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Analyzing the Impact of Public Capital on Private Capital Productivity in a Panel of African Nations

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Abstract: This research contributes to the ongoing discourse concerning the efficiency of public capital and its influence on the productivity of private capital and total factor productivity within African economies. Employing the standard production approach, we include public capital as a distinct input to assess its specific impact on output growth and the enhancement of total factor productivity. We argue that public capital, predominantly manifesting through infrastructure, constitutes an indispensable element for fostering growth. Fundamental to the productivity of private capital is its reliance on a sufficient stock of public infrastructure for operational efficiency. Our empirical analysis reveals that public capital exhibits a substantive long-term influence on output growth and the productivity of private capital. However, in the short term, the discernible impact of public capital is less pronounced. Moreover, while public capital emerges as a noticeable factor in output growth, its influence on total factor productivity remains relatively subdued.

Keywords: public capital; economic growth; total factor productivity; Africa

Citation: Ezzahid, Elhadj, and Hamid Rafik. 2024. Analyzing the Impact of Public Capital on Private Capital Productivity in a Panel of African Nations. *Economies* 12: 118. https://doi.org/10.3390/economies12050118

Academic Editor: Bruce Morley

Received: 28 March 2024
Revised: 2 May 2024
Accepted: 7 May 2024
Published: 14 May 2024

1. Introduction

Assessing the extent to which public infrastructures, such as roads, highways, electricity networks, airports, railways, and other facilities designed for public use can boost output growth and productivity is of paramount importance to policy makers. Central to the objective of this paper is the sign and magnitude of the elasticity of output per unit of private capital with respect to public capital and the contribution of the latter to total factor productivity (henceforth, TFP).[1]

Undeniably, public infrastructures play a pivotal role in supporting the private sector, given that the production of goods and services typically necessitates the transportation of essential inputs such as energy, water, and other vital components—a task unfeasible for the private sector to accomplish on its own.[2] Hence, a logical presupposition arises regarding the indispensability of public infrastructure to foster sustained economic growth.

Nevertheless, government-provided infrastructure can potentially create distortions if it starts to displace private investment. Barro (1990)'s endogenous growth model posits that as the proportion of government spending in the gross domestic product (GDP) expands, the economy's growth rate also increases until it attains an optimal point, beyond which it begins to decline. Thus, the provisioning of infrastructure by the government in African nations might not be optimal due to inadequate public investment.

For private capital to be productive, it needs an efficient and diversified infrastructure. That is, the productivity of private investment is contingent upon the existence of a robust stock of public capital surpassing a specific threshold.[3] Thus, the productivity of public capital is expected upon reaching this threshold, serving as an essential requirement for the operation of the private sector.

It is crucial to study the effect of public capital on private capital in African nations for several reasons. First, public capital can enhance the productivity and growth of the

private sector by providing essential infrastructure and services that the private sector cannot or will not provide on its own. Second, public capital can also affect the allocation and efficiency of private capital by creating positive or negative externalities, depending on the quality and quantity of public investment. Third, public capital can have implications for the fiscal and macroeconomic stability, as it involves public spending, borrowing, and taxation decisions. Therefore, studying the effect of public capital on private capital can help policy-makers design optimal public investment strategies that can maximize the benefits and minimize the costs of public capital for the private sector and the economy as a whole.

This study focuses on Africa for several reasons. First, infrastructure in Africa significantly lags behind that of most other developing nations (Foster and Briceño-Garmendia 2010). Second, infrastructure is a major catalyst for economic growth, productivity enhancement, and a facilitator of trade (Donaubauer et al. 2018; Aschauer 1989).

This work aims to shed light on the contribution of public capital to the productivity of private capital in African economies, using the standard production function approach and data from 1960 to 2017. The rest of this paper is organized as follows. Section 2 deals reviewis the literature on the nexus between public capital and growth. Section 3 outlines the channels through which public infrastructure affects output and productivity. Section 4 details the empirical approach. Section 4 presents the model. Section 5 discusses the data and stylized facts. Section 6 presents the results. Finally, Section 7 concludes.

2. Public Capital and Growth

The potential role of public capital in enhancing economic growth and productivity poses a challenging relationship to measure empirically. This stems from the difficulties in estimating the stock of public capital, requiring assumptions about its initial value, depreciation rate, and the price deflator of public investment (Everhart and Sumlinski 2001).

While it is the case that the stock of public capital is the sum of public investments made each year minus the depreciation rate, studying the impact of public capital instead of investment is more relevant due to the fact that it takes a long time for public projects to have a positive return manifested through the enhanced productivity of the private sector.

While there is abundant research studying empirically public capital in relation to output growth and private capital, there is, however, none for the case of African economies. Thus, further research is imperative to assess the influence of public capital on growth. Such task is not only of great importance from an academic perspective, but it can also guide policy making by shifting attention on the likely equal importance of public capital as, in recent years, there has been increased interest in the primordial role of the private sector.[4]

Estimates of capital stock, both public and private, are predicated on assumptions related to initial stock levels and depreciation rates, potentially leading to inaccuracies. Consequently, empirical studies could exhibit biases in determining the extent of public capital's contribution to growth, particularly in countries with unsatisfactory statistical systems.

Government investment might not effectively translate into intended infrastructure like roads, bridges, or public buildings due to inefficiencies. Inefficient government investments might be costly due to corruption and the rent-seeking behavior of politicians and bureaucrats (Keefer and Knack 2007). Indeed, the aggregate data used by experts to estimate public capital stock might not accurately reflect the real physical capital available.

Significant infrastructure gaps are observed in African countries. Increases in factor inputs at the initial stages of development are assumed to generate high returns due to high marginal productivity. Accordingly, we should expect to find elasticities of output with respect to public capital to be relatively higher in African economies compared to advanced and middle-income economies. The main rationale for this assumption is the observed gaps of public infrastructures in Africa, especially in sub-Saharan countries.

The empirical literature presents a varied spectrum regarding the impact of public capital on economic growth. Some studies find a negative contribution, while others highlight its significance in fostering growth (Ligthart and Suárez 2011). In these studies, public

capital is typically integrated as a factor input alongside labor and private capital within production functions.[5] Bom and Ligthart's (2014) meta-regression analysis, examining 578 estimates from 68 studies between 1983 and 2008, revealed short-run output elasticities of about 0.083, long-run elasticities around 0.122, with an average output elasticity of approximately 0.106, signifying its substantial contribution to growth.

In contrast, Aschauer (1989), in a seminal paper which aimed to investigate the 1970s productivity decline in the U.S, finds a remarkable 0.39% increase in output per unit of private capital after a 1% rise in the public–private capital ratio. This elasticity starkly contrasts with the average 0.106 found in Bom and Ligthart's meta-analysis. However, critiques from authors like Munnell (1990) challenged the credibility of Aschauer's results, considering them disproportionately high relative to common findings in the literature.

Ouédraogo et al. (2019) estimated the impact of public investment on private investment in sub-Saharan African countries, revealing an overall positive effect of public investment on its private counterpart. Similarly, Henderson and Kumbhakar (2006) explored a panel encompassing 48 states,[6] estimating a positive and significant return on public capital.

