationarity of data. Pereira and Andraz [39] 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 non-contemporary effects. The most critical issue in Aschauer [3] 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 [78] confirms 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 the 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 and Bennathan [70] pointed out that a panel data estimation methodology may address the causality issue in infrastructure growth relationship. Canning and Bennathan [70] argue that pooling the data across the countries may allow for identification of a long-run relationship. Canning and Pedroni [79] 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 the VAR approach in the infrastructure–growth nexus is because VAR adequately addresses the above mentioned econometric issued comprehensively. Brons et al. [41] point out that the static nature of the 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 misspecification. The VAR approach to the 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 the 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 assumptions. The VAR results indicate the accumulated long-term variations in each explanatory variable because of an initial shock in public capital.

Some previous studies [22,80,81] 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 [82] is appropriate to take into account the endogeneity problem in the regressors and the serial correlation problem. According to Phillips [83], FMOLS provides an approach to unrestricted regression for a time series that takes advantage of data non-stationarity, without being explicit about the presence or number of any unit roots and cointegration relations. The FMOLS methodology proposed by Phillips [83] is a semiparametric approach which address 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. FMOLS methodology provides optimal estimates of cointegrating regressions [84]. This method has the advantage of eliminating the sample bias and correcting for endogeneity resulting from co-integrated relationships and serial correlation effects.

Following Christopoulos and Tsionas [84] and Di Iorio and Fachin [85] we specify the following data generation process:

$$y_t = \alpha + x_t'\beta + \mu_t\ , \tag{5}$$

$$x_t = x_{t-1} + \varepsilon_t, \tag{6}$$

where yt is a scalar time series and xt is a kx1 vector of time series. Intercept term α is included as deterministic component in the model.

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

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

$$\frac{1}{\sqrt{T}} \sum_{t=1}^{Tr} \omega_t \to B(r) = \sqrt{\Omega}\, W(r), \tag{7}$$

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 as follows:

$$\Omega = \sum_{i=-\infty}^{\infty} E\left[\omega_i\, ,\, \omega_{t-i}'\right]. \tag{8}$$

One side long run covariance matrix is as follows:

$$\chi = \sum_{i=-\infty}^{\infty} E\left[\omega_i\,,\,\omega'_{t-i}\right]. \tag{9}$$

Both Ω and χ can be rewired as follows:

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

Let's denote $X_t = diag(x_{1t}, \ldots, x_{Nt})$ and $Y_t = ((y_{1t}, \ldots, y_{Nt})'$, $\Omega_{\mu\varepsilon} = \left(\Omega_{\mu\mu} - \Omega_{\mu\varepsilon}\Omega_{\mu\mu}^{-1}\Omega_{\mu\varepsilon}\right)$ Denoting by an hat a consistent estimate, then

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

$$\begin{aligned} \tilde{y}_{it}^{+} &= y_{it} - \hat{\Omega}_{\mu\varepsilon}^{ii}\left(\hat{\Omega}_{\varepsilon\varepsilon}^{ii}\right)^{-1}\Delta x_{it}, \\ \mathrm{I} &= 1,\,2,\,\ldots,\,\mathrm{N}, \end{aligned} \tag{10}$$

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

FMOLS estimator can be define as follows

$$\hat{\beta} = \left(\sum_{t=1}^{T} X_t X'_t\right)^{-1}\left(\sum_{t=1}^{T} X_t \tilde{Y}_t^{+} - T\hat{\psi}_i\right), \tag{11}$$

Fully modified ordinary least squares (FMOLS) estimation methodology, developed by Phillips [82], has been employed in this study to examine the contribution of infrastructure investment on aggregate and sub-sectors of the economy. FMOLS estimators are asymptotically unbiased and have a fully efficient mixture normal asymptotic, allowing for standard Wald tests using asymptotic Chi-square statistical inference. The empirical analysis is based on time series data over the period from 1972–2015. Definition of variables used and the data source is given in Appendix A.

5. Results

5.1. 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. Ignoring the time-series properties of the variables under study may lead to misleading conclusions when modeling relationships between variables. Therefore, the analysis of the data started with augmented Dickey–Fuller (ADF) and Phillips–Parron (PP) unit root tests. Unit root test results, reported in Table 1, reveal that all variables included in our analysis are first difference stationary. The null hypothesis of a unit root for all variables at levels cannot be rejected, even at a 10% level of significance, and the first difference is rejected at the 1% level of significance. PP [86] tests have been used to control serial correlation and heteroscedasticity problems in the error term. However, both the ADF and PP tests have a low power against the alternative hypothesis that the series is stationary [87]. ADF and PP tests of the unit root are upward biased in rejecting the null hypothesis of a unit root. One possible solution to these problems, proposed by Kwiatkowski et al. [88], is to use the stationarity test under the null hypothesis.

