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Public infrastructural development and economic performance in Africa: a new evidence from panel data analysis

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Abstract
This study examined the effects of both aggregate and disaggregated infrastructural development indices (such as transport, electricity, ICT, and water and sanitation infrastructure indices) on economic performance in Africa. The study used the dynamic system GMM framework and found that both aggregate and disaggregated infrastructural development indices impact positively on GDP per capita growth in Africa. These impacts were shown to be significant in all cases, except for the transportation infrastructure index. The results overwhelmingly confirmed the prevalence of the symmetric hypothesis in the infrastructure–growth relationship in Africa. The study also found some evidence in support of the significant roles of capital, labour and initial GDP per capita in Africa's economic performance, while the role of trade remained negative and muted. The study concluded that through effective public administration, African leaders and policymakers can promote economic performance on the continent by evolving policies that favour increased infrastructural development, human capital development and capital accumulation.

Keywords Infrastructure · Economic performance · System GMM · Africa

JEL Classification H54 · F43 · C23 · N17

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1 Introduction

Economic research on infrastructural development has witnessed increased interest from scholars in recent times, and some have expressed support for the symmetric impact of infrastructure on economic growth (Levoli et al. 2019; Nugraha et al. 2020). Consequently, policymakers and governments in various economies, especially in Africa, have recognized that there is need for them to evolve and implement policies that will increase investments in basic infrastructures as a means of enhancing economic performance on a sustainable basis. Unfortunately, Africa's share of developed infrastructures has remained dismal compared to other regions of the world. For instance, just as in other African countries, most schools in Kenya have very low investments in information and communication technology (ICT) infrastructure, and this has been attributed to high costs in the procurement protocols (Bariu 2020).

One main feature of the extant literature is that most studies have hardly focussed on the disaggregated indices of infrastructural development, such as transportation and ICT infrastructure indices. Some of the existing studies (such as Hussain et al. 2019, which studied Asian countries; Bottasso et al. 2018, which studied Brazil; and Baita 2020, which studied Economic Community of West African States, ECOWAS; Pereira and Pereira 2020, which studied Portugal) centred on the role that aggregate infrastructure plays in delivering improved trade. Pereira and Pereira (2020) specifically found a positive and significant impact of infrastructure development on both traded and non-traded industries. Nazneen et al. (2019) found symmetry between China–Pakistan Economic Corridor (CPEC) infrastructural development and perceived tourism cost. The study demonstrated that people are more likely to support tourism even in prevailing higher costs. Castelnovo et al. (2018) examined the economic impact of the procurement events of the Large Hadron Collider (i.e. largest scale research infrastructure) using balance-sheet data of supply companies. The study found significant symmetry between procurement and company research and development, knowledge creation and economic performance. Clearly, the extant literature has hardly classified infrastructures as hard infrastructures (like transport and telecommunications) and soft infrastructures (like financial infrastructures and border-transport efficiency) so that the impacts of these disaggregated forms of infrastructure can be highlighted.

Some aspects of the extant literature have also focussed on the role of infrastructure in advancing growth. Some of such studies have found evidence in support of symmetric effect of infrastructure on growth (Sama and Afuge 2016 studied in Cameroon; Amos and Jidda 2018 studied Nigeria; Samir and Mefteh 2020 studied a panel of 63 countries). Studies that investigated South Asia and Indonesia have also established symmetric infrastructure–growth relationship as well as mutual causal feedbacks (Sahoo and Dash 2012; Khan et al. 2020; Kurniesih 2020). Wang et al. (2020b) also found that improved efficiency of urban infrastructures in Chinese cities lead to improved economic growth, while Heshmati and Rashidghalam (2020) found significant positive correlations between urban infrastructure and urbanization in China. Lin and Chen (2020) used a panel tobit model to show that land transport infrastructure, technological progress and industrial structure have positive and significant influence on China's manufacturing industry.

In spite of the important roles of infrastructure in advancing trade, tourism and growth as shown in the foregoing paragraphs, some studies in the extant literature have also demonstrated that the role of infrastructure as a driver of economic performance is largely muted. Luiz (2010) evinced this in Africa, while Enilolobo and Sodeinde (2019) showed it in Nigeria's industrial sector. These studies argued that even though infrastructure is necessary, it is not a sufficient condition for economic development. Zolfaghari et al. (2020) investigated the effects of economic (water, energy and ICT) and social (health and education) infrastructures on income inequality in Iranian provinces, and found that improvements in economic and social infrastructures reduce income inequality.

However, the new financial commitments to African infrastructure in 2018 totalled USD 101 billion (Organisation for Economic Corporation and Development–ECD, 2021). The origin of these new commitments was: 37% African governments; 26% China; 22% Infrastructure Consortium for Africa (ICA) members; 12% private sector and 2% Arab Co-ordination Group. Compared to 2017, the new commitments in 2018 increased by approximately 12%, mostly from higher financing by African governments and the inclusion of some sub-national financing, along with a major increase in new commitments from Chinese sources, which rose from USD 19 billion in 2017 to USD 26 billion in 2018, including a USD 5.8 billion commitment to a 3.5 GW hydro complex in Nigeria which will take 6 years to complete. The sectoral distribution of total new commitments in 2018 was 44% energy, 33% transport, 13% water, 7% ICT and 4% multisector (ICA 2019).