Ligthart (2000) estimated the effect of public capital on output growth in Portugal. Employing the production function approach and the unrestricted vector autoregressive model (VAR) with yearly data spanning from 1965 to 1995, the study unveiled public capital's crucial role as a determinant of long-term growth. The elasticity of output concerning public capital in this analysis aligned with prior literature, standing at 0.19.

Arslanalp et al. (2010) examined the impact of public capital across OECD (Organisation for Economic Co-operation and Development) and developing countries, using data from 1960 to 2001. Their findings indicated a positive elasticity of output with respect to public capital. Notably, for non-OECD nations, the elasticity was relatively higher, with a public capital coefficient at 0.13, while developing countries exhibited an insignificant coefficient of public capital.

Bleaney et al. (2001) uses a panel data model to investigate the effects of distortionary taxes, that is, taxes that cause inefficiencies in the economy by discouraging consumption and saving, and government expenditures for OECD countries. Their results aligned with the predictions of Barro's endogenous growth model. Likewise, Ramirez (2002) analyzed the correlation between public spending on infrastructure and labor productivity in Mexico. Through cointegration analysis, their study concluded that government spending on infrastructure, rather than overall government investment, significantly influenced the growth of labor productivity.

Ram (1996) conducted an estimation in which output is a function of the shares of private and public investments in GDP, along with the annual growth rate of exports. The findings revealed that public investment exhibited notably higher productivity compared to its private counterpart.

Examining the role of public capital accumulation in output growth for 28 developing countries between 1981 and 1991, Dessus and Herrera (2000) employed a simultaneous equations model. Their conclusion pointed towards the positive impact of public capital accumulation on long-term growth. However, they highlighted an indirect crowding-out effect of private capital accumulation resulting from public capital formation.

In this regard, Holtz-Eakin (1992) argued that it is counter-intuitive to suggest that the public provision of roads, bridges, water, sewage facilities, and other components of infrastructure do not affect production directly. However, the study acknowledged that certain public projects might not be subject to cost–benefit constraints and could survive despite being unproductive. Consequently, the study emphasized the limitations of using aggregate data to convincingly establish public capital as the sole driver of improvements in private productivity.

Compared to the cited literature (see Table 1), this study is an empirical contribution regarding the effect of public capital, firstly on output in the short- and long-term; secondly, on the productivity of private capital; thirdly, on the total factor productivity in the context

of African economies. In this context, this study seeks to fill the gap regarding empirical studies assessing the elasticity of output with respect to public capital.

Table 1. A summary of the literature on the efficiency of public capital.

Study	Focus	Key Findings
Ram (1996)	Output estimation based on private and public investments	Public investment has a higher productivity compared to private investment.
Dessus and Herrera (2000)	Role of public capital in output growth	Positive impact of public capital accumulation on long-term growth, yet noted indirect crowding-out effect on private capital.
Holtz-Eakin (1992)	Public infrastructure's impact on production	Disputes counter-intuitive idea of no direct impact but acknowledges some unproductive public projects due to cost–benefit constraints.
Ligthart (2000)	Effect of public capital on output growth in Portugal	Public capital found as a crucial determinant of long-term growth, showing a certain elasticity of output concerning public capital.
Arslanalp et al. (2010)	Impact of public capital across OECD and developing countries	Positive elasticity of output concerning public capital, with relatively higher impact for non-OECD nations, while developing countries exhibited an insignificant coefficient.
Bleaney et al. (2001)	Effects of distortionary taxes and government expenditures	Aligns with predictions of Barro's endogenous growth model, exploring the impact on OECD countries.
Henderson and Kumbhakar (2006)	Return on public capital for a panel of 48 states	Shows a positive and significant return on public capital.
Ramirez (2002)	Correlation between public spending on infrastructure and growth	Government spending on infrastructure, rather than overall government investment, significantly influences the growth of labor productivity.
Aschauer (1989)	1970s productivity decline and public–private capital ratio	Indicates a substantial increase in output per unit of private capital with a rise in the public–private capital ratio, a finding challenged due to disproportionately high results.

Source: authors.

The Dynamics of Public Capital, Private Capital, and Output

Exogenous growth models place significant emphasis on investment for transitional dynamics and achieving steady-state growth. However, earlier models like that of Solow (1956) did not differentiate between the impacts of private and public capital on these dynamics. Private capital notably enhances output directly by bolstering the economy's productive resources and indirectly by fostering technological advancements, thereby enhancing overall efficiency.

Conversely, public capital, largely represented by infrastructure, does not directly impact production. Instead, its role lies in enhancing the efficacy of private capital and labor productivity, facilitating the adoption of new technologies and modes of production. Yet, due to the absence of a direct pricing mechanism for government services, which are primarily financed through taxes or borrowing, the allocation of public capital might not always be optimally managed.

In a neoclassical framework of economic growth, positive technological shocks are presumed to be the primary catalyst for long-term growth. Easterly and Levine (2001) found empirical evidence that corroborates this assertion, suggesting that TFP stands as a significant driver of economic growth. Without the productivity gains, the growth of per capita income would have been substantially lower in industrialized economies. Additionally, within Solow's growth model, the accumulation of physical capital contributes to per capita output growth only until the steady state is reached. Subsequently, sustained growth is predominantly derived from exogenous technological changes.[7]

In light of what precedes, we believe that the absence of robust public infrastructure hinders the private sector from propelling productivity, even in the presence of other growth catalysts such as technology, physical and human capital, and well-established institutions. For instance, if we consider a set stock of private inputs—where k is a broad concept of capital, covering both human and physical capital—alongside institutions ensuring property rights, law enforcement, and contract enforcement, the private sector's inability to access crucial elements like roads, energy, or water directly impedes output generation.

To illustrate, assuming Cobb–Douglass technology, $y = A{\cdot}k^{\alpha}g^{1-\alpha}$, with low levels of g, output will be low despite sufficient endowments of k. Therefore, it follows that public infrastructure is necessary to spur the emergence of growth in the private sector.

Boosting the stock of public capital necessitates public investment which can be funded through taxes or borrowing. However, taxes, once they exceed a certain threshold, can introduce distortions,[8] hindering growth rather than facilitating it. Although external borrowing can be effective, it is not a sustainable strategy when the social rate of return to public investment falls below the cost of borrowing.

Despite public capital being a major input in the production function besides private inputs, it does not necessarily contribute significantly to growth. One of the reasons why public investment does not contribute to the growth of private production is its crowding out effect of private investment (see, Sundararajan and Thakur 1980; Higgins and Link 1981, among others). This was one of the chief counter arguments to public spending since it was first advocated by Keynes. Financing public spending through taxes reduces the resources available to the private sector, resulting in decreased private investment and, consequently, reduced overall growth.[9]

Alternatively, when public spending is funded through borrowing, the heightened demand for loanable funds raises interest rates, making it costlier for the private sector to invest, thereby suppressing private production. Inefficient public investment further complicates the financing of public projects through taxes or external borrowing, as investor trust correlates closely with the economy's fiscal position. Proponents of deficit spending contend that judicious public borrowing, invested in projects stimulating private investment, can indirectly enable new channels of production and directly bolster aggregate demand through classical Keynesian channels.

