PUBLIC INFRASTRUCTURE INVESTMENT AND THE EFFICIENCY PARADOX: EMPIRICAL EVIDENCE FROM SELECTED ASIAN ECONOMIES



PIDE
PAKISTAN INSTITUTE OF DEVELOPMENT ECONOMICS

By

Name: Akbar khan

PIDE2023FMPHILECO01

Supervisor

Dr. Haider Ali

M.Phil Economics

PIDE School of Economics

Pakistan Institute of Development Economics, Islamabad

2026

PAKISTAN INSTITUTE OF DEVELOPMENT ECONOMICS

Pakistan Institute of Development Economics, Islamabad

PIDE School of Economics

CERTIFICATE

This is to certify that this thesis entitled: **"Public Infrastructure Investment and the Efficiency Paradox: Empirical Evidence from Selected Asian Economies"** submitted by **Mr. Akbar Khan** is accepted in its present form by the School of Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in Master of Philosophy in Economics.

Supervisor: **Dr. Haider Ali** Signature: _____

Internal Examiner: **Dr. Iftikhar Ahmad** Signature: _____

External Examiner: **Dr. Hasan Muhammad Mohsin** Signature: _____

Director, PSE
PIDE School of Economics: **Dr. Iftikhar Ahmad** Signature: _____

Dedication

To my beloved parents, whose prayers and sacrifices made this journey possible and to the martyrs of Mangi Dam, Ziarat, this work is a humble tribute to their resilience and strength.

ACKNOWLEDGEMENTS

I wish to extend my heartfelt thanks to my supervisor, Dr. Haider, for his invaluable mentorship throughout this research. Their support has gone far beyond what words can capture. Their guidance helped me navigate the challenges of academic complexities while instilling in me the principles of dedication, and intellectual honesty.

I am also profoundly grateful to my parents, whose deep respect for wisdom and knowledge has continually guided me in my journey to grow as a scholar. Their teachings on curiosity and the joy of learning have been a constant source of inspiration beyond what words can express.

I want to express my gratitude to all of you for being my support throughout this journey.

Abstract

This study empirically examines the efficiency paradox of public infrastructure investment across eight South and Southeast Asian economies using panel data over the period 1996 to 2019. The efficiency paradox, as formalized by Berg et al. (2018), posits that Low Efficiency Countries (LECs) may derive paradoxically higher long-run growth returns from public investment than High Efficiency Countries (HECs) when public and private capital are complements rather than substitutes. Public investment efficiency coefficients are estimated using the law of motion for public capital within a Fixed Effects framework, while the complementarity between public and private capital is examined through a log-linearized interaction framework motivated by the nested CES production structure of Sato (1967), with the interaction term capturing the conditional marginal effect of public capital on output given the level of private capital.

Estimated efficiency coefficients reveal significant cross-country heterogeneity, ranging from 42 percent in Sri Lanka and 47 percent in Pakistan to 86 percent in India and 78 percent in Malaysia. Government investment flows exert a positive and significant short-run effect on GDP per capita, with a long-run multiplier of 0.604, while accumulated public capital stock exhibits negative or insignificant long-run coefficient, a flow-stock duality broadly consistent with the efficiency paradox. The interaction between public and private capital is positive but statistically insignificant, providing directional evidence of complementarity. Institutional quality and human capital exhibit weak moderating effects, consistent with institutional threshold effects in the regional context. Trade openness emerges as the most robust and consistently positive determinant of growth across all specifications. The findings suggest that sustained public investment commitments, complemented by improvements in public investment management capacity at the planning, procurement, and implementation stages, are essential for translating infrastructure spending into productive long-run capital accumulation.

Keywords: Public Infrastructure Investment, Efficiency Paradox, Public Investment Efficiency, Public-Private Capital stock Complementarity, South and Southeast Asia, Economic Growth

Table of Contents

Chapter 1 1

Introduction 1

1.1 Background 1

1.2 Research Problem 4

1.3 Research Gap and Contribution 8

1.4 Research questions 9

1.5 Research Objective 10

1.6 Research Hypotheses 10

1.7 Conceptual Framework 11

Chapter 2 14

Literature Review 14

2.1 Theoretical Foundations 14

2.2 Early Empirical Evidence 14

2.3 Critiques of Production Function Approach 15

2.4 Behavioral and Cost Function Models 17

2.5 VAR and Panel Approaches 17

2.6 Empirical Evidence from the Regional countries 18

2.7 Substitutability Between Public and Private Capital 20

2.8 Infrastructure Governance and Investment Efficiency 21

2.9 Research Gap 22

Chapter 3 23

Data and methodology 23

3.1 Data and Variables: 23

3.2 Construction of Variables: 27

3.3 Theoretical framework 28
3.4 Model specification 29
3.5 Estimation Techniques 32
3.6 Static Panel Analysis 34
3.7 Dynamic Panel analysis 36
Chapter 4 40
Result and Discussion 40
4.1Descriptive statistics 40
4.2 Static Panel Results: 43
4.3 Dynamic Panel Result 46
4.3.1 Public and Private Capital Dynamics: The Efficiency Paradox 52
4.3.2 Institutional Quality and Human Capital: Limited Moderating Effects 54
Chapter 5 56
Conclusion and Policy recommendations 56
5.1 Conclusion 56
5.2 Limitation of the Study 56
5.3 Policy Recommendations 59
References 61
Appendix 69

List of tables

Table 1.1: Average Net Marginal Productivity of Capital (nMPK%) by Country……...3
Table 3.1: Discription of the Variables 25
Table 4.1: Descriptive Statistics..... 42
Table 4.2: Fixed effect regression (Dependent Variable: Public Capital Stocks)..... 44
Table 4.3: Efficiency Results for different countries 44
Table 4.4: System GMM results (Dependent Vairable is Real GDP per capita 48
Table 4.5: Long Run Multipliers Derived From System GMM Estimates 50
Table 5: List of Selected Countries..... 69
Table 6: Fixed Effect Regression Result (Model 1)..... 69
Table 7:Fixed Effect Regression Result (Model 2)..... 70
Table 8: Fixed Effect Regression Results (Model 3)..... 70
Table 9: Correlation Matrix 71

List of Figures

Figure.1.1 Infrastructure Investment In East Asian Countries 2
Figure1.2 Infrastructure Investment Rate..... 4
Figure 3.1 Conceptual Framework 13

Chapter 1

Introduction

1.1 Background

Public investment in infrastructure is regarded as a crucial economic activity for modern state to stimulate the economic growth in an economy. The industrial revolution and the innovations associated with it had shifted the focus form the inadequate infrastructure to more sustainable infrastructure that can facilitate societal development and economic growth. The infrastructure services are mainly divided into two categories physical and social infrastructure. The former is also known as economic infrastructure and includes the basic systems that support the economy, while the latter refers to infrastructure that supports quality of life and human development. Similarly, "Social overhead capital" (SOC) refers to a broad range of activities that fall under the umbrella term of infrastructure (World Bank, 1994).

The demand for the public infrastructure such as transportation linkage, energy sources, urban facilities and social services have increased over time, as these improve productivity opportunities and lower cost for the firms operating in competitive market and also elevate the values of assets for the poor (Bajar & Rajeev, 2016; Sahoo et al., 2010; Fan et al., 2004). These capital have influences through various channels such as direct investment in infrastructure, improving competitiveness which in turn lead to effects like generating employment opportunities for the unemployed individuals in the region (Javid, 2019).

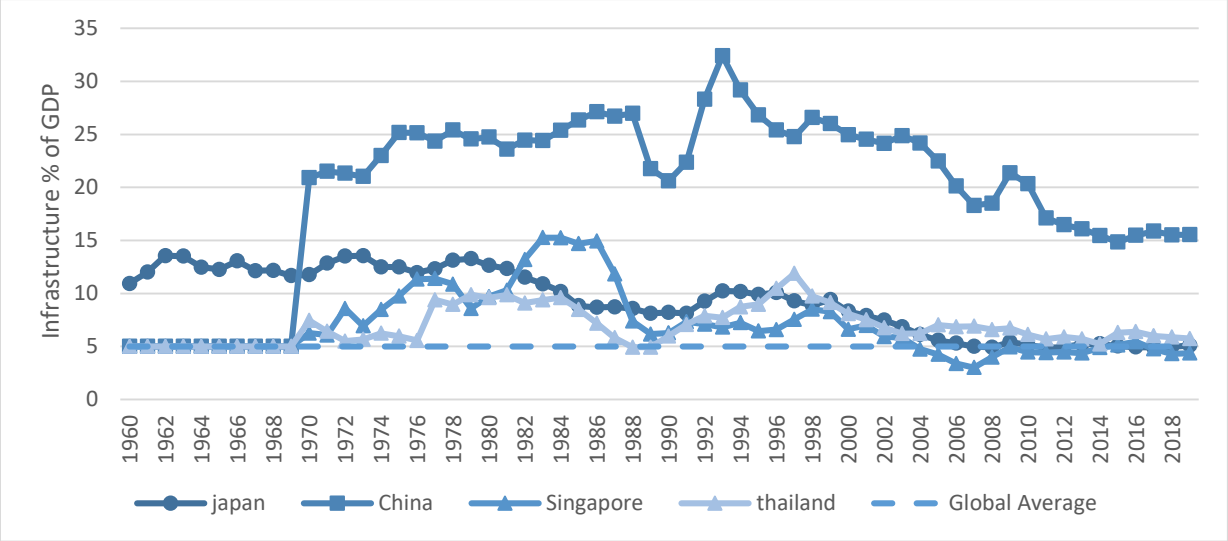
Recognizing the significance of public investment, governments around the world have increased public investment in such infrastructures projects (Foster, Rana, & Gorgulu, 2022), partly because of the countercyclical policies advocated by Keynes to stabilize the economy through more government spending and partly due to high demand for public investment. This can be confirmed from the literature (Deleidi, Iafrate, & Levrero, 2020; Foster, Vagliasindi, & Gorgulu, 2022) on the fiscal multiplier of government spending stating that overall the highest fiscal multiplier in OECD counties is associated with public spending on infrastructure in long run of about 1.5 within 2 to 5 year (Vagliasindi & Gorgulu, 2021).

For developing countries, the potential of public infrastructure investment is expected to be high. Recent empirical evidence shows that in developing countries, public investment yields a

significant long-run output multiplier of approximately 1.1 on average over five years, rising to 1.6 in contexts with high investment efficiency and sufficient fiscal space (Adarov, Clements, & Jalles, 2024). In support of these findings, Gechert and Rannenberg's (2018) meta-regression analysis of 98 studies confirms that public investment multipliers can exceed 1.4 under average conditions and reach as high as 2.1 during economic downturns, particularly when coordinated with accommodative monetary policy. This shows that the effectiveness of fiscal policy does not apply across contexts but rather it is dependent on macroeconomic factors and institutional contexts.

Several developing nations have heavily invested in infrastructure at the start of their economic development. Figure 1.1 shows that investment in infrastructure as a share of GDP exceeds the global average of 5%. Also highlighting that countries like China, Japan and Singapore exhibits higher infrastructure investment as a share of GDP during the early stages of economic

Figure.1.1 Infrastructure Investment In East Asian Countries



development. This trend reflects aggressive public investment strategies aimed at urbanization and industrial growth. In contrast, developed economies maintain relatively stable but lower infrastructure spending over time.

Due to the lack of time series data the empirical justification for the higher public investment returns are ambiguous in developing nations (Warner, 2014; Chakraborty & Dabla-Norris, 2011). However, proxy measures such as the marginal product of capital offer insights into potential

returns. Nell and Thirlwall (2014) shows that gross Marginal product of capital which is unadjusted for average ratio of gross fixed capital formation is 21 % in low income countries and 13% in high income countries while nMPK (adjusted net marginal product of capital) for low in income countries is low of about 4% while for high income countries it is 9%. Table 1.1 below presents average adjusted Net Marginal Product of Capital (nMPK) for selected countries, used here as a proxy for the returns on public infrastructure investment. Since nMPK measures how productive capital is, it can increase the expected returns on investment, with an assumption that public capital is used efficiently. While ROI focuses on financial returns, nMPK reflects how much output is generated from investment.

Inefficiencies in public investment, such as poor project selection and low institutional quality, suggest that public investment may not be beneficial, as it can crowd out private investment and lower productivity (Cavallo & Daude, 2011). But the lower initial stock of public sector and the existing stock of capital in developing countries is inadequate, improvement could be beneficial. However, the dire need of public investment, and the financing of these public investment has shifted the focus towards the efficiency improvements for financially constrained countries (Kapsoli, Tewodaj, & Verdier, 2023).

Table 1.1 Average Net Marginal Product of Capital (nMPK %) by Country

Developed Countries	**nMPK (%)**	**Developing Countries**	**nMPK (%)**
Japan	4.91%	China	19.72%
United States	3.96%	Indonesia	6.78%
Germany	6.79%	Bangladesh	6.39%
France	3.99%	Mongolia	2.36%

In Pakistan, infrastructure over time has been financed by the government and foreign aids. Pakistan's total investment to GDP is 13.4% in FY2024, and the infrastructure investment rate is 1.1% of GDP, which is low compared to other countries in the region (Figure 2). The state of infrastructure in Pakistan can be gauged by the fact that Pakistan ranks 125th in infrastructure among 140 countries, indicating that there are significant challenges in this area (GII, 2024). Such as regulatory and bureaucratic delays that hinder project execution, significant urban infrastructure

gaps in water, sanitation, and housing, with 43% of the population lacking safely managed water and 18% without basic sanitation, and growing climate vulnerabilities that threaten infrastructure stability.

The problems are not peculiar to Pakistan but most of the countries in South and South east Asia like Bangladesh, Nepal, and Sri Lanka are characterized by the same factors which include low levels of public investments of less than 3%, poor institutional capacity, and lack of infrastructure, although their macroeconomic factors are different. As an example, Bangladesh is spending about 2.8% of the GDP in infrastructure, but the country has a high congestion and urban resilience. Nepal has issues of inefficient capital budgets, whereas Sri Lanka, even with generally more infrastructure expenditure in the past, has problems of inefficiencies by using debts to fund projects and delays in project execution.

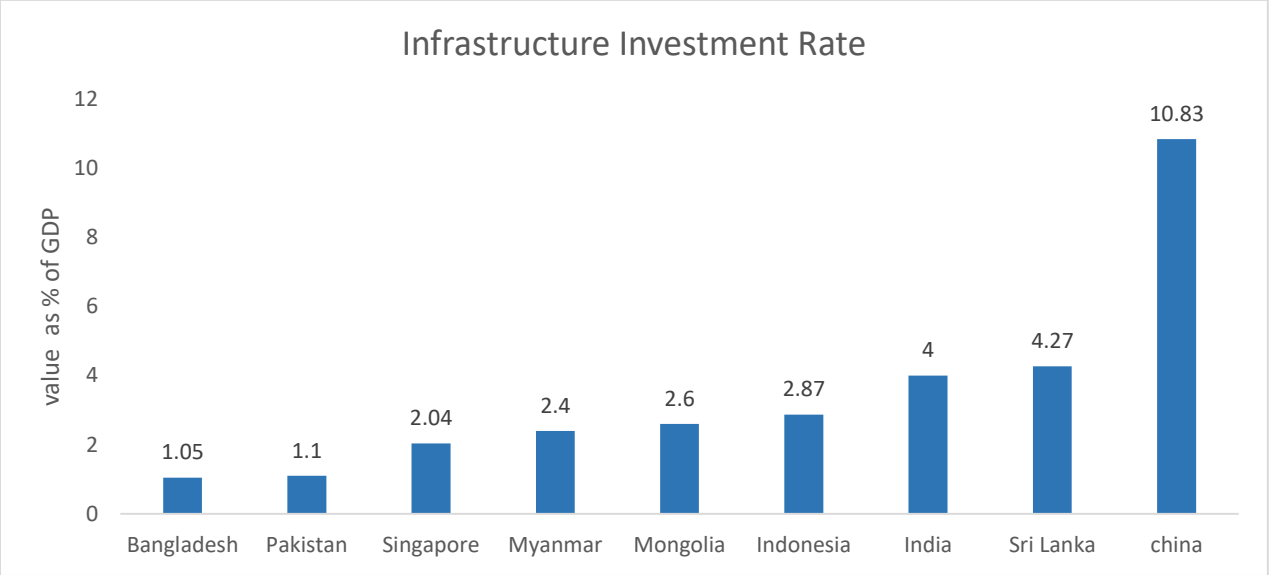


Figure1.2 Infrastructure Investment Rate

Source: Asian development bank

1.2 Research Problem

Public infrastructure investment plays a critical role in fostering economic development, especially in low and middle-income countries where constraints in transport, energy, and communication systems limits private sector productivity and inclusive growth. Inadequate infrastructure often

leads to higher production costs, supply chain inefficiencies, and limited access to markets outcomes that are especially pronounced in countries with weak institutional capacity.

Growth strategies in the last decade of the 20th century has provided somewhat fewer desirable outcomes for most of the less developed countries which now being term as "Middle Income trap". The increasing stress of the debt and successful transitions towards the sustainable energy have blurred the dream of shifting towards the high-income strata. The World Bank, in its latest report, identifies three steps for less developed nations to avoid the "Middle Income Trap." The first and foremost is increasing investment; the second and third are fostering innovation and facilitating the infusion of foreign technologies into the domestic economy. Again, for successful infusion, necessary requirement is availability of sustainable infrastructure in the host countries (World Bank 2024).