The following stylized facts can be observed from the foregoing discussions. The first fact is that there is mixed evidence in the extant literature on the role of infrastructure as a key driver of economic performance. The second fact is that there is paucity of studies in the extant literature on the infrastructure–growth nexus in Africa, especially studies that centred on the roles of infrastructure at disaggregated level. Studies that focus only on aggregate infrastructural index do not allow for proper targeting of economic policies. The third fact is that the few studies in Africa are mainly country-specific investigations. This shows that a large scope still needs to be covered towards understanding the effects of infrastructure at aggregate and disaggregated levels on economic performance in Africa. To fill this gap, this study investigated the dynamic effects of aggregate and disaggregated infrastructural development indices (such as transport, electricity, ICT, and water and sanitation infrastructure indices) on economic performance of Africa. The system GMM estimator is used to achieve this objective.

2 An overview of the empirical literature

This section provides an overview of studies in the literature on the relationship between: transportation infrastructure and economic growth; ICT infrastructure and economic growth; and electricity infrastructure and economic growth.

2.1 Transportation infrastructure and economic growth

Investment in transportation infrastructure has been recognized as a crucial growth-promoting strategy (Crescenzi et al. 2016). Some recent studies have validated this conclusion on the symmetric impacts of transport infrastructures on economic growth, and these include Kauzen et al. (2020) for Tanzania, Kalan and Gokasar (2020) for Turkey, Popov (2020) for Russia, Hanedar and Uysal (2020) for the Ottman Empire, Babatunde (2018) for Nigeria, Stawiarska (2018) for Poland, Cigu et al. (2019) and Vlahinić Lenz, et al. (2018) for European Union (EU) economies and Xueliang (2013) for China. In India, studies that have found either mutual feedbacks between road infrastructure and economic growth or a unidirectional causality from rail infrastructure to economic growth include Pradhan and Bagchi (2013) and Vidyarthi and Mishra (2020). Furthermore, Saidi et al. (2018) used the generalized method of moments (GMM) technique to establish that transport energy consumption, transport infrastructure and economic growth share positive correlations in Middle East and North African (MENA) countries. The study also used panel causality procedure to demonstrate that a feedback effect exists between economic growth and each of transport energy consumption and transport infrastructure with economic growth.

Some empirical studies have also found mixed results on the transport infrastructure–economic growth relationship. Gherghina et al. (2018) studied EU economies for the growth effects of main modes of transport and found that while road, inland waterways, maritime and air transport infrastructure impact positively on growth, railway transport impacts negatively on growth. Yu et al. (2013) also confirmed the positive spillover effects of transport infrastructure in China. However, some studies have also found neutral spillover effects of transport infrastructure for some countries (e.g. Luz et al. 2016). Wang et al. (2020a) used dynamic spatial modelling approach to show that transport infrastructure is crucial in improving national economic growth of Brazil, Russia and India; however, in the case of East and Central Asia, Commonwealth of Independent States and South Asia countries, the study found that transport infrastructure spillover effects were significantly negative. The study also showed that transport infrastructure exerts positive influence on growth in Central and Eastern Europe. This study shows that there could be substantial regional differences on the growth effects of transport infrastructure. Ogundipe et al. (2020) used GMM regression to investigate the role of road infrastructure on foreign direct investment (FDI) influx in ECOWAS and found that the responsiveness of FDI to physical infrastructures and the responsiveness of economic growth to road infrastructures declined.

2.2 ICT infrastructure and economic growth

David (2019) found bidirectional causal relationship between telecommunication infrastructures and economic growth in selected African countries. Similarly, David and Grobler (2020) found that ICT penetration encourages economic growth in Africa. Maji and Waziri (2020) used panel data of 45 African countries to show that improvements in ICT penetration and renewable energy consumption enhance environmental sustainability in Sub-Saharan Africa (SSA). Rice and Martin (2018) found that investment in ICT infrastructure is a strategic resource for smart city infrastructure and economic improvement, which is indispensable in the development of communities, regions and urban environments in Australia. Studies that corroborate the symmetric role that ICT infrastructures play in economic improvements in Europe are Adam (2020) and Toader et al. (2018). Lee et al. (2017) also found symmetric effect of ICT infrastructure on growth while distinguishing between the roles of strong and weak institutions. Na et al. (2019) found symmetric relationship between ICT–motorway interaction and productivity growth in developed economies, while Leng et al. (2020) also established symmetric relationship between ICT infrastructure and rural income diversification in China.

In developing countries, Cataldo et al. (2019) also established symmetric relationship between ICT and MSME's revenues and profits. The study also showed that company size matters so that the smaller the company the higher the ICT impact on revenue. Cheng et al. (2020) used GMM and principal component analysis techniques to investigate the nexus among financial development, ICT diffusion and economic growth in a panel of 72 countries. The study found that even though ICT diffusion promotes economic growth in high income economies, the relationship remained ambiguous in middle- and low-income economies. The study, however, revealed that increasing mobile usage rather than internet usage promotes growth in low- and middle-income economies, and that interacting ICT and financial development promotes growth across all income levels. Some other studies have also focussed on ICT infrastructure and the Nigerian economy and found some interesting results (Orjiet al. 2020; Ogbuabor et al. 2020, Orji et al. 2016).