Barro's seminal work in 1990 delineates two categories of public expenditures. The first pertains to productive investments that significantly contribute to long-term growth, while the second category involves expenditures deemed irrelevant to growth, such as spending on social services. Tax reductions on investment stimulate growth by incentivizing the private sector to invest, much like public spending aimed at enforcing property rights and maintaining law and order, which, in turn, enhances the returns on private capital. Conversely, distortionary taxes impede private investment, thereby diminishing long-term growth. Building upon this, the Barro and Sala-i-Martin (1992) model assumes n producers generating output y (where the aggregate output is represented as $Y = ny$) using the Cobb–Douglas technology:

$$y = Ak^{1-\alpha}g^{\alpha},$$

where A is technology, k represents a broad concept of capital[10] per producer ($k = K/n$), g represents the government-provided services per producer ($g = G/n$); G and K represents aggregate public and private capitals. Government finances its services through a propor-

tional tax on output τ and levies a lump-sum tax L.[11] The government is subject to the following constraint:

$$ng + C = L + \tau ny,$$

where C represents government consumption, i.e., non-investment goods that are not included in the production function. They showed that the growth rate $\varnothing$ is as follows:

$$\varnothing = \lambda(1-\tau)(1-\alpha)A^{\frac{1}{1-\alpha}}\left(\frac{g}{y}\right)^{\alpha/(1-\alpha)} - \mu,$$

where λ and μ are parameters in the utility function. This equation illustrates that distortionary taxes diminish the growth rate, whereas government-provided services denoted by 'g' augment growth. Non-distortionary taxes, specifically L, exhibit no impact on growth. It is noteworthy that government consumption does not affect the growth rate. However, within the model, there is the assumption that the government maintains a balanced budget, thereby avoiding surpluses or deficits. Bleaney et al. (2001) conducted a test on the aforementioned model, yielding robust results that affirm its assertions—highlighting the enduring impact of fiscal policy on economic growth.

3. The Channels through Which Public Infrastructure Affect Output and Productivity

There are many channels through which public investment can affect output and TFP (see Figure 1). One type of public investment might not be enough to encourage growth because the private sector needs many infrastructures in order to function efficiently. The following figure is a list of the main components of public capital and how they contribute to improving output and TFP.

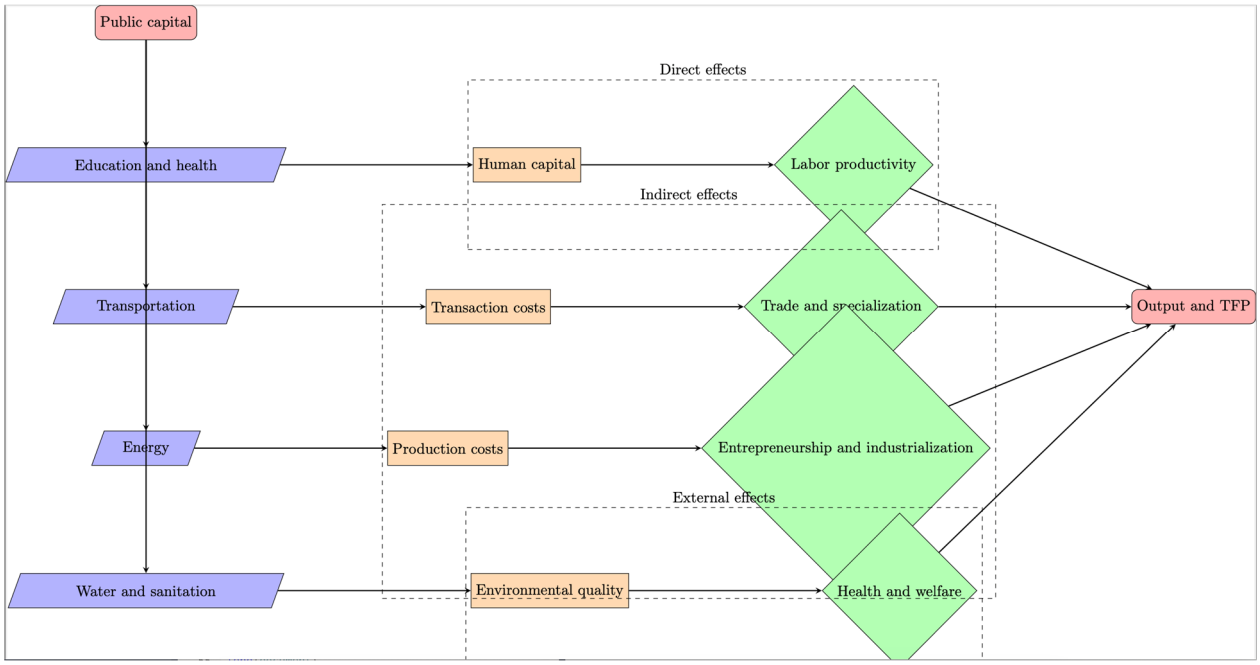

Figure 1. The channels through which public capital influences output and productivity. Source: authors.

Roads play a primordial role in bolstering private sector productivity by significantly reducing transaction costs. Agrawal et al. (2017) conducted a study utilizing data on highways, railroads, and routes, aiming to unveil the impact of inter-state transportation on regional innovation. Their empirical findings revealed that a 10% increase in the stock of highways correlates with a 1.7% surge in registered patents. Moreover, they highlighted the underestimated influence of transportation infrastructure on economic

growth. Interconnecting regions through roads yields a dual benefit—it allows regions to leverage their specialized production by trading surplus goods and fosters interdependence, enabling regional specialization.

In the context of the African continent, the expansion of road networks is poised to significantly enhance continental and global trade. The expansion and creation of transportation channels across African countries will likely streamline the movement of goods, fostering increased trade links. Importantly, transportation infrastructure not only eases the movement of goods but also facilitates the mobility of factors of production (Buys et al. 2006; Arvis et al. 2007).

From a microeconomic perspective, a firm endowed with specific factor inputs experiences enhanced productivity due to reduced transaction costs stemming from either the construction of new public roads or the enhancement of existing ones. This improvement enables the firm to generate more output using the same input levels, effectively elevating the total factor productivity. An essential characteristic of publicly provided infrastructures is their broad-reaching benefit to numerous private agents. This reasoning extends to various public infrastructures that facilitate transportation. Supporting this assertion, in the case of manufacturing establishments in India during the period 1998–2012, Kailthya and Kambhampati (2022) found that a 1% increase in road density correlates with a 0.25% rise in TFP.

Considering the aforementioned points, the inefficiency of public investment in an environment marked by a limited stock of transportation infrastructure does not stem from the inherent ineffectiveness of public capital itself. Instead, it often relates to the challenges in implementing and managing public projects, issues like corruption, and the elevated costs of public investment. Dzhumashev (2014) illustrates that, at lower levels of the government's share in GDP, corruption significantly hampers the efficiency of public spending, consequently impacting overall growth.