The inefficiencies and financing issues related to the various infrastructure projects imply that developing countries should reduce their investment in the infrastructure as it will provide less return on investment. Historically, IMF-led programs in the 1980s to 2000s often emphasized fiscal consolidation, encouraging reductions in public infrastructure spending due to concerns over its limited productivity (Stuart, 1992). Aligning with the IMF Infrastructure Governance Report, estimating that developing countries experience a 53% efficiency loss in public infrastructure investment due to weaknesses in infrastructure governance particularly in the public sector's capacity for planning, allocating, and implementing investment projects.

Similarly, Chakraborty & Dabla-Norris, (2011) emphasize that the effectiveness of public investment largely depends on its quality. In contexts where institutional capacity is weak and absorptive capacity is limited, scaling up infrastructure investment without first addressing governance issues could diminish the growth impact and effectively lowering returns on investment (ROI). Suggesting that countries with limited absorptive capacity should refrain from large investment scaling until institutions improve.

However, the traditional view that public investment slackness restricts the output growth in low efficiency countries (LEC) is somewhat vague. The recent work of (Berg et al., 2018) challenges the conventional wisdom that increased public investment in low-efficiency countries yields lower growth impacts compared to more efficient countries. Berg et al. (2018) has demonstrated this

result through neoclassical endogenous growth model identifying that incase of cobbs Douglas production function the result of increased public investment in both low- and high-income countries are the same.

Berg et al. (2018) also points out that there is *"efficiency paradox"* in the context of public investment, which depends on the elasticity of substitution between private and public capital when modeled using a CES production function. It argues that when the elasticity of substitution is less than one, meaning private and public capital are not easily substitutable there are higher growth payoffs from a surge in public investment in low-efficiency countries (LECs). This is because in many LECs, the private sector is heavily dependent on public infrastructure to operate effectively (Miyamoto et al., 2020). When elasticity of substitution between public and private capital is limited, public investment does not crowd out private investment; instead, it complements it. Weak infrastructure in these countries often creates systemic bottlenecks such as poor transport, unreliable electricity, and limited connectivity preventing full utilization of existing private capital. Thus, even if public investment is not highly efficient, it plays a critical role in unlocking the productivity of private capital and supporting overall economic growth.

The Varying degree of institutional quality and human capital among the countries the Paradox present us with the opportunity to look for the public investment yields in long-run in low-efficiency developing countries. It would require moving beyond the single country studies towards the comparative panel approach that incorporates cross country heterogeneity in governance, public investment efficiency, and macroeconomic conditions.

In this context, this study identifies three interconnected empirical puzzles that motivate the research. First, several South and Southeast Asian economies have sustained high levels of public investment over extended periods yet continue to exhibit wide disparities in long-run output growth. This mismatch between investment volume and growth outcomes suggests that the quantity of public spending alone is insufficient to explain cross-country growth differences, pointing instead to underlying differences in the productivity with which investment is converted into economically useful capital. Second, the process of infrastructure accumulation itself may become systematically inefficient over time. In developing economies, public capital stocks are vulnerable to poor project selection, political interference, procurement weaknesses, and inadequate maintenance financing. When these institutional failures are persistent, the

accumulated stock of public capital may not reflect an equivalent accumulation of economically productive assets a problem Pritchett (2000) terms the divergence between investment effort and actual capital formation. In the South and Southeast Asian context, where PIMA data indicate average efficiency losses of 53 percent, this divergence is not marginal but structural. Third, and most critically, these two facts together give rise to what Berg et al. (2018) formally identify as the efficiency paradox of public investment.

The paradox can be understood precisely as follows. In the standard view, countries with higher institutional quality and better public investment management High Efficiency Countries (HECs) are expected to derive greater growth returns from infrastructure spending because a larger fraction of each dollar invested is successfully converted into productive capital. Low Efficiency Countries (LECs), by contrast, are assumed to waste a significant portion of public investment through poor governance and misallocation, and are therefore expected to derive lower growth returns. This conventional wisdom forms the basis of policy prescriptions that advise fiscally constrained developing countries to prioritize institutional reform before scaling up public investment.

The efficiency paradox challenges this directly. It arises from the theoretical result that the return on investment in public infrastructure depends not only on the efficiency of capital conversion but also on the elasticity of substitution between public and private capital. When this elasticity is less than one, meaning public and private capital are complements and the private sector's productive capacity is structurally dependent on public infrastructure Low Efficiency Countries derive paradoxically higher long-run growth returns from public investment than High Efficiency Countries. This is because in LECs, existing private capital is severely underutilized due to infrastructure bottlenecks. Even an inefficiently converted addition to public capital relieves these bottlenecks and unlocks private productivity that would otherwise remain suppressed. The paradox therefore does not imply that inefficiency is desirable rather, it implies that where private capital is heavily dependent on public infrastructure and infrastructure deficits are binding, the marginal growth return to public investment is higher precisely because the baseline infrastructure stock is so inadequate. Whether this theoretical proposition holds empirically across the diverse institutional and macroeconomic environments of South and Southeast Asia and under what conditions it is most likely to manifest constitutes the central research puzzle of this study.

1.3 Research Gap and Contribution

There is the substantial body of literature on public infrastructure investment and economic growth, several important gaps remain that this study aims to address.

The first and most basic gap is the empirical status of the efficiency paradox. Although the efficiency paradox has been proposed by Berg et al. (2018), it is still a theoretical result based on a CES production framework, and has not been tested systematically at the regional level. The empirical literature already available on public investment and growth for developing countries has largely been based on Cobb-Douglas production functions, assuming that the elasticity of substitution between inputs is unitary, and therefore cannot capture the paradox condition that $\sigma < 1$. Studies that do employ CES specifications, such as An et al. (2019) and An et al. (2022) are for high-income or European economies whose institutional conditions are different from those in South and Southeast Asian economies. So, it is unknown whether the efficiency paradox exists in a context of developing countries with infrastructure constraints, governance quality is heterogeneous, and capital scarcity remains a structural constraint.

The second gap is with respect to the scope and comparability of the regional studies. The existing literature on the public investment and growth relationship in South and Southeast Asia largely consists of time-series analysis of individual countries or subnational panel studies that fail to capture macro-level interactions or the variation in institutional capacity and investment efficiency across countries. Studies such as Javid (2019) and Qazi and Ammad (2021) for Pakistan, Sahoo and Dash (2009) for India, and Ahmed, Hossain, and Tareque (2020) for Bangladesh provide valuable country specific insights but do not test for a systematic variation in the efficiency of public investment and its complementarity with private capital across countries with different institutional environments. In addition, previous studies have largely studied only one aspect of infrastructure spending, such as transport or energy, and neglected the overall macroeconomic and institutional environment that shapes the capacity of infrastructure investments to generate productive capital stock (Calderon and Serven, 2004; Romp and De Haan, 2007; Pereira and Andraz, 2013).

The third gap is related to the selection South and Southeast Asia in a comparative panel setting. Although both sub-regions experience similar structural pressures related to rapid urbanization,

increasing energy demand, and high infrastructure gaps, there are significant variations in their institutional capacity, investment efficiency, and public and private capital complementarities. There is also significant variation across the region in the efficiency of public investment, with the lowest at 42 percent in Sri Lanka and 47 percent in Pakistan, and the highest at 86 percent in India and 78 percent in Malaysia. This broad institutional and efficiency differences in a similar regional development environment provides an empirically compelling context for examining the existence of the efficiency paradox under different institutional settings. There has been no previous attempt to apply a cross regional comparative framework that aggregates these economies and considers their heterogeneity to test this specific theoretical proposition.

The fourth gap is the methodological. Although the IMF Investment and Capital Stock Dataset (2021) constructed by the Perpetual Inventory Method (PIM) has been applied in global benchmarking exercises, it has never been used in a regional panel framework that simultaneously tests public investment efficiency, capital complementarity and the moderating effects of institutional quality and human capital, using a static fixed effect estimation and dynamic System GMM approach. The relevance of the use of PIM based capital stock series is especially high because it takes into account depreciation and the investment flows in the past, and provide a better picture of the infrastructure base than proxy indicators, which were used in the previous studies.

This study aims to use a comparative panel approach to empirically examine the efficiency paradox in the eight South and Southeast Asian economies from 1996 to 2019. The study has three important contributions to the literature. First, empirical application of the Berg et al. (2018) efficiency paradox, with a nested CES production structure and panel econometric approaches. Second, it makes a clear distinction between the short-run growth impact of public investment flows and the long-run productivity impact from the public capital stocks. Third, it includes institutional quality and human capital as conditioning factors to study the moderation effect on the public capital accumulation and economic growth relationship of governance and human capital, contributing to the broader literature on the conditional effectiveness of public investment.

1.4 Research questions

- Does the efficiency paradox hold across developing countries with differing levels of institutional quality, human capital and public investment efficiency?

- How does public capital affect output growth in the short run and long run across countries?

1.5 Research Objective

Following are the objective of the study

- To measure the public infrastructure investment efficiency using motion of public spending equation suggested by Berg et al., (2018)

  $$\dot{G} = \varepsilon I_g - \delta G \qquad 0 < \varepsilon \leq 1$$

  where G is public capital stock, I_g is government investment spending, ε is the efficiency coefficient, and δ is depreciation rate.
- To find the elasticity of substitution between the private and public capital. whether they are complements or substitutes.
- To assess the moderating role of institutional quality and human capital in the relationship between public investment and economic growth.

1.6 Research Hypotheses

Based on the theoretical framework proposed by Berg et al. (2018) and the conceptual framework, the study proposes the following four hypotheses.

H1: Public investment flows have a positive and significant effect on economic growth in the short run.

H2: Accumulated public capital stock exhibits negative or diminishing long-run productivity effects in low efficiency economies, reflecting the inefficient conversion of investment spending into productive capital.

H3: The elasticity of substitution between public and private capital is less than one, indicating a complementary relationship in which private sector productivity is dependent on the availability of public infrastructure.

H4: Institutional quality and human capital positively moderate the relationship between public capital accumulation and economic growth, though their effects may be constrained by institutional threshold effects in the South and Southeast Asian context.

1.7 Conceptual Framework

The conceptual framework of the study is based on the endogenous growth theories and is based on the theoretical approach of Berg et al. (2018) to conceptualize the key relationships under study. In contrast to treating public investment, capital accumulation, institutional quality and economic growth as separate variables, the framework regards them as parts of an interconnected system where the productivity of public investment is not only related to the amount of public investment but also to the structural and institutional conditions under which public investment is made and converted into economically useful capital.

The first stage concerns public investment and the transformation of that investment into capital stock. The productive public capital stock (G) is not automatically accumulated with Government investment spending (Ig). Based on Berg et al. (2018) the investment-capital accumulation relationship is controlled by an efficiency coefficient (ε) with $0 < \varepsilon \leq 1$. If $\varepsilon = 1$, all public investment will be transformed into productive capital. If $\varepsilon < 1$, then some of the spending is lost due to institutional failures including poor project selection, inefficient project procurement, cost overruns, and poor maintenance. In the South and Southeast Asian context, where PIMA data indicate average efficiency losses of 53 percent, this conversion gap is a structural feature of public investment rather than an exception. The first stage of the framework therefore establishes that public capital stock is not simply the cumulative sum of government spending but a function of both investment flows and the institutional environment in which they occur.

The second stage concerns the interaction between public and private capital in the production process. Once public capital is accumulated, its growth effect depends critically on how it relates to private capital in the production function. Following the nested CES production framework of Sato (1967), the elasticity of substitution σ_2 between public capital (G) and private capital (K), determines whether the two forms of capital are complements or substitutes. If $\sigma_2 < 1$, private sector productivity is dependent on the availability of public infrastructure and the two forms of capital cannot easily replace one another. In this complementarity condition, additions to public capital unlock the productivity of existing private capital by relieving infrastructure bottlenecks, even if those additions are made inefficiently. This is the structural condition that gives rise to the efficiency paradox the theoretical result that low-efficiency countries may derive higher long-run

growth returns from public investment than high-efficiency countries, precisely because their private capital is more severely constrained by infrastructure deficits.

The third stage concerns the moderating role of institutional quality and human capital. While the first two stages establish the core efficiency paradox mechanism, the framework recognizes that the magnitude of the growth return to public investment is also conditioned by broader structural factors. Institutional quality capturing governance effectiveness, rule of law, control of corruption, and regulatory quality determines how effectively the public investment management system selects, implements, and maintains infrastructure projects, thereby influencing both ε and the productivity of the accumulated capital stock. Human capital, reflecting the education and skill levels of the labor force, shapes the absorptive capacity of the economy to productively utilize public infrastructure. Countries with higher human capital may extract greater growth returns from a given level of public capital stock because their labor force is better equipped to complement physical infrastructure with productive economic activity. These two variables therefore enter the framework not as direct drivers of growth but as conditioning factors that modify the relationship between public capital accumulation and output.

The fourth stage concerns the growth outcome and the efficiency paradox test. The ultimate dependent variable of the study is economic growth, measured as real GDP per capita. The framework posits that the growth return to public investment the return on investment (ROI) is a function of three interacting elements: the output elasticity of public infrastructure, the efficiency of capital conversion, and the elasticity of substitution between public and private capital. As derived from the CES framework in Chapter 3, when $\sigma < 1$, the ROI is inversely related to ε meaning that countries with lower efficiency derive higher growth returns, constituting the efficiency paradox. The empirical analysis tests whether this theoretical relationship holds across the selected South and Southeast Asian economies, and whether institutional quality and human capital moderate its magnitude.

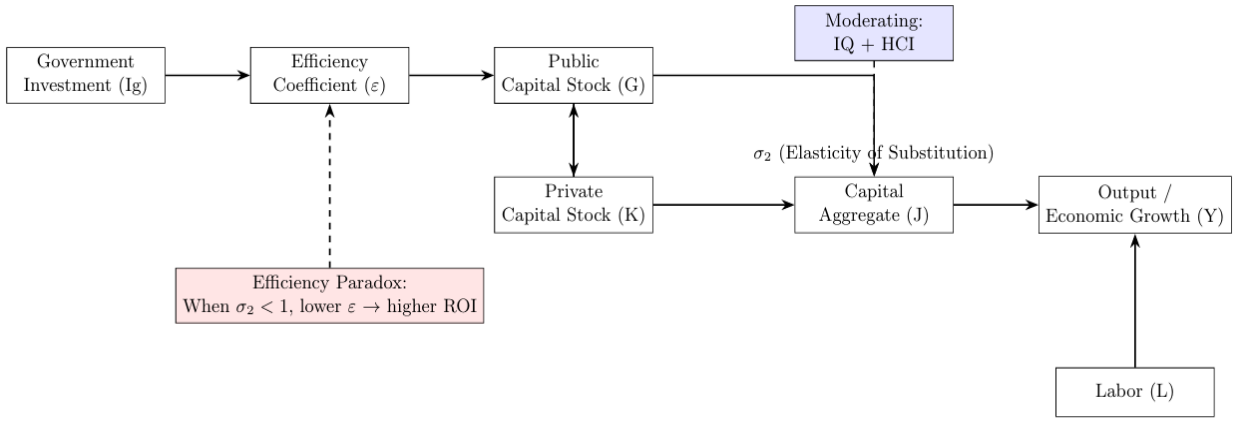


Figure 3.1 Conceptual Framework

Chapter 2

Literature Review

2.1 Theoretical Foundations

The relationship between infrastructure and growth can be traced back to endogenous growth models, such as those proposed by Romer (1986) and Lucas (1988), which acknowledges the role of knowledge spillovers and human capital in driving long-term growth. Barro (1990) also expanded this model by adding public infrastructure as an important input in the production function by proposing that government investment in infrastructure may increase productivity of the private sector, as well as boost economy. The processes of growth are, however, complex due to the constraints that arise as pointed out by Arrow and Kurz (1970) and these include irreversible investment that may cause stagnation and change the optimal growth path.

The discussion has always surrounded the contribution of public infrastructure in the productivity and economic growth of a given economy. With this regard, a number of studies have investigated the complex roles of this type of investments on economic results. The fact that public infrastructure can play a pivotal role in economic growth can be gauged from the notable series of analyses by (Aschauer,1989a, 1989b). While explaining the productivity slowdown in the private sector in the 1970s and 1980s, he proposed that the dominant factor in this slowdown was not the oil price shock, high energy prices, or low investment in research and development, but rather the decline in public infrastructure. Explaining that the nonmilitary public capital stock of the U.S. could directly increase productivity growth.

2.2 Early Empirical Evidence

In similar vein the analysis of the Munnell (1992) have suggested that a 1% increase in the public capital stock could increase the output productivity of about 0.34% in USA. Sturm, Kuper, and de Haan (1996) provides thorough analyses of the advancements that transpired after Aschauer's research. According to Sturm et al. (1996), “public capital probably enhances economic growth”, providing empirical evidence that many OECD countries reduced public investment from the

1970s to the 1990s, potentially retarding economic growth. They provided a more cautious estimate of the positive effect of public capital on growth.

However, subsequent studies, such as Lau and Sin (1997) and (Eisner, 1991; Gramlich, 1994), have questioned these findings, pointing to methodological issues such as reverse causality, specification, and the potential for spurious correlations (Aaron, 1990; Tatom, 1991). Lau and Sin (1997) found that the elasticity of output with respect to public capital was much lower (0.11) and that the evidence did not support the endogenous growth model with public infrastructure. Instead, they suggested that private capital spillovers may play a more significant role in driving growth.

