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Logistics Infrastructure Investment and Economic Growth in Africa: China's Role in the Context of One Belt One Road

Aihu Wang* Adolphe Bertrand Chedjou
School of Business Administration, South China University of Technology, Guangzhou 510640, China

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Abstract
The goal of this research is to sort out a comprehensive assessment of the Chinese logistics infrastructure investments and their effects on economic growth in African countries. Based on econometric estimates for a sample of 54 countries from 2000-2015, we develop an index infrastructure stocks and estimate growth accounting equations to investigate the impact of infrastructure investment on growth. Using an econometric technique suitable for dynamic panel data bases of the empirical framework developed by D. A. Aschauer, the analysis reveals that there is a significant relationship between infrastructure, private Chinese capital and economic growth in Africa.

Keywords: Logistics Infrastructure Investment, Economic Growth, China-Africa, One Belt One Road

1. Introduction

In recent years, Africa has been a subject of numerous debates and scholarly research concerning its intricate economic challenges. Despite several works, publications and policy recommendations in various fields, a large percentage of the African population is still living below the poverty line and its economic development continues to face many obstacles. Subsequently in political independence years, in many African countries, an infrastructure designed for the economic structure of the time was not of major concern. The infrastructure development, though not sufficient to meet the residential demand, was enough to support a reasonably strong economic growth from the early 1960s up to the 1970s in the oil shocks (Brunel 2004). From then to the mid-1990s, the macroeconomic situation became rather gloomy and many policies were then put in place to promote regional trade or meet economic agreements intended to increase the continental market size. There has been an increased urbanization of the continent with 40% (505 million)[1] of the population living in urban areas in 2017 as compared to 30% in 1990.This change has come with a growing inadequacy between infrastructural need and its supply. In fact, the regain in growth in the late 1990s and early 2000s did not see any adjustment in terms of size, composition and quality of the infrastructure; nevertheless, many Africa specialists argue that infrastructure development would be a major contributor to faster, better and fairer growth for the next ten to twenty years.

Energy, water, sanitation, telecoms, transport and logistics have long been considered by most African heads of state as the most essential concerns for which resources are needed. Though investigations reveal that these concerns are valid and urgent, they also shed light on the need for better infrastructure services as critical to the quality of life of the poorest population. So today, African policymakers understand that infrastructural development is central to the future well-being of its populations. It is certainly in this view that the importance of infrastructure was most recently endorsed as part of the commission for Africa report. However, Africa needs to keep the momentum of sustainable growth to improve the overall standard of living of its population and reduce poverty, and the role of infrastructure is pivotal as recognized in the literature (Aschauer 1989, Munnell 1990, Roller and Waverman 2001, Calder´on and Serv´en 2003, Canning and Pedroni 2004, Fedderke et al. 2006, Zou Wei 2008, Pravakar Sahoo and Ranjan Kumar Dash 2009, Nannan Yu, Martin de Jong, Servaas Storm and Jianing Mi 2012, Beketite Ehuitche 2014, Chakamera and Paul Alagidede 2017, Biruk Birhanu Ashenafi 2017). Moreover, investment in physical and social infrastructure not only directly affects the poor positively but also indirectly in many ways[2] (Pereira 2000, Amadi Chukwuemeka, Nyekachi and Ugondah 2013, Adesoye, A. Bolaji 2014). Furthermore, infrastructure development is one of the major factors contributing to overall economic development. On the other hand, lack of infrastructure creates bottlenecks for sustainable growth and poverty reduction. Hence, infrastructure development contributes to investment and growth through an increase in productivity and efficiency and acts as a link between resources and factories, people and jobs and products and market.

There have been a few studies examining the role of transport infrastructure on economic growth in Africa during the last decade. The purpose of this paper is to add to the research field of infrastructure and economic

[1] United nations, Department of Economic and Social Affairs, Population Division 2017
[2] such as: (1) direct investment in infrastructure creates production facilities and stimulates economic activities; (2) it reduces transaction costs and trade costs, improving competitiveness; and (3) it provides employment opportunities and physical and social infrastructure to the poor; (4) it provides rapid access at the national and international market; (5) it provides good living level by better infrastructure.

growth in Africa the Chinese investment contribution especially in transport infrastructure projects in Africa from 2000 to 2015. In other words, we intend to show how Chinese financing in transport infrastructures such as roads, highways and railways impacts Africa's economic growth. Our research is motivated by the work of Ashauer (1989) on the productivity of private and public capital. The same work focuses on the mission of china regarding investment on infrastructure development on the African continent. Although the quest for raw materials for china industry and opening of new market destination is the main goal of the new initiative, One belt One road, the initiative is still a catalyzing factor for china's investment in Africa.