2.3 Electricity infrastructure and economic growth

Horvat et al. (2020) demonstrated positive influence of investments in infrastructure project on economic and human development in East African countries. Similarly, Ouédraogo (2010) found the existence of equilibrium relationship and feedback hypothesis between electricity consumption and economic growth in Burkina Faso, while Solarin and Shahbaz (2013) found similar patterns between urbanization and electricity consumption in Angola. In the United Arab Emirates, Shahbaz et al. (2014) validated this existence of cointegration and feedback hypothesis between electricity consumption and carbon dioxide emissions, while Karanfil and Li (2015) obtained similar results among Organization of Petroleum Exporting Countries (OPEC) member economies. Contrary to these studies, Akinwale et al. (2013) did not find any evidence in support of the feedback hypothesis in Nigeria and the study attributed this to low levels of electricity consumption due to low generation and distribution.

The foregoing overview of the literature shows that few studies in Africa have investigated the relationship between infrastructural development (especially at disaggregated levels like ICT, transport and electricity infrastructures) and economic performance. Most of the studies in the literature focussed on other regions like Asia and Europe. The few studies conducted for African economies were mainly country-specific studies that focussed on Nigeria, Cameroon, Angola or Burkina Faso. Furthermore, the role of water and sanitation infrastructure in Africa's economic performance is yet to be investigated. To fill these gaps, this study investigates the infrastructure–growth relationship in Africa while accounting for aggregate infrastructural index and disaggregated infrastructural development indices (such as transport, ICT, electricity, and water and sanitation infrastructural development indices). This is to allow for a more comprehensive understanding of the infrastructure–growth nexus in Africa.

3 Data and methodology

3.1 The data

This study covered the period 2010–2018 and included forty-nine (49) African countries, namely: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo Rep, Congo Dem. Rep., Cote d'Ivoire, Egypt, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe and eSwatini. This time period lies at the juncture between the post-Global Financial Crisis and the pre-Covid-19 Pandemic era. This choice rests on the urgent need to evolve policies that will guide African economies as we move into the post-Covid-19 era (i.e. the post-crisis era).

The infrastructure variables included in the study are: aggregate Africa infrastructure development index (AIDI), transport composite index (tcindex), electricity composite index (ecindex), ICT composite index (ictindex), and Water and Sanitation composite index (waterindex). The data for these infrastructural indices were taken from the 2020 Africa Infrastructure Development Index (African Development Bank 2020). This study used gross domestic product (GDP) per capita (gdpp) as a measure for economic growth/performance, while other variables included in the study are: labour force (measured as population of people aged 15–64), capital (measured as gross capital formation in percentage of GDP), urbanization level (measured as urban population over the total population) and trade (measured as percentage of GDP). The data for these variables were taken from the 2020 World Development Indicators (World Bank 2020). Some of the empirical studies that support the inclusion of these variables in this study are Sahoo and Dash (2012), Glass et al. (2019), Wang et al. (2020b), and Maji and Waziri (2020).

Table 1 reports the summary statistics of all the variables for Africa as a whole. We find that the mean GDP per capita for Africa as whole is seen to be $2758.29. In terms of infrastructural development, the statistics indicate that Africa as a whole recorded a mean infrastructural development index of 24.85%, which is quite low. Among the four components of infrastructural development index, the water and sanitation index recorded the highest mean value of 61.32%, while the ICT index recorded the least mean value of 9.55%. This corroborates the submission of Bariu (2020) in the first paragraph of Sect. 1 of this paper. The statistics in Table 1 also shows a low urbanization level in Africa with a mean value of 43.54%. This is not

Table 1 Summary statistics of all the variables

Variables	Mean	std	Between	Within	N	n	T
Gdpp	2758.288	3359.81	3342.397	565.5312	441	49	9
Aidiindex	24.8527	20.8141	20.5788	4.1764	441	49	9
Tcindex	11.1581	12.4239	12.4686	1.3091	441	49	9
Ecindex	10.7443	18.9307	18.8503	3.082	441	49	9
Ictindex	9.5461	10.4362	8.2036	6.5451	441	49	9
Waterindex	61.3236	20.2687	20.1672	3.3912	441	49	9
Trade	74.8136	33.8459	32.6935	9.8101	441	49	9
Urban_level	0.4354	0.1775	0.1786	0.0134	441	49	9
Capital	24.5547	9.6392	8.3941	4.8661	441	49	9
Labour	12,700,000	17,400,000	17,500,000	1,538,254	441	49	9

std denotes standard deviation

surprising given the fact that many people on the continent still live in rural communities and hinterlands while surviving on subsistence farming. All the variables in Table 1 exhibited both between and within variations, across time and space.

3.2 Model specification

Recall that this study seeks to investigate the dynamic effects of aggregate and disaggregated indices of infrastructural development (transport, electricity, ICT, and water and sanitation) on economic performance in Africa. To achieve this objective, we begin by considering a logarithmic dynamic panel vector model. Let $P_{i,t}$ denote a 1×1 vector of GDP per capita of the various economies (which is our measure for economic performance), and let ψ be the corresponding parameter vector. Let $I_{i,t}$ denote a 5×1 vector of infrastructural development variables and let ϕ be the corresponding 1×5 vector of regressor parameters $\left(\phi_{i,t}^{\text{aidiindex}}, \phi_{i,t}^{\text{tcindex}}, \phi_{i,t}^{\text{ecindex}}, \phi_{i,t}^{\text{ictindex}}, \phi_{i,t}^{\text{waterindex}}\right)$. Similarly, let $C_{i,t}$ denote a 4×1 vector of other control variables for which δ is the corresponding 1×4 vector of control parameters $\left(\delta_{i,t}^{\text{urban}_{\text{level}}}, \delta_{i,t}^{\text{trade}}, \delta_{i,t}^{\text{capital}}, \delta_{i,t}^{\text{labour}}\right)$. Then, the underlying model for this study can be specified as follows:

