# EFFECT OF PUBLIC INFRASTRUCTURE ON ECONOMIC PRODUCTIVITY IN SELECTED AFRICAN COUNTRIES

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*ABSTRACT*

*The absence of public infrastructure (such as electricity, transportation, ICT, water, and sanitation) and resilient institutions has been the critical reason for the inability of many African countries (Nigeria inclusive) to unlock their respective productivity gains in the last five decades. Based on extensive and relevant literature reviewed, this study investigated the impact of public infrastructure and other control variables (such as natural resource rents, human capital, and population growth) on economic productivity in thirty selected African countries for the period from 2005 to 2019, employing the generalized method of moments (GMM) and auto regressive distributed lag (ARDL) as baseline methodologies, and the fully modified ordinary least squares (FMOLS) and the forecast error variance decomposition (FEVD) – a variant of the vector autoregressive (VAR) model and vector error correction mechanism (VECM) for robustness checks. The estimation results from the various methodologies revealed that public infrastructure, governance factors, human capital, and natural resource rents have a positive and significant impact on economic productivity, and this supports the consensus view in a myriad of economic literature reviewed. However, the impact of population growth exerts a negative influence. Arising from the aforesaid findings, this study recommends that governments of African countries should: improve the quality of spending on public infrastructure to further boost economic productivity; provide favourable institutional and political environments for the economy to thrive; build more resilient human capital to stimulate stronger* *productivity growth; and discourage population growth in the region by instituting deliberate population control policies.*

**Keywords:** Infrastructure, productivity, institution, panel data models, Africa.

**JEL classification:** H54, D24, 043, C33, O55

## 1. Introduction

Infrastructure remains a veritable tool for enhancing economic productivity and sustaining economic growth in developing, emerging, and developed economies. It generally serves as a critical enabler for productivity and represents an opportunity to leapfrog a more reliable and resilient public capital. However, its absence may act as a constraint to a country's productivity and sustainable economic growth. In Africa, an inadequate supply of productive infrastructure in the areas of electricity, transportation, information and communication technology, water, and sanitation remains a key factor hindering industrialization on the continent. The insufficient stock of capital may be linked with the financing gap in the development of Africa's infrastructure. For instance, new estimates by the African Development Bank suggest that about $130 to $170 billion a year will be required to meet the infrastructure needs of the continent. Chinzara, Dessus and Dreyhaupt (2023) reiterated the World Bank's position that the sub-Saharan African (SSA) region requires about 7.1% of its GDP annually to bridge the financing gaps in infrastructure. Undoubtedly, financing gaps are one of the fundamental reasons for the huge infrastructural deficits in Africa. Moreover, the poor state of infrastructure across the region has reduced national economic growth in various countries by two percentage points every year and has cut business productivity by as much as 40%. This has hampered efficiency and economic competitiveness. However, the growth per worker in Africa has been largely driven by long-term growth in physical capital, and suitable investments in public infrastructure will serve as a dependable prerequisite for the efficient implementation of the African Continental Free Trade Area. There is no doubt that infrastructural deficits in the African continent are the bane of the region's productivity growth, and closing the infrastructural gaps will spur the continent's economic productivity.

It is somewhat surprising that most economic studies on the public infrastructure and economic productivity nexus were developed in isolation from the vast literature on economic growth, and the claim of infrastructure-constrained productivity growth lacks sufficient empirical evidence, hence the motivation this study. From a related perspective, numerous economic studies considering the link between public infrastructure and economic productivity seem to have little or no strong empirical consensus on the role aggregate public infrastructure (comprising electricity, transportation, ICT, water, and sanitation) would play in improving the economic productivity of Africa, taking into account institutional governance and other key macroeconomic aggregates. However, the scant empirical evidence underlying this public infrastructure-productivity growth nexus remains controversial, and this has motivated this study to provide a tractable empirical assessment of public capital accumulation, governance factors (and other control variables) for economic productivity growth. To our knowledge, an empirical assessment of the influence of key governance indicators on the economic productivity of Africa does not exist in recent empirical discourse. Much of the extant literature focuses on evaluating the impact of core macroeconomic variables on total factor productivity (TFP). Based on the aforementioned, the objective of this study is to empirically investigate the effect of public infrastructure and other control variables (such as natural resource rents, governance factors, and human capital and population growth) on economic productivity in thirty selected African countries for the period 2005 to 2019, employing different econometric methodologies.

The study includes thirty African countries that cut across West Africa, North Africa, Central Africa, East Africa, and South Africa regions. The selection of countries across different political and economic regional zones is aimed at ensuring fair representation and mitigating the study against the bias of excluding any region. The study stands out by employing a variety of methodologies to ensure the consistency and robustness of the various estimates obtained to allow for informed policy recommendations. These methodologies include the generalized method of moments (GMM) and auto-regressive distributed lag (ARDL) as the baseline methodologies, while the fully modified ordinary least squares (FMOLS) and the forecast error variance decomposition variant of the vector autoregressive (VAR) model and vector error correction mechanism (VECM) are utilized for robustness checks. The study covers a period of fifteen years (2005 – 2019). The choice of this period is largely influenced by the availability of data. The study comprises the following sections: introduction, literature review, empirical models and estimation techniques, empirical tests and estimation, policy perspective, and conclusion.

## 2. Literature Review

### 2.1 Empirical literature review

#### 2.1.1 *Cross-country Studies*

Multidimensional factors determine productivity and growth across developing and developed countries. These determinants include macroeconomic and institutional factors. For example, Loko and Diouf (2009) explored the influence of the key determinants of total factor productivity growth in sixty-two developed, emerging, and developing countries over the period 1970 to 2005, using a principal component analysis and a dynamic panel data model. The study revealed that reforms aimed at enhancing human capital, increasing trade volume, attracting foreign direct investment, improving the business environment, and encouraging women to enter the work force could accelerate economic productivity gains.