Electricity networks stand as a vital component of infrastructure, acting as the lifeblood of economic production in developed economies. In fact, electricity infrastructure is indispensable for technology-intensive machinery and high-end devices, acknowledged in literature as pivotal drivers of productivity. Lowering energy costs for established businesses can substantially reduce their overall expenses and bolster their output. Extending electricity networks to previously unelectrified rural areas offers households the capacity to operate electric appliances for household tasks, have access to illumination during night hours, facilitate tasks like well-digging and installing water pumps, ultimately leading to increased agricultural production. Several studies demonstrate the positive impact of energy consumption on economic growth (e.g., Stern et al. 2019; Banerjee et al. 2017; Saidi and Hammami 2015).

While the private sector can supply electricity, the initial phases of establishing large-scale energy infrastructures in impoverished nations often demand substantial investments, making them more feasible by the government. Conversely, large-scale infrastructures that might not yield immediate or medium-term profits might not attract private sector involvement.

Investments in healthcare and education play a pivotal role in enhancing the quality of human capital, a well-explored concept in the literature. Alongside these, the provision of essential infrastructures is indispensable for fostering skilled human capital, especially for firms engaged in technology-intensive goods.

Tsaurai and Ndou (2019) conducted an analysis on the influence of infrastructure and human capital development on economic growth in transitional economies. Employing dynamic panel and generalized methods of moments estimators (GMMs), the study spans 25 transitional economies from 1995 to 2015. The findings underscore the importance of the interaction between infrastructure and human capital development in bolstering economic growth in transitional economies. This study recommends policies focusing on augmenting human capital development to amplify the capacity of infrastructure development in influencing economic growth.

Finally, Canning and Bennathan (2000) explore the impacts of infrastructure and human capital on economic development utilizing cross-country data spanning from 1950 to 1992. Their research estimates a production function encompassing infrastructure and human capital as inputs while controlling for geographical, institutional, and openness factors. The study affirms the significant and positive effects of both infrastructure and human capital on output per worker. Furthermore, it highlights that, in countries with higher levels of human capital, the marginal product of infrastructure is proportionally higher.

While each public infrastructure component independently influences output, the collective execution of multiple public projects—such as roads, highways, electricity networks, telecommunication infrastructures, dams, and sewer facilities—yields a cumulative and amplified effect on overall growth. A synchronized increase in these varied infrastructure components significantly contributes to economic development. Conversely, an isolated surge in one aspect, like public investment in roads without a concurrent development of other public facilities, is unlikely to manifest noticeable impacts on output growth. This understanding, although challenging to empirically test, strongly advocates for a comprehensive expansion of various public infrastructure components throughout the African continent.

4. Model

To estimate the elasticity of output with respect to the public capital stock, we use a standard Cobb–Douglas production function, such as that in Aschauer (1989):

$$Y_{it} = F(N_{it}, K_{it}, G_{it}) = A_{it} N_{it}^{e_N} K_{it}^{e_K} G_{it}^{e_G} \tag{1}$$

where Y_{it} is output, A_{it} is the level of productivity, N_{it} is labor, K_{it} is private capital, and G_{it} is the public capital stock. $e_{N,}$ e_K, and e_G are the elasticity of output with respect to labor, private and public capital, respectively. The subscripts i and t represent the country and time variables, respectively. It is possible to include other kinds of capital such as human and institutional capital, but we assume that they indirectly affect the growth rate via their impact on the productivity measure A_{it}.

Following the work of Aschauer (1989), we introduce natural logarithms which yield the following equation:

$$y_{it} = a_{it} + e_N \cdot n_{it} + e_K \cdot k_{it} + e_G \cdot g_{it}, \tag{2}$$

This equation does not assume any restrictions on the parameters, assuming that competitive markets private inputs will be paid their marginal products. It is assumed that government services make private inputs more productive and allow for increasing returns over all inputs. It is assumed that there are constant returns to scale over private inputs but increasing returns to scale over all inputs, i.e., $e_N + e_K = 1$. Thus, we obtain the following equation:

$$y_{it} = a_{it} + e_N \cdot n_{it} + (1 - e_N) \cdot k_{it} + e_G \cdot g_{it} \tag{3}$$

Simplifying yields the following:

$$y_{it} = a_{it} + e_N \cdot n_{it} + k_{it} - e_N \cdot k_{it} + e_G \cdot g_{it} \tag{4}$$

Therefore:

$$y_{it} - k_{it} = a_{it} + e_N \cdot (n_{it} - k_{it}) + e_G \cdot g_{it} \tag{5}$$

Additionally, productivity is given by:

$$p_{it} = y_{it} - s_N \cdot n_{it} - s_k \cdot k_{it} = a_{it} + e_G \cdot g_{it} \tag{6}$$

Equation (5) expresses output per unit of capital as a function of productivity, the labor–capital ratio, and the stock of public capital, while Equation (6) expresses total factor productivity as a function of technical progress and the flow of government services assuming it is related to the stock of public capital, where s_N and s_k are factor shares.

For several reasons, the assumption of increasing returns to scale over all inputs may not hold. For instance, the costs of public investment, corruption, and the depreciation of public capital over time make it impossible to assume increasing returns. Assuming constant returns to scale over all inputs, that is, $e_N + e_K + e_G = 1$, yields the following specification:

$$\begin{aligned} y_{it} &= a_{it} + e_N \cdot n_{it} + (1 - e_N - e_G) \cdot k_{it} + e_G \cdot g_{it} \\ y_{it} &= a_{it} + e_N \cdot n_{it} + k_{it} - e_N \cdot k_{it} - e_G \cdot k_{it} + e_G \cdot g_{it} \\ y_{it} - k_{it} &= a_{it} + e_N \cdot (n_{it} - k_{it}) + e_G \cdot (g_{it} - k_{it}) \end{aligned} \tag{7}$$

To obtain the expression of total factor productivity, as in Aschauer (1989), we assume that the private factor shares s_N and s_k are proportional to their respective marginal productivities of labor and the private stock of capital e_N and e_K, that is, $s_i = \theta \cdot e_i$, where $i = N, K$. In case $\theta = 0$, i.e., productivities of private inputs are not related to their shares, this specification yields Equation (6), where it is a special case of the following equation.

$$\begin{aligned} p_{it} &= a_{it} + e_G \cdot g_{it} - e_G (s_K \cdot k_{it} + s_N \cdot n_{it}) \\ p_{it} &= a_{it} + e_G \cdot (g_{\,it} - i_{it}) \end{aligned} \tag{8}$$

where $i = s_K \cdot k_{it} + s_N \cdot n_{it}$ is a combination of private factor inputs, which can be interpreted as the stock of public capital per unit of private inputs.

5. Data and Stylized Facts

The dataset is constructed using estimates of public and private capital from the IMF Investment and Capital Stock Dataset (2019) and the PWT 9.1. (Penn World Table) Output and the estimates of the stocks of public and private capitals are taken from the World Economic Outlook while labor is taken from PWT.