$$\ln P_{i,t} = \ln P_{i,t-1}\psi + \ln I_{i,t}\phi + \ln C_{i,t}\delta + \pi_{i,t}$$

where: $\pi_{i,t} = \lambda_i + \varepsilon_{i,t}$, where λ_i is the country-specific effect and the error term, $\varepsilon_{i,t} \sim iidN\left(0, \sigma_\varepsilon^2\right)$, shows no contemporaneous serial correlation, $E\left[\varepsilon_{i,t}^{\prime}, \varepsilon_{i,s}\right] = 0$. $i = 1, 2, \ldots, 49$ and $t = 1, 2, \ldots, 9$. For the regressors to be used as valid instruments, two moment conditions must be true: $E\left(I_{i,t}, C_{i,t}, \pi_{i,t}\right) = 0$ and $\text{Cov}\left(I_{i,t}, C_{i,t}, \lambda_i\right) \neq 0$, that is, regressor exogeneity and panel level collinearity, respectively. In other words, the regressors must be independent of the error term $\varepsilon_{i,t}$ and of each other from country j to k, while at the same time, share some similarities between country j and k, provided $j \neq k$. By differencing method, we are able to eliminate the panel level effects as the number of cross-sectional units N (i.e. the number of countries included in the study) becomes large while the period covered, T, remains fixed. This is necessary in order to obtain consistent estimates of the generalized method of moments (GMM) estimator ψ, while maintaining the moment conditions in line with Arellano and Bond (1991). Given the above moment conditions, the infrastructure variables and the other covariates and their lags are used as instruments in the GMM model framework, forming a matrix $B' = \left(I_{i,t}, \ldots, I_{i,t-1}, C_{i,t}, \ldots, C_{i,t-1,}\Omega\right)$ without loss of generality and exogeneity $E\left(B', \Delta\pi_{i,t}\right) = 0$**.** Then, we take the product of the instrumental variable matrix and Eq. (1), while employing the method of generalized least squares to get the one step and asymptotically efficient two-step GMM estimators following Baum et al. (2003). Here, Δ denotes the first-difference operator, while Ω represents the vector of other included GMM instruments.

The Sargan and Hansen test of over-identifying restrictions as proposed by Arellano and Bond (1991) and Hansen (1982) was employed using the system GMM technique. The system GMM estimator has some advantages when compared to the difference GMM estimator. It accommodates for finite sample bias in the difference GMM estimator. Windmeijer (2005) suggested the correction of the standard errors in the instrumental variables' matrix B', using expansion by Taylor series that accounts for the estimation of B_i. This provides more accurate approximation in finite samples, assuming linearity of all moment conditions. Given this bias due to weak instrumentation (Blundell and Bond 1998), a weak stationary restriction on the initial conditions processes leads to much efficiency gains using the system GMM in the lagged coefficient matrix of economic performance $P_{i,t-1}$ in Eq. (1). Furthermore, the work of Blundell and Bond (2000) shows that system GMM estimator not only improves precision but also reduces the finite sample bias in the first-difference GMM estimator. Besides, some recent studies in the extant literature (e.g. Saidi et al. 2018; Maji and Waziri 2020; Ogundipe et al. 2020; Cheng et al. 2020) support the use of system GMM technique in investigating infrastructure–growth relationships.

4 Results and discussions

This empirical analysis began by testing for cross-sectional dependence in the panel. This is because ignoring cross-sectional dependence in a dynamic panel model will lead to inefficient estimates in a panel of large cross-sectional units (N) and small time period (T) (Sarafidis and Robertson 2009). The tests for cross-sectional dependence in this study mainly followed Pesaran (2004), which is asymptotically efficient in panels with large cross-sectional units and small time periods. However, other tests for cross-sectional dependence employed as robustness checks on the results from Pesaran (2004) approach include Friedman (1937) and Frees (1995). Table 2 reports the results of these tests for cross-sectional dependence. The results overwhelmingly revealed the predominance of cross-sectional independence in the panel for this study.

Table 3 presents the results of the system GMM regressions for this study. We included each index of infrastructural development in a separate model to avoid the

Table 2 Cross-sectional dependence tests

Ln_Equation	Ln_gdpp_tc	Ln_gdpp_ec	Ln_gdpp_ict	Ln_gdpp_wc	Ln_gdpp_aidi
Pesaran-fe	0.6360 (0.510)	0.5880 (0.498)	0.1162 (0.502)	1.0000 (0.524)	0.2807 (0.520)
Pesaran-re	0.3591 (0.532)	0.3359 (0.544)	0.1222 (0.519)	0.6294 (0.512)	0.5305 (0.532)
Friedman-fe	1.0000 (0.531)	1.0000 (0.539)	1.0000 (0.501)	1.0000 (0.519)	1.0000 (0.530)
Friedman-re	1.0000 (0.532)	1.0000 (0.599)	1.0000 (0.529)	1.0000 (0.532)	1.0000 (0.534)
Frees'-fe	0.4923 (0.531)	0.5676 (00.539)	0.4923 (0.501)	0.4923 (0.498)	0.4923 (0.530)
Frees'-re	0.4923 (0.532)	0.4923 (0.599)	0.4923 (0.529)	0.4923 (0.519)	0.4923 (0.532)
Decision	CID	CID	CID	CID	CID