Our work is organized as follow. Section2 provides a overview of literature; Section3 deals with Chinese infrastructure and logistics infrastructure investment in Africa; Section4 provides the theoretical framework; Section5 focuses on econometric model, analysis and result and finally, Section6 provides conclusions and policy implications.

2. Literature Review

The empirical research on the role of infrastructure in economic growth started after the seminal work by Aschauer (1989), in which he found that the output elasticity of public capital is very high, ranging from 0.38 to 0.56. In addition, he stated that lack of infrastructure spending leads to slowdown of productivity growth in the US. Aschauer (1989) used annual macroeconomic time series data of the US on the 1949–1985 period to find that the public-sector capital was at least twice as productive as the private sector capital in the aggregate. Supporting Aschauer, Munnell (1990) and Garcia-Mil`a and McGuire (1992) also found high output elasticity of public investment on infrastructure, though comparatively lower than Aschauer's. However, over time, several economists have questioned the estimates of this first wave of researchers arguing that they are implausibly high (see, for instance, Gramlich 1994 and Garcia-Mil`a et al. 1996). The high output elasticity of infrastructure highlighted by Aschauer has been criticized on methodological grounds, i.e. reverse causation from productivity to public capital and a spurious correlation due to non-stationary of the data (Gramlich 1994; Holtz-Eakin and Schwartz 1995; Garcia-Mila et al. 1996).

Nevertheless, a series of country-level studies support Aschauer's finding, though with lower elasticity, and demonstrate that infrastructure has a positive and significant impact on output of growth. Some of the important studies in the infrastructure and economic growth are those by Pravakar Sahoo, Ranjan Kumar and Geethanjali (2010), Pravakar Sahoo and Ranjan Kumar Dash (2009), Beketite Ehuitche (2014), Norman V. Loayza and Rei Odawara (2010). Pereira (2000), using a multivariate time-series framework for the US over the period 1956–1997, found that public investment on different types of physical infrastructure is a powerful means of promoting economic growth as it crowds in private investment in different sectors and increases the private output.

In addition to the problem of the definition of public or private capital and the identification of its main components, there is also a problem of measurement. Detailed data on government and private spending are not always available. Therefore, most studies have used physical measures of infrastructure by introducing a variable for its physical stock in econometric models such as roads, rails, air, energy, communications, electricity, water sanitation, telephone, health and internet used; which are the most used typologies in the empirical analysis (David Canning and Peter Pedroni; Cieslik & Kaniewska, 2004). Some authors have proposed to measure infrastructure not only by considering the stock component, but also by taking into account its quality or quantity, measured by scaling the stock of existing infrastructure with the number of people who can potentially benefit from it and utilize it (Chengete Chakamera and Paul Alagidede, 2017; Sergi Lanau, 2017) or by dividing it by the area.

The contribution of the different types of infrastructure has found by Caldero´ n and Serve´n (2003) using GMM estimates of a Cobb-Douglas production technology for a panel of 101 countries for the period 1960–1997, Caldero'n *et al.* have found a positive and significant output contributions of three types of infrastructure assets: telecommunications, transport, and power for Latin American countries. Furthermore, the study suggests that the per capita output gap between Latin America and East Asia over the 1980s and 1990s can be attributed to the slowdown in Latin America's infrastructure accumulation in those years. Canning and Pedroni (2004) investigated the long-run consequences of infrastructure provision on per capita income in a panel of countries over the period 1950–1992. Though they found a positive contribution of infrastructure facilities up to some equilibrium level, infrastructure provision above a growth maximizing level leads to diversion of resources from other productive uses and reduces long-run income. Chengete Chakamera and Paul Alagidede (2017) examined the growth effects of infrastructure stock and quality in Sub Saharan Africa (SSA). Using the Generalized Method of Moments for the panel data of 43 countries in SSA for the period 2000-2014 to bring out a strong evidence of positive effect of infrastructure development on economic growth with most contribution coming from infrastructure stock, Chengete *et al* found that the quality-growth effect is weak, thus giving credence to the combined effects of infrastructure stock and quality on growth, especially in regions with moderately high quality, and smaller in those with poorer quality. Their Results reveal that the long-term quality effect is higher than the short-term's. Sergi Lanau (2017) examined the effects of improvements in infrastructure on sectorial growth and firm-level investment, focusing on six Latin American countries. Sergi Lanau exploited the heterogeneity in the quality of infrastructure across countries and the intrinsic variation in the dependence of sectors on infrastructure and found that better infrastructure favors growth and investment.