We chose the estimates of the capital stocks rather than gross capital formations because, in our view, it is the stock of capital that explains output rather than its mere annual change. Investment is merely a means to increase the available stock and replaces the capital that is worn out due to depreciation.

Output estimates of private and public capitals are in billions constant 2011 international dollars, whilst labor is in millions of persons engaged. The dataset includes observations of a large sample of African countries (48) from 1960 to 2015. Our data are rich in that the number of observations is large enough to allow for robust estimates. This is one of the strong points in our study which makes it an outlier compared to the preceding literature. However, our panel is not strongly balanced due to missing data for some countries, especially in the early sample period.

The key indicators in Table 2 suggest a positive correlation between private investment and GDP growth. Indeed, countries such as Ethiopia and Tanzania show robust growth alongside higher rates of private investment. The link between public investment and GDP growth is less clear where there is no consistent pattern across the data set. The share of private capital in GDP generally exceeds the share of public capital, but this does not guarantee growth, as evidenced by the negative growth rates in Angola and Nigeria. Thus, greater private investment can have a greater influence on GDP growth.

Table 3 shows that private capital has a stronger correlation coefficient with output than public capital. We also observe that both types of capital are highly correlated with each other.

A robust correlation emerges between the public stock of capital and long-term output, as evident from the scatter plot depicting a concurrent rise in public capital and output (Figure 2). Consequently, one might posit potential causal effects from public capital to output or vice versa. However, the interpretation of this causal relationship and the direction of causation requires careful consideration. While it may be enticing to assert that public capital contributes to output growth given its role as a factor input, it is crucial to exercise caution. One should acknowledge that heightened output not only stems from

increased public capital but also contributes to elevated government revenues, consequently fostering a higher level of public investment and augmenting the stock of public capital.

Table 2. Key indicators for a selection of African countries.

Country	Year	GDP Growth	Private Invesement (% in GDP)	Public Investment (% in GDP)	Private Capital (% in GDP)	Public Capital (% in GDP)
Botswana	2016	4.3%	21.1%	8.00%	162.8%	90.00%
	2017	2.9%	18.5%	7.3%	169.6%	92.00%
	2018	4.5%	19.6%	7.1%	170.7%	91.8%
	2019	3.00%	21.3%	6.2%	175.2%	92.7%
Algeria	2016	3.2%	15.7%	8.8%	132.1%	118.00%
	2017	1.3%	16.5%	8.5%	138.4%	120.9%
	2018	1.2%	18.00%	7.5%	145.2%	123.4%
	2019	0.8%	16.3%	9.2%	153.6%	125.4%
Angola	2016	−2.6%	20.00%	3.5%	193.1%	115.00%
	2017	−0.1%	13.4%	5.2%	202.5%	114.5%
	2018	−2.00%	14.00%	3.9%	208.7%	118.00%
	2019	−1.5%	14.5%	3.1%	214.2%	119.4%
Egypt	2016	4.3%	3.8%	3.3%	42.1%	50.3%
	2017	4.2%	3.8%	3.4%	41.8%	49.7%
	2018	5.3%	3.5%	4.5%	41.00%	48.7%
	2019	5.6%	4.3%	4.2%	40.00%	48.7%
Ethiopia	2016	7.6%	14.4%	9.9%	51.8%	61.00%
	2017	9.5%	16.1%	8.7%	58.1%	63.2%
	2018	6.9%	15.9%	8.2%	66.7%	65.7%
	2019	8.3%	19.1%	8.9%	73.4%	66.7%
Ghana	2016	3.4%	11.2%	1.8%	139.6%	26.4%
	2017	8.1%	10.7%	1.5%	132.2%	25.2%
	2018	6.3%	12.2%	0.8%	127.5%	24.2%
	2019	6.5%	10.00%	1.00%	124.3%	22.7%
Kenya	2016	5.9%	7.3%	6.5%	92.7%	38.6%
	2017	4.8%	8.3%	5.8%	90.4%	41.6%
	2018	6.3%	8.1%	5.4%	88.1%	43.1%
	2019	5.4%	7.6%	5.5%	86.6%	44.4%
Morocco	2016	3.2%	23.7%	5.6%	235.00%	51.3%
	2017	5.8%	22.3%	5.2%	231.9%	51.9%
	2018	3.8%	21.9%	4.9%	232.2%	53.2%
	2019	3.6%	22.4%	4.4%	232.5%	54.2%
Nigeria	2016	−1.6%	7.3%	1.3%	97.2%	61.00%
	2017	0.8%	6.5%	1.8%	98.3%	59.7%
	2018	1.9%	7.6%	1.4%	97.4%	58.3%
	2019	2.2%	8.6%	1.2%	97.3%	56.3%
South Africa	2016	0.4%	13.5%	2.7%	157.3%	45.5%
	2017	1.4%	13.4%	2.7%	159.6%	45.9%
	2018	0.8%	13.2%	2.6%	162.8%	46.6%
	2019	0.2%	13.3%	2.4%	166.5%	47.4%
Tanzania	2016	6.9%	13.00%	5.5%	91.9%	46.6%
	2017	6.8%	13.8%	6.2%	94.3%	47.7%
	2018	7.00%	14.9%	6.5%	97.00%	49.1%
	2019	7.00%	16.3%	6.9%	100.5%	50.8%

Source: authors based on data from (IMF Investment and Capital Stock Dataset 2021).

Table 3. Correlations between output, private capital, and public capital—all variables are in natural logarithms.

Variables	Output	Private Capital	Public Capital
Output	1.00		
Private capital	0.922	1.00	
Public capital	0.851	0.878	1.00

Source: authors.

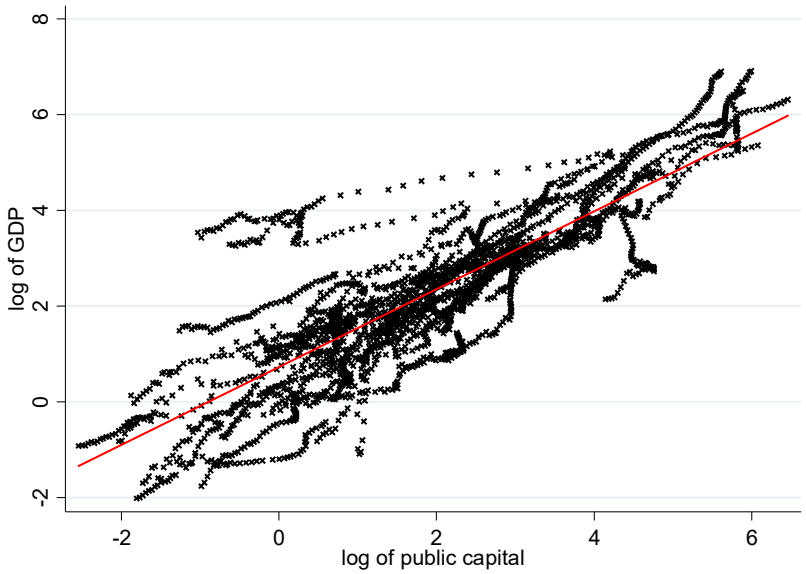

Figure 2. Output and public capital. Source: authors, on the basis of data from PWT and IMF.