Table 1. Unit Root Test.

	Level			First Difference		
	ADF	**PP**	**KPSS**	**ADF**	**PP**	**KPSS**
Aggregate Economy						
GDP	−1.64	−1.48	0.19 [a]	−10.4 [a]	−9.61 [a]	0.23
Capital Stock	−1.99	−1.99	0.39 [a]	−6.98 [a]	−6.97 [a]	0.21
Human Capital	−2.0	−2.26	0.77 [a]	−6.6 [a]	−6.57 [a]	0.06
Aggregate Investment	−2.46	−2.38	0.23 [a]	−7.03 [a]	−7.34 [a]	0.12
Public Investment	−2.4	−4.15 [a]	0.20 [a]	−6.67 [a]	−6.77 [a]	0.05
Private Investment	−2.58	−2.59	0.11 [a]	−7.1 [a]	−7.09 [a]	0.06
Electricity	−2.41	−2.3	0.19 [a]	−7.8 [a]	−7.82 [a]	0.06
Roads & Telecommunication	−2.31	−2.42	0.12 [a]	−5.62[a]	−6.55 [a]	0.22
Industry						
GDP	−1.43	−1.45	0.19 [a]	−6.95 [a]	−6.95 [a]	0.08
Capital Stock	−151	−1.47	0.38 [a]	−6.28 [a]	−6.29 [a]	0.31
Human Capital	−0.87	−1.02	0.69 [a]	−5.27 [a]	−5.37 [a]	0.08
Aggregate Investment	−1.87	−1.83	0.19 [a]	−6.36 [a]	−6.44 [a]	0.30
Public Investment	−2.11	−2.03	0.21 [a]	−6.39 [a]	−6.44 [a]	0.31
Private Investment	−2.33	−2.41	0.12 [a]	−6.35 [a]	−6.36 [a]	0.13
Electricity	−2.12	−2.03	0.19 [a]	−7.36 [a]	−7.37 [a]	0.06
Roads & Telecommunication	−1.54	−1.39	0.13	−5.8 [a]	−5.76 [a]	0.20
Agriculture						
GDP	1.93	1.94	0.15 [a]	−6.92 [a]	−7.37 [a]	0.27
Capital Stock	2.41	−2.41	0.77 [a]	−6.14 [a]	−7.61 [a]	0.17
Human Capital	−1.94	−1.94	0.81 [a]	−5.47 [a]	−5.41 [a]	0.06
Aggregate Investment	−2.03	−2.15	0.19 [a]	−6.73 [a]	−6.94 [a]	0.33
Public Investment	−2.55	−2.52	0.21 [a]	−6.72 [a]	−6.82 [a]	0.35
Private Investment	−2.45	−2.51	0.11 [a]	−6.31 [a]	−6.31 [a]	0.11
Electricity	−2.44	−2.43	0.19 [a]	−7.39 [a]	−7.4 [a]	0.23
Roads & Telecommunication	−2.25	−2.36	0.74 [a]	−5.82 [a]	−7.01 [a]	0.23
Services						
GDP	−2.69	−2.55	0.16 [a]	−8.57 [a]	−8.69 [a]	0.27
Capital Stock	−3.37	−1.82	0.69 [a]	−5.6 [a]	−5.27 [a]	0.18
Human Capital	−2.13	−2.23	0.72 [a]	−6.22 [a]	−6.22 [a]	0.06
Aggregate Investment	−2.29	−2.22	0.22 [a]	−6.55 [a]	−7.12 [a]	0.32
Public Investment	−2.4	−2.32	0.21 [a]	−6.46 [a]	−6.53 [a]	0.30
Private Investment	−2.67	−2.68	0.12 [a]	−6.49 [a]	−6.49 [a]	0.11
Electricity	−2.41	−2.36	0.19	−7.41 [a]	−7.42 [a]	
Roads & Telecommunication	−3.46 [b]	−2.62	0.69 [a]	−6.35 [a]	−8.81 [a]	0.31

Capital Stock, is calculated by subtracting the capital stock of power, transport, and roads from the total capital stock. Note [a], [b], [c] indicate rejection of the null hypothesis of unit root at the 1%, 5%, and 10% levels of significance.