The differences in output elasticity estimates across studies ranging from Aschauer's (1989) landmark estimate of 0.39 to Lau and Sin's (1997) much lower estimate of 0.11 is not merely a reflection of different data but is related to methodological differences. Aschauer (1989) employed a single-equation OLS regression using aggregate time-series data for the United States, a specification that is particularly vulnerable to spurious correlations arising from the non-stationarity of macroeconomic variables and to simultaneity bias, since output growth and public investment are jointly determined. When Munnell (1992) extended the analysis to state-level panel data, the estimate fell to 0.34, suggesting that the aggregate time-series approach inflated the elasticity by opposing national-level trends. The further reduction to 0.11 by Lau and Sin (1997) reflected the application of cointegration techniques that account for the long-run non-stationarity of the variables a methodological refinement that removes the spurious component of the estimated relationship. This pattern of declining elasticity estimates as econometric methods improved established an important methodological lesson for the literature that the apparent productivity of public capital is sensitive to the choice of estimator, the level of data aggregation, and the treatment of non-stationarity, a lesson that directly informs the panel econometric approach adopted in this study

2.3 Critiques of Production Function Approach

The increased debate on substantial effect of public infrastructure on productivity has influenced the researcher to look for the effect of public infrastructure on the productivity of private capital. (Holtz-Eakin, 1994) have estimated the production function controlling for the region-specific characteristics on state level data. The results suggested that using aggregate data on public

infrastructure has essentially no role in effecting the private sector productivity. Concerning the methodological issues in analysis of the Aschauer (1989), Ford and Poret (1991), using a cross-country panel data approach and a production function framework while controlling for endogeneity and specification biases, provide a more nuanced picture of the productivity effects of public infrastructure. Their findings suggest diminishing returns to public capital investment. The paper also disaggregates public infrastructure investment into different categories (e.g., transport, energy, communications) to determine which sectors contribute most to private-sector productivity. The findings reveal high differences across countries, which stresses the importance of the variation effectiveness of the public capital relies on the initial economic conditions.

As there has been growing controversy over the shortcomings of the production function approach and its tendency to overestimate outcomes, Bom and Ligthart, (2008) surveyed 76 previous studies using meta-analysis basis and meta-regression. Their goal was to gauge the impact of the public infrastructure on economic output correcting the potential errors in the studies. The findings indicate the actual impact of the random effects model is 0.081 of the public capital, implying that the public infrastructure does increase economic growth, however the effect is not as high as previous studies proposed. This is much lower than Aschauer's (1989) estimate of 0.39, showing that using better econometric methods is important to get more accurate results on public capital's role in the economy.

The meta-regression analysis of Bom and Ligthart (2008) is particularly usefull in this regard. Their survey of 76 studies identifies several systematic sources of upward bias in earlier elasticity estimates. First, studies using aggregate rather than disaggregated data tend to produce higher elasticity estimates because aggregate public capital stocks include both productive and non-productive components, inflating the apparent contribution of infrastructure to output. Second, studies that fail to control for country-specific fixed effects attribute cross-sectional variation in income levels — which may reflect historical, geographic, or institutional differences — to public capital, overstating its causal role. Third, the choice of functional form matters significantly — studies imposing a Cobb-Douglas production function assume a unitary elasticity of substitution between inputs by construction, which may itself bias the estimated output elasticity of public capital upward when the true elasticity of substitution between public and private capital is less than one. This last point is directly relevant to the present study, which employs a nested CES

production framework precisely to avoid this restrictive assumption and to allow the data to determine whether public and private capital are complements or substitutes.

2.4 Behavioral and Cost Function Models

The other approach in the literature is the behavioral approach, which offers an alternative to the production function method. In this approach, public capital is included in the cost and profit functions as a fixed input that is not directly paid for. This makes it easier to study how it affects productivity in the private sector. Many studies have used this method to address the limitations of the traditional production function approach. Berndt and Hansson (1991) analyzed Sweden using annual data from 1960 to 1988 with a dual cost function approach. Their findings suggest that private sector costs in the manufacturing industry are directly influenced by the level of public infrastructure capital. An increase in public infrastructure capital leads to a reduction in private sector costs. Similarly, Rovolis and Spence (2002). research on different regions within Greek divides public infrastructure into two types: "productive" and "social" infrastructure. The study found that productive infrastructure helps lower private sector costs, while social infrastructure has little impact using the dual cost function approach. It also showed that public infrastructure can replace labor and intermediate inputs but works together with private capital.

Seitz and Licht (1995) provides similar results for the 11 states of Germany stating that there is significant cost reduction with increase in public capital infrastructure services and it compliments private investment. Nadiri and Mamuneas (1994a) analyze the impact of publicly financed infrastructure and R&D capital on the cost and productivity of 12 manufacturing industries in the U.S. They emphasize that public capital reduces firm costs and conclude that public capital contributes more to multifactor productivity than R&D but the rates of returns of the R&D and private capital is more than that of the Public capital (Nadiri & Mamuneas,1994b).

2.5 VAR and Panel Approaches

In both of the above approaches, a major problem arises when determining the causal relationship based on theory. However, this issue can be resolved using the VAR approach, which is primarily data-driven and requires minimal imposition from economic theory. Public infrastructure capital may have an indirect effect on output through a third variable, such as private investment. Erenburg, (1993) uses two-equation system, employing full information maximum likelihood with

nonlinear parameter restrictions, indicating a supportive relationship between past government spending and private investment. VAR model has been employed by Creel & Poilon, (2008) to the panel of 6 European countries including (Austria, Belgium, France, Germany, Italy and the Netherlands) and regional panel of (French region) showing that public capital is a significant determinant of output but to lesser degree as compared to the overall public investment. Similarly, for the OECD countries public capital has positive effects on output (Kamps, 2005).

The shift toward VAR and panel approaches in the literature represents a methodological response to two fundamental limitations of the production function approach the inability to address simultaneity between public investment and output, and the failure to capture dynamic feedback effects through which public capital may influence growth with long and variable lags. The VAR framework of Kamps (2005), applied to 22 OECD countries, allows public capital to affect output through multiple channels simultaneously without imposing the theoretical restrictions of a structural production function. However, in panels with short time dimensions, degrees of freedom problems may reduce the precision of impulse response functions, and the reduced-form VAR cannot identify the structural parameters of interest specifically the efficiency coefficient and the elasticity of substitution between public and private capital. These limitations motivate the present study's adoption of System GMM, which combines the dynamic flexibility of panel approaches with the structural grounding of a production function specification while explicitly addressing endogeneity through internal instruments.

2.6 Empirical Evidence from the Regional countries

Several empirical studies from South and Southeast Asian countries have investigated the relationship between public investment and economic growth, particularly in the context of infrastructure development, fiscal conditions, and institutional quality.

In India, Sahoo and Dash (2009) used cointegration and VAR techniques to examine the impact of infrastructure investment on economic growth. Their findings indicate a strong long-run relationship between infrastructure development and GDP growth, with causality running from infrastructure to output. Similarly, Chakraborty and Dabla-Norris (2011) show that public investment effectiveness in India is heavily influenced by institutional capacity, suggesting that reforms in infrastructure governance can significantly enhance the growth payoff.

In case of Pakistan several studies have analyzes the effect of different types of investment activities such as public and private investment in infrastructure on the output, overall economic growth, as well as their effects on inter-regional and sectoral level. Expressing that marginal productivities of both type of investment differs across different sectors overall the public infrastructure investment has higher impact on economic growth than private investment (Javid 2019). Similarly, the work of Ahmed, Abbas, and Ahmed (2013) examined the disaggregated effects of public infrastructure investment in Pakistan on growth and welfare, considering different modes of financing such as international borrowing and production taxes. Using a computable general equilibrium (CGE) model combined with a microsimulation approach, the study reveals that GDP and household consumption increase in both the short and long run with borrowing-financed public infrastructure investment. It also shows a reduction in income inequality by increasing wages and employment in Pakistan.

Infrastructure can significantly affect the flow of FDI in developing nation like Pakistan Rehman et al. (2011) have used ARDL to cointegration to assess the infrastructure as an important determinant of attracting FDI flows, stating that a 1% increase in infrastructure leads to a 1.03% increase in FDI inflows in the short run and a 1.31% increase in the long run. With respect to private investment public infrastructure investment is more complex as it expanded with response to private needs rather than complimenting capital formation in private sector (Looney,1997). Qazi & Ammad, (2021) has estimated the aggregated and sector wise effect public investment on the marginal productivity in different sector, it has also estimated the substitutability effect of public investment on private investment and along that it has estimated the sector wise effect of public investment on employment. The results indicate that almost all type of public investment have positive effect on output through both crowding in and labor absorption effects.

In Bangladesh over the period 1985–2019 Ahmed, Hossain, and Tareque (2020) examine the roles of infrastructure, financial development, and human capital in Bangladesh's long-term growth, finding a strong impact of infrastructure and human capital using an Autoregressive Distributed Lag (ARDL) bounds testing approach along with Granger causality analysis. Empirical evidence from Southeast Asia shows that public infrastructure investment supports economic growth and private sector development. In Indonesia and Malaysia, such investment boosts private capital formation and GDP, especially under stable macroeconomic conditions (Munnell & Cook, 1990).

In the Philippines and Thailand, Calderón and Servén (2010) find that infrastructure quality and quantity are key drivers of growth and equity, with stronger effects in countries with better institutions.

2.7 Substitutability Between Public and Private Capital

On the substitution of public and private capital, several studies have raised their concerns about the perfect elasticity of substitution between public capital and private capital in the Cobb–Douglas function approach of measuring public capital effects in the production process. Studies such as An et al. (2019) examine the substitutability between public and private capital using a two-level CES production function across 151 countries. They find a high but imperfect elasticity of substitution, estimated around three, particularly in emerging economies. Similar analysis has been provided by An et al. (2022), using firm-level data from over 7,000 European manufacturing firms, which gave a high estimate of elasticity of substitution of 3.45 between public and private capital, challenging the classical notion of complementarity.

But elasticity of substitution of capital between the public and the private capitals on the part of the developing countries has been empirically approximated in studies such as Bom and Ligthart (2014) and Pereira and Andraz (2013), implying that the elasticity is usually lower than one and as such that the public and the private capital are complements as opposed to substitutes. This is the case though in some sectors like telecommunications or energy production, it is possible to partially replace the government infrastructure with the company's infrastructure particularly with favorable regulatory environment and with the encouragement of public-private partnerships (PPPs) (Estache & Serebrisky, 2004).

The divergence between the high elasticity estimates of An et al. (2019, 2022) approximately 3.0 to 3.45 and the sub-unity estimates found in developing economies such as Bom and Ligthart (2014) and Pereira and Andraz (2013) reflects fundamental differences in economic context rather than simply methodological variation. In high-income economies, well-developed private sector infrastructure and supportive regulatory frameworks allow firms to substitute public infrastructure with privately financed alternatives, producing high elasticity estimates. In developing economies, by contrast, the private sector lacks both the capital and regulatory environment to substitute for public infrastructure in core sectors, making public and private capital structurally complementary.

As Berg et al. (2018) demonstrate, the efficiency paradox holds precisely in this complementarity condition where elasticity of substitution is less than one making the developing country evidence of Bom and Ligthart (2014) and Pereira and Andraz (2013) directly applicable to the South and Southeast Asian context examined in this study

By examining the developmental environment of Pakistan where infrastructure is inadequate and gaps are still large, the World Bank (2023), implies that infrastructural government expenditure is essential and cannot be fully substituted by private capital. The distortive nature of state- owned enterprises (SOEs) of Pakistan, pointing out how special treatment to finance and subsidies crowds out private sector and undermines competition in the market. The role of Public–Private Partnerships (PPP) in Pakistan has been hindered by the absence of a clear strategic vision and the lack of key enabling conditions, such as well-defined regulatory frameworks (Ahmad, Khan, & Khan, 2016).

2.8 Infrastructure Governance and Investment Efficiency

The efficiency of public capital can be defined as the ratio between the economic cost and the accounting cost Pritchett (2000). Using empirical and conceptual reasoning, the author shows that considering government investment as equal to capital stocks assumes perfect efficiency of public investment, which is not true in the real world. Inefficiencies in public investment can arise from a range of various factors such as the public investment management system, political interference in project selection, and weak medium-term fiscal financing (Baum, Mogues, & Verdier, 2020). Using benchmarking a widely used methodology of efficiency measurement, the authors estimate that improving infrastructure governance could increase infrastructure output by up to 65% in low-income developing countries, where the average efficiency gap reaches 53% and can be as high as 96%.

A study using principal component analysis of IMF Pubic Investment Management Assessment (PIMA) data identifies project management, appraisal, procurement, funding availability, and project selection as key institutional bottlenecks affecting public investment efficiency in low-income developing countries. The mean score of effective LIDCs at the three (PIMA) phases of planning, allocation, and implementation is slightly more than 1.5, which means that some of the

fundamental requirements are not achieved, and the allocation phase is the most inefficient, showing established inefficiencies in resource allocation and maintenance financing.

2.9 Research Gap

The currently available literature on the linkage between public investment in infrastructure and economic growth is mostly restricted to the analysis of one country, with time-series methods being used in most of the studies. Others are confined to subnational or regional-level panel studies, which overlook macro-level interactions and cross-country variation. There is lack of empirical work that examines infrastructure's impact on economic growth over an extended period across lower middle-income countries, particularly in the context of South and Southeast Asia. Additionally, earlier research has typically focused on only one dimension of infrastructure such as transport or energy without accounting for broader economic and institutional conditions (Ahmed & Nishat, 2014; Chingoiro & Mbulawa, 2016; Maingi, 2007).

This study seeks to fill the gap by adopting a comparative panel framework that examines how the growth effects of public infrastructure investment vary with institutional quality, and human capital factors that may condition whether public investment crowds in or crowds out private activity. Specifically, to empirically tests the efficiency paradox proposed by Berg et al. (2018), which suggests that countries with weaker institutions and lower investment efficiency may still experience higher marginal growth returns from public investment, particularly when public and private capital are complementary and not easily substitutable.

Chapter 3

Data and methodology

This chapter aims to provide an overview of the research methodology to investigate the efficiency paradox related to the Public infrastructure investment and it possible effect on the economic growth. The study takes the quantitative methodology with secondary panel data and econometrics techniques. It uses panel data techniques that are used in analyzing macroeconomic relationships over time across countries, making interactions dynamic, heterogeneous and possible feedback effects.

3.1 Data and Variables:

The study is concerned with the dynamic relationship between the infrastructure investment and economic growth, focusing South and Southeast Asian economies where infrastructure gaps remain a major challenge to achieve sustained economic growth[1]. These countries are selected due to their strategic importance in the changing global production and investment landscape, as the global supply chain increasingly shifts toward Asia in search of low-risk, high-return destinations. The selected economies represent a diverse yet comparable set of developing and emerging markets that share common structural features such as rapid urbanization, South Asia alone, city populations grew by over 130 million between 2001 and 2011 and are expected to rise by another 250 million by 2030, creating immense pressure on existing infrastructure. Similarly, energy needs are expected to increase by 70% by 2040 (world bank 2016). At the same time, the selected countries differ terms of institutional capacity, and investment efficiency. This provide a justification to analyze the dynamic public infrastructure investment in these countries while addressing the core objectives of the study.

The study uses General Government investment, Public capital stock, Private capital stock, labor, and Output (GDP) in the context of public infrastructure investment and the efficiency paradox allowing for institutional quality and human capital difference, we employ panel data set for the selected countries over the period of 1996 to 2019. The countries are selected on the basis of data

[1] See table 5 in appendix for the list of countries

availability, institutional diversity and comparability within a regional development context. The data for the economic variable is acquired from "IMF Investment and Capital Stock Dataset, 2021" which includes Annual Data on the following mentioned variables. In the empirical analysis, economic growth (measured as change in output) serves as the dependent variable, while Public capital stock, Private capital stock, and labor employment are the independent variables, and Institutional Quality Index and human capital index are included as control variables.

The choice of variables for this study is based on the theoretical and empirical foundations within the infrastructure and growth literature. The dependent variable is economic growth as it will be used to gauge the productive effort of an economy in general which is the level of efficiency of capital and labor utilization. Both classical and modern growth theories such as the Solow-Swan model and endogenous growth model appreciate output as the main outcome of accumulation of factors and increment in productivity (Barro, 1990; Mankiw, Romer and Weil, 1992). To determine the long-term effects of government investment on output, public capital stock, which is a cumulative infrastructure including paved roads, energy and water systems are incorporated. The role of infrastructure in boosting efficiency of the private sector was found by Aschauer (1989) and Calderon and Serven (2004), who discovered that increased stock of public capital has a positive correlation with productivity and growth. Government investment in the form of gross fixed capital formation is added to bring in short run fiscal efforts and the dynamic adjustment in the spending of infrastructure.

Likewise, private capital stock and its accumulation represent the productive capacity of the private sector and are important for testing the complementarity or substitution effects between public and private capital (Berg et al., 2018). Labor is included as a core production input to prevent omitted variable bias, while human capital and institutional quality serve as control variables to account for variations in productivity and governance. Human capital, following the augmented Solow model, reflects education and skill levels that shape returns to physical capital (Mankiw et al., 1992), and institutional quality capturing governance, rule of law, and corruption control determines how effectively infrastructure translates into economic growth (Acemoglu & Robinson, 2012; North, 1990). Following the empirical growth literature (Barro and Lee, 1996; Mankiw et al., 1992; Sala-i-Martin, 1997), several control variables are included to capture the broader determinants of economic growth.