Most studies consider one single infrastructure sector (Fernald, 1999; Roller & Waverman, 2001). Sometimes, an aggregate index of the stock of infrastructure is computed, which is motivated by the fact that there is a high correlation among measures of the different kinds of infrastructures (Pravakar Sahoo and Ranjan Kumar Dash, 2012). Pravakar Sahoo and Ranjan Kumar Dash (2012) examined the output elasticity of infrastructure for four South Asian countries, using panel cointegration techniques for the period 1980–2005. Pravakar *et al.* developed an index of infrastructure stocks and investigated the impact of infrastructure on output. Pravakar found a long-run equilibrium relationship between output of growth and infrastructure along with other relevant variables.

Many other studies have focused on the relation between transport infrastructure and economic growth. Zou Wei (2008) examined data of 24 provinces of China in 1985-1998 and pointed out that the inequality of transport infrastructure is one of the main factors leading to growth inequality across provinces. Nannan Yu, Martin de Jong, Servaas Storm and Jianing Mi, (2012) examined the causal links between transport infrastructure investment and economic growth in China at national and regional levels, using time series data covering the 1978–2008 periods. The empirical findings show that, there is unidirectional Granger causality from economic growth to transport infrastructure; at the regional level, in the long run and that there is, in the affluent eastern region, a bidirectional causality while in the low-income central and western regions there is a unidirectional Granger causality between economic growth and transport infrastructure. Pravakar Sahoo, Ranjan Kumar and Geethanjali (2010), have examined the role of infrastructure in the promotion of economic growth in China for the period 1975 to 2007. Pravakar *et al.* used an autoregressive-distributed lag model (ARDL) developed by Pesaran *et al.* (2001) and the generalized methods of moments(GMM) developed by Hansen (1982) shows that infrastructure stock, labor force, public and private investments have played an important role in economic growth in China. Pravakar *et al.* concluded that infrastructure development in China had a significant positive contribution to growth on both private and public investment. The research of Pravakar also approved that there is unidirectional causality from infrastructure development to output of growth justifying China's high spending on infrastructure development since the early nineties. Chiara F. Del Bo and Massimo Florio (2012). In the evidence from the EU regions, are examined the return to infrastructure in the European Union Regions in the spatial framework. To account for growth spillovers among regions, their research used a Spatial Durbin model to estimate the data for 262 European NUTS2 regions in 2007. Chiara *et al*. confirmed in their results the important role of infrastructure and identified the highest rates of return associated with telecommunication, quality and accessibility of transportation networks, with a positive impact of roads and railways.

While some findings have supported a positive effect of infrastructure capital on growth, some authors have found different results. Puga (2002), for example, showed that decreasing transport costs for goods and services may further depress peripheral regions, thus possibly go against the guiding principles of the EU regional policy. Holl (2003) provided evidence of negative spillover effects of motorways on the location of new manufacturing establishments in Spanish municipalities, while Moreno and Lopez-Bazo (2007) provided evidence in favor of negative spillovers at the regional level in Spain.

The number of research focuses on the role of infrastructure on economic growth in Africa isn't enough this last decade. Some of them have examined the different aspects of the role of infrastructure on economic growth in sub-Saharan Africa. As the Economic Commission for Africa report (2005) and Sachs *et al.* (2004) have indeed both identified that significant infrastructure expenditure is needed in South Sahara Africa. Their estimate of the annual needs range from 9% to 13% of GDP for almost the next 10 years. Fedderke, Perkins, and Luiz (2006) used the endogenous growth theory to show that investment in infrastructure leads to economic growth in South Africa directly and indirectly (the latter by raising the marginal productivity of capital). However, there is weak evidence of feedback from output to infrastructure; while the finding of an infrastructure growth impact is robust. Amadi Chukwuemeka, Nyekachi and Ugondah (2013), in the public spending on transport infrastructure and economic growth in Nigeria, used Ordinary Least Square (OLS) regression method and found that public spending on transport infrastructure is insignificant and negatively related to growth.

Adesoye A. Bolaji (2014), in the effects of infrastructural financing on economic growth in Nigeria, used method employed from work of collision (1993). The ordinary least square method was used and the result analysis revealed that government community service infrastructure spending, private infrastructure, broad money supply, and total population, exert positive influence on economic growth. Following the results, the government was recommended to reduce the rate of domestic and external debts meant for infrastructural projects and the public sector was encouraged to finance more high capital intensive infrastructural projects in order to make their growth contributions significant. Biruk Birhanu Ashenafi (2017) studied the relation between infrastructure development and economic growth in Ethiopia. Using ARDL, bounds tests, and ECM, it was shown that long run estimation for both economic and social sector infrastructure development have a positive impact on economic growth. Based on the finding, it would be more effective if government gave due attention to the quality aspect of the development of health sector and government huge intervention in the economy in private investment role in the economy.