As opposed to others, the test by Kwiatkowski et al. [88] assumes that the series is stationary under the null. The KPSS test is a residuals-based test and residuals are obtained from the OLS regression. The unit root tests results are also confirmed by the Kwiatkowski–Phillips–Schmid–Shin (KPSS) test, in which the null hypothesis is stationary. However, literature criticized the standard unit-root tests for ignoring the possible existence of structural breaks in the series and the low power of the tests [89]. Perron [90] concluded that, because of the existence of structural breaks in the series, results of standard unit root test might be biased towards the non-rejection of a unit root. To deal with the problem of the existence of a structural break in the data, we use a structural break unit root test which allows identification of a structural break endogenously from the data. The structural break unit root tests are reported in Table 2.

Table 2. Unit Root Test with Structural Break.

	Aggregate Eco		Industry		Agriculture		Services	
	ADF-Stat	**Break Year**	**ADF-Stat**	**Break Year**	**ADF-Stat**	**Break Year**	**ADF-Stat**	**Break Year**
				Level				
GDP	−5.01 [a]	1994	−3.59	1990	−4.48	1990	−4.23	1996
Capital Stock	−4.95 [c]	2002	−4.71	2004	−5.36 [c]	1996	−4.81	1985
Human Capital	−5.06 [c]	1998	−4.86	1990	−7.85 [a]	1990	−3.27	1996
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
EPP *	−4.21	1994	−4.43	1994	−4.15	1994	−3.84	1996
TPP *	−5.68 [b]	2003	−6.02 [a]	2005	−5.26 [c]	2005	−5.68 [c]	2003
				First Difference				
GDP	–	–	−7.94 [a]	1994	−7.67 [a]	1996	−9.14 [a]	2002
Capital Stock	−8.06 [a]	2009	−6.41 [a]	2009	−6.80 [a]	2000	−9.50 [a]	1986
Human Capital	−7.39 [a]	1992	−6.39 [a]	1994	–	–	−7.4	1992
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
EPP *	−9.14 [a]	2004	−8.65 [a]	2004	−8.76 [a]	2004	-8.68 [a]	2004
TPP *	–	–	–	–	–	–	–	–

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

The structural breaks observed during periods of the 1990s 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 year average life spans were the significant hurdles for consistent macroeconomic policies. The first structural break in our data, from 1994, reflects the impact of pest attacks on the agriculture sector, political instability, and viral attacks on crops, an electricity crisis, and a devastating flood in the country. During this period, Pakistan's economy performed below its potential, GDP growth declined sharply, and there was a balance of payment crisis due to the widened current account balance. At that time, the country failed to attract foreign investment to boost the economy. Since the early 1990s, the gap between demand and supply of electricity has been widening, resulting in prolonged load shedding. To combat the electricity shortage, in 1994 the government encouraged the private sector to invest in energy infrastructure and the Private Power and Infrastructure Board (PPIB) was established. The government articulated a long-term energy development plan through the involvement of a public-private partnership to enhance the power generation capacity. Hydropower was also opened to the private sector in 2003. In 1998, in the aftermath of a nuclear test, economic sanctions were imposed and the freezing of the foreign currency account resulted in a significant drop in worker's remittances, exports earning, aid, and other capital inflows. As a consequence of GDP growth, private investment and the external sector were severely affected. The structural breaks unit root test, reported in Table 4, 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 the first difference, even at the 1% level of significance. However, the null hypothesis of a unit root for human capital in the agriculture sector is not rejected at level.

5.2. Coinegration Test

We tested for the long run relationship among the variable of interest using the trace and maximum eigenvalue statistic from Johansen [91,92]. The Johansen maximum likelihood cointegration results are reported in Table 3.

Table 3. Johansen Co-Integration Tests.

	Trace Statistic				
	r = 0 (63.8)	**r ≤ 1 (42.9)**	**r ≤ 2 (25.8)**	**r ≤ 3 (12.5)**	
Aggregate Investment in Infrastructure					
Whole 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					
Whole 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
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					
Whole 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					
Whole 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					
Whole 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. The number in the brackets denotes the critical values at the 5% level of significance. * indicates rejection of the null hypothesis of no co-integration at the 5% level of significance.

The hypothesis of no cointegrating vector is rejected for all different cases. The cointegration test confirmed the existence of a long run relationship for different specifications of all sectors of the economy.