Table 3.1 Description of the variables

S/n	Variable	Defination	Source
1	Public capital stock (G)	Government outlay, in terms of money, and as physical stock, in terms of infrastructure. This can include capital like highways, bridges, schools, hospitals, utilities, and public transportation system.	IMF (1996-2019)
2	Private capital stock (K)	Private capital stock is the value of physical capital owned by private entities and plays a crucial role in driving economic activity, investment, and growth within the private sector.	IMF (1960-2019)
3	Labor or Employment (L)	Employment is the number of people working or actively seeking work in a labor market. OR work that is done in exchange for wages or other forms of compensation.	IMF 1968-2022
4	Total government spending	Government spending refers to money spent by the public sector on the acquisition of goods and provision of services such as education, healthcare, social protection, and defense.	IMF 1996-2019
5	GDP (Y)	(GDP), is the total monetary or market value of all the final goods and services produced within a country's borders in a specific time period.	IMF 1996-2019
6	Institutional quality	Institutional quality is the extent to which political, legal, and administrative institutions function transparently, efficiently, and accountably, ensuring rule of law, protection of property rights, control of corruption, regulatory quality, and public sector effectiveness.	World Bank 1996-2019
7	Human capital index	Human Capital refers to the productive capacity of individuals, based on their education, skills, health, and knowledge. The Human Capital Index (HCI) measures the expected productivity of a child born today, relative to a benchmark of full health and complete education, by the time they reach adulthood.	World bank 1996-2019
8	Trade openness	Integration of a country to the global economy. Measure as the sum of import and export of goods and services as a percentage of GDP	WDI 1996-2019
9	Government Size	The extent to which the government is involved in an economy. It is measured as the final consumption expenditure as a percentage of GDP	WDI 1996-2019
10	Inflation	It is the rate at which the price of goods and services increases over time. It is measured as the log difference of CPI	WDI 1996-2019
11	Financial Development	Defined as the accessibility, and stability of a country's financial institutions and markets. Measured as the total credit provided to the private sector as percentage of GDP	WDI 1996-2019

Several clarifications regarding variable measurement and transformation are needed. First, the core production variables GDP, public capital stock, private capital stock, and government investment are all expressed in billions of constant 2017 international dollars adjusted for purchasing power parity (PPP), ensuring cross-country comparability by eliminating the effects of

inflation and exchange rate differences. In the static panel models, these variables enter in natural logarithm form to reduce skewness, stabilize variances, and allow coefficients to be interpreted as elasticities. In the dynamic System GMM models, capital stock variables are expressed as ratios to GDP rather than log levels, following the five-year averaging approach adopted to smooth short-run fluctuations and avoid instrument proliferation.

Second, the labor variable reflect the total labor force measured in millions of persons. This unit of measurement is consistent with the IMF Investment and Capital Stock Dataset, where all factor inputs are expressed at a scale compatible with the capital stock variables measured in billions of constant 2017 international dollars. The variable enters the static models in natural logarithm form (lnL) to ensure comparability with the other log-transformed production variables.

Third, the institutional quality composite index is constructed using Principal Component Analysis applied to the six World Governance Indicators, following Kaufmann et al. (2010). The first principal component, which captures the dominant dimension of institutional variation explaining the largest share of cross-country variance, is retained as the composite index. Since this index already represents a standardized score, no further logarithmic transformation is applied. Fourth, all capital stock variables are constructed using the Perpetual Inventory Method as detailed in Section 3.2, which converts annual investment flows into stock measures by accounting for historical investment accumulation and time-varying depreciation rates.

Institutional quality reflects the effectiveness of governance, rule of law, and control of corruption, which influence the efficiency of resource allocation and investment decisions. Human capital index represents the level of education and health that enhances labor productivity. Trade openness, defined as the sum of exports and imports as a percentage of GDP, measures the extent of a country's integration with the global economy. Financial development is the percentage of domestic credit to private sector as percentage of GDP which captures the depth and accessibility of financial markets and institutions (Zergawu, Walle, & Giménez-Gómez,

2020). Government size measured as government final consumption expenditure relative to GDP indicates the scale of public expenditure and helps to understand the government's role in the economy (Nawaz, 2015). Finally, inflation measured as log difference of CPI, serves as a proxy

for macroeconomic stability, as high inflation often distorts investment incentives and erodes purchasing power, thereby hindering growth.

3.2 Construction of Variables:

The capital sock and private capital stock variables had been constructed using Perpetual Inventory Method (PIM), this methodology was applied by Kamps (2006) and Gupta (2014) and several other author for single country such as (Siddiqui, 2004; Malik, 2008). The PIM allows for the conversion of flow variables, such as annual public investment, into a stock measure by accounting for past investments and depreciation over time.

$$K_{i,t+1} = \left(1 - \delta_{i,t}\right)K_{i,t} + \left(1 - \frac{\delta_{i,t}}{2}\right) I_{i,t} \tag{2.9}$$

where

- $K_{i,t+1}$ is the stock of public or private capital for country i at the beginning of period.
- $\delta_{i,t}$ is the time varying depreciation rate (which is assumed as increasing over time for high income due to the rising levels of income and introduction of shorter life spans technologies.
- $I_{i,t}$ represents gross fixed capital formation (either public or private) during period t under the assumption that newly invested capital becomes productive halfway through the period.

The PIM methodology uses various inputs, including investment data, initial capital stock, and the depreciation rate over time. Since most countries do not have data on initial capital stock, following Kamps (2006), the initial capital stock is estimated under the assumption that total investment grew at a constant annual rate of 4% prior to the first observation year. This methodological approach provides a more accurate representation of the public capital stock, which is important for analyzing its role in economic growth and productivity. The variables for government investment, public capital stock, private investment, private capital stock, are expressed in billions of constant 2017 international dollars (PPP-adjusted) to maintain consistency and eliminate the effects of inflation and exchange rate fluctuations.

The data of institutional quality has been acquired from the world governance indicators (WGI) by the World Bank providing six different measures capturing different dimensions of institutions.

These indicators include: (i) control of corruption, (ii) go effectiveness, (iii) political stability and absence of violence/terrorism, (iv) quality, (v) rule of law, and (vi) voice and accountability. The indicator rang to +2.5. The low value indicates bad quality institution and vice versa. Since these six indicators are highly correlated, a composite institutional quality index was created using Principal Component Analysis (PCA), following Kaufmann et al. (2010), to capture the dominant institutional dimension explaining the largest variance.

3.3 Theoretical framework

Economic theories suggest that the investment is regarded as the important factor of production as it can increase output and have effect either on level or on the growth rate depending upon the marginal return. The endogenous growth theories of Lucas (1988) and Romer (1990) suggest that long term economic growth depends perilously on the accumulation of human and physical capital, unlike earlier neoclassical growth models (Solow 1956), which attribute long-term growth to exogenous technological progress. Public investment has a significant effect on economic growth by stimulating aggregate demand and expanding the productive capacity of private capital (Miyamoto et al., 2020).

Distinction between Public investment or public capital expenditure and current expenditure of the government is necessary because the former refer to the investment that generate physical asset. Two main aspects of public investment define its contributing effect: efficiency and productivity. While related, these terms are conceptually distinct. Efficiency is linked to capital accumulation and may vary across countries, whereas productivity is related to the concept of infrastructure governance. The efficiency paradox arises when countries with weaker institutions or lower efficiency exhibit higher growth returns from public investment, suggesting that the productivity of public capital depends on structural conditions rather than investment size alone.

A critical distinction underlying the empirical framework of this study concerns three related but conceptually distinct concepts that are frequently conflated in the public investment literature government investment flows, accumulated public capital stock, and public investment efficiency. Government investment flow (Ig) is an annual expenditure by the public sector on infrastructure and capital projects. As a flow variable, it generates an immediate demand stimulus through the Keynesian channel raising aggregate demand, generating employment, and stimulating economic

activity in the short run. Its growth effect is therefore expected to be positive and relatively immediate, largely independent of the institutional environment in which it occurs.

Accumulated public capital stock (G), by contrast, is a stock variable representing the cumulative value of all past public investment net of depreciation. Unlike investment flows, its growth effect operates through the supply side of the economy enhancing private sector productivity, reducing transaction costs, and improving connectivity over the long run. How much of the investment flow successfully translates into productive capital stock depends on public investment efficiency (ε), which captures the fraction of government spending that is converted into economically useful infrastructure. When ε is low, a significant portion of spending is lost to poor project selection, cost overruns, and inadequate maintenance, meaning the accumulated stock grows more slowly than investment figures suggest.

This three-way distinction has direct implications for how the empirical results of this study should be interpreted. Since government investment flows and accumulated public capital stock operate through fundamentally different channels demand stimulus in the short run and supply-side productivity in the long run respectively. It is possible for the two to yield different and apparently contradictory results within the same empirical framework. A positive coefficient on investment flows alongside a negative or insignificant coefficient on accumulated capital stock does not reflect an inconsistency in the analysis, rather it reflects the structural gap between what governments spend on infrastructure and what that spending ultimately delivers in terms of productive capital. This gap is precisely what the efficiency coefficient ε measures, and it is this gap that the efficiency paradox framework seeks to explain.

3.4 Model specification

The returns of the public investment can be a good way of assessing the effectiveness of the government spending to improve the economic growth and achieve development objectives. In assessing the effects of government investment in infrastructure on the growth of the economy, it is very essential to consider a production function in which all factors of production are taken into consideration.

We use the CES production function to discuss the efficiency paradox of the investment in the public infrastructure. Berg et al. (2019) present that Cobb-Douglas production function outlines a marginal situation, where the results are unchanged meaning they might be independent of the efficiency factor of the investment. Besides, the single-equation Cobb-Douglas production function is also criticized in literature due to its static methodology and inability to address simultaneity among variables, and failure to adequately capture lagged effects (Pereira & Andraz, 2013).

A nested CES production function can be used which is based on the ease with which a privately held capital can be substituted with government infrastructure. The research adopts the two level CES production function initially developed by Sato (1967) to estimate the elasticity of the variables. During the first phase, the capital is summed up, both the private and the public, and at the second phase, the capital aggregate is summed up with the labour. This functional form is particularly well off to examine the efficiency paradox since it permits you to approximate the elasticity of substitution of public and private capital as well as composite capital and labor independently. It is quite a point to understand whether public and private capital are complements or substitutes and such elasticities are the clue to determining what such is. It is also quite significant in determining whether the public investment boosts output more in less efficient-environment.

The Sato CES production function is a valuable and commonly employed model, despite its strong assumptions, such as constant substitution rate between inputs and a specific sequence for input combination. It helps us measure how easily public and private capital can be substituted for each other. However, for the biasness, robustness checks will be conducted using alternative specifications and sub-sample estimations that allow elasticities to vary across institutional quality tiers. These extra steps will help ensure that our findings are reliable and not just the result of using one specific model.

An important clarification concerns the relationship between the theoretical CES framework and the empirical strategy employed in this study. While the nested CES production function of Sato (1967) provides the theoretical basis for deriving the efficiency paradox condition specifically that the return on investment is higher in low efficiency countries when $\sigma_2 <$, the direct structural estimation of σ_2 from the CES framework requires deriving the first-order conditions of the CES

function and estimating the resulting reduced-form parameters through nonlinear regression techniques. Such nonlinear CES estimation is computationally demanding and sensitive to initial conditions, particularly in panels with a small cross-sectional dimension such as the eight-country sample employed in this study. Consequently, the interaction term between public and private capital stocks employed in this study does not directly measure σ_2 as a structural CES parameter. Rather, it captures the conditional marginal effect of public capital on output given the level of private capital providing empirical evidence on the direction of the complementarity that the CES theory identifies, without directly quantifying the structural elasticity of substitution. This is an acknowledged methodological limitation of the study.

$$Y = F(G, K, L) \tag{3.1}$$

Where Y is real output, K is stock private capital, L is total labor and G is stock of public capital. While using production function for the analysis the functional form of the function is necessary to be specified. We will use the nested production function for constant elasticity of substitution between the various variables in our analysis. The function form followed as given below.

$$Y = A[bJ^{\frac{\sigma_1 - 1}{\sigma_1}} + (1-b)L^{\frac{\sigma_1 - 1}{\sigma_1}}]^{\frac{\sigma_1}{\sigma_1 - 1}} \tag{3.2}$$

where

$$J = \left[cK^{\frac{\sigma_2 - 1}{\sigma_2}} + (1-c)G^{\frac{\sigma_2 - 1}{\sigma_2}}\right]^{\frac{\sigma_2}{\sigma_2 - 1}} \tag{3.3}$$

- *b* and *c* are the CES distribution parameters
- σ_2 is the elasticity of substitution between the private capital stock *K* and infrastructure *G*.
- σ_1 is the elasticity of substitution between capital services *J* and labour *L*.
- If σ2>1\sigma_2 > 1σ2>1, public and private capital are substitutes; if σ2<1\sigma_2 < 1σ2<1, they are complements, indicating stronger public investment spillovers to private output.

To evaluate the public infrastructure investment, we will use the equation of return to investment (ROI) as followed

$$ROI \equiv \frac{dY}{dI_g} = \left(\frac{dY}{DG}\frac{G}{y}\right) * \left(\frac{dG}{dI_g} * I_g/G\right) \tag{3.4}$$

First term in equation is the output elasticity of infrastructure (OEG), and the second term is elasticity of public capital to public investment. Form the capital accumulation equation in steady state the second term is always unity. So the only source of variation in the (ROI) of public infrastructure investment is (OEG).

Form equation 2 and 3 we can get the long run outcome of the output elasticity of Infrastructure as given below.

$$\frac{dY}{dG}\frac{G}{y} = b(1-c)\left(\frac{AG}{Y}\right)^{\frac{\sigma_1-1}{\sigma_1}}\left(\frac{J}{G}\right)^{\frac{\sigma_1-\sigma_2}{\sigma_1\sigma_2}}$$

(3.5)

Rearranging the equation 5 and it becomes

$$\frac{dY}{dG}\frac{G}{y} = \eta\left(\frac{A\varepsilon\upsilon}{\delta}\right)^{\frac{\sigma_1-1}{\sigma_1}}\left(\frac{J}{G}\right)^{\frac{\sigma_1-\sigma_2}{\sigma_1\sigma_2}} \quad (3.6)$$

- η is the income share of infrastructure and ν is the investment rate.

In case of non-nested CES production function where $\sigma_1 = \sigma_2 = \sigma$ from equation 6 we have

$$\widehat{OEG} = \frac{(\sigma-1)}{\sigma}\hat{\varepsilon} \quad (3.7)$$

where hat denotes a logarithmic differential.

If σ>1, the Output Elasticity of Growth (OEG) rises with ε, leading to an increase in the Return on Investment (ROI). Consequently, the growth payoff is higher in the High-Efficiency Countries (HEC), aligning with conventional policy wisdom. But this result isn't very strong. When σ<1, there is an efficiency paradox: the ROI and the long-term growth effect are both higher in the Low-Efficiency Countries (LEC).

3.5 Estimation Techniques

Researchers used a number of different econometric methods to try to figure out how public spending, efficiency, and economic growth are related. The Fixed Effects (FE) and Random Effects (RE) models are mostly used in conventional studies to account for the country-level heterogeneity (Aschauer, 1989; Calderon and Serven, 2004; Kamps, 2006). Dynamic estimators such as the Generalized Method of Moments (GMM) and the Panel Vector Autoregression (Panel VAR/SVAR) have recently been used in empirical studies to address endogeneity, feedback, and

time persistence (Pereira & Andraz, 2013; Romp & de Haan, 2007). Based on the previous literature, this study will use both the general and dynamic panel design to achieve the objectives of the study because the two are complementary and will provide an overall understanding of both short-term and long-term relationships.

The choice of estimation strategy in this study is driven by the nature of the relationships between variables and the specific econometric problems that arise in panel data analysis of public investment and growth. Before outlining the estimation techniques, it is necessary to classify the variables by their endogeneity status, as this classification directly determines the appropriate estimator and instrument strategy.

The dependent variable real GDP per capita is treated as endogenous by definition, since current output is influenced by its own past values through adjustment costs and capital accumulation dynamics. Public capital stock (GstockGDP) and private capital stock (Kstock_GDP) are also treated as endogenous, as both are jointly determined with output, higher GDP growth generates greater fiscal space for public investment while simultaneously attracting private capital formation, creating a bidirectional relationship that cannot be addressed through OLS or Fixed Effects estimation alone. Government investment per capita (lnGinv_pc) is treated as predetermined influenced by past output through the fiscal revenue constraint but not simultaneously determined with current output. The control variables trade openness, government size, inflation, and financial development are treated as strictly exogenous, determined by broader macroeconomic factors rather than annual fluctuations in GDP per capita. Institutional quality and human capital are similarly treated as strictly exogenous, reflecting slow-moving structural characteristics that change over decades rather than in response to short-run output movements.

This classification motivates the progression of estimation strategies in this study. The Fixed Effects model controls for time-invariant country-specific heterogeneity and is appropriate for estimating long-run relationships between capital stocks and output. However it cannot address simultaneity between endogenous regressors and the dependent variable, account for the dynamic persistence of GDP per capita, or capture the distinction between short-run demand effects of investment flows and long-run productivity effects of accumulated capital stock. The System GMM estimator addresses these limitations by instrumenting endogenous variables using their own lagged levels and differences and incorporating the lagged dependent variable to capture

dynamic adjustment. The two approaches are therefore complementary Fixed Effects establishing long-run structural relationships and System GMM capturing dynamic adjustment while correcting for endogeneity.

3.6 Static Panel Analysis

To achieve its primary goal of evaluating the effectiveness of public infrastructure investment, the research uses static panel analysis. This approach is useful for determining long-term relationships while accounting for unobserved, time-invariant variations across countries. Both the Random Effects Model (REM) and the Fixed Effects Model (FEM) are used to estimate the models.