In the case of Pesaran and Friedman, the values reported are the p values for the tests, but in the case of Frees' equations, alpha values are reported at 5%. Average absolute values are reported in parentheses. CID denotes cross-sectional independence

Table 3 System GMM RESULTS for Africa (dependent variable = GDP per capita (a measure of economic performance))

Regressors	(A)	(B)	(C)	(D)	(E)
Initial GDP per capita (gdpp_L1)	0.0003***	0.0002***	0.0002***	0.0003***	0.0002***
Urbanization level	0.4920	0.4100	0.1990	0.2680	0.1570
Trade	−0.0444	−0.1070	−0.0971	−0.0499	−0.0064
Capital	0.1860	0.1940	0.2000**	0.2050**	0.2030*
Labour	0.1190**	−0.0556	−0.0051	0.0617	0.0238
Transport infrastructure	0.1090				
Electricity infrastructure		0.2410***			
ICT infrastructure			0.4060***		
Water infrastructure				0.7230***	
Aggregate infrastructure index					0.410***
Diagnostic checks					
AR(2)	0.440	0.481	0.399	0.529	0.503
No. of Instruments/groups	26/48	25/45	27/45	25/45	28/45
Hansen's J-stat	0.101	0.160	0.153	0.251	0.223
Observations	381	353	353	354	353

*denotes significant at 10% level, **denotes significant at 5% level, and ***denotes significant at 1% level. In all cases, each index of infrastructural development is included in a separate equation to avoid the problem of collinearity

problem of collinearity. Thus, model (A) included transport infrastructure index as a regressor, while models (B), (C), (D) and (E) included electricity infrastructure index, ICT infrastructure index, water and sanitation infrastructure index and aggregate infrastructure index, respectively. Other regressors such as initial GDP per capita (i.e. the first lag of GDP per capita), urbanization level, trade, capital and labour force were included in all the models.

We find that the coefficient of initial GDP per capita is positive and statistically significant even at the 1% level in all the models. This result is somewhat interesting as it presents a twist to the widely held view that most African economies are low-income economies. This result is also contrary to the findings of Tumwebaze and Ijjo (2015), which established that the effect of initial GDP per capita was statistically insignificant even though it was positive. Nonetheless, our finding is consistent with theoretical expectation. It is also consistent with Levine and Renelt (1992), which studied 101 countries and found that initial GDP per capita is a key determinant of GDP per capita growth. Thus, this study has established that initial GDP per capita impacts positively and significantly on GDP per capita growth in Africa.

We find that the coefficient of urbanization level remained positive but statistically insignificant in all the models. This means that the level of urbanization is not an important driver of GDP per capita growth in Africa. The positive relationship between urbanization and GDP per capita growth established in this study is consistent with the findings of Arouri et al. (2014), which found similar positive result for Africa. Arouri et al. (2014) explained that urbanization facilitates human capital accumulation, which in turn drives growth as suggested by the endogenous growth theories. However, contrary to our finding that the role of urbanization is statistically insignificant, the results of Arouri et al. (2014) showed a significant relationship. The insignificant relationship established in this study may be due to the low level of urbanization in most African economies. Table 1 shows the average level of urbanization in Africa to be 43.54%, which is quite low.

We find that the coefficient of trade remained negative and statistically insignificant throughout. This means that trade is not an important driver of GDP per capita growth in Africa. This result is contrary to the trade-led hypothesis, which posits that trade liberalization enhances growth through spillover effects. However, the result is consistent with some recent empirical evidence in Africa, such as Ogbuabor et al. (2019) and Iheonu et al. (2017), which found that trade openness may be hindering growth in West Africa. These studies attributed the undesirable role of trade in Africa to a number of factors, such as high level of trade diversion, low volumes of trade among African economies and high negative trade balances among African economies, among others.

We find that the coefficient of capital is positive in all case. However, the role of capital is statistically significant at the 5% level in models (C) and (D), while it is significant at the 10% level in model (E). Hence, we have established some evidence that capital plays an important role in GDP per capita growth in Africa. This is consistent with theoretical expectation as suggested by the new growth theory. This theory explains that accumulation of physical capital is an important factor in the economic growth process. Our finding is also consistent with the bulk of recent empirical evidence in Africa, such as Iheonu et al. (2017), Tumwebaze and Ijjo (2015) and Ogbuabor et al. (2019). This study therefore concludes that capital is an important driver of GDP per capita growth in Africa.

The results in Table 3 indicate that the role of labour is mixed. While models (A), (D) and (E) recorded positive coefficients for labour, models (B) and (C) recorded negative coefficient. Thus, we find that majority of the models in Table 3 indicate that the effect of labour force on GDP per capita growth in Africa is positive. However, only model (A), which controlled for transport infrastructure development, recorded statistically significant impact for labour at the 5% level, while the role of labour remained statistically insignificant in all other cases. The majority result which shows that labour impacts positively on GDP per capita growth is consistent with economic expectation as posited by the new growth theory. It is also consistent with majority of the recent studies in the literature, such as Iheonu et al. (2017), Tumwebaze and Ijjo (2015) and Ogbuabor et al. (2019). Overall, most of our results indicate that labour contributes positively to GDP per capita growth in Africa, but its contribution remains largely insignificant.