There is a consensus that the determinants of total factor productivity create the needed impetus for enhancing national economic productivity and development. This position is supported by a study (Kim and Laoyza, 2019) covering over one hundred countries from 1985 to 2015, which utilized principal component analysis to compute the overall total factor productivity determinant index and the variance decomposition to assess the contributions of each determinant, and discovered that the highest contributor among the determinants to total factor productivity growth was market efficiency for OECD countries and education for developing countries. The study emphasized that productivity improvement via appropriate public infrastructure is a key enabler of sustained economic growth and development. In a similar, though earlier study across SSA countries from 1965 to 2000, using the fixed effect technique as well as the seemingly unrelated regression, Njikam, Binam and Tachi (2006) assessed the factors behind the varying total factor productivity growths across the region. They found that openness to world trade contributes to total factor productivity only if issues related to key economic aggregates like poor transport, weak infrastructure, erratic supply of electricity, and poor governance factors like corruption are addressed. It follows from the study that physical capital accumulation, the size of financial sector and population growth are significant factors influencing economic productivity in SSA countries.

Turyarceba et al. (2017) investigated the key determinants of total factor productivity growth in Africa (inclusive of thirty-five SSA countries) from 2002 to 2012 using stationary and co-integration panel data estimation techniques. The study emphasized that economic factors such as inflation, domestic credit to private sector, human capital and ICT are key drivers of economic productivity growth in Africa. The study advocates that total factor productivity is a veritable stimulant of Africa's productive capabilities, and that improved TFP indicates better level of technology, strong human capital and larger economic returns for the various economies in Africa.

The ineffectiveness of market-based and political institutions in driving total factor productivity growth in Africa accounts for the relatively weak economic growth experienced in most African economies over the last few decades. Fediran and Akanbi (2017) confirmed this view in a study that examined the nexus between institutions and total factor productivity in twenty-six sub-Saharan African countries from 1990 to 2011. The study revealed that there is a consistent positive and significant relationship between institutions and total factor productivity. The study reiterated that market-based institutions exert more prominent influence on economic productivity than the more frequently explored political institutions.

There is no doubt that public infrastructure is a necessary driver for increasing economic productivity and sustaining economic growth. However, the economic costs of poor infrastructure quality and insufficient capital stocks will likely have significant consequences on Africa's total factor productivity growth. Fediran and Akanbi (2017) investigated the link between public infrastructure and productivity growth in SSA countries during the period 1990 to 2011. The study revealed that quality infrastructure would lead to greater productivity. This study, however, emphasizes that despite the varied empirical consensus for the nexus between public infrastructure and total factor productivity, public infrastructure remains an important potential determinant worthy of consideration in research efforts investigating the determinants of economic productivity growth in Africa.

Several cross-country studies have empirically evaluated the impact of infrastructure development on economic growth. For instance, Ighodaro (2021) assessed the impact of the disaggregated components of information and communication technology on economic growth in thirty-eight selected SSA countries using various panel data econometric methodologies. The empirical results from the study revealed that the various components of aggregate ICT infrastructure in SSA exert a catalytic and significant effect on economic growth, except for electricity access. The study further reinforced the importance of infrastructure in driving economic productivity. In a related development, Ibragimova, Wang, and Ivanov (2021) conducted extensive empirical assessment on the impact of infrastructure on output and productivity growth in Africa from 1999 to 2019. The empirical outcome from the study showed that infrastructure exerts a positive and significant effect on output and productivity growth in Africa.

In terms of the effect of key economic variables on infrastructural development in Africa, Arodoye and Sowemimo (2022) investigated the impact of natural resource revenue on infrastructural development in SSA from 2005 to 2018 employing the GMM and FMOLS methodologies. The empirical outcome revealed that natural resource revenue exerts a negative and not significant impact on the infrastructural development of Africa. However, mixed findings were observed in terms of the impact of natural resource rents on the various disaggregated components of infrastructure. This study further reinforces the fact that investment in infrastructure capital will spur the marginal productivity of public capital services and, by extension, drive economic growth.

Chinzara, Dessus and Dreyhaupt (2023) analysed the determinants of private participation infrastructure of thirty-six African countries from 2008 to 2019 using variants of panel econometric methodologies. The findings from the study reveal that the quality of institutions is a dependable driver of private participation in infrastructure. The study also indicates that other macroeconomic variables like the size of the economy, trade openness and measures of macroeconomic stability are significant determinants of infrastructural development in Africa. In a related development, Kapsoli, Mogues and Verdier (2023) employed stochastic frontier and bootstrapped data analysis to evaluate the efficiency scores of infrastructure-growth nexus of across countries and income groups. The study revealed that a significant increase in investment efficiency scores would indicate progressive influence of infrastructural development on national development.

### 2.1.2 *Country-specific Studies*

Kumo (2022) empirically investigated the key factors that contribute to economic growth and productivity in Sierra Leone from 1980 to 2019. The study revealed that severe gaps in the various infrastructural types (like electricity, transportation, etc.) and institutions in the country significantly contributed to the slow growth in total factor productivity. Another study, though country-specific in the African continent, investigated the effect of some macroeconomic factors on total factor productivity. Degu and Bekele (2019) investigated the impact of selected macroeconomic variables such as trade openness, inflation, government expenditure, credit extended, foreign direct investment and natural disasters, on total factor productivity in Ethiopia using the autoregressive distributed lag econometric techniques from 1991 to 2018. The study indicated that foreign direct investment, government expenditure and drought negatively and significantly affected total factor productivity, while credit extended exhibited a positive and significant influence on TFP, while inflation and trade openness were insignificant.

Other studies offer excellently empirical and theoretical insights into the factors driving economic productivity, such as Andreas (1997), although not directly related to total factor productivity. This study examined the impact of road infrastructure on private production using data from the manufacturing sector of eleven Bundesländer from 1970 to 1993, and it found that road infrastructure is significant for production in the manufacturing sector. The results suggest that public infrastructure like roads propel economic productivity and tend to accelerate sustained economic growth and development.

Kalu (2021) empirically investigated the impact of infrastructural development on value addition in agricultural output in Nigeria from 1981 to

2016 employing the error correction mechanism and the Granger causality test. The findings showed that infrastructure has a significant influence on agricultural output in Nigeria, and this suggests that infrastructural development is an "enabler" of economic productivity in Nigeria via its contribution to agricultural outputs. In another sectoral study, Ibrahim (2019) analysed the impact of infrastructural development on industrial output in Nigeria from 1981 to 2015 employing the dynamic ordinary least squares estimation technique, and the empirical results revealed that the disaggregated components of infrastructure had a positive and significant effect on industrialization in Nigeria. These studies indicate that appropriate infrastructure remains the most significant prerequisite for implementing multi-sectoral development in Nigeria.