In macro panel data, variables such as output, investment, and capital stock are typically not normally distributed due to scale differences and long-tailed economic values. While non normality does not bias coefficient estimates in Fixed or Random Effects estimations, it may affect the precision of standard errors and hypothesis tests, particularly in small samples. To mitigate this, all level variables are transformed into natural logarithms to reduce skewness and stabilize variances.

To estimate the efficiency with which public investment is converted into productive public capital, the study follows the law of motion for public capital proposed by Berg et al. (2018):

$$\dot{G}_{it} = \varepsilon I_{it} - \delta G_{it} \tag{3.8}$$

and express all relevant variables as ratios to GDP. After accounting for the decomposition of the time derivative of the ratio (G/Y), the identity becomes.

$$\Delta\left(\frac{G}{Y}\right) + \delta\left(\frac{G}{Y}\right)_{i,t-1} + \left(\frac{G}{Y}\right)_{i,t-1} g_{y,it} = \varepsilon\left(\frac{I_g}{Y}\right)_{it}$$

(3.8.1)

Where $g_{y,it}$ denotes real GDP growth. The left-hand side forms the adjusted change in public capital-to-output ratio.

$$dG_{adj} = \Delta\left(\frac{G}{Y}\right) + \delta\left(\frac{G}{Y}\right)_{i,t-1} + \left(\frac{G}{Y}\right)_{i,t-1} g_{y,it}$$

(3.8.2)

Where represents dG_{adj} the adjusted change in the public capital-to-output ratio, and $g_{y,it}$ denotes real GDP growth. Fixing the depreciation rate δ according to country income classification, the

efficiency coefficient ε is estimated by regressing dG_{adj} on the scaled public investment-to-output ratio $\left(\frac{I_g}{Y}\right)_{it}$.

Since each country exhibits unique, time-invariant characteristics such as institutional structure, governance quality, and policy implementation capacity that may influence the efficiency of public investment, the study employs a Fixed Effects Model (FEM). The FEM controls for this unobserved heterogeneity across countries, ensuring that efficiency differences are captured by within-country variation over time rather than cross-country structural differences. To address Objective of the study measuring the efficiency with which public investment is converted into productive public capital stock the following Fixed Effects model is estimated based on the law of motion for public capital proposed by Berg et al. (2018):

$$\text{Model 1:} \quad dG_{adj,it} = \varepsilon \left(\frac{I_g}{Y}\right)_{it} + \mu_i + \varepsilon_{it} \tag{3.9}$$

Where μ_i captures country specific fixed effects and ε_{it} is the idiosyncratic error term. Robust standard errors clustered at the country level are used to correct for heteroskedasticity and serial correlation within countries.

Static panel analysis is also employed to examine the second and third objective of the study which is estimating the elasticity of substitution and growth effects of public and private capital stocks without considering dynamic adjustments over time. This study uses three widely used estimation methodologies for this analysis: Pooled Ordinary Least Squares (OLS), Fixed Effects Model (FEM), and Random Effects Model (REM). The Breusch-Pagan (BP) Lagrange Multiplier test decides whether to use Pooled OLS or REM. If the null hypothesis is accepted, it means that there is no significant difference between countries, which means that Pooled OLS should be used. If the null hypothesis is rejected, it means that REM should be used. The Hausman test is used to choose between REM and FEM to further prove that REM is the right choice. The rejection of the null hypothesis in the Hausman test signifies a preference for FEM over REM. The study employs the FEM to precisely account for country-specific heterogeneity which is unobservable recognizing that each country possesses different characteristics that influence growth outcomes. To address Objective estimating the conditional marginal effect of public capital on output and assessing whether public and private capital are complements or substitutes the following three

static panel models are estimated, incorporating an interaction term between public and private capital stocks:

Model 1

$$lnY_{it} = \beta_0 + \beta_1 lnGinv_{it} + \beta_2 lnG_{it} + \beta_3 lnK_{it} + \beta_4 lnk_lnG_{it} + \beta_5 lnL_{it} + \alpha_{it} + \varepsilon_{it} \quad (3.10)$$

Model 2

$$lnY_{it} = \beta_0 + \beta_1 lnGinv_{it} + \beta_2 lnG_{it} + \beta_3 lnK_{it} + \beta_4 lnk_{lnG\,it} + \beta_5 IQ_{it} + \beta_6 lnG_IQ_{it} + \beta_7 lnL_{it} + \alpha_{it} + \varepsilon_{it} \quad (3.11)$$

Model 3

$$lnY_{it} = \beta_0 + \beta_1 lnGinv_{it} + \beta_2 lnG_{it} + \beta_3 lnK_{it} + \beta_4 lnk_{lnG\,it} + \beta_5 HCI_{it} + \beta_6 lnG_HCI_{it} + \beta_7 lnL_{it} + \alpha_{it} + \varepsilon_{it} \quad (3.12)$$

Where

i represents the cross-sectional units (countries)

t represents the time period (1996-2019)

β_x are the coefficients of the explanatory variables

α_{it} is the idiosyncratic error term, and

ε_{it} captures the time-invariant country-specific effects accounting for unobserved heterogeneity.

3.7 Dynamic Panel analysis

Dynamic panel analysis is employed to capture the persistence and dynamic adjustments in the relationship between economic growth and its determinants over time. Unlike static models, dynamic panel estimations account for the fact that current economic performance is influenced not only by contemporaneous factors but also by past outcomes. This approach incorporates the lagged dependent variable as a regressor to control for inertia and feedback effects in growth processes. However, the inclusion of the lagged dependent variable may lead to endogeneity problems due to its correlation with the error term. To address this issue, the study employs the Generalized Method of Moments (GMM) estimators developed by Arellano and Bond (1991) and extended by Blundell and Bond (1998), which utilize internal instruments to correct for endogeneity, omitted variable bias, and measurement errors.

While the static Fixed Effects models provide important insights into long-run relationships between capital stocks and output, they are subject to three econometric limitations that the

dynamic System GMM framework is designed to address. First, the Fixed Effects estimator assumes strict exogeneity of all regressors conditional on the country fixed effect, an assumption violated when public and private capital stocks are simultaneously determined with output, leading to inconsistent parameter estimates. Second, static models do not account for the dynamic persistence of GDP per capita, where current output is strongly influenced by past output through adjustment costs and structural inertia, leading to omitted variable bias when the lagged dependent variable is excluded. Third, the static framework cannot capture the conceptually important distinction between the immediate demand stimulus effect of investment flows and the longer-run productivity effect of accumulated capital stock.

The System GMM estimator addresses all three limitations simultaneously instrumenting endogenous regressors with their own lagged values, incorporating the lagged dependent variable to capture persistence, and estimating both short-run and long-run coefficients within a unified dynamic framework. To address Objective of assessing the moderating role of institutional quality and human capital Models 7, 8, and 9 introduce these conditioning variables within the System GMM framework, allowing their effects to be estimated net of endogeneity and dynamic persistence.

The dynamic analysis uses five-year averaged data to smooth short term fluctuations and minimize the impact of cyclical variations and also to avoid the problem of proliferation (Zergawu, Walle, & Giménez-Gómez, 2020). The dynamic model includes GDP per capita as the dependent variable, while the explanatory variables consist of ratio of public capital stock to GDP, ratio of private capital stock to GDP, government investment per capita, and labor force. The lagged value of GDP per capita is introduced to capture the dynamic effects of past growth. Our baseline model is a multiplicative interaction model.

$$y_{it} = \alpha + \beta y_{it-1} + \gamma X_{it} + \theta GK_{it} + \delta Z_{it} + \mu_i + e_{it} \quad (3.13)$$

Where

Y_{it} is GDP per capita
Y_{it-1} is lag of GDP per capita
β is persistence term
X_{it} is vector of explanatory variables
Z_{it} is vector of control variables
θ is complementarity between public and private capital stocks
μ_i is fixed effect error term.

Between the two main GMM approaches difference GMM and system GMM the study adopts the system GMM estimator, as it provides more efficient and reliable estimates, especially when the variables show high persistence over time. System GMM combines equations in levels and first differences, using lagged levels and lagged differences of the variables as instruments to address potential endogeneity.

The validity of the instruments in the GMM estimation is assessed using the Hansen J test, where a p-value greater than 0.05 indicates that the instruments are valid. Additionally, the Arellano–Bond AR(2) test is conducted to detect any second-order serial correlation, with a p-value greater than 0.05 confirming the absence of serial correlation. Based on this framework, the dynamic models for the study can be expressed as follows:

Model 4

$$\ln \text{rgdp}_{c_{it}} = \alpha L.ln\text{gdp}_{c_{it-1}} + \beta_1 lnGinv_{pc_{it}} + \beta_2 Gstock_{GDP_{it}} + \beta_3 Kstock_{GDP_{it}} + \beta_4 GKstock_{it} + \delta_1 To_{it} + \delta_2 Gsize_{it} + \mu_i + \varepsilon_{it} \quad (3.14)$$

Model 5

$$\ln \text{rgdp}_{c_{it}} = \alpha L.ln\text{gdp}_{c_{it-1}} + \beta_1 Gstock_{GDP_{it}} + \beta_2 Kstock_{GDP_{it}} + \delta_1 To_{it} + \delta_2 Gsize_{it} + \delta_3 inf_{it} + \delta_3 Fd_{it} + \mu_i + \varepsilon_{it} \quad (3.15)$$

Model 6

$$\ln \text{rgdp}_{c_{it}} = \alpha L.ln\text{gdp}_{c_{it-1}} + \beta_1 Gstock_{GDP_{it}} + \beta_2 Kstock_{GDP_{it}} + \delta_1 To_{it} + \delta_3 inf_{it} + \delta_3 Fd_{it} + \mu_i + \varepsilon_{it} \quad (3.16)$$

Model 7

$$\ln \text{rgdp}_{c_{it}} = \alpha L.ln\text{gdp}_{c_{it-1}} + \beta_1 Gstock_{GDP_{it}} + \delta_1 Iq_{it} + \delta_2 To_{it} + \delta_3 Gsize_{it} + \mu_i + \varepsilon_{it} \quad (3.18)$$

Model 8

$$\ln \text{rgdp}_{c_{it}} = \alpha L.ln\text{gdp}_{c_{it-1}} + \beta_1 Gstock_{GDP_{it}} + \delta_1 Hci_{it} + \delta_2 To_{it} + \delta_3 Gsize_{it} + \mu_i + \varepsilon_{it} \quad (3.19)$$

Model 9

$$\ln \text{rgdp}_{c_{it}} = \alpha L.ln\text{gdp}_{c_{it-1}} + \beta_1 Gstock_{GDP_{it}} + \delta_1 Iq_{it} + \delta_1 Hci_{it} + \delta_2 To_{it} + \delta_3 Gsize_{it} + \mu_i + \varepsilon_{it} \quad (3.20)$$

Where $\ln \text{rgdp}_{c_{it}}$ is the dependent variable and $L.ln\text{gdp}_{c_{it-1}}$ is lag of dependent variable to capture the effect of persistence over time across different countries. β_x is the coefficient of

explanatory variables, δ_x is the coefficient of control variables and μ_i captures unobserved fixed effect of heterogeneity across countries.

Chapter 4
Result and Discussion

4.1Descriptive statistics

The descriptive statistics provides preliminary insights of the macroeconomic structure and cross-country variation within the full sample, as well as the South Asian and Southeast Asian subgroups. All macro variables such as GDP, public capital stock, and private capital stock are expressed in constant 2017 prices to ensure comparability across regions and over time. Labor is measured as the total labor force, while growth rate, trade openness, inflation, financial development, institutional quality, and human capital capture key structural and macroeconomic dynamics relevant to long-term development. Table 4.1 provides the descriptive statistics for the variables used in the analysis.

The full sample comprises almost 384 observations for all the variables over the period of 1996–2019, providing a sufficiently large dataset to capture long-term economic trends across the selected countries. The average annual GDP for the full sample is $676.55 billion, with high standard deviation of $1,301.22 billion, indicating substantial heterogeneity in economic size across countries in the region. South Asia economically bigger than Southeast Asia with an annual GDP of 884.28 billion against 514.98 billion. It also has significantly higher standard deviation of $1,832.55 billion as compared to $589.73 billion, indicating that the regional economies are highly unequal in terms of their economic aspects. South Asia has an average annual GDP growth rate of 5.40 which is high as compared to the 4.97% of Southeast Asia. Nonetheless, the growth rate varies significantly across countries and time periods, with a minimum of −14.07 percent and a maximum of 23.20 percent across the full sample. The presence of extreme values at both ends of the distribution reflects episodes of severe economic contraction and rapid expansion that characterize the macroeconomic volatility of developing economies in South and Southeast Asia over the 1996–2019 period. This variability underscores the importance of controlling for macroeconomic conditions through the inclusion of inflation, trade openness, and government size as control variables in the regression models.

Government investment in South Asia of $45.44 billion twice to that of southeast Asia $23.67 billion. South Asia also has a higher public capital stock of $535.08billion compared with the Southeast Asian $281.69billion. The same applies to the case of private capital stock whereby

South Asia averages at $1,062.43 billion compared to the 933.19 billion of Southeast Asia. Nevertheless, the large standard deviation numbers, particularly in the stocks of public capital SD $1,165.46B in South Asia, indicate that the differences between countries in the region are big. These trends indicate that the South Asian economies are more dependent on the public and private investment but with a greater variance within the countries. Southeast Asian countries on the other hand have more stable and consistent accumulation of capital.

The two areas also differ on the basis of quality of their labor market and institutions. South Asia has labor force of approximately 80 million people that is more than the Southeast Asia labor force of approximately 30 million people. The reason behind this is that South Asia is a country with a high population and not more productive. Southeast Asia, however, is more developed in terms of human capital, as its average human capital index is 2.36. Southeast Asia also has good institutions and a growing economy, with averages of 0.14 and 59.09. Also, Southeast Asia is much more connected to global markets, with a trade openness rate of 135.01% compared to 59.62%. These disparities indicate that while South Asia's growth is supported by scale and investment, while Southeast Asia benefits from higher human capital, stronger institutions, and higher trade with global economies.

Before moving on to the regression analysis, some clarifications to the descriptive statistics in Table 4.1 are needed. The comparison of capital stock in South and Southeast Asia should be treated with some caution because of the high-country size bias introduced by India's economic scale. India alone accounts for the majority of the South Asian regional averages for GDP, public capital stock, and private capital stock meaning that the higher South Asian averages reflect India's dominance rather than uniformly higher infrastructure intensity across the sub-region. A more informative comparison of infrastructure development across countries would use per capita values or capital stock to GDP ratios, which is precisely the transformation adopted in the dynamic System GMM models, where capital stocks are expressed as ratios to GDP to ensure cross-country comparability net of size differences.

Second, the labor variable values ranging from 0.00 to 0.53 with a full sample mean of 0.05 reflect the total labor force measured in billions of persons, consistent with the IMF Investment

Table 4. 1 Descriptive Statistics

Full Sample					
Variables	**Count**	**Mean**	**Sd**	**Min**	**Max**
GDP (Y)	384	676.55	1301.22	1.89	9163.54
Growth rate (g_gdp2)	368	5.16	3.50	14.07	23.20
Govt investment (Ginv)	384	33.19	71.90	0.51	490.51
Public Capital Stock (G)	384	392.55	811.22	2.16	5446.44
Private Capital Stock (K)	384	989.73	1927.69	1.09	13487.68
Labor (l)	384	0.05	0.11	0.00	0.53
Financial Development (Fd)	384	48.03	35.51	3.12	158.51
Inflation (inf)	384	3.37	0.99	1.00	8.70
Trade Openness (To)	384	102.03	78.79	21.46	437.33
Govt Size (Gsize)	384	11.48	4.81	4.73	29.58
Instituitonal Quality (iq)	384	-0.13	2.05	-4.40	5.64
Human Capital index (hci)	360	2.19	0.50	1.35	3.21
South Asia					
GDP (Y)	168	884.28	1832.55	1.89	9163.54
Growth rate (g_gdp2)	161	5.40	3.30	-14.07	23.20
Govt investment (Ginv)	168	45.44	104.32	0.51	490.51
Public Capital Stock (G)	168	535.08	1165.46	2.16	5446.44
Private Capital Stock (K)	168	1062.43	2451.56	1.09	13487.68
Labor (l)	168	0.08	0.16	0.00	0.53
Financial Development (Fd)	168	33.81	13.83	6.96	78.95
Inflation (inf)	168	3.04	0.66	1.69	6.12
Trade Openness (To)	168	59.62	31.31	21.46	165.98
Govt Size (Gsize)	168	11.55	4.78	4.73	23.94
Instituitonal Quality (iq)	168	-0.47	2.22	-4.40	5.41
Human Capital index (hci)	144	1.94	0.46	1.35	2.91
Southeast Asia					
GDP (Y)	216	514.98	589.73	13.42	3109.65
Growth rate (g_gdp2)	207	4.97	3.63	14.07	13.56
Govt investment (Ginv)	216	23.67	23.40	0.57	106.38
Public Capital Stock (G)	216	281.69	298.37	5.78	1151.27
Private Capital Stock (K)	216	933.19	1394.27	6.01	7483.93
Labor (l)	216	0.03	0.03	0.00	0.14
Financial Development (Fd)	216	59.09	42.62	3.12	158.51
Inflation (inf)	216	3.62	1.12	1.00	8.70
Trade Openness (To)	216	135.01	88.32	37.42	437.33
Govt Size (Gsize)	216	11.43	4.84	4.80	29.58
Instituitonal Quality (iq)	216	0.14	1.88	-4.29	5.64
Human Capital index (hci)	216	2.36	0.46	1.45	3.21

and Capital Stock Dataset scaling where all factor inputs are expressed at a scale compatible with capital stock variables measured in billions of constant 2017 international dollars. A mean of 0.05

therefore represents approximately 50 million workers, while the maximum of 0.53 corresponds to India's labor force of approximately 530 million both entirely plausible values for the countries in the sample. Third, the minimum growth rate value of −14.07 percent reported for both the full sample and the Southeast Asian subsample warrants clarification. This extreme minimum value reflects a severe economic contraction experienced by one country in the sample during a specific crisis period within the observation window of 1996–2019. The presence of this extreme observation is acknowledged as a source of distributional asymmetry in the growth variable, and its influence on the regression results is mitigated by the use of five-year averaged data in the dynamic panel models, which smooths out such short-run cyclical extremes

4.2 Static Panel Results:

The normality of the variables has been checked using the skewness and kurtosis test. The results indicate that all the main variables, including output (Y), public investment (Ginv), public capital (G), private capital (K), labour (L), and other institutional and macroeconomic controls, reject the null hypothesis of normality at the 1% significance level ($p < 0.01$). Which suggest that the distributions of these variables are significantly skewed and exhibit excess kurtosis which often present in panel data due to cross country heterogeneity, scale differences, and time dynamics. In line with this the logarithmic transformation was applied to the core production variables (Y, G, Ginv, K, L) to reduce skewness. Moreover, non-normality does not invalidate the empirical analysis because panel model such as Fixed Effects and System GMM do not require variables to be normally distributed (Blundell & Bond, 1998). These model rely on large-sample asymptotic and moment conditions that remain valid under non-normality. Therefore, although the normality test was reported for descriptive purposes, the lack of normality does not bias or undermine the validity of the estimated results. This view is consistent with econometric literature, which emphasizes that GMM and panel data methods remain robust even when the data exhibit non-normality (Roodman, 2009; Wooldridge, 2010).