We find that all the indices of infrastructural development exert positive influence on GDP per capita growth in Africa, which is consistent with economic expectation and the symmetric hypothesis, which supports the view that infrastructural development promotes growth. The results further indicate that while the influence of electricity infrastructure, ICT infrastructure, water and sanitation infrastructure and aggregate infrastructure indices are all statistically significant at the 1% level, the influence of transport infrastructure is statistically insignificant. Overall, we find overwhelming evidence that infrastructural development impacts positively and significantly on GDP per capita growth in Africa. This is also consistent with the bulk of recent studies in the extant literature, such as Kalan and Gokasar (2020), Popov (2020), Hanedar and Uysal (2020), Wang et al. (2020a,b), Cheng et al. (2020), Nugraha et al. (2020), Stawiarska (2018), Cigu et al. (2019), Rice and Martin (2018) and Toader et al. (2018). These studies have investigated the infrastructure–growth relationship in countries and regions outside Africa and found evidence in support of the important role that infrastructure plays as a driver of growth.

At this point, the results of this study have shown that infrastructural development impacts positively and significantly on GDP per capita growth in Africa. This is, however, contrary to the widely held view that Africa has been facing huge infrastructural deficit problem, at least in the last two decades (Mafusire et al. 2017; Orji et al. 2017). Indeed, this view raises the concern that our results may not have sufficiently captured the realities of African economies. However, a deeper investigation into recent economic dynamics in individual African economies indicates that our results are consistent with the realities of these economies. To see this, let us consider the activities of the African Finance Corporation (AFC),[1] which was established in 2007 to address Africa's infrastructure development needs by driving private sector-led infrastructure investments across Africa. To date, AFC has invested at least US$ 7.2 billion in funding infrastructural and development projects in power, telecommunications, transportation and logistics, heavy industries, and natural resources sectors in 32 African countries. In the power sector, for instance, some of the AFC's projects include: Cenpower Kpone Independent Power Producer (IPP) in Ghana; Caebolica Wind Farm in Cape Verde; 450 MW IPP In Republic of Benin; 350 MW IPP in Ghana; 300 MW IPP in Mozambique; 420 MW Nachtigal Hydroelectric Project in Cameroon; 44 MW Singrobo Hydro Power Plant in Cote D'Ivoire; Kenya Power and Lighting Company in Kenya; 60 MW Red Sea Wind Power Project in Djibouti; Hakan 80 MW peat-fired IPP in Rwanda; and Maamba Collieries Limited Power Plant in Zambia. Apart from AFC, individual African

[1] The information provided here on African Finance Corporation was obtained from its official website https://www.africafc.org/. This information was corroborated by Zubairu (2019).

economies have also been investing and reforming their power sectors. The significant impact of electricity infrastructure on GDP per capita growth as shown in our results aptly captures these realities.

In the ICT sector, AFC has funded a number of telecommunication companies such as Main One Cable System, MTN Nigeria and IHS Towers. The Main One Cable System is quite significant because it links countries on the west coast of Africa to Europe and other parts of the world through an undersea fibre optic cable system. It has a large bandwidth that is almost 20 times the available satellite capacity across Sub-Saharan Africa. Apart from these efforts from AFC towards developing Africa's ICT infrastructure, many African economies have also witnessed other private sector and public sector-led investments in their ICT sectors in recent years. Our results aptly captured these dynamics by highlighting the important role the ICT sector is playing in Africa's GDP per capita growth. In the transportation sector, some AFC projects include: Bakwena Toll Road in South Africa; Henri Konan Bedie Bridge in Cote d'Ivoire; Ethiopian Airline Expansion; Ghana Airport Company; Gabon Special Economic Zone; and Port d'Abidjan. Many African economies have also been witnessing other public and private sector-led investments in their transport sector, and our results rightly captured these realities. Indeed, the various infrastructural development efforts in Africa in recent years have been reflected in the overall increasing trend observed in aggregate infrastructural development index of most African economies over the period 2010–2018, which is consistent with our findings in this study. These trends are shown in Appendix, which shows the plots of the aggregate infrastructural development index for all the African economies captured in this study.[2]

5 Concluding and policy recommendations

This study was mainly motivated by the paucity of studies in the extant literature on the infrastructure–growth nexus in Africa, especially studies that centred on the roles of infrastructure at disaggregated level. The study, therefore, investigated the dynamic effects of aggregate and disaggregated infrastructural development indices (such as transport, electricity, ICT, and water and sanitation infrastructure indices) on economic performance in Africa. The study used the system GMM framework. The results indicate that both aggregate and disaggregated infrastructural development indices impact significantly and positively on GDP per capita growth in Africa, except for transportation infrastructural development index. The results overwhelmingly confirmed the prevalence of the symmetric hypothesis in the infrastructure–growth relationship in Africa. Similarly, the role of trade remained negative and insignificant throughout.