In the audit of theoretical and empirical literature so far, there is unanimity of findings on the relationship between public infrastructure and economic productivity (total factor productivity) under varied institutional environments, which has remained positive and significant in most developing, emerging, and developed countries. However, the claim of infrastructure-constrained economic productivity lacks sufficient empirical evidence in Africa, hence the motivation for this study.

### 2.2 Theoretical literature review

Aschauer (1989) emphasized the critical roles played by public sector capital (like infrastructure) in the productive activities of every economy – that is, the effect of publicly-provided infrastructure on private sector productivity. In light of this, the author modified the traditional production function with the introduction of public sector capital and enunciated that the modified production function exerted a significant influence on private sector productivity. In support of Aschauer's framework, Barro (1990) evaluated the imperatives of the endogenous growth model in analysing the role of capital accumulation in output growth, and argued that government's productive expenditure (i.e., expenditure on infrastructure) is the key driver of its contribution to current production. In a similar development, endogenous growth theories emphasize the role of government policies (including institutional choices that maintain property rights and free markets) in enhancing long-term productivity growth through capital accumulation. In addition to government policies, other forces like the accumulation of human capital, fertility decisions, and diffusion of technology also play a significant role in explaining the interactive impact of public capital and institutions on economic productivity. Also, Nguyen and Bui (2022) noted that, in the neoclassical growth model, productivity growth is predominantly impacted by the growth of resources and technology.

In the most celebrated work of Agenor (2006), the author proposed a theory of long-run development based on public infrastructure as an "enabler" of growth in developing and developed countries, and emphasized that the upsurge in the share of public investment expenditure facilitates productivity growth, savings, and engenders high growth steady state. The theory extensively considered a budget-neutral shift in public spending toward investment in public infrastructure and assumed that the degree of efficiency of public infrastructure is a veritable instrument to stimulate the stock of public capital itself. However, the proposition by the author left out human capital accumulation and endogenous technological progress and did not expansively account for demographic factors.

Shanks and Barnes (2008) explained that there are two fundamental mechanisms by which countries' infrastructures can transmit into desired productivity gains. These include a "free input" effect – the impact of private-sector productivity that arises from the provision of public infrastructure at no charge to users, and a "productive spillover" effect – an improvement in productivity that arises because users of infrastructure are able to reorganize their production, access inputs or produce more or new products. As a practical example of the role played by a disaggregated component of infrastructure on economic productivity, Zhang and Cheng (2023) assessed the fundamental role played by transportation infrastructure in public physical capital accumulation and long-term economic growth with special attention to the impacts of its externalities on economic growth.

## 3. Empirical Models, Estimation Techniques and Data

The model specifications for this study are rooted in the aggregate production function with the stocks of private and public capitals, labour, as well as the index of technical efficiency as inputs. Interestingly, the output of the traditional production function describes the productivity gains from government investments in public capitals by taking into account institutional and political environments. Following Aschauer (1989), Barro (1990), Shanks and Barnes (2008), Nguyen and Bui (2008) and Zhang and Cheng (2023) and the theory of infrastructure-led development by Agenor (2006), and other relevant empirical literature on the interrelationships among public infrastructure, governance and economic productivity, the various empirical models for this study are deeply entrenched in panel econometric frameworks, and are provided in the different subsections below.

### 3.1 Generalized Method of Moments odel (GMM)

This is a panel data model employed in this study to show the interrelationships among public infrastructure, governance factors, and economic productivity in selected African countries.

$$PROD_{it} = f[INFRA_{it}, GOV\_INDEX_{it}, NATR_{it}, HC_{it}, POPGR_{it}] \quad (1a)$$

$$PROD_{it} = \beta_0 + \sum_{j=1}^{5} \beta_j X_{it} + V_{it} \quad (1b)$$

$$X_{it} = f[INFRA_{it}, GOV\_INDEX_{it}, NATR_{it}, HC_{it}, POPGR_{it}] \quad (1c)$$

The variables in our econometric model in equation (1b) include: $PROD_{it}$ (total factor productivity growth representing economic productivity), $INFRA_{it}$ (aggregate infrastructure index which serves as a composite index for electricity, transportation, ICT, water and sanitation infrastructures), $GOV_{it}$ (governance indicators Index – derived from the PCA for six governance indicators: voice and accountability, government effectiveness, control of corruption, rule of law, regulatory quality, absence of violence, and political stability), $NATR_{it}$ (natural resource rent as a percentage of GDP), $HC_{it}$ (human capital index) and $POPGR_{it}$ (population growth). Our explanatory variables ($X_{it}$) are in two separate categories, $INFRA_{it}$ and $GOV_{it}$ are the target explanatory variables while $NATR_{it}$, $HC_{it}$ and $POPGR_{it}$

are the control variables. In addition, the error term ($V_{it}$) is normally distributed.

In this study, our choice of the GMM is borne out of the conviction of its appropriateness and adequacy in addressing issues such as endogeneity, simultaneity bias, reverse causality among regressors, and its ability to relate more robustly to a myriad of heteroscedasticity. In addition, the GMM is well-suited for obtaining relatively efficient estimators that can account for both positive and negative autocorrelations (Arellano and Bond, 1991). Moreover, the additional moment conditions from the GMM will yield more precise estimates than other instrumental variable techniques (Blundell and Bond, 1998). The GMM can be applied more frequently to unobserved models when the explanatory variables are not strictly exogenous, even after controlling for an unobserved effect (Wooldridge, 2001). Hence, following the various characterizations by Arellano and Bond (1991), Blundell and Bond (1998) and Wooldridge (2001), this study transforms the model in equation (1b) into the generalized method of moments. The GMM model specified in equation 2(a) and 2(b) relates economic productivity to its own lag, and lags of both the target and control explanatory variables, as specified below.

$$PROD_{it} = \delta_0 + \delta_1 PROD_{it-1} + \sum_{j=2}^{k} \delta_j X_{it-1} + \tau_{it} + \mu_{it} \qquad (2a)$$

$$\Delta PROD_{it} = \alpha_0 + \alpha_1 \Delta PROD_{it-1} + \sum_{j=2}^{k} \alpha_j \Delta X_{it-1} + \varepsilon_{it} \qquad (2b)$$

The moment conditions provided from the specifications in equations 2(a) and 2(b) are:

Moment Condition: $E[f(X_j, \alpha_j)] = 0,$ for all $t$ (3)

where: $E$ is the expected value of random variable, $X_j$ represents the vector of random variables, $\alpha_j =$ vector of parameters, and $\tau_{it}$ = unobserved country fixed effect and $\Delta =$ first difference operator.