Figure 3 illustrates a parallel evolution of private and public capital, indicating that as public investment rises, private capital tends to follow suit, and vice versa. While it is plausible to posit that public infrastructures enhance the productivity of the private sector, the nature of this relationship is not strictly linear. The impact of public infrastructure is not instantaneous due to the prolonged duration required for the completion of public projects, and its effects endure as long as measures are in place to counterbalance depreciation-related losses.

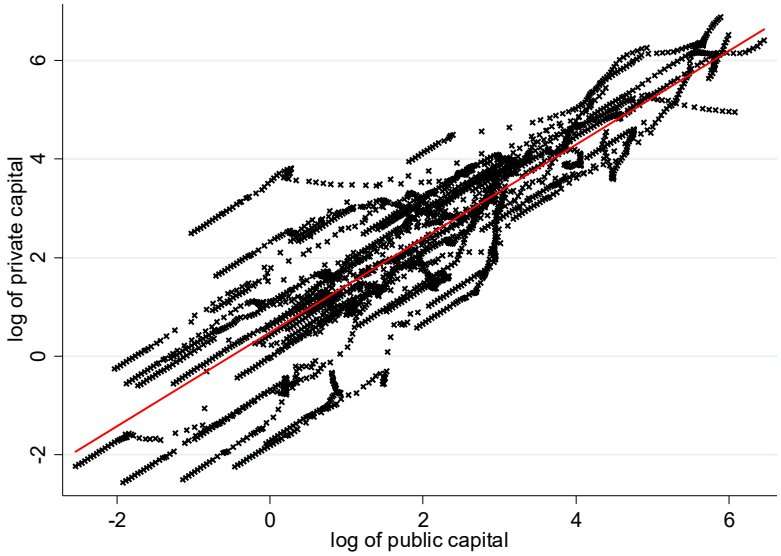

Figure 3. Private and public capital. Source: authors, on the basis of data from PWT and IMF.

Conversely, the relationship may also unfold in the reverse direction: an increase in private business production can lead to augmented government resources, subsequently resulting in the expansion of public infrastructures through increased public investment.

To examine the relationship between public and private investment, we present a scatterplot in Figure 4. Notably, at lower levels of both types of investment, a high correlation is observed; however, as we move farther from the scatter plot's center, this correlation diminishes. The noteworthy observation from this figure is as follows: there are discernible fits both above and below the fitted line, signifying heterogeneity within our sample. This variability may stem from the nonlinearity inherent in the relationship between private and public investment.

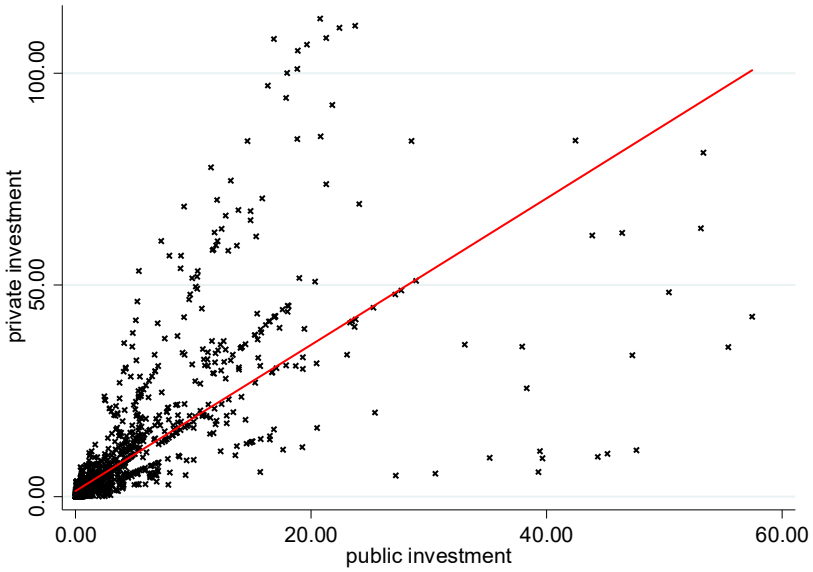

Figure 4. Private investment and public investment. Source: authors, on the basis of data from PWT and IMF.

For certain countries, a complementary pattern emerges between the two investment types, indicating a positive relationship. In contrast, for others, elevated levels of public investment do not appear to correspond to increased private investment, suggesting a potential crowding-out effect of private investment by its public counterpart. This underscores the nuanced and varied nature of the interactions between public and private investment across different countries in our sample.

In Figure 5, discernible heterogeneity is apparent among African countries concerning the behavior of the share of public investment in output. Notably, the fitted line remains unaffected by time, signifying that public investment consistently follows the same growth trajectory as output. Arslanalp et al. (2010) demonstrated that, for both developing and OECD countries, this share tends to increase until it reaches a peak of 60%, after which it starts to decline. Easterly and Levine (2001) underscored that, while capital accumulation growth is persistent, output growth does not exhibit the same consistency over time.

Enhancing the efficiency of public investment stands as a potential avenue for African countries to improve their infrastructure quality without compromising their fiscal position. Additionally, insights from cross-country regressions suggest that the quality of institutions serves as the primary determinant of public investment efficiency in sub-Saharan African countries (Barhoumi et al. 2018).

Figure 6 encapsulates the core objective of this paper by illustrating the relationship between the evolution of total factor productivity (TFP) and public capital. The scatterplot, featuring the logarithm of TFP and public capital, underscores the dataset's inherent heterogeneity. Establishing a clear and robust relationship between TFP and the stock of public capital proves challenging. The fitted line, exhibiting a slight downward slope,

suggests a potential negative impact of public capital growth on total factor productivity. The correlation between the logarithms of TFP and the stock of public capital stands at approximately −0.01, affirming a weak association, a finding further substantiated in our empirical analysis.

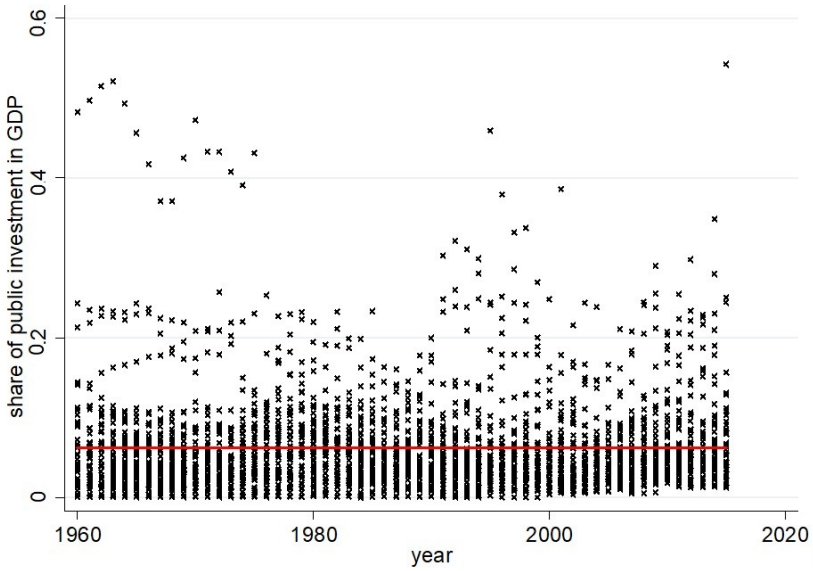

Figure 5. Share of public investment in output. Source: authors, on the basis of data from PWT and IMF.