These findings indicate that there is need for policymakers and leaders in Africa to coordinate efforts at the level of African Union towards enhancing the

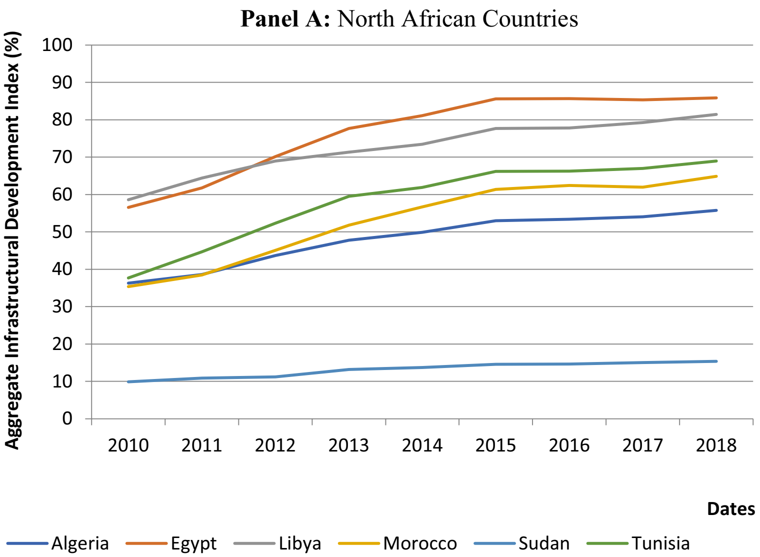
[2] Notice from Appendix that countries like Cape Verde and Gabon that are members of AFC recorded high aggregate infrastructural indices over the years, while countries like Niger and Sudan that are non-AFC members recorded low aggregate infrastructural indices.

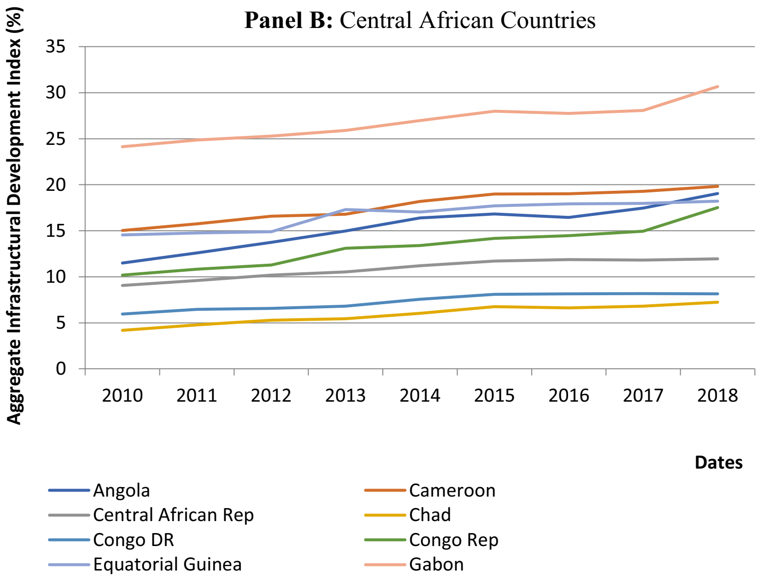
continent's infrastructural sector as a means of boosting both intra- and extra-Africa's trade. This is particularly important given that the results showed that the role of transportation infrastructure index is muted while the role of trade remained negative and insignificant in all the models. Thus, African leaders and policymakers should work together towards solving the continent's infrastructural challenges. This study particularly encourages African economies that are yet to join the AFC to do so and take advantage of the expertise and facilities available from it. In addition, African economies should also explore private–public partnership (PPP) schemes as a smart means of funding their infrastructural needs. Such schemes should be targeted at building transport, power, ICT and other infrastructures to support the real and competitive sectors, especially the exporting areas that are linked to the global market. These can be done in the following ways. First, African countries, especially those that are non-AFC members, should partner with AFC to bridge the deficit in the continent's transportation infrastructure. These are in terms of maintaining, renovating or building new link roads, seaports and airports within and between African economies to promote both intra- and inter-trades, which would enhance economic performance. Secondly, African countries should improve their power-generation and distribution systems with good and habitual maintenance culture. Partnering with AFC, United Nations and other PPP schemes should be explored to fund the continent's electricity infrastructure. Currently, AFC has funded few power-generation projects in some African countries such as Ghana, Cape Verde, Benin, Mozambique, Cameroon, Kenya, Djibouti, Rwanda and Zambia. Thirdly, the efforts by AFC in some African countries should be consolidated. Policymakers in African countries should evolve and implement policies that would encourage the spread of fixed lines, mobile phones and internet penetrations (especially the 4G or 5G network cables) to increase accessibility in African countries.

The study also found some evidence in support of the significant roles of capital, labour and initial GDP per capita in Africa's economic performance. The positive and significant roles of capital and labour indicates that policymakers and leaders in Africa should reform their economies in favour of increased human capital development (through technology-transfer, trainings and increased investments to boost domestic production of intermediate and finished products), physical capital accumulation and resource mobilization for increased investments. This means that at the level of the African Union, leaders and policymakers should be encouraged to make their respective domestic environments friendlier to existing investors and attractive to prospective ones through effective public administration. Overall, this study concludes that policies that favour increased infrastructural development, human capital development and capital accumulation are needed to promote economic performance in Africa.