### 3.2 Autoregressive Distributed Lag model (ARDL)

This study specified the ARDL model for this study, not as a stand-alone model but to complement the GMM model to allow us ascertain the consistency of the various parameter estimates from our benchmark empirical models. The general panel ARDL framework for this study, given a time period of t= 1, 2…..T and cross sections of I = 1, 2 ,…… N, is:

$$PROD_{it} = \partial_0 + \partial_1 PROD_{it-1} + \partial_j \sum_{j=1}^{5} X_{it-j} + \mu_i + \varepsilon_{it} \quad (4a)$$

$X_{it}$ = explanatory variables,

$\partial$ = coefficient of lagged dependent variable,

$\mu$ = fixed effect and

$\varepsilon_i$ = error term

Normal distributions of the model are $PROD_{it} = \max(\sum \Delta PROD_{it}, 0)$ and $X_{it} = \max(\sum \Delta X_{it}, 0)$

Capturing the short run and long run effects of public infrastructure, governance and other control variables on economic productivity:

$$\Delta PROD_{it} = \phi_i PROD_{it-1} + \eta_i X_{it-j} + \alpha_j \Delta PROD_{it-1} + \partial_j \sum_{j=1}^{5} \Delta X_{it-j} + \mu_i + \varepsilon_{it} \quad (4b)$$

$\phi$ and $\eta$ = parameters of the long run impacts; $\alpha$ and $\partial$ = parameters of the short run impacts.

Incorporating the long run, short run and speed of adjustments:

$$\Delta PROD_{it} = \alpha_j \Delta PROD_{it-1} + \partial_j \sum_{j=1}^{5} \Delta X_{it-j} + \phi_l [PROD_{it-1} - \{\beta_0 + \beta_{il} X_{it-j}\}] + \varepsilon_{it} \quad (4c)$$

$\alpha$ and $\partial$ = short-run impact parameters,

$\beta's$ = long-run impact parameters,

$\Delta$ = first difference operators,

$\phi$ = speed of adjustment and

$\varepsilon_{it}$ = time-varying disturbance.

### 3.3 Forecast error variance decompositions (Vector Autoregressive (VAR) / Vector Error Correction (VEC)) models

This study employs the conventional Vector Autoregressive (VAR) model to ascertain the simultaneous inter-relationships among the variables, and by extension introduced the Vector Error Correction Model (VECM) by introducing first difference operator ($\Delta$) and error correction term ($EC_{it-1}$). This makes the latter more comprehensive and dynamic, and allows it to serve as a vehicle for the integration of the short-run and long-run movements among the variables (Engle and Granger, 1987). In addition to the characterization of the VAR/VEC models, the inclusion of the dependent variable as part of the regressors assuages the problems of endogeneity among the variables. Interestingly, the VAR/VEC models are complementary model(s) in this study. They complement the GMM, and help in ascertaining the consistency and robustness of the parameter estimates of the estimated relationships in our respective models. The general frameworks of the VAR (equation 5a) /VEC (equation 5b) models are as shown below:

$$Z_{it} = \eta_0 + \sum_{j=1}^{k} \eta_j Z_{it-1} + \ell_{it} \qquad (5a)$$

$$\Delta Z_{it} = \pi_0 + \sum_{j=1}^{k} \pi_j \Delta Z_{it-1} + \phi EC_{it-1} + \omega_{it} \qquad (5b)$$

where:

$Z_{it}$ = the vector of all the six variables in the VAR/VEC models ($PROD_{it,} INFRA_{it}, GOV\_INDEX_{it}, NATR_{it}, HC_{it} and POPGR_{it}$)

$Z_{it-1}$ = the vector of the lagged variables in the VAR/VEC models,

$\eta$ = both the intercept and slope coefficients in the VAR model,

$\ell$ = error term in the VAR model,

$\pi$ = both the intercept and slope coefficients in the VEC model,

$EC_{it-1}$ = error correction term

$\phi$ = coefficient of the error correction term capturing the speed of adjustment

$\omega_{it}$ = the error term in the VEC model.

**3.4 Panel Data Fully-modified Ordinary Least Squares (PFMOLS)**

The PFMOLS model is estimated based on the following cointegrated system panel time series model, thus:

$$y_{it} = \alpha_0 + \alpha_{it}\beta + \varepsilon_{it} \tag{6a}$$

$$\chi_{it} = \chi_{it} + \varepsilon_{it} \tag{6b}$$

The study specified the following panel FMOLS model as:

$$PROD_{it} = \alpha_{it} + \beta_i \sum_{i=1}^{n} X_{it} + \varepsilon_{it} \tag{6c}$$

where:

$X_{it}$ represents the vector of explanatory variables and

$\varepsilon_{it}$ represents the error term

To address the question of the impact of public infrastructure, governance, and other control variables like natural resource revenue, human capital, and population growth on economic productivity in selected African countries, this methodology further complements those of the GMM and ARDL models to check the consistency of our empirical results. It is considerably appropriate and adequate in addressing the practical consequences of autocorrelation, endogeneity, heterogeneity, and simultaneity bias that may occur in our panel data regression model and it provides substantial empirical evidence for examining the long-run relationship among the variables in a typical panel data model (Phillips, 1993; Dritsakis & Stamatiou, 2017; Pedroni, 2001).