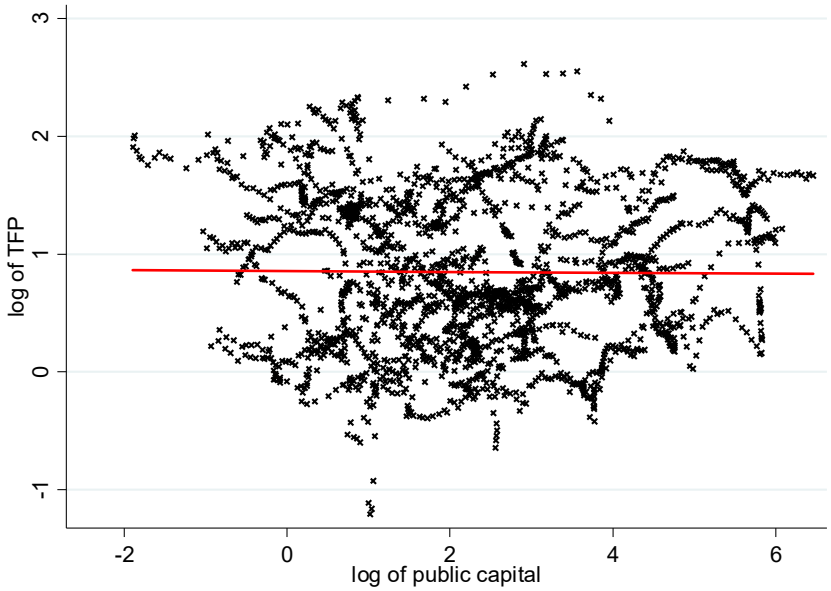

Figure 6. TFP and public capital. Source: authors, on the basis of data from PWT and IMF.

6. Results

This study uses the standard production function approach where all variables are expressed in natural logarithms. The Cobb–Douglas production function assumes that factor inputs are assumed to cause output. The main equations to be estimated are the following:

$$y_{it} - k_{it} = a_1 + a_2 \cdot t + a_3 \cdot (n_{it} - k_{it}) + a_4 \cdot (g_{it} - k_{it}) + a_5 \cdot g_{it} + a_6 \cdot k_{it} + u_i + e_{it} \quad (9)$$

And

$$p_{it} = b_1 + b_2 \cdot t + b_3 \cdot (g_{it} - i_{it}) + u_i + e_{it} \quad (10)$$

where u_i is the country's specific effect, e_{it} is the error term, and $i_{it} = s_K \cdot k_{it} + s_N \cdot n_{it}$[12] is our estimate of the combination of private inputs. We included the time variable to isolate time-dependent fluctuations from being attributed to changes in factor inputs.

While we have employed a fixed-effects model, it is noteworthy that a random effects model was also considered, yielding very similar results. The rationale for choosing the fixed effects approach lies in the desire to capture the idiosyncratic characteristics unique to each country. The decision to opt for fixed effects acknowledges the importance of considering and accounting for the specific attributes of individual countries in our estimation process.

Equation (11) (Table 4) establishes a relationship between output, labor, private capital, and public capital in logarithmic levels, aiming to capture the long-term impact of public capital on output growth. A 1% increase in the stock of public capital results in a growth of output by 0.128%, aligning with previous literature employing panel data. Similarly, Aschauer (1990), analyzing panel data for the United States, identified an output elasticity of 0.11 concerning public capital. Similarly, Munnell (1992), also for the case of the US panel data, reported an estimate ranging from 0.14 to 0.17 for output's elasticity with respect to public capital. In the meta-regression conducted by Bom and Ligthart (2014), the long-run elasticity of output with respect to public capital is found to be 0.122.

Table 4. Output (y).[13]

Equation	Estimation Method	Constant	Time	n	k	g
(11) [a]	Fixed effects	−15.17 ***	0.0081 ***	0.323 ***	0.380 ***	0.128 ***
		(−5.68)	(6.00)	(7.07)	(24.48)	(8.30)

[a] F(4;2217) = 3303.41, p-value = 0.00; R^2: within = 0.85. *** significant at 5% acceptance threshold.

Equation (12) (Table 5) is estimated in first logarithmic differences, capturing the short-term effects of factor inputs on economic growth. Notably, the elasticity of output concerning public capital in this equation is markedly lower than that estimated in Equation (11), amounting to only 0.086. This discrepancy may be attributed to the observation that increases in public capital require some time before being productive. It is noteworthy that private inputs make a meaningful contribution to growth even in the short run; a 1% increase in the stock of private capital results in output growth of 0.281. However, their impact is more pronounced in the long run.

Table 5. Output in first logarithmic differences (Δy).

Equation	Estimation Method	Constant	Time	Δn	Δk	Δg
(12) [a]	Fixed effects	−0.47 ***	0.000 ***	0.272 ***	0.281 ***	0.086 ***
		(−2.44)	(2.52)	(5.62)	(9.06)	(2.47)

[a] F(4;2167) = 40.25 ***; R^2: within = 0.06, between = 0.52, overall = 0.08. *** significant at 5% acceptance threshold.

To assess the assumption of constant returns to scale over all inputs, a test was conducted to determine whether the coefficients associated with labor, private, and public capital add up to one. The Fischer statistic obtained is in the order of F(1,2217) = 13.02, with a p-value lower than 1%, indicating that we can accept the assumption of constant returns to scale and, consequently, reject the assumption of increasing returns to scale.

Equation (13) (Table 6) relates the output per unit of private capital to labor–private capital and public–private capital ratios. A 1% increase in the public–private capital ratio results in a substantial 0.133% increase in output per unit of private capital. This finding underscores the significant role of public capital in enhancing the productivity of private capital in African economies, highlighting its crucial contribution to overall economic growth.

Table 6. Output per unit of capital $(y - k)$.

Equation	Estimation Method	Constant	Time	$n - k$	$g - k$	g	k
(13) [a]	Fixed effects	−5.85 *** (−8.55)	0.003 *** (9.87)	0.481 *** (38.63)	0.133 *** (8.58)		
(14) [b]	Fixed effects	−15.172 *** (−5.68)	0.008 *** (6.00)	0.323 *** (7.07)		0.128 *** (8.30)	−0.296 *** (−6.19)

[a] F(3;2118) = 744.85 ***; R^2: within = 0.50, between = 0.50, overall = 0.48. [b] F(4;2217) = 564.92 ***; R^2: within = 0.50, between = 0.47, overall = 0.45. *** significant at 5% acceptance threshold.