5.3. Growth Impacts of Aggregate Infrastructure Investment

We have estimated the impact of public and private infrastructure investment on the aggregate economy and sectoral output over the period from 1972 to 2015 using fully modified ordinary least squares (FOLS) methodology. We also incorporated the dummy for structural breaks in the data. Empirical results, reported in Table 4, show the effect of infrastructure investment on the aggregate economy, the industrial, agriculture, and services sector economy. Marginal contribution of aggregate investment in infrastructure to real GDP per worker is positive and statistically significant for the aggregate as well as for the sub-sector, i.e., industrial, agriculture, and services sectors. In almost in all models, the estimated coefficients of investment in infrastructure are significant at the 1% level of significance. However, the impact of aggregate infrastructure investment on the aggregate and sub-sectors 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 the services sector (0.06). For the Spanish economy, Cantos et al. [29] examined the impact of transport and road infrastructure on four different sectors of the economy, namely agriculture, industry, construction, and business services and found much higher elasticity in agriculture (0.124) than in industry (0.067) and in the services sector (0.013). When the total investment in infrastructure is disaggregated into the public, and private sector, positive and statistically significant effects are obtained in the case of public sector infrastructure investment for the aggregate, as well as for sub-sectors 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 to the services sectors. The impact of private infrastructure investment on the aggregate economy is not statistically different from zero. Estimated elasticities of non-infrastructure capital stock are not statistically different from zero for industrial and agriculture sector, while this is positive and significant for the services sector. The elasticity of human capital for the aggregate and for all 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 the agriculture (0.49) sector than and in the industry and services sector, which is (0.28).

Table 4. Aggregate Investment in Infrastructure: Public vs. Private Dependent Variable. (GDP per worker).

	Whole Economy		**Industrial**		**Agricultural**		**Services**	
Capital Stock	0.03 (0.67)	0.08 ^{b} (2.30)	−0.02 (−0.28)	−0.01 (−0.13)	−0.03 (−1.20)	−0.01 (−1.42)	0.21 ^{c} (5.70)	0.12 ^{c} (3.42)
Human Capital	0.21 ^{c} (3.01)	0.45 ^{c} (9.63)	0.28 (2.47) ^{b}	0.34 ^{c} (3.47)	0.49 ^{c} (6.91)	0.29 ^{c} (10.1)	0.28 ^{c} (4.15)	0.25 ^{c} (4.98)
Aggregate Infra	0.19 ^{c} (6.97)		0.32 ^{c} (4.83)		0.11 ^{c} (2.96)		0.06 ^{b} (2.58)	
Public		0.08 ^{c} (9.87)		0.17 ^{c} (5.06)		0.07 ^{c} (10.8)		0.06 ^{c} (5.0)
Private		0.003 (0.45)		0.06 ^{b} (2.09)		0.12 ^{c} (13.4)		−0.04 ^{b} (−2.84)
Constar	6.95 ^{c} (7.99)	4.89 ^{c} (9.49)	4.48 ^{c} (3.54)	4.51 ^{c} (4.02)	4.20 ^{c} (7.58)	5.92 ^{c} (4.78)	5.62 ^{c} (6.32)	7.30 ^{c} (9.55)
Trend	−0.01 (−3.09)		0.01 ^{c} (7.76)	0.02 ^{c} (8.67)			0.01 ^{c} (8.27)	0.0 ^{c} (10.1)
Structural Break	0.05 ^{c} (3.02)	0.09 ^{c} (6.53)	0.07 ^{b} (2.29)	0.07 ^{b} (2.48)	−0.11 ^{c} (−4.43)	−0.01 (−1.38)	0.06 ^{c} (3.65)	0.0 ^{a} (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}, ^{b}, and ^{c} indicate rejection of the null hypotheses at the 10%, 5%, and 1% significance levels, respectively.

When public and private investment is separately introduced in the regression equation, the highest elasticity of human capital is observed for industry (0.34), then in agriculture (0.29), and in the services sector (0.25). The estimated coefficient of public sector infrastructure investment is higher than private sector infrastructure investment for the aggregate economy and the 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 more important role in the industrial sector, while the private infrastructure investment role is more significant in the agriculture sector. Our findings contradict with those of Zou [93], who found that private investment contributed more to economic growth than public investment, in the case of the USA.