## 4. Data Description and Sources

This study employed a panel dataset of thirty countries for the period of fifteen years (2005 to 2019). The dependent variable, that is economic productivity (*prod*), was represented with total factor productivity growth (*TFP*). The level of (relative) total factor productivity was provided by the Penn World Table (PWT) Version10.01, and the data series were obtained by setting the total factor productivity at constant national prices of 2017 equal to 1. In terms of the explanatory variables, the human capital index (*hci*) was obtained from the PWT (Version 10.01), and its values were based on the years of schooling and returns to education. The annual population growth rate (*popgr*) and total natural resource rents (percentage of GDP), (*natr*) were obtained from the World Development Indicators (World Bank, 2022). This study estimated the governance index variable (*gov_index*) from six governance indicators: voice and accountability, government effectiveness, control of corruption, rule of law, regulatory quality, and absence of violence and political stability. These indicators were obtained from the World Bank World Governance Indicators, using the Principal Component Analysis (PCA) to mitigate the practical consequences of multicollinearity on our empirical outcomes. The aggregate infrastructure index (*infra*) serves as proxy for public infrastructure. The dataset for the aggregate infrastructure index is based on four major component indices: Transport Composite Index, Electricity Index (Net Generation – KWh per inhabitant), ICT Component Index, and Water and Sanitation Component Index. The dataset was obtained from the 2019 Africa Infrastructure Development Index (AIDI) of the African Development Bank. The index provides comprehensive information on the status and progress of infrastructure development in African countries, and it will capture the multi-dimensional nature and heterogeneity of infrastructure across the thirty countries and periods under consideration in this study. The various data, measurement, and sources are described in Table 1.

**Table 1:** Data Measurement/Description and Sources

| S/N | Indicator Name | Abbreviation | Variable Definition/Measurement | Source |
|---|---|---|---|---|
| 1 | Economic Productivity | PROD | Total Factor Productivity (TFP) at constant national prices(2017=1) | Penn World Tables 10.01, 2020 (See, Feenstra,Inklaar,& Timmer (2015) |
| 2 | Aggregate Infrastructure | INFRA | Computed from four composite indices of transport composite index(km per 10,000 inhabitants); electricity index(kwh per inhabitants); ICT Composite index(total phone subscriptions(per 100 inhabitants); Water and Sanitation composite index(improved water source(%population with access), improved sanitation facilities(% of population with access) | African Development Bank's Africa Infrastructure Development Index(AIDI), 2019 |
| 3 | Governance Indicator | GOV | Computed with the Principal Component Analysis(PCA) technique from six institutional variables(voice and accountability, government effectiveness, control of corruption, rule of law, regulatory quality, and absence of violence and political stability) | World Governance Indicators (WGI), World Bank |
| 4 | Natural Resource Revenue | NATR | Natural resource rent (Sum of rents from oil, natural gas, coal, minerals, and forest resources) as percentage of GDP | World Bank's World Development Indicator Database |
| 5 | Human Capital | HC | Computed based on years of schooling and returns to education | PWT 10.01(See, Feenstar, Inklaar & Timmer, 2015) |
| 6 | Population growth | POPGR | Population growth (annual percentage) is computed from total population by exponential rate of growth of the total population | World Bank's World Development Indicator Database |

## 5. Empirical Test and Estimation

The residual cross-section dependence test is shown in Table 2. This test is aimed at analysing the likelihood of the impact of spatial patterns on the various error terms of the respective panel datasets employed in this study. The analysis is crucial as it will enable us make informed decisions about the choice of the estimation approaches, specifically between the homogeneous and heterogeneous approaches for panel unit root and co integration analysis.

**Table 2:** Residual Cross-Section Dependence Test

| *Test* | *Statistics* | *d.f* | *Probability* |
|---|---|---|---|
| *Breusch-Pegan LM* | 2170.17* | 435 | 0.00 |
| *Pesaran Scaled LM* | 58.83* | | 0.00 |
| *Pesaran CD* | 0.21 | | 0.84 |

*Note:* (*) 1% significance level

The results from the various test statistics (Breuch-Pegan, Pesaran Scaled, and Pesaran CD) are statistically significant at 1%, which implies that the null hypothesis, of no cross-sectional statistical dependence in residuals of the panel data utilized for the study, is rejected. Consequently, there are high possibilities of linear and statistical interdependence among the residuals, and this will necessitate the adoption of heterogeneous unit root and co integration techniques (unit root techniques like, Im, Pesaran and Shin W-stat; ADF and PP; and co-integration techniques like Pedroni) for this study, while those of homogeneous approaches (like that of unit roots – Levin, Lin and Chu T*, and Kao's approach for co-integration) will be reported for emphasis.

The empirical findings from the various panel unit root test statistics (such as LLC, IPC, ADF and PP) are reported in Table 3. The results reveal that economic productivity, aggregate infrastructure index, governance index, natural resource rent, and population growth are stationary at 1% and 10% significance levels. Only human capital index is not significant at any level. However, all the variables (including human capital index) are stationary in first differences, as shown by the t-values at 1% significance level. Hence, with the aforesaid, the variables meet econometric conditions that qualify them to be utilized for further estimation.

Regarding the co-integration test, the results reveal that the Kao residual statistic is significant at 1%, indicating the presence of a long-run relationship among the variables in a model of homogenous panel data settings. Similarly, the co-integration test results, in terms of the heterogeneous panel data framework, show that all the co-integration test statistics are significant at 1% significance level, with the exception of v-statistic and rho statistic. Thus, most of the results from our co-integration test reveal that all the variables used for estimation are likely to converge in the long run, further highlighting the reliability of our model for policymaking.