Equation (14) (Table 6) facilitates separate estimates for the coefficients associated with public and private capital. Specifically, a 1% increase in public capital is associated with an approximate 0.13% rise in private capital's productivity. This result underscores the pivotal role of public capital in augmenting the productivity of the private sector.

Equation (15) (Table 7) shows that a 1% increase in public capital causes only a 0.053% increase in total factor productivity. Upon including private inputs, the response of total factor productivity to a 1% increase in public capital rises to 0.128% (Equation (16), Table 7), which indicates the presence of serial correlation among explanatory variables. Equation (17) (Table 7) relates TFP to public capital and the combination of private inputs. We observe that the combination of private inputs carries a negative sign, which is in accordance with the assumption of constant returns to scale. Equation (18) (Table 7) exhibits the strong relationship between public capital per unit of the combination of private inputs and TFP. A 1% increase in the public capital per combination of private inputs raises total factor productivity by 0.13%.

Table 7. Total factor productivity (p).

Equation	Estimation Method	Constant	Time	g	k	n	i	$g - i$
(15 [a]	Fixed effects	3.671 *** (3.73)	−0.001 *** (−2.65)	0.053 *** (4.53)	–	–	–	–
(16) [b]	Fixed effects	−15.172 *** (−5.68)	0.008 *** (6.00)	0.128 *** (8.30)	−0.104 *** (−6.72)	−0.328 *** (7.19)	–	–
(17) [c]	Fixed effects	−7.190 (−4.52)	0.004 (5.03)	0.142 (9.46)	–	–	−0.266 (−9.22)	–
(18) [d]	Fixed effects	0.820 (1.25)	−0.000 (−0.06)	–	–	–	–	0.13 (8.65)

[a] F(2;2219) = 11.78 ***; R^2: within = 0.01, between = 0.01, overall = 0.00. [b] F(4;2217)= 30.96 ***; R^2: within = 0.05, between = 0.36, overall = 0.28. [c] F(3;2218) = 36.48 ***; R^2: within = 0.04, between = 0.32, overall = 0.25. [d] F(2;2219) = 38.96 ***; R^2: within = 0.03, between = 0.31, overall = 0.25. *** significant at 5% acceptance threshold.

The results of our empirical testing show that public capital is a significant contributor to the private sector's productivity. However, its direct impact on TFP is small. Nonetheless, upon including private inputs in the specification, this impact increases significantly due to the strong correlation between public capital and private inputs. Moreover, our results are supportive of the assumption of constant returns to scale. Public capital seems to have a significant impact on output growth in the long run. However, in the short run, its impact on growth is unnoticeable.

7. Conclusions

This study is a contribution to the debate over the effectiveness of public capital and its contribution to the growth of output and TFP. Indeed, this study advances the empirical literature on public capital's impact on output and private capital productivity both in the short and long term, as well as on total factor productivity in the context of African economies. We address a significant gap in the literature by estimating the elasticity of

output with respect to public capital for the case of African economies, highlighting its substantial long-term influence on output growth and the productivity of private capital. Although the short-term effects are less marked, and the impact on total factor productivity is subdued, our findings underscore the critical role of public capital in economic growth.

It is important to note that economic growth in Africa is not matching what we should expect from a continent that is rich with natural resources and, on the other hand, has an abundant supply, though unskilled, of labor. Using the standard production function approach, we estimated the elasticity of output with respect to public capital and tested the assumption of constant returns to scale. Our results show that public capital is an important contributor to output in the long run. We also estimated the response of private capital's productivity to changes in public capital. Our empirical model shows that public capital is a significant factor in enhancing private capital's productivity. However, we were unable to find a strong association between public capital and total factor productivity.

The study of the dynamics of economic growth assigns a primordial role to institutional quality which, through its role in spurring a climate that favors private incentives and lowering transaction costs, is the main driver of economic growth (Acemoglu et al. 2005; North 1991). Therefore, forthcoming studies dealing with the same issue should control for the impact of institutions on the efficiency of both public and private investments. The magnitude of the impact of public capital on output in African economies is in accordance with the preceding literature that uses panel data. Consequently, our model is in favor of more public investment in infrastructure to boost the productivity of the private sector. As it is well documented in the literature, factor inputs alone are not enough for growth and productivity enhancement (Easterly and Levine 2001). It is important to bear in mind that one of the caveats in our dataset is the degree of its accuracy, since the statistical system in African countries is far from being satisfactory.

Author Contributions: Conceptualization, E.E. and H.R.; methodology, E.E. and H.R.; software, H.R.; validation, E.E.; formal analysis, H.R.; investigation, H.R.; resources, H.R.; data curation, H.R.; writing—original draft preparation, H.R.; writing—review and editing, H.R. and E.E.; visualization, H.R.; supervision, E.E.; project administration, E.E.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data used in this study can be accessible at: https://www.rug.nl/ggdc/productivity/pwt/pwt-releases/pwt9.1?lang=en and https://data.imf.org/?sk=1ce8a55f-cfa7-4bc0-bce2-256ee65ac0e4 (accessed on 2 May2024).

Conflicts of Interest: The authors declare no conflict of interest.

Notes

1 From a public policy perspective, the higher the elasticity, the more fruitful it is to invest in public facilities.

2 We assume that the private sector is unable to provide infrastructure on its own.

3 According to Pereira and Andraz (2013), the output elasticity of public capital is 0.093 when the public capital stock is below the threshold level of 72.4% of GDP and 0.193 when it is over the threshold.

4 The Washington Consensus has placed emphasis on privatization and the transfer of state-owned enterprises and other forms of public property to the private sector.

5 Typically, a log-linearized Cobb–Douglas function is used either in levels or in first differences. When estimating the elasticity of output with respect to public capital in logarithmic levels, a concern arises about potential spurious regression due to the upward sloping trend of factor inputs. Conversely, employing estimation in first logarithmic differences addresses this issue, although it compromises the long-term relationship between output and the public capital stock.

6 Specifically, 48 American states.

[7] Within the well-known neoclassical Solow (1956) growth model, an uptick in the saving rate initially elevates the capital stock to its steady state level. Beyond this point, additional investment primarily serves to offset the per capita depreciation of capital. Once the economy reaches its steady state, sustained growth predominantly arises from exogenous technological shocks.

[8] Taxes diminish the pool of wealth accessible to the private sector, thereby exerting a negative influence on private incentives.

[9] This rationale holds when factor accumulation is considered the primary growth driver. However, if public expenditure on infrastructure has the capacity to enhance total factor productivity and offset the loss incurred from a decrease in gross capital formation, the likelihood of crowding out private investment diminishes.

[10] k includes human and physical capital.

[11] The particularity of lump sum taxes is that they do not increase proportionally to the growth of output and in this model are considered to be non-distortionary, that is, they have no effect on private incentives to invest in k.

[12] Factor shares are derived from estimating the Cobb–Douglass production function where the standard elasticities of labor and private capital are approximations of s_K and s_N.

[13] Between parentheses are the t-Student statistics.

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