To examine the role of investment in infrastructure by type of infrastructure, we disaggregated infrastructure investment into investment in electricity generation distribution, gas distribution, and transport communication (the results are reported in Table 5). The estimated elasticity of energy and road infrastructure is positive and statistically significant for both the economy as a whole and for the sub-sector of the economy. However, the results are very heterogeneous in terms of the magnitude of elasticity across the sectors. The marginal contribution of investment in roads and telecommunication is higher than the marginal contribution of investment in the energy sector in the correspondence sector, except for the services sector. The findings indicate that the infrastructure related variables—energy, road, and telecommunication—have positive significant coefficients at the 1% significance level for different specifications. The impact of investment in electricity and gas distribution has the highest elasticity in the industrial sector (0.13), then in aggregate economy (0.09), while the elasticities are very small in the agricultural (0.04) and services sector (0.05).

Table 5. Investment in Infrastructure: Dependent Variable GDP worker.

	Whole Economy	Industrial	Agricultural	Services
Capital Stock	0.20 ^{b}	0.02	0.12 ^{c}	0.20 ^{c}
	(2.82)	(0.06)	(17.4)	(9.59)
Human Capital	0.40 ^{c}	0.28 ^{c}	0.18 ^{c}	0.26 ^{c}
	(4.28)	(3.14)	(7.74)	(6.94)
Energy	0.09 ^{c}	0.13 ^{c}	0.04 ^{c}	0.05 ^{c}
	(3.91)	(5.27)	(10.8)	(6.04)
Roads & Tele	0.12 ^{b}	0.22 ^{c}	0.14 ^{c}	0.03 ^{b}
	(2.70)	(5.44)	(19.8)	(2.16)
Constant	4.39 ^{c}	5.78 ^{c}	19.89 ^{c}	6.43 ^{c}
	(5.52)	(4.99)	(32.1)	(12.4)
Trend		0.01 ^{c}	0.01 ^{c}	0.01 ^{c}
		(7.73)	(15.5)	(14.3)
Structural Break	0.02	0.06	0.03 ^{c}	0.04 ^{c}
	(0.44)	(1.24)	(6.24)	(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}, ^{b} and ^{c} indicate rejection of the null hypotheses at the 10%, 5% and 1% significance levels respectively.

Similarly, the elasticity of roads and telecommunications investment is higher in the industry (0.22) than in agriculture (0.14), and in the service sector is (0.03). The sectoral analysis reveals that investment in electricity and gas distribution, roads, and telecommunication networks 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 an adequate provision of electricity, roads, and telecommunication networks. Our results for disaggregated infrastructure investment are in line with those of [94]. Pereira [95] established that all types public investment are positively significant in explaining economic growth. Core infrastructure investment in gas and electricity facilities, the transport system, the water supply, and sewerage systems was found to have higher marginal returns.

The telecommunication infrastructure assists producers, consumers, businesses, and other stakeholders 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.

Agénor [1] pointed out that public investment in infrastructure may stimulate the marginal productivity of capital and labor. As a consequence of a reduction in the marginal production costs of inputs, the level of private production may rise. This scale effect may lead to higher private investment and may, thereby, enhance the production capacity. This implies that public investment in infrastructure is complementary to other investments and inadequate or insufficient infrastructure investment is a constraint to other investment, particularly for private investors. Therefore, it restrains economic growth. The theoretical literature on infrastructure investment and economic growth pinpoints five important channels through which investment in infrastructure boost economic growth.

These channels include the following: (1) Direct input into the production function (2) that complements the other inputs. (3) Infrastructure investments can stimulate human capital accumulation. (4) Infrastructure investment can increase aggregate demand in the economy through expansionary infrastructure investment and (5) can also serve as an instrument to guide industrial policy. The government could try to initiate this channel by investing in specific infrastructure projects to increase industrial production in the country [94].

6. Conclusions

There is a general consensus, among policy-makers and economists, that investment is crucial to development and economic prosperity, but there are inconclusive views on the relative importance of public, private, and other components of investment for economic growth. Understanding the components of investments that accelerate economic performance has an important policy implication. More recently, Pakistan faces economic difficulties, such as the widening of the current account and balance of payments deficits, growing external debt, and declining growth rates. These economic problems have led to a fundamental review of development strategies. Specially, sentiment in policy making circles has turned against government intervention on a large scale and toward greater market dependency on the allocation and use of public funds. The aim of this study is to see the role of private sector in the development of infrastructure in Pakistan. It is generally believed that private sector investment is more efficient and productive, but no empirical evidence is available. Therefore, the policies designed to encourage the private infrastructure investment should be based on proven fact, rather than based on theory.