**Table 3:** Panel Unit Root and Co integration Test Results

| Dependent Variable : Total Factor Productivity Growth (Economic Productivity), Period: 2005-2019 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Unit Root Test | | | | Co integration Tests | | | | |
| | | | | | Kao Residual | Pedroni | | | |
| | *llc* | *Ipc* | *Adf* | *Pp* | *Adf* | *v-statistic* | *rho statistic* | *pp statistic* | *adf statistic* |
| *Prod* | -6.55* | -0.31 | 75.00*** | 61.41 | | -3.11 | 4.34 | -5.09* | -1.82** |
| *Infra* | -3.08* | 3.96 | 22.02 | 11.71 | | | | | |
| *gov_index* | -0.73 | 0.93 | 46.99 | 100.76* | -2.33* | | | | |
| *Natr* | -3.78* | -1.31*** | 73.91 | 56.03 | | | | | |
| *Hc* | 6.48 | 9.98 | 16.92 | 65.84 | | | | | |
| *popgr* | -8.31* | -4.60* | 128.75* | 94.27* | | | | | |
| | | | | | | | *group rho* | *group pp* | *group adf* |
| | | | | | | | 6.05 | -13.68* | -2.82* |
| Δ *prod* | -3.74* | -3.02* | 98.68* | 219.18* | | | | | |
| Δ *infra* | -3.43* | -3.94* | 106.51* | 183.36* | | | | | |
| Δ *gov_index* | -6.52* | -7.17* | 160.62* | 373.69* | | | | | |
| Δ *natr* | -14.80* | -9.77* | 205.44* | 337.46* | | | | | |
| Δ *hc* | -8.62* | -3.97* | 101.88* | 187.95* | | | | | |
| Δ *popgr* | -8.44* | -6.40* | 147.42 | 115.09* | | | | | |

*Note:* *** =** rejection of the null hypotheses of non-stationarity and non-convergence/non-convergence/con-cointegration @ (*)(**)(***) 1%, 5% and 10% respectively. LLC = Levin, Lin & Chu T*, IPS = Im, Pesaran and Shin W-Stat.

## 5.1 Model estimation results and analysis (Baseline analysis)

The GMM panel model was employed to address potential issues of endogeneity bias, heterogeneity, simultaneity, and reverse causation challenges in our model, while the ARDL will complement the GMM to elicit the short- and long-run estimates from our model. However, the two estimation techniques serve as our baseline methodologies in estimating the relationship between public infrastructure and economic productivity in selected African countries. The estimation results are reported in Tables 4 and 5. The results of the GMM are reported in Table 4.

**Table 4:** GMM Estimation Results

| Dependent Variable | Explanatory Variable | $\Delta$ $\text{infra}_{t-1}$ | $\Delta$ $\text{gov\_index}_{t-1}$ | $\Delta$ $\text{natr}_{t-1}$ | $\Delta$ $\text{hc}_{t-1}$ | $\Delta$ $\text{popgr}_{t-1}$ | $\Delta$ $\text{prod}_{t-1}$ |
|---|---|---|---|---|---|---|---|
| *Prod* | | 0.026 | 0.011*** | 0.007* | 0.204* | -0.008 | 0.789* |
| | | (1.184) | (1.790) | (3.063) | (2.646) | (-1.167) | (16.209) |
| | $\Delta$ $infra_{t-1}$ | | 0.006 | -0.065 | 0.226* | -0.056 | 0.217* |
| | | | (1.048) | (-0.142) | (4.418) | (-0.322) | (4.316) |
| | $\Delta$ $gov\_index_{t-1}$ | -0.077* | | 0.165* | 0.026* | -0.187* | 0.129 |
| | | (-5.747) | | (2.710) | (5.713) | (-9.261) | (11.454) |
| | $\Delta$ $natr_{t-1}$ | -0.070* | 0.036 | | -0.008 | -0.001 | -0.014** |
| | | (-10.546) | (0.918) | | (0.007) | (-0.068) | (-1.957) |
| | $\Delta$ $hc_{t-1}$ | 3.825* | 1.228** | -1.881 | | 0.217 | 0.977* |
| | | (24.999) | (1.941) | (-1.072) | | (0.415) | (4.308) |
| | $\Delta$ $popgr_{t-1}$ | -0.647 | -0.142* | -0.004 | 0.015** | | 0.092 |
| | | (-1.537) | (-2.619) | (-0.079) | (2.291) | | (0.001) |
| | $\Delta$ $prod_{t-1}$ | 0.937* | 2.877 | -1.139* | -0.187* | 1.351* | |
| | | (7.402) | (0.001) | (-2.876) | (-6.526) | (8.252) | |
| | *J-statistics* | 27.189 | 26.672 | 27.896 | 24.522 | 20.089 | 24.008 |
| | | (0.347) | (0.372) | (0.313) | (0.489) | (0.742) | (0.519) |
| | *AR(1)* | 2.429* | -0.757 | 0.148 | | 2.150** | -0.395 |
| | | (0.015) | (0.449) | (0.882) | | (0.032) | (0.693) |
| | *AR(2)* | 1.892 | 0.475 | -3.218* | 1.756*** | -1.343 | -0.226 |

| Dependent Variable | Explanatory Variable | $\Delta$ $infra_{t-1}$ | $\Delta$ $gov\_index_{t-1}$ | $\Delta$ $natr_{t-1}$ | $\Delta$ $hc_{t-1}$ | $\Delta$ $popgr_{t-1}$ | $\Delta$ $prod_{t-1}$ |
|---|---|---|---|---|---|---|---|
| | | (0.171) | (0.635) | (0.001) | (0.079) | (0.179) | (0.821) |
| | *overall j-statistics* | | | 23.870 | | | |
| | | | | (0.469) | | | |
| | *overall AR(1)* | | | -2.350* | | | |
| | | | | (0.177) | | | |
| | | | | -1.365 | | | |
| | *overall AR(2)* | | | (0.172) | | | |

*Notes:* (*) (**) (***) significance levels at 1%. 5% and 10 % respectively.

(i) t-statistics in parenthesis, and the probabilities values of diagnostic statistics also in parenthesis.

(ii) (ii) J-statistics test the over identification of instruments

(iii) (iii) Arellano and Bond Serial Correlation Test – First and Second Orders (AR(1) & AR(2)

The study employed the generalized method of moments (GMM) estimation approach to ascertain the empirical relationships among public infrastructure, governance, and economic productivity in selected African countries. The estimation of the GMM model produced various empirical results, which are presented in Table 4. The results show that the impact of public infrastructure ($infra_{t-1}$) was 0.026, which suggests a positive but non-significant effect, while institution, as indicated by governance index ($gov\_index_{t-1}$) made a positive and significant impact of 0.011 at the 5% level. Natural resource rent ($natr_{t-1}$) made an impressive positive and significant impact of 0.007 at the 1% significance level. Similarly, the impact of human capital ($hc_{t-1}$) was 0.204, which indicates a positive and significant influence on economic productivity. Conversely, the impact of population growth (*popgr*) was -0.008, indicating a negative though non-significant influence on economic productivity. The results underscore the importance of higher levels of public infrastructure, human capital and natural resource revenue, as well as an improved institutional environment, in enhancing economic productivity in selected African countries. In the results, the population growth variable shows a negative impact. The own impact of economic productivity ($prod_{t\_1}$) was 0.789, which is observed to be significant at 1%, an indication that economic productivity fortifies itself. In terms of the interactions among the variables in the model, the result shows that the impact of economic productivity on public infrastructure was 0.937, which indicates a positive influence and significant impact at 1% while the governance index exerted a positive but non-significant influence on public infrastructure.