Appendix

See Fig. 1





Panel C: West African Countries

Fig. 1 Plots of Aggregate Infrastructural Development Index (2010 – 2018). Panel **a**: North African Countries, Panel **b**: Central African Countries, Panel **c**: West African Countries, Panel **d**: Southern African Countries, Panel **e** East African Countries. *Notes*: The graphs were drawn with data from AfDB (2020)

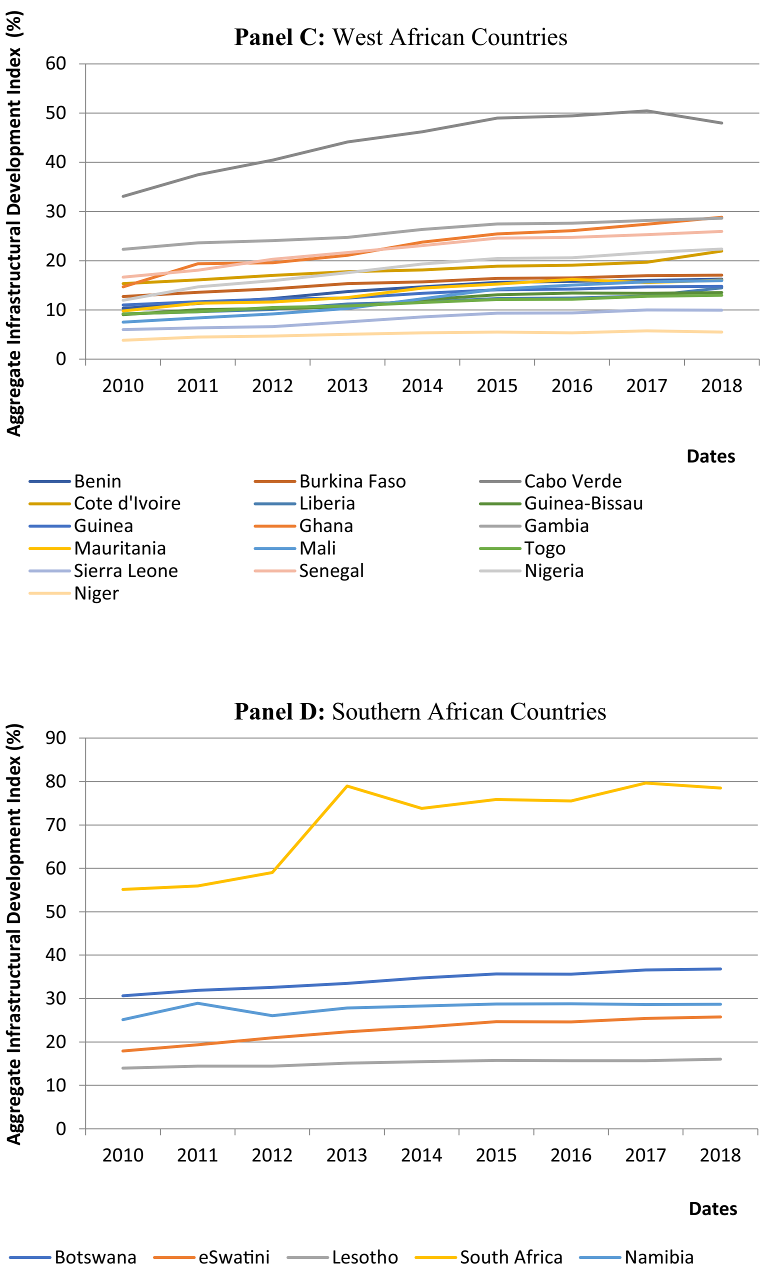


Fig. 1 (continued)

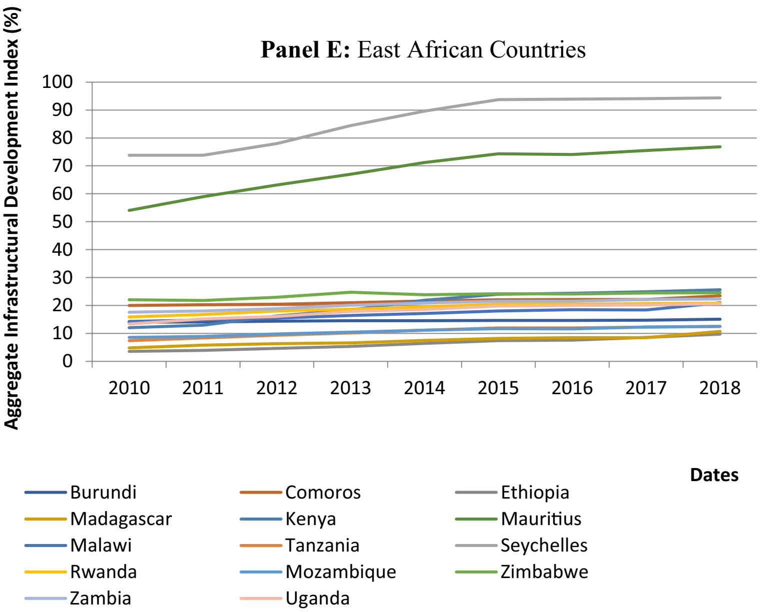


Fig. 1 (continued)

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The positive and significant impact of infrastructure, capital and labour as revealed in this novel study indicate that policymakers and leaders in Africa should reform their economies in favour of increased infrastructure, human capital development, physical capital accumulation and resource mobilization for increased investments through effective public administration.

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