To examine the within-country effect of government investment on public capital stocks, a fixed-effects regression model was estimated with clustered standard errors at the country level from equation (3.9). The results indicate that government investment have a strong and statistically significant positive effect on the adjusted change in public capital (Table 4.1). In particular, a one-unit rise in government spending raises public capital stocks by about 0.78 units ($\beta = 0.7795$, $p <$

0.01). This implies that increased public investment correlates with significant enhancements in the accumulation of public capital over time.

Table 4. 1 Fixed effect regression result (Dependent Variable: Public capital Stocks)

Variables	Coefficients	Standard error	t-stats	P- Value
Government investment	**0.7795184***	0.1347221	5.79	0.000
Constant	0.0019128	0.0060696	0.32	0.761
F(1,8) = 33.48				R-squared (Within) = 0.2683
Prob > F = 0.0004				R-squared: Overall = 0.7372
***, *, and * denote significance at 1%, 5%, and 10% respectively.				

The finding aligns with existing literature indicating that public investment generally can have a positive and significant effect on public capital accumulation. For instance, Aschauer (1989) shows that increases in government investment greatly facilitate the expansion of productive public capital. Kamps (2004) also finds that government investment flows have a positive effect on public capital stocks in OECD countries. Furthermore, recent cross-country analyses, including IMF (2015), underscore that nations with more effective public investment management transform investments into productive capital more efficiently. Thus, the empirical findings align with established international evidence that government investment is an essential driver of public capital accumulation.

Table 4. 2 Efficiency Results for different countries

Country	Efficiency Coefficient	SE	P-Value
Bangladesh	.6315249	.2199817	.0082174
India	.8558071	.2311243	.0010584
Indonesia	.5957555	.2637109	.0328467
Malaysia	.7763637	.116265	5.36e-07
Pakistan	.4681393	.1947737	.0239801
Philippines	.5740609	.1995413	.0080996
Sri Lanka	.4186906	.1978333	.0444422
Vietnam	.5367821	.1845101	.0075014

The country specific estimates of efficiency indicate that there is a significant variations in the productivity of the public investment across the sampled economies. India has the largest

efficiency rate of 85% that is significant at 1%. This implies that the accumulation of the public capital in India is efficient in relation to other countries. Sri Lanka 42%, and Pakistan 46%, on the other hand, have low efficiency estimates, which are still significant. This could probably be attributed to structural and institutional obstacles which complicate the process of transforming public investment into productive public capital. Bangladesh, Indonesia, the Philippines, and Vietnam are medium performers having moderate efficiency estimates with statistical significance.

The implication of this is that there is partial but not full effectiveness of the processes of public investment. In general, these findings indicate that the role of the public investment in building public capital is common in all countries, though the degree of efficiency varies significantly. This is likely due to variations in the quality of governing, systems applied to the administration of the public investment, the institutional capacity and stability of the macroeconomic conditions. The difference between countries provides us with valuable concepts about how to maximize the productivity of the public investment, particularly in those countries that are not performing well.

The fixed-effects estimates provide a starting point of reference but they have to be closely analyzed due to their limitations associated with them. First, it lacks significant structural elements influencing the productive behavior of public investment such as quality of governance, human capital and financial development and trade openness. These constitute all that the literature proposes to be relevant with regards to the level of accumulation of the public capital across different countries (Rajaram et al., 2014; Dabla-Norris et al., 2012; Berg et al., 2012). Second, the simultaneity and reverse causality cannot be explained by the use of the model of stationary regimes; governments may expend more in investing due to the poor infrastructure conditions, financial limitations or adverse economic shocks, hence skewing the efficiency measures of investment.

The fixed-effects estimator merely presents the average correlation, and it does not take into account dynamic variations, capital accumulation persistence, as well as connection among investment, rise in output, and fiscal space. These constraints bring out the importance of being dynamic. The model is further analyzed within the system GMM framework, which explicitly accounts endogeneity, uses lagged dependent variables, captures adjustment dynamics, and uses structural control variables. The dynamic GMM estimator gives a better analysis of the interaction between public investment, institutional quality and macroeconomic conditions that helps in the

explanation of the accumulation of public capital and general parable of efficiency paradox in South and Southeast Asian region.

4.3 Dynamic Panel Result

Table 4.1 presents the results of the Dynamic Panel System GMM. Which show that there is a strong long-term connection between the previous and current levels of GDP per capita in all of the models. The lagged dependent variable (L.lnrgdp_c) is very important and has positive coefficients (between 0.80 and 0.94). This proves that output persistence is real. This is expected to be see in the long run standard growth models, making it clear that we need to use a dynamic model instead of a static one because economic performance change overtime because of adjustment costs, structural rigidities, and the ways that capital accumulates.

A key conclusion is concerned with two impacts of the public investment. The result of Model 1 shows the effect of government investment per capita has a positive and significant effect on GDP per capita, the coefficient of which is 0.11. This also argues that public investment is an economic activity that contributes to economic growth in terms of enhancing productive factors (Aschauer, 1989). This conclusion is supported by the results of Table 4.2 that reflects the outcomes of the analysis of the static panel and indicates that the flows of the public investments are productive in the short-term. But in a sharp contrast, the accumulated public capital stock (Gstock_GDP) does show a negative and statistically significant coefficient in some particular specifications. This means that even though with high public investment, the capital stock doesn't help the economy grow. The difference between the short-term effects of public investment flows and the long-term effects of accumulated capital stock is what makes managing the capital stock so inefficient. This observation aligns with Hulten's (1996) assertion that the quality, maintenance, and management of infrastructure assets may be more significant than the actual level of investment.

A negative coefficient on accumulated public capital stock does not necessarily imply that public infrastructure directly reduces economic output. Several alternative econometric explanations must be considered. First, the high correlation between public capital stock and private capital stock reported at 0.975 in the correlation matrix in the Appendix raises the possibility that multicollinearity may affect the precision of individual coefficient estimates, particularly in models where both stock variables are included simultaneously. Second, the negative relationship between the capital stock and growth might be due to reverse causality: governments in slow

growing economies may respond by scaling up public investment as a countercyclical measure, creating a negative association between the capital stock and growth that reflects fiscal policy responses to poor performance rather than a genuine negative productivity effect of infrastructure. Third, measurement limitations in the PIM-based capital stock series, particularly the assumed depreciation rates and initial capital stock estimates may cause the measured stock to overstate the true productive capital in countries with known maintenance deficits such as Pakistan and Sri Lanka. Fourth, the long gestation periods of infrastructure investments in developing economies mean that some capital accumulated toward the end of the observation period may not yet have generated detectable productivity returns within the 1996–2019 window. With these caveats in mind, the negative coefficient is interpreted in this study as broadly consistent with the efficiency paradox framework reflecting the structural gap between investment effort and productive capital accumulation in low efficiency environments rather than as evidence of a direct negative causal effect of public infrastructure on economic growth.

This duality of positive returns to public investment flows and negative returns to public capital stock points to a structural challenge. The countries in the sample appears to be accumulating public assets that do not generate proportional economic returns due to weaknesses in investment planning, implementation, and maintenance. This result aligns with (Pritchett, 2000; Easterly & Levine, 2001) concept of "capability traps" and “white elephants” where public investment doesn't translate into productive capital. This gap between effective accumulation and ineffective utilization lies at the heart of the public capital efficiency paradox. Similarly, Trade openness (To) and government size (Gsize) behave consistently with expectations. Higher openness is strongly and positively associated with growth across all models, reflecting the importance of external integration for small and emerging economies in South and South east Asia. Government size has a positive but weaker effect, suggesting that moderate government presence supports productivity confirming the finding of (Safi & Maurya, 2025; Nam & Ryu, 2024).

Table 4.4 System GMM results (Dependent Variables is Real GDP Per Capita)

Variable	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
L.lnrgdp_c	**0.813*** **	**0.943*** **	**0.907*** **	**0.903*** **	**0.914*** **	**0.915*** **
	(-0.025)	**(-0.03)**	**(-0.03)**	**(-0.026)**	**(-0.032)**	**(-0.029)**
Constant	1.263***	0.812***	0.911***	0.915***	0.885***	0.802***
	(-0.13)	(-0.168)	(-0.186)	(-0.175)	(-0.207)	(-0.168)
Gstock_GDP	**-0.403****	0.011	-0.078	**-0.142***	-0 .114	**-0.157***
	(-0.151)	(-0.069)	(-0.081)	**(-0.07)**	(-0.067)	**(-0.075)**
Kstock_GDP	-0.036	-0.047	-0.025	–	–	–
	(-0.056)	(-0.041)	(-0.037)			
lnGinv_pc	**0.113*** **	–	–	–	–	–
	(-0.018)					
GKstock_GD	0.103	–	–	–	–	–
	-0.087					
To	**0.00046****	**0.00064****	**0.00074*** **	**0.00078*** **	**0.00073****	**0.00062****
	(-0.00016)	**(-0.00024)**	**(-0.00024)**	**(-0.00022)**	**(-0.00029)**	**(-0.00023)**
Gsize	**0.00386****	–	0.00793	**0.01053***	0.00464	0.00466
	(-0.00175)		(-0.00514)	**(-0.00509)**	(-0.00658)	(-0.00557)
Inf	**–**	**-0.0372****	–	–	–	–
		-0.0166				
Fd	–	-0.00011	–	–	–	–
		(-0.00039)				
Iq	–	–	–	-0.0139	–	**-0.0242*** **
				(-0.0084)		**(-0.0056)**
Hci	–	–	–	–	-0.0035	0.0416
					(-0.0419)	(-0.0356)
Instruments	51	32	31	32	32	33
AR(1) p-val	0.23	0.718	0.452	0.281	0.458	0.21
AR(2) p-val	0.6	0.74	0.535	0.372	0.688	0.569
Hansen p-val	1	0.989	0.949	0.96	0.981	0.99

***,**. and * denote significance at 1 %, 5 %, and 10 % respectively. Standard errors of variables are reported in parenthesis

*Note: The panel comprises 8 countries (cross-sectional groups) across all models. Instrument counts per model are as follows: Model 4 = 51 instruments, Model 5 = 32 instruments, Model 6 = 31 instruments, Model 7 = 32 instruments, Model 8 = 32 instruments, Model 9 = 33 instruments. All models employ collapsed instruments and restricted lag ranges to mitigate instrument proliferation, following Roodman (2009). The instruments-to-groups ratio ranges from 3.9 to 6.4 across models, which exceeds the conventional rule of thumb that instruments should not outnumber groups. This limitation is acknowledged and is addressed through the use of collapsed instruments and the consistency of results across multiple specifications. **, ** and * denote significance at the 1%, 5%, and 10% levels respectively. Standard errors are reported in parentheses*

These findings both support and extend the existing empirical literature in important ways. The positive short-run effect of government investment flows on GDP per capita with a short-run coefficient of 0.113 and a long-run multiplier of 0.604 in Model 4 is broadly consistent with the fiscal multiplier evidence reviewed by Vagliasindi and Gorgulu (2021) and Deleidi, Iafrate, and Levrero (2020), who find positive output multipliers for public investment particularly in developing country contexts. However the finding diverges from the early landmark estimates of Aschauer (1989) and Munnell (1992), who reported large positive elasticities of public capital stock on output of 0.39 and 0.34 respectively for the United States.

The contrast between these positive stock elasticities for OECD economies and the negative or insignificant stock coefficients found in the present study for South and Southeast Asia is not surprising when the institutional and efficiency contexts are compared. Aschauer (1989) and Munnell (1992) were examining economies with high public investment management capacity, well-maintained infrastructure assets, and strong institutional frameworks conditions under which accumulated capital stock reliably translates into productive economic capacity. In the South and Southeast Asian context, where efficiency coefficients range from 42 to 86 percent and where infrastructure maintenance financing is systematically inadequate, the same translation mechanism is far weaker, producing the flow-stock duality. This regional divergence is consistent with the cross-country evidence of Calderon, Moral-Benito, and Serven (2015), who find that the productivity of public capital varies significantly across countries and is conditional on the quality of the institutional environment a finding that the present study corroborates and extends to the South and Southeast Asian regional context.

Given the high degree of output persistence reflected in the lagged GDP per capita coefficients ranging from 0.813 to 0.943 across models the short-run coefficients reported in Table 4.3 substantially understate the total long-run growth effects of the explanatory variables. To provide a complete dynamic interpretation, long-run multipliers are derived using the standard formula $LR = \beta / (1 - \alpha)$, where β is the short-run coefficient and α is the persistence coefficient on the lagged dependent variable. Table 4.4 presents the long-run multipliers for the key variables across the most informative model specifications.

Table 4.5: Long-Run Multipliers Derived from System GMM Estimates

Variable	Model 4	Model 5	Model 7	Model 9
Persistence coefficient (α)	0.813	0.943	0.903	0.915
Government investment (lnGinv_pc)	0.604***	—	—	—
Public capital stock (Gstock_GDP)	−2.155**	0.193	−1.464***	−1.847***
Trade openness (To)	0.00246**	0.01123**	0.00804***	0.00729**
Government size (Gsize)	0.0206**	—	0.1085***	—
Inflation (Inf)	—	−0.653**	—	—
Institutional quality (Iq)	—	—	−0.1433	−0.2847***

Note: Long-run multipliers are computed as $\beta / (1 - \alpha)$. Significance levels are inherited from the corresponding short-run coefficients in Table 4.3 indicates the variable was not included in that model specification. The derivation of long-run multipliers from short-run System GMM coefficients follows the approach of Zergawu, Walle, and Gimenez-Gomez (2020) and Blundell and Bond (1998).

The long run multipliers show a much larger picture of the dynamic effects estimated in the short run. In particular, the government investment on GDP per capita in Model 4 is 0.604 approximately five times larger than the short-run coefficient of 0.113 indicating that the full growth return to public investment spending takes considerable time to materialize through the capital accumulation and productivity channels identified in the theoretical framework. This finding reinforces the importance of sustained and consistent public investment commitments rather than episodic spending increases in the South and Southeast Asian context.

The long-run effect of accumulated public capital stock is substantially more negative than the short-run coefficients suggest, ranging from −1.464 in Model 7 to −2.155 in Model 4. These amplified negative long-run effects reflect the compounding nature of capital stock inefficiency over time when public capital is accumulated at low efficiency, the stock grows more slowly than investment spending suggests while simultaneously failing to generate proportional productivity gains, creating a widening gap between investment effort and economic return that deepens over the long run. Trade openness consistently shows positive and amplified long-run effects across all

specifications, reinforcing its role as a sustained driver of growth through external integration and technology transfer. The long-run effect of institutional quality remains negative and larger in magnitude than the short-run coefficient in Model 9, consistent with the threshold effects discussed in Section 4.3.2 suggesting that institutional improvements have not yet reached the level required to generate positive growth returns from public capital in the regional context.

The reliability of the System GMM estimates is assessed through the standard diagnostic tests reported in Table 4.3. Several technical clarification are warranted regarding the interpretation of these diagnostics. The Arellano-Bond AR(1) test examines whether there is first-order serial correlation in the differenced residuals. In standard System GMM applications, a significant AR(1) statistic is expected and acceptable, as first-order serial correlation in differences arises mechanically from the differencing transformation. However, the AR(1) p-values reported across all models — ranging from 0.21 to 0.718 — are insignificant, indicating the absence of detectable first-order serial correlation in the differenced residuals. This result is not unexpected given that the dynamic analysis employs five-year averaged data to smooth short-run fluctuations, as discussed in Section 3.7. The averaging transformation substantially reduces the autocorrelation structure of the residuals, making first-order serial correlation in the differenced residuals undetectable even when the underlying model is correctly specified. The critical diagnostic for instrument validity in this context is therefore the AR(2) test, which examines whether there is second-order serial correlation in the differenced residuals a condition that would invalidate the use of twice-lagged levels as instruments. The AR(2) p-values remain comfortably insignificant across all models, ranging from 0.372 to 0.74, confirming the absence of second-order serial correlation and supporting the validity of the instrument strategy.