The other results in the table demonstrate the varying levels of interactions among the variables in the GMM model. In terms of the diagnostic results obtained from our estimated model, the overall first-order and second-order autoregressive coefficients satisfy the condition that the first order should be significant, hence, the result is statistically significant, which indicates the absence of autocorrelation among the variables in the model estimated. Also, the overall J-statistics is not statistically significant, which suggests the acceptance of the null hypothesis and indicates the absence of the consequence of instruments over identification. This further confirms the validity of the various instruments employed across the myriad of regression analyses and the reliability of the model for policymaking. The short-run and long-run results from the ARDL estimation technique are reported in Table 5, illustrating the role of the various regressors in economic productivity.

**Table 5:** ARDL / PMG Model Estimation Results

| *Dependent Variable: Economic Productivity(PROD)* | | |
|---|---|---|
| *Lag Structure:(1,1); Model Selection Method: Akaike Information Criteria* | | |
| Variables | Shor- run coefficients | Long-run coefficients |
| *Infra* | 0.008 | 0.049* |
| | (0.103) | (4.469) |
| *gov_index* | -0.006 | 0.023* |
| | (-0.358) | (3.749) |
| *Natr* | -0.013 | 0.026* |
| | (-0.969) | (5.324) |
| *Hc* | 0.261 | 0.333* |
| | (0.971) | (4.649) |
| *Popgr* | -0.018 | -0.010 |
| | (-0.451) | (-1.284) |
| Constant | -2.211 | |
| | (-0.775) | |
| Error correction term (adjustment) | -0.439* | |

| | |
|---|---|
| | (-6.645) |

*Note:* (*) significance levels at 1%; (i) T-statistics in parenthesis.

The estimates of aggregate public infrastructure, both the short-run and long-run, show positive impacts of 0.008 and 0.049 respectively. However, that of the long run shows an impressive and significant influence at 1%, and further aligns with the consensus view in economic literature that infrastructure is a key driver of economic productivity. On the other hand, governance indicators and natural resource rents made positive and significant impacts of 0.023 and 0.026 at the 1% significance level in the long run, but were positive and not significant in the short run. This suggests that infrastructure contributes more significantly to economic productivity in Africa in the long run compared to governance factors and natural resource rents. However, population growth shows a negative impact, while human capital exerts a positive and significant impact in the long run. Overall, the results indicate that public infrastructure has a much larger dominant and significant impact on economic productivity in Africa. The negative, significant, and less than unity error correction term of the ARDL model indicates that economic productivity has a relatively moderate speed to converge towards public infrastructure, governance factors, and other control variables.

### 5.2 Robustness checks

The robustness of the baseline estimation results was assessed by examining the sensitivity of our parameter estimates through the use of other relevant econometric methodologies like the panel FMOLS and the Forecast Error Variance Decomposition (FEVD), which is a variant of the VAR/VECM model. The findings from the sensitivity analysis reveal that our main findings remain unchanged, thus further validating our findings in this study. The estimation results from the GMM and ARDL can therefore be considered robust. The re-estimation results for our robustness checks are reported in Tables 6 and 7 respectively, once again emphasizing the positive and significant effect of public infrastructure on economic productivity in Africa.

**Table 6:** Dependent Variable: Total Factor Productivity Growth (Economic Productivity), Period: 2005 – 2019

| Explanatory variables | pFMOLS coefficients | t-statistics |
|---|---|---|
| *Infra* | 0.007* | (2.908) |
| *gov_index* | 0.024* | (24.593) |
| *Natr* | 0.018* | (12.146) |
| *Hc* | 0.091* | (9.398) |
| *Popgr* | -0.001 | (-0.572) |
| R squared | 0.103 | |
| adj R squared | 0.094 | |

*Notes:* (*) 1% significance level; pFMOLS – Panel Fully Modified Ordinary Least Squares.

The study employed the Panel Fully Modified Ordinary Least Squares (PFMOLS) methodology to ensure the robustness of our empirical results. This become necessary because PFMOLS has been found to be more appropriate and adequate for investigating long-run relationship of panel datasets, as it addresses issues of serial correlation, endogeneity, heterogeneity, and simultaneity bias (Phillips, 1993; Dritsakis & Stamatiou 2017; and Pedroni, 2001). The results, as reported in Table 6, show that public infrastructure, governance factors, human capital, and natural resource rents exerted positive and significant impacts on economic productivity at the 1% significance levels. However, population growth negatively influenced economic productivity. These findings are consistent with our previous empirical outcomes and align with the consensus in the literature that public infrastructure positively drives economic productivity.

**Table 7:** Forecast Performance of Key Determinants of Economic Productivity to Total Factor Productivity

| Periods | Prod | *infra* | *gov_index* | *natr* | *Hc* | *popgr* |
|---|---|---|---|---|---|---|
| 1 | 100.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 99.455 | 0.000 | 0.175 | 0.123 | 0.223 | 0.024 |
| 3 | 98.962 | 0.032 | 0.169 | 0.311 | 0.382 | 0.145 |
| Average | **99.209** | **0.016** | **0.172** | **0.217** | **0.303** | **0.084** |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | 98.719 | 0.055 | 0.157 | 0.391 | 0.493 | 0.185 |
| 5 | 98.608 | 0.075 | 0.147 | 0.430 | 0.568 | 0.172 |
| 6 | 98.479 | 0.094 | 0.143 | 0.474 | 0.617 | 0.193 |
| Average | **98.905** | **0.045** | **0.160** | **0.324** | **0.431** | **0.134** |
| 7 | 98.331 | 0.121 | 0.143 | 0.515 | 0.651 | 0.239 |
| 8 | 98.180 | 0.154 | 0.146 | 0.548 | 0.676 | 0.295 |
| 9 | 98.018 | 0.192 | 0.152 | 0.577 | 0.697 | 0.365 |
| 10 | 97.838 | 0.232 | 0.158 | 0.603 | 0.711 | 0.457 |
| Average | **98.610** | **0.092** | **0.157** | **0.410** | **0.523** | **0.208** |

The Forecast Error Variance Decomposition results (or simply variance decomposition), as reported in Table 7, are aimed at analysing the overall effects of public infrastructure, governance factors, and other regressors on economic productivity. It allows us to determine the variance in economic productivity explained by the decomposition into the shares of each regressor, identifying the highest contributor among the regressors corresponding to the variance in economic productivity. This helps us validate the robustness of our estimates from the baseline estimations. The results are reported over ten periods.