Against this background, in this study, we empirically examine the contribution of public and private infrastructure investment on the aggregate output and sub-sectors of the economy by employing an infrastructure augmented production-function approach. The output elasticity of infrastructure is estimated by taking into account the several limitations of past studies on the infrastructure-growth relationship. The fully modified ordinary least squares (FMOLS) technique was employed to address the issue of endogeneity due to unobservable factors. The empirical analysis encompasses the estimation of a production function relating output per worker to non-infrastructure capital, human capital, and infrastructure capital. In order to quantify the impact of infrastructure investment on economic activity in Pakistan, three different compositions of disaggregated infrastructure were used in empirical analysis, as follows: (1) Total investment in infrastructure; (2) public and private infrastructure investment separately; and (3) in the third stage we analyzed the separate impact of investment in roads, telecommunication, and power. Improvement in infrastructure indicators generates externalities that may spread out across the different sectors of the economy. Therefore, in this paper, we also estimate the contribution of infrastructure on different sub-sectors of the economy.

We find that the marginal contribution of aggregate investment in infrastructure to the real GDP per worker is positive and statistically significant for the aggregate as well as for the sub-sectors of the economy. The estimated elasticity of public infrastructure investment for the industrial sector (0.32) is higher than the agricultural sector (0.11) and the services sector (0.06). In the case of private infrastructure investment, statistically significant and positive estimates are obtained for the industrial and agricultural sectors, while it is harmful to the services sectors. The marginal contribution of investment in roads and telecommunication is higher than the marginal contribution of investment in the energy sector and in the correspondence sector, except for the services sector. The impact of investment in electricity and gas distribution is higher in the industrial sector (0.13) than in the aggregate economy (0.09), while these elasticities are very small in the 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 the agriculture (0.14) and service sectors (0.03).

These findings are obtained in a framework that controls for reverse causation, endogeneity, and structural breaks in the data, and pass a variety of statistical tests that show no evidence of model misspecification. From this, we can conclude that our empirical findings are significant, not only statistically but also economically.

There are substantial differences in the impact of private, public, and other types of infrastructure investments on economic growth and there are also significant sectoral variations in the effect of both public and private infrastructure investment. In most of the cases, public infrastructure investment has a more significant impact on economic growth than private infrastructure investment. There are several important policy implications in these findings. The results suggest that it is important to make a distinction between the respective roles, for each sector of the economy, played by public, private, and other components of infrastructure investment. Evidence suggests that a clear need to improve the productivity of infrastructure by more rigorously identifying the type of infrastructure investment that has a positive impact and is likely to complement private sector infrastructure investment.

Public investment in infrastructure can have a strong impact on private capital information by providing the necessary infrastructure, such as roads, electricity, telecommunications, health, and education. Therefore, the government should aim to create an environment in which private investment becomes more attractive. In this context, the Government should ensure a stable macroeconomic environment, adequate legal and institutional arrangements for the protection of private property, and adequate access to credit and to import inputs by private investors. The involvement of the private sector in the provision of infrastructure would help to control the tight budgetary situation.

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Appendix A

Table A1. Data Source and variable definition.

Variable Name	Definition
Gross Domestic Product (GDP)	Constant Price
Industrial GDP (Rs Million)	Constant Price
Agriculture GDP (Rs Million)	Constant Price
Services Sector GDP (Rs Million)	Constant Price
Capital Stock [a] (Rs Million)	Gross fixed capital formation (Constant Price)
Human Capital (in Million)	Total number of pupils enrolled at secondary level in public and private school
Labor Force (in Million)	
Aggregate infrastructure Investment (Rs Million)	Sum of gross fixed capital formation of public and private sector in electricity generation distribution, gas distribution, and transport and communication
Public Infrastructure Investment (Rs Million)	Sum of gross fixed capital formation of public sector in electricity generation distribution, gas distribution, and transport and communication
Private Infrastructure Investment (Rs Million)	Sum of gross fixed capital formation of private sector in electricity generation distribution, gas distribution, and transport and communication
Investment in Energy sector (Rs Million)	sum of public and private investment in electricity generation distribution, gas distribution
Investment in Transport and telecommunication (Rs Million)	Sum of public and private investment in and transport communication.

[a] Capital Stock is calculated by subtraction the public and private investment in electricity generation distribution, gas distribution and transport communication. Data Source: Data on all variables are taken from Hand Book of Statistics, State Bank of Pakistan.

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