The Hansen test of over-identifying restrictions yields consistently high p-values ranging from 0.949 to 1.000 across the six models. While high Hansen p-values are conventionally interpreted as evidence of instrument validity, values this close to unity warrant a degree of caution, as they may indicate instrument proliferation a condition in which an excessive number of instruments relative to the number of cross-sectional units causes the Hansen test to lose power and become uninformative (Roodman, 2009). With 8 countries in the panel and instrument counts ranging from 31 to 51 across models, the instruments-to-groups ratio is relatively high in some specifications, raising the possibility that the Hansen test is weakened by proliferation. To mitigate this concern,

collapsed instruments and restricted lag ranges were employed throughout the dynamic estimation, following the recommendation of Roodman (2009). These steps reduce the instrument count relative to the uncollapsed alternative while preserving the efficiency gains of System GMM. The Hansen results should therefore be interpreted as broadly supportive of instrument validity rather than as definitive confirmation, and the robustness of the findings is further supported by the consistency of coefficient signs and magnitudes across the multiple model specifications reported in Table 4.3. Collectively, these diagnostics provide reasonable support for the validity of the System GMM specifications, though the limitations arising from the small cross-sectional dimension of the panel are acknowledged as a constraint on the precision of the instrument diagnostics.

4.3.1 Public and Private Capital Dynamics: The Efficiency Paradox

The main objective of the study is to figure out how the investments of both the public and the private sectors work together or against each other to help the economy grow. Before estimating the preferred System GMM model, the variable General Government investment per capita was left out because it was found to be multicollinear with Public capital stock and Private capital stock in models 5 to 9. This step ensured that the model captured the long-run interaction between capital stocks rather than being distorted by highly correlated investment flow variables. The interaction term between public and private capital (GKstock_GDP) in model 1 became central for identifying whether these two forms of capital reinforce each other or function as substitutes.

The interaction coefficient between public and private capital in Model 1 is small and statistically insignificant. Which indicates a low elasticity of substitution between public and private capital. Theoretically, an elasticity less than one suggests complementarity, while an elasticity greater than one indicates substitutability. However, the value of the interaction term of about 0.103 is not only insignificant but also extremely small, implying neither meaningful complementarity nor clear substitutability. In practice, this means that more public capital does not make private capital more productive. The negative value of the coefficient on public capital stock, which ranges from -0.14 to -0.157 in Model 7 and Model 8, also supports the idea that there is no complementarity. The negative coefficient on public capital stock ranging from −0.142 to −0.157 in Models 7 and 9 suggests that, within the present sample and model specifications, accumulated public capital stock is associated with lower GDP per capita in the long run. However, this association should be

interpreted cautiously rather than as a definitive causal finding. As discussed in Section 4.3, the negative coefficient may partially reflect multicollinearity between capital stock variables, reverse causality from countercyclical fiscal responses, measurement limitations in the PIM-based capital stock series, or the long gestation periods of infrastructure returns that extend beyond the observation window. What the finding robustly supports is the interpretation that the accumulated public capital stock in South and Southeast Asian economies has not generated growth returns proportional to the investment effort expended a conclusion that is consistent with the low efficiency coefficients in Table 4.3 and with the broader efficiency paradox framework of Berg et al. (2018), without requiring the stronger causal claim that public infrastructure directly reduces output.

The results provide empirical support for the efficiency paradox in the South and Southeast Asian context, though this support must be interpreted carefully given the limitations of the empirical proxy employed. The estimated interaction between public and private capital stocks is very small and statistically insignificant in Model 1, which is directionally consistent with the theoretical interpretation of the efficiency paradox a low or insignificant interaction coefficient in a context where efficiency coefficients are below unity suggests that public and private capital are weakly complementary rather than strongly substitutable, consistent with the $\sigma_2 < 1$ condition. This result aligns with the theoretical prediction that in low efficiency environments, the private sector's productive capacity is constrained by infrastructure bottlenecks rather than substituted by private alternatives. While the flow of public investment generates positive short-run growth effects as shown in Model 4, the long-run productivity of accumulated public capital stock is not proportional to investment effort, reflecting the efficiency losses documented in Table 4.3. Taken together, these findings are consistent with the efficiency paradox proposition of Berg et al. (2018) that the growth payoff to public investment in low efficiency environments is shaped more by the complementarity between public and private capital and the relief of infrastructure bottlenecks than by the efficiency of capital conversion itself.

The finding of weak complementarity between public and private capital reflected in the small and insignificant interaction coefficient of 0.103 in Model 1 is consistent with the sub-unity elasticity estimates reported for developing economy contexts by Bom and Ligthart (2014) and Pereira and Andraz (2013), which imply complementarity rather than substitutability between the two forms

of capital. This contrasts with the high elasticity estimates of An et al. (2019, 2022) for high-income and European economies, reflecting the fundamental contextual difference between economies where private infrastructure markets are well developed and those where private capital remains structurally dependent on public infrastructure. At the regional level, the finding aligns with the crowding-in evidence of Javid (2019) and Qazi and Ammad (2021) for Pakistan, though the present study finds this complementarity to be weaker and statistically insignificant at the aggregate panel level than sector-specific analyses suggest. Taken together, these results support the conclusion that complementarity between public and private capital is a characteristic feature of developing economy contexts and precisely the condition under which the efficiency paradox of Berg et al. (2018) holds.

4.3.2 Institutional Quality and Human Capital: Limited Moderating Effects

The System GMM analysis indicates that institutional quality and human capital have weak moderating impacts on South Asian countries on public capital productivity. As opposed to theoretical expectations, both variables do not significantly contribute to increase productivity of the public capital. The negative coefficient of -0.0139 of institutional quality in model 9 is still found to be statistically significant. This Negative relationship aligns with the results of Bizimana et al. (2021). This could be a manifestation of threshold effects as suggested by Pritchett et al. (2010) whereby institutional improvements only begin to have tangible benefits once some level of state capability is achieved. Most of the South and South East Asian nations can fail to meet this threshold.

The institutional effects are also difficult to measure due to measurement limitations. Traditional indicators tend to ignore project-level variables like the quality of procurement, maintenance, rigor in planning and the ability to execute the infrastructure that directly dictate the outcome of infrastructure. According to Andrews (2010) this is what is termed as “institutional isomorphism” whereby nations end up using the global best practices that seem to work well in theory but do not in practice because of misalignment based on the contextual factors (Andrews, 2010). Likewise, the triviality of the moderating role of human capital in both model 8 and model 9 with the values between (-0.0035 and 0.0416) the following results are comparable to the outcome of (Siddiqui and Rehman, 2017). This goes against Nelson-Phelps (1966) hypothesis, which states that skills alone cannot be able to increase productivity of infrastructure. The human capital is limited to

enhance the use of public capital because of structural issues that include skills mismatches (Sohail, 2025), insufficient training in technical skills, and external migration (Benhabib and Spiegel, 2002; Roy, 2008).

The weak moderating effects of institutional quality and human capital found in this study contrast with the positive and significant moderating roles documented in broader cross-country studies. Zergawu, Walle, and Gimenez-Gomez (2020) find that the joint impact of infrastructure and institutions on economic growth is positive and significant in a global panel, while Calderon and Serven (2010) find stronger infrastructure growth effects in countries with better institutions in Sub-Saharan Africa. This divergence is informative rather than contradictory it suggests that the moderating role of institutional quality is subject to threshold effects, whereby governance improvements only begin to enhance infrastructure productivity once a minimum level of state capability is achieved. As Pritchett, Woolcock, and Andrews (2010) document, many developing economies exhibit institutional isomorphism formal governance structures that resemble best practice but fail to deliver equivalent functional outcomes due to deep-rooted implementation constraints. In the South and Southeast Asian context, where PIMA scores indicate that even basic public investment management requirements are not consistently met, this threshold has likely not yet been reached making the present study's null finding for institutional moderation a substantively important result in itself.

Chapter 5

Conclusion and Policy recommendations

5.1 Conclusion

The study is focused on efficiency paradox of investment in public infrastructure in South and Southeast Asia through an elaborate econometric analysis that integrates endogenous growth model with both the static and dynamic panel models on the basis of 1996 to 2019 panel data. The study combined the stocks of capital with both the private and the public to include the institutional quality and the human capital to the analysis, which advanced the study beyond the traditional development regressions to determine not only whether the accumulated stock of the public capital is economically productive in the long run, but whether the accumulation level of the capital stock was as well.

The results of the panel that is not dynamic confirms that the government investment is converted into the accumulation of public capital in all nations, but with a considerable degree of inefficiency between the countries in the region. The conversion efficiency in countries like India and Malaysia is relatively high whereas the countries like Pakistan and Sri Lanka are relatively low. These discrepancies highlight that the productivity of the public investment is not universal across nations, but, instead, is determined by the underlying structural and institutional conditions and not by the amount of spending per se.

The dynamic System GMM estimates give a clearer perspective. Although the impact of the public investment flows on economic growth in short term is positive and statistically significant, accumulation of the capital stock of the type of public capital has always been found to have either negative or statistically insignificant effect on the economic growth in the long term. This is the divide that is at the center of the public capital efficiency paradox. The findings show that in spite of the fact that the governments still spend a huge amount of money on infrastructure, the capital stock obtained usually does not bring about sustained productivity increases. Poor selection of projects, delays in implementation, inadequate maintenance and misaligning of resources seem to water down the long term growth benefits of infrastructure expenditure. This conclusion is also supported by the interaction between the public and the private capital. The interaction term is

found to be very small with a statistically significant value of 0. Rather than prompting individual investment, it seems that inefficient capital formation on the part of the government crowds out such investment. This loose connection of the state infrastructure and the productivity of the private sector is an essential limitation to the long-term development of the area.

Contrary to the expectations of the theory, institutional quality and human capital is not very strong positive moderators of public capital productivity in the dynamic models. The insignificant consequences imply that institutional changes in terms of improvements and reforms of institutions are not enough to increase infrastructure productivity unless more profound governance capabilities and technical execution capacities are strengthened. These results indicate that there are institutional thresholds and implementation traps present in most South and Southeast Asian economies, where formal governance structures exist but fail to translate into effective infrastructure outcomes. In general, the results reveal the fact that the payoff of growth on the investment in the public infrastructure in South and Southeast Asia is much more significantly conditioned by the efficiency, governance, and consistency with the needs of the private sector than by the amount of spending. Capital investments combined with ineffective institutions and project management are most likely to generate capital returns that are low and initiate long term fiscal liabilities and yet they do not result in a sustained growth.

The findings suggest that the policy needs to be changed to effective-based models of managing public investments rather than input-based investment policy models. To convert infrastructure expenditure into productive capital we must enhance project valuation, procurement and monitoring; ensure that infrastructure investment is coordinate with private sector investment and ensure that infrastructure is maintained. It is without such types of changes that increased government investment will not solve infrastructure issues and will not result in sustained economic growth.

Finally, this research study has contributed to the current empirical research since it has been conducted on the regional bases providing evidence on the paradox in the efficiency of public capital that uses a dynamic framework. Industry specific infrastructure data, maintenance expenditure and project specific governance variables have to be also included in further studies to further decouple the processes through which the efficiency of public investment can be increased and made growth promoting.

5.2 Limitations of the Study

While this study makes several contributions to the empirical literature on public infrastructure investment and the efficiency paradox, it is subject to one important limitations that should be acknowledged.

The most significant methodological limitation concerns the measurement of the relationship between public and private capital. The study's second objective examining the complementarity or substitutability between public and private capital is theoretically grounded in the nested CES production framework of Sato (1967), which specifies the elasticity of substitution parameter σ_2 as the key structural parameter determining whether the efficiency paradox holds. However, the direct structural estimation of σ_2 from the CES framework requires deriving the first-order conditions of the CES production function and estimating the resulting reduced-form parameters through nonlinear regression techniques. Given the small cross-sectional dimension of the present sample eight countries and data unavailability the nonlinear CES estimation is not feasible without substantial risk of identification failure and sensitivity to initial conditions.

As a practical alternative, the study employs a log-linearized interaction term between public and private capital stocks in the static panel models as an empirical proxy for the complementarity or substitutability relationship. While this interaction term captures the conditional marginal effect of public capital on output given the level of private capital, which is directionally informative about the nature of the public-private capital relationship it does not directly measure σ_2 as a structural CES parameter. The coefficient on the interaction term therefore reflects the association between the joint accumulation of public and private capital and output growth, rather than a structurally identified elasticity of substitution derived from the CES production function. This distinction is important: a finding of a positive but insignificant interaction coefficient is consistent with weak complementarity but cannot be interpreted as a direct estimate of $\sigma_2 < 1$ in the structural CES sense. Future research employing nonlinear CES estimation on a larger cross-country panel covering a broader set of developing economies with greater institutional variation would be better positioned to directly test the $\sigma_2 < 1$ condition required for the efficiency paradox and to provide a structurally identified estimate of the elasticity of substitution between public and private capital.

5.3 Policy Recommendations

The empirical findings of this study provide valuable insights for policymakers across South and Southeast Asia. The recommendations are as follows:

I. In light of this research study first and foremost a clear and methodological assessment framework is needed to timely assess the infrastructure needs of an economy. The framework should consist of three main steps
   1. Identifying factors which affects infrastructure investment decisions.
   2. Quantifying identified Factors.
   3. Ranking infrastructure projects

II. Policymakers must abandon the fixation on infrastructure spending as a measure of success. The research provides that a major portion of public investment never translates into productive capital. The negative long-run coefficient on public capital stock further confirms that accumulation without efficiency is nonviable. Policymakers should institutionalize mandatory efficiency audits for all major public investment projects and link budget allocations to demonstrated conversion performance.

III. Incompatible public and private capital suggests that current infrastructure investment does not crowd in private sector. All major infrastructure proposals must include a rigorous assessment of private sector complementarity. To make Public-Private Partnerships (PPPs) credible, governments must establish independent PPP units and commit to binding dispute resolution mechanisms that protect private investors from sovereign risk.

IV. The finding that institutional quality does not significantly moderate the growth impact of public capital exposes the failure of decades of governance reforms. Standard indicators of governance are not translating into better infrastructure outcomes. This means that years of trying to improve institutions by adopting foreign “best practices” have not worked on the ground. Policymakers should focus directly on fixing the concrete problems that delay or weaken infrastructure projects.

V. The effect of human capital on public capital productivity points to a fundamental skills mismatch and brain drain of skilled labor. Ministries of Education and Labor must restructure technical and vocational training around industry needs rather than traditional curricula.

Governments should consider targeted service obligations for publicly financed higher education.

References

Munnell, A. H. (1990). Is there a shortfall in public capital investment? An overview. *Is there a shortfall in public capital investment*, 1-20.

Robinson, J. A., & Acemoglu, D. (2012). *Why nations fail: The origins of power, prosperity and poverty* (pp. 45-47). London: Profile.

Adarov, A., Clements, B., & Jalles, J. T. (2024). *Revisiting Public Investment Multipliers*. World Bank.

Ahmad, S., Khan, S., & Khan, S. W. (2016). Developing Infrastructure through Public Private Partnerships; Understanding the Elements of the Enabling Environment. *Business & Economic Review*, *8*(1), 19-34.

Ahmed, F., Hossain, M. J., & Tareque, M. (2020). Investigating the roles of physical infrastructure, financial development and human capital on economic growth in Bangladesh. *Journal of infrastructure Development*, *12*(2), 154-175.

Ahmed, Q. M., & Ali, S. A. (2014). *Public investment efficiency and sectoral economic growth in Pakistan* (Vol. 22). Intl Food Policy Res Inst.

Ahmed, S., & Nishat, M. (2014). The impact of infrastructure expenditure on economic growth of Pakistan. *Journal of Social and Economic Policy*, 11, 93–101.

Ahmed, V., Abbas, A., & Ahmed, S. (2013). Public infrastructure and economic growth in Pakistan: a dynamic CGE-microsimulation analysis. In *Infrastructure and economic growth in Asia* (pp. 117-143). Cham: Springer International Publishing.

An, Z., Kangur, A., & Papageorgiou, C. (2019). On the substitution of private and public capital in production. *European Economic Review*, *118*, 296-311.

An, Z., Zhang, F., & Li, H. (2022). Elasticity of substitution between public and private capital: Evidence from manufacturing firms in Europe. *Economics Letters*, *219*, 110780.

Arrow, K. J., & Kurz, M. (1970). Optimal growth with irreversible investment in a Ramsey model. *Econometrica: Journal of the Econometric Society*, 331-344.

Aschauer, D. A. (1989). Does public capital crowd out private capital?. *Journal of monetary economics*, *24*(2), 171-188.

Aschauer, D. A. (1989). Is public expenditure productive?. *Journal of monetary economics*, *23*(2), 177-200.

Bajar, S., & Rajeev, M. (2016). The impact of infrastructure provisioning on inequality in India: does the level of development matter?. *Journal of Comparative Asian Development*, *15*(1), 122-155.

Barro, R. J. (1990). Government spending in a simple model of endogeneous growth. *Journal of political economy*, *98*(5, Part 2), S103-S125.

Baum, A., Mogues, T., & Verdier, G. (2020). Getting the most from public investment. *Well spent: How strong infrastructure governance can end waste in public investment*, 30-49.