The own shocks in economic productivity provide substantial explanation for the variance in itself. A notable trend is that the contribution of public infrastructure across periodic classifications increases, and accounts for the average of 0.016 to 0.092. This further reinforces the consensus that public infrastructure is a key driver of economic productivity. Meanwhile, the contribution of governance indicators increases at the first horizon and later decreases. However, natural resource rent, human capital index, and population growth show significant contributions to the variations in economic productivity.

The finding of the positive impact of public infrastructure on economic productivity in this study aligns with numerous studies both within Africa and in other countries outside the continent. Some of these studies include Fediran and Akanbi (2017) in SSA countries, Kim and Laoyza (2019) in OECD countries and Andreas (1997) in Bundeslander. Similarly, the positive impact of governance or institutions on economic productivity in this study is consistent with the findings of Njikam et al. (2006) in SSA countries, Fediran and Akanbi (2017) in SSA countries, and Loko and Diouf (2009) in developed, developing, and emerging countries.

In terms of the control variables, the finding on the impact of natural resource rent on economic productivity is positive, and this a clear departure from extant literature on the public capital-productivity growth nexus. The role of human capital on economic productivity is positive, and this aligns with the study of Turyarceba et al. (2017) in SSA countries. Conversely, the negative role of population growth corroborates the results of the study by Njikam et al. (2006) in SSA countries. This study extends the frontier of previous empirical literature by demonstrating a much stronger influence of public infrastructure compared to those of institutional factors on economic productivity. In addition, the introduction of natural resource revenue into the physical capital – productivity model makes the study stand out.

## 6. Policy Perspectives

This study employed a series of econometric techniques (such as GMM, ARDL, and FEVD), and the econometric toolkits-produced empirical results in support of the significantly dominant role of public infrastructure and governance in driving economic productivity in Africa. It revealed that the impact of public infrastructure superseded that of the governance factors in terms of size effects. Furthermore, natural resource revenue and human capital positively impacted economic productivity, while population growth exerted a negative influence on economic productivity.

In light of the aforesaid empirical outcomes, it is pertinent to provide policy options to appropriately and adequately manage variables that stimulate economic productivity in order to avoid weak productive capabilities of African economies in the future. The following policy recommendations are rooted from our empirical findings and will be useful in repositioning Africa's economic productivity growth experience:

1. Public infrastructure contributes positively and significantly to productivity growth in Africa. Therefore, there is a need to improve the quality of spending, particularly on critical public infrastructure such as electricity, transportation, ICT, and water sanitation, to further enhance the productive base of African economies.

2. Governance also enhances economic productivity. To further drive economic productivity, governments of African countries should complement increased budgetary spending on public infrastructure with supportive institutions and policies. This includes measures and incentives that will promote economic growth and stability, as well as enhance the control of corruption, rule of law, regulatory qualities, political stability, government effectiveness, and accountability.
3. Human capital shows a positive impact on economic productivity. Therefore, governments of African countries seeking to enhance economic productivity should invest in improving human capital by promoting regular training for employees and upgrading management capabilities across different ministries, departments, and agencies.
4. Natural resource revenue significantly contributes to improving economic productivity, hence, governments of the various African countries should focus on building strong institutional mechanisms to channel their enormous natural resource revenue into building resilient public infrastructure that will translate into enhanced economic productivity.
5. Population growth discourages economic productivity. Therefore, the various African countries should institute policies to curtail their population growth rates.

## 7. Conclusion

This study empirically investigated critical variables (like public infrastructure, institution, natural resource rents, etc.) influencing economic productivity in selected African countries, which is of significant interest to policy researchers, including policy makers and advisors, due to its importance in providing a tractable macroeconomic framework to capture the contributory impacts of public capital accumulation and institutions on productivity growth. Despite the myriad of empirical results on public capital accumulation and productivity growth nexus, there is still no unanimity in most literature on the impressive and positive role of public infrastructure on economic productivity in Africa. However, there is also a handful of literature that shows mixed results for the role of institutions, which are considered to be either positive or negative. This present study spans the period 2005 to 2019 and investigated a sample of thirty

African countries, employing panel data econometric techniques of GMM, ARDL, VAR/VEC- FEVD, and PFMOLS. The majority of our empirical outcomes across the various estimation techniques reveal that public infrastructure, governance factors, human capital, and natural resource rent have positive and significant impacts on economic productivity, and this support the consensus view from previous empirical studies. Again, the impact of population growth is negative, though not significant. Economic productivity was also found to adjust moderately to changes in public infrastructure, governance, and other explanatory variables. Arising from the aforementioned empirical results, this study makes some policy recommendations which include: improving the quality of spending on critical public infrastructure to enhance economic productivity; providing a favourable institutional environment for the economy to thrive; building more resilient human capital, and discouraging population growth.

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**Selected African Countries for the Study**

| | | |
|---|---|---|
| Angola | Kenya | Senegal |
| Benin | Lesotho | Sierra Leone |
| Botswana | Mauritania | South Africa |
| Burkina Faso | Mauritius | Sudan |
| Burundi | Morocco | eSwatini |
| Cameroun | Mozambique | Tanzania |
| Central Africa Republic | Namibia | Togo |
| Côte d' Ivoire | Niger | Tunisia |
| Egypt | Nigeria | Zambia |
| Gabon | Rwanda | Zimbabwe |