Benhabib, J., & Spiegel, M. M. (2005). Human capital and technology diffusion. *Handbook of economic growth*, *1*, 935-966.

Berg, A., Buffie, E. F., Pattillo, C., Portillo, R., Presbitero, A. F., & Zanna, L. F. (2019). Some misconceptions about public investment efficiency and growth. *Economica*, *86*(342), 409-430.

Berg, A., Ostry, J. D., & Zettelmeyer, J. (2012). What makes growth sustained?. *Journal of Development Economics*, *98*(2), 149-166.

Berndt, E. R., & Hansson, B. (1991). Measuring the contribution of public infrastructure capital in Sweden.

Bizimana, O., Echeverri, L. J., Thomas, S., & Yoo, J. (2021). *Scaling Up quality infrastructure investment*. International Monetary Fund.

Bloom, D. E., Canning, D., & Fink, G. (2008). Urbanization and the wealth of nations. *Science*, *319*(5864), 772-775.

Blundell, R., & Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of econometrics*, *87*(1), 115-143.

Borensztein, E., De Gregorio, J., & Lee, J. W. (1998). How does foreign direct investment affect economic growth?. *Journal of international Economics*, *45*(1), 115-135.

Calderon, C. A., & Serven, L. (2014). The effects of infrastructure development on growth and income distribution. *Annals of Economics and Finance*, *15*(2), 521-534.

Calderón, C., & Servén, L. (2010). Infrastructure and economic development in Sub-Saharan Africa. *Journal of African Economies*, *19*(suppl_1), i13-i87.

Calderón, C., Moral-Benito, E., & Servén, L. (2015). Is infrastructure capital productive? A dynamic heterogeneous approach. *Journal of Applied Econometrics*, *30*(2), 177-198.

Chakraborty, S., & Dabla-Norris, E. (2011). The quality of public investment. *The B.E. Journal of Macroeconomics, 11(1)*, Article 27.

Chingoiro, S., & Mbulawa, S. (2016). Economic growth and infrastructure expenditure in Kenya: A Granger-Causality approach. *Int'l J. Soc. Sci. Stud.*, *4*, 1.

Creel, J., & Poilon, G. (2008). Is public capital productive in Europe?. *International Review of Applied Economics*, *22*(6), 673-691.

Dabla-Norris, E., Brumby, J., Kyobe, A., Mills, Z., & Papageorgiou, C. (2012). Investing in public investment: an index of public investment efficiency. *Journal of Economic Growth*, *17*(3), 235-266.

Deleidi, M., Iafrate, F., & Levrero, E. S. (2020). Public investment fiscal multipliers: An empirical assessment for European countries. *Structural Change and Economic Dynamics*, *52*, 354-365.

Eberhardt, M., & Teal, F. (2011). Econometrics for grumblers: a new look at the literature on cross-country growth empirics. *Journal of economic Surveys*, *25*(1), 109-155.

Eisner, R. (1991). Infrastructure and regional economic performance: comment. *New England Economic Review*, (Sep), 47-58.

Erenburg, S. J. (1993). The real effects of public investment on private investment. *Applied Economics*, *25*(6), 831-837.

Zhang, X., & Fan, S. (2004). How productive is infrastructure? A new approach and evidence from rural India. *American Journal of Agricultural Economics*, *86*(2), 492-501.

Ford, R., & Poret, P. (1991). *Infrastructure and private-sector productivity* (No. 91). OECD Publishing.

Foster, V., Rana, A., & Gorgulu, N. (2022). Understanding public spending trends for infrastructure in developing countries. *Policy research working paper*, *9903*.

Foster, V., Rana, A., & Gorgulu, N. (2022). Understanding public spending trends for infrastructure in developing countries. *Policy research working paper*, *9903*.

Gechert, S., & Rannenberg, A. (2018). Which fiscal multipliers are regime-dependent? A meta-regression analysis. *Journal of Economic Surveys*, *32*(4), 1160-1182.

Gómez-Antonio, M., & Fingleton, B. (2012). Analyzing the impact of public capital stock using the NEG wage equation: A spatial panel data approach. *Journal of Regional Science*, *52*(3), 486-502.

Gramlich, E. M. (1994). Infrastructure investment: A review essay. *Journal of economic literature*, *32*(3), 1176-1196.

Gupta, S., Kangur, A., Papageorgiou, C., & Wane, A. (2014). Efficiency-adjusted public capital and growth. *World development*, *57*, 164-178.

Henderson, V. (2003). The urbanization process and economic growth: The so-what question. *Journal of Economic growth*, *8*(1), 47-71.

Henningsen, A., Henningsen, G., & van der Werf, E. (2019). Capital-labour-energy substitution in a nested CES framework: A replication and update of Kemfert (1998). *Energy Economics*, *82*, 16-25.

Inada, K. I. (1963). On a two-sector model of economic growth: Comments and a generalization. *The Review of Economic Studies*, *30*(2), 119-127.

International Monetary Fund. Fiscal Affairs Department. (2023). *Pakistan: Technical assistance report—Public investment management assessment (PIMA) and climate PIMA* (IMF Staff Country Reports No. 2023/370). https://doi.org/10.5089/9798400259784.002

Javid, M. (2019). Public and private infrastructure investment and economic growth in Pakistan: An aggregate and disaggregate analysis. *Sustainability*, *11*(12), 3359.

Jha, J. (2022). Crowding-in or Crowding-Out? Complementarity and Substitutability Between Public and Private Investment in Pakistan. *The Journal of Developing Areas*, *56*(4), 247-261.

Kamps, C. (2005). The dynamic effects of public capital: VAR evidence for 22 OECD countries. *International Tax and Public Finance*, *12*(4), 533-558.

Kamps, C. (2006). New estimates of government net capital stocks for 22 OECD countries, 1960–2001. *IMF staff papers*, *53*(1), 120-150.

Kmenta, J. (1967). On estimation of the CES production function. *International Economic Review*, *8*(2), 180-189.

Lau, S. H. P., & Sin, C. Y. (1997). Public infrastructure and economic growth: time-series properties and evidence. *Economic Record*, *73*(221), 125-135.

Loayza, N., & Wada, T. (2012). *Public infrastructure trends and gaps in Pakistan* (Policy Research Working Paper No. 6148). World Bank. https://doi.org/10.11588/xarep.00003597

Looney, R. E. (1997). Infrastructure and private sector investment in Pakistan. *Journal of Asian Economics*, *8*(3), 393-420.

Lucas Jr, R. E. (1988). On the mechanics of economic development. *Journal of monetary economics*, *22*(1), 3-42.

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. *The quarterly journal of economics*, *107*(2), 407-437.

Middleton, R. (2002). William Russell Easterly. The Elusive Quest for Growth: Economists' Adventures and Misadventures in the Tropics. Cambridge, Mass.: MIT Press, 2001. xiii+ 342 pp. ISBN 0-262-05065-X, $29.95. *Enterprise & Society*, *3*(1), 189-190.

Miyamoto, H., Baum, A., Gueorguiev, N., Honda, J., & Walker, S. (2020). Growth impact of public investment and the role of infrastructure governance. *Well Spent: How strong infrastructure governance can end waste in public investment*, 15-29.

Zubair, M. A., Cheema, S., Inam, Z., & Khalid, M. (2023). *Reforming the Federal Public Sector Development Programme* (No. 2023: 10). Pakistan Institute of Development Economics.

Munnell, A. H. (1992). Policy watch: infrastructure investment and economic growth. *Journal of economic perspectives*, *6*(4), 189-198.

Nam, H. J., & Ryu, D. (2024). Does trade openness promote economic growth in developing countries? *Journal of International Financial Markets, Institutions and Money*, *93*, 101985.

Nawaz, S., Iqbal, N., & Khan, M. A. (2014). The impact of institutional quality on economic growth: Panel evidence. *The Pakistan Development Review*, 15-31.

Nell, K. S., & Thirlwall, A. P. (2014). *Explaining Differences in the Productivity of Capital Across Countries in the Context of 'New'Growth Theory* (No. 1412). School of Economics Discussion Papers.

Nguyen, C. T., & Trinh, L. T. (2018). The impacts of public investment on private investment and economic growth: Evidence from Vietnam. *Journal of Asian Business and Economic Studies*, *25*(1), 15-32.

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge university press.

Ban, A. O. K., & Okagawa, A. (2008). Estimation of substitution elasticities for CGE models. *Discussion papers in economics and business*, *16*.

Pereira, A. M., & Andraz, J. M. (2013). On the economic effects of public infrastructure investment: A survey of the international evidence. *Journal of economic development*, *38*(4), 1-37.

Pereira, A. M., & De Frutos, R. F. (1999). Public capital accumulation and private sector performance. *Journal of Urban economics*, *46*(2), 300-322.

Pritchett, L. (2000). The tyranny of concepts: CUDIE (cumulated, depreciated, investment effort) is not capital. *Journal of Economic Growth*, *5*(4), 361-384.

Pritchett, L., Woolcock, M., & Andrews, M. (2010). Capability traps? The mechanisms of persistent implementation failure. *Center for Global Development working paper*, (234).

Qazi, M. A., & Ammad, S. (2021). Public investment efficiency and sectoral economic growth in Pakistan. *Development Policy Review*, *39*(3), 450-470.

Rajaram, A., Kaiser, K., Le, T. M., Kim, J. H., & Frank, J. (2014). *The power of public investment management: Transforming resources into assets for growth*. World Bank Publications.

Rehman, C. A., Ilyas, M., Alam, H. M., & Akram, M. (2011). The impact of infrastructure on foreign direct investment: The case of Pakistan. *International Journal of Business and Management*, *6*(5), 268.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of political economy*, *94*(5), 1002-1037.

Romer, P. M. (1990). Endogenous technological change. *Journal of political Economy*, *98*(5, Part 2), S71-S102.

Romp, W., & De Haan, J. (2007). Public capital and economic growth: A critical survey. *Perspektiven der wirtschaftspolitik*, *8*(S1), 6-52.

Rovolis, A., & Spence, N. (2002). Duality theory and cost function analysis in a regional context: the impact of public infrastructure capital in the Greek regions. *The Annals of Regional Science*, *36*(1), 55-78.

Roy, S. (2008). *Technology diffusion and total factor productivity growth*. Louisiana State University and Agricultural & Mechanical College.

Saeed, N., Hyder, K., Ali, A., & Ahmad, E. (2006). The impact of public investment on private investment: A disaggregated analysis [with comments]. *The Pakistan Development Review*, 639-663.

Safi, N., & Maurya, N. K. (2025). An Empirical Analysis of Trade Openness and Economic Growth in South Asian Countries. *Journal of Social Sciences and Humanities*, *2*(3), 94-112.

Sahoo, P., & Dash, R. K. (2009). Infrastructure development and economic growth in India. *Journal of the Asia Pacific economy*, *14*(4), 351-365.

Sahoo, P., & Dash, R. K. (2012). Economic growth in South Asia: Role of infrastructure. *The Journal of International Trade & Economic Development*, *21*(2), 217-252.

Seitz, H., & Licht, G. (1995). The impact of public infrastructure capital on regional manufacturing production cost. *Regional Studies*, *29*(3), 231-240.

Siddiqui, A., & Rehman, A. U. (2017). The human capital and economic growth nexus: in East and South Asia. *Applied Economics*, *49*(28), 2697-2710.

Sims, C. A. (1980). Macroeconomics and reality. *Econometrica: journal of the Econometric Society*, 1-48.

Sohail, R. A. O. (2025). Infrastructure Without People: The Hidden Crisis of Human Capital in Pakistan's Growth Strategy. *INNOVAPATH*, *1*(3), 4-4.

Solow, R. M. (1956). A contribution to the theory of economic growth. *The quarterly journal of economics*, *70*(1), 65-94.

State Bank of Pakistan. (2020). The Pakistan infrastructure report. Infrastructure Taskforce, State Bank of Pakistan. https://www.sbp.org.pk/departments/ihfd/InfrastructureTaskForceReport.pdf

STUART, B. C. (1992). Structural adjustment and the role of the IMF. *Structural Adjustment and Macroeconomic Policy Is-sues, Washington: Fondo Monetario Internacional*.

Sturm, J. E., Kuper, G. H., & De Haan, J. (1998). Modelling government investment and economic growth on a macro level: a review. *Market behaviour and macroeconomic modelling*, 359-406.

Tatom, J. A. (1991). Public capital and private sector performance. *Federal Reserve Bank of StLouis Review*, *73*, 3-15.

Vagliasindi, M., & Gorgulu, N. (2021). What have we learned about the effectiveness of infrastructure investment as a fiscal stimulus. *A literature review*.

Warner, M. A. M. (2014). *Public investment as an engine of growth*. International Monetary Fund.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The stata journal*, *9(1)*, 86-136.

World Bank. (2022, November 11). *The effectiveness of infrastructure investment as a fiscal stimulus: What we've learned*. World Bank Blogs. https://blogs.worldbank.org/en/developmenttalk/effectiveness-infrastructure-investment-fiscal-stimulus-what-weve-learned

World Bank. (2023). *Transforming Pakistan's private sector: Policy note 3 – Facilitating a dynamic, productive, and environmentally sustainable economy* [Policy note]. https://thedocs.worldbank.org/en/doc/95b90def3bc7b2971a2db6ac90d260f2-0310062023/original/Pakistan-Reforms-For-A-Brighter-Future-Policy-Note-3-Transforming-Pakistan-s-Private-Sector.pdf

World Development Report 2024: The Middle-Income Trap. (2024). World Bank. https://www.worldbank.org/en/publication/wdr2024

Zergawu, Y. Z., Walle, Y. M., & Giménez-Gómez, J. M. (2020). The joint impact of infrastructure and institutions on economic growth. *Journal of Institutional Economics*, *16*(4), 481-502.

Appendix

***Table 5*:** List of Selected Countries

Southeast Asian Countries	South Asian Countries
Brunei Darussalam	India
Cambodia	Bangladesh
Indonesia	Pakistan
Malaysia	Sri Lanka
Maldives	Nepal
Myanmar	Bhutan
Philippines	
Singapore	
Thailand	
Vietnam	

***Table 6*:** Fixed Effects Regression Results (Model 1)

Variable	Coefficient	Std. Error	t-stat	p-value
ln_Ginv	0.1092	0.0522	2.09	0.054 *
ln_K	0.4038	0.1365	2.96	0.010 **
ln_G	–0.1122	0.1147	–0.98	0.343
lnK_lnG	0.0226	0.0129	1.76	0.1
ln_L	0.502	0.1846	2.72	0.016 **
Constant	–5.4480	2.9327	–1.86	0.083 *

F(5,15) = 160.59 R^2 (overall) = 0.9656
Prob > F = 0.0000
***, *, * denote significance at the 1%, 5%, and 10% levels, respectively.

***Table 7*:** Fixed Effects Regression Results (Model 2)

Variable	Coefficient	Std. Error	t-stat	p-value
ln_Ginv	0.1112	0.0516	2.16	0.048 **
ln_K	0.4062	0.1366	2.97	0.009 **
ln_G	–0.1147	0.1136	–1.01	0.329
lnK_lnG	0.0223	0.0128	1.74	0.102
iq	0.00864	0.01046	0.83	0.422
lnG_iq	–0.00028	0.0021	–0.13	0.896
ln_L	0.5078	0.1813	2.8	0.013 **
Constant	–5.5370	2.8685	–1.93	0.073 *
F(7,15) = 221.13				R^2 (overall) = 0.9654
Prob > F = 0.0000				
***, *, * denote significance at the 1%, 5%, and 10% levels, respectively.				

***Table 8*:** Fixed Effects Regression Results (Model 3)

Variable	Coefficient	Std. Error	t-stat	p-value
ln_Ginv	0.1602	0.0399	4.02	0.001 ***
ln_K	0.2153	0.084	2.56	0.022 **
ln_G	0.00966	0.1231	0.08	0.939
lnK_lnG	0.0283	0.00885	3.2	0.006 ***
iq	0.0103	0.01535	0.67	0.514
hci	0.1726	0.1596	1.08	0.298
lnG_iq	–0.00107	0.00277	–0.38	0.706
lnG_H	–0.02699	0.03128	–0.86	0.403
ln_L	0.607	0.1276	4.76	0.000 ***
Constant	–7.067	2.1931	–3.22	0.006 ***
F(9,14) = 112.55				R^2 (overall) = 0.9561
Prob > F = 0.0000				
***, *, * denote significance at the 1%, 5%, and 10% levels, respectively.				

Table 9 Correlation Matrix

	ln_y	ln_G	ln_Ginv	ln_K	ln_L	hci	iq	To	Fd	Gsize	inf
ln_y	1										
ln_G	0.9679*	1									
ln_Ginv	0.9254*	0.9587*	1								
ln_K	0.9739*	0.9753*	0.9148*	1							
ln_L	0.8946*	0.8149*	0.7914*	0.8067*	1						
hci	0.2009*	0.2462*	0.2054*	0.3125*	-0.1442*	1					
iq	0.1730*	0.1914*	0.1250*	0.2279*	0.087	0.3434*	1				
To	-0.0679	-0.0162	0.02	-0.0261	-0.2884*	0.4555*	-0.0173	1			
Fd	0.2917*	0.3866*	0.3868*	0.3656*	0.0268	0.5165*	0.0291	0.6137*	1		
Gsize	-0.3980*	-0.2716*	-0.2775*	-0.293*	-0.5699*	0.3709*	0.2089*	0.0304	0.0239	1	
inf	-0.1251*	-0.029	-0.0417	-0.0476	-0.3679*	0.3503*	0.0628	0.3928*	0.3471*	0.3086*	1