3. Current Status and Development Trend of African Logistics Infrastructure Sector

3.1- Infrastructure investment in Africa

Infrastructure can play an important role in promoting economic growth in Africa. Certainly, bottlenecks in African development have affected its international competitiveness, the cost of doing business, impeded foreign direct investment (FDI) and international trade, and retarded its overall economic performance. In this section, we examine the state of infrastructure throughout Africa over the past four decades and look at the reasons for the decline of investment and its poor infrastructure development.

3.1.1- Decline of investment level

There are several reasons for Africa's poor infrastructure development and its effects or role on the viability of economic progress on the continent. In 2014, Africa's infrastructure investment reached $74.5 billion, and annual spending needs for maintaining current endowment levels estimated at $100 billion[1] (2015 dollars). Almost half of the financing comes from governments, the rest including loans and grants from development partners. Table1 (Appendix1) provides a comparison of gross fixed capital formation across major regions of the world from 1960 up to now. Statistics of GFCF (Gross fixed capital formation) are not available for Africa prior to 1980 but the juxtaposition or estimation of GFCF is revealing. Firstly, Africa consistently scores the lowest across the five world's regions or continents; high income countries had the highest investment levels in 1960 but were overtaken by low and middle income countries more recently especially as a result of the performance of emerging economies in Asia. Secondly, even more disturbing has been the declining investment trend within Africa since 1980. So not only is it the lowest but it has also fallen more rapidly over the past few decades even though stabilizing and even slightly rising since 2000.

The comparison above is further reinforced by the Table2 (Appendix2) which provides a country by country comparison of GFCF across Africa since 1997. The trend is downward almost uniformly across the countries until 1999 and by 2000 number of countries had gross fixed capital formation ratios of around 10 percent including Angola, Central African Republic, Ivory Coast, Comoros, Libya, Malawi and Niger. Ratios in some countries including Angola, Cameroon, CAR, Ivory Coast, Congo Dem Rep, Egypt, Guinea, Kenya, Liberia, Malawi, Mauritius, Mai, Madagascar, Somalia, South Sudan, South Africa, Sierra Leone, Sudan, and Zimbabwe remained around 20% in 2015. If one examines Africa's poor economic growth performance against these gross fixed capital formation ratios then there will less be of a mystery surrounding the continent's economic results especially when considering the extraordinary investment rates in parts of Asia and in turn their high growth rates. The reason for which Africa has faced low investment levels so precipitously can be explained by the lower level of infrastructure existing.

3.1.2- Reasons for poor infrastructure

The independence of numerous African countries has been a fact, but not a reality; all of them have benefited only of infrastructures necessary for the colonizer to convey the mining and agricultural exploitation outside of Africa. From the independence year up to now, nothing has been done for many African countries to improve and increase the stock of Africa infrastructure capable of improving the standard of living of its populations and its economic growth.

Authors, like Migdal (1988, p. 10) thought that African states were not ready to reply like independent states in the 1960s. For Migdal, the spirit of decolonization was at first purpose to enable the African states to take charge of themselves and carry out actions for the construction of the continent and develop its economy. We establish that nothing was made by the heads of African countries to ameliorate the level and development of infrastructure logistics since the year of independence. Following the previous remark, many authors have noted the lack of building infrastructure under several points of view.

For Mbombog Mbog Bassong (2014), the greatest gap was the fact that African leaders remained to the service of the colonizer, oppressing and torturing their people for their own and colonizer interest and nothing was made to improve level of infrastructure logistics and live through the continent. Jean Paul Pougala (2012), esteems that the West by a mechanism of conservation of the colonization has influenced accession to power of the several heads of state to the benefit of their mission of Africa impoverishment; as example is, the famous currency (Franc of the Africa Colony French FCFA) and international monetary fund measured on the size of the western interest. Pougala reveals well the mismanagement of the leaders and longevity to power by force and electoral corruption which do not encourage an infrastructure investment policy.

Mehlang Chang (2011) said in the interview on CCTV and in his book that African people have suffered for long time for three main reasons. Firstly, African heads of state have double nationality (French and their country nationality); in this case it would be understandable to ask whether they serve France interest or their own countries.

[1] The 12th Annual Meeting of the infrastructure consortium of Africa(ICA), 2016 November 22; https://www.icafrica.org/fileadmin/documents/2016/Background_Paper_summary_13oct16.pdf

Secondly, they have kept the colonial money that it is an obstacle to their countries' development. Finally, he said that 50% of the African reserve money is lodge in French treasure and serves for the payment of French unemployed.

3.2- Logistics Infrastructure stock in Africa

Though the infrastructure stock has considerable potential for growth in Africa, it doesn't attract investment to the level of this potential. Transport logistics infrastructures would strengthen African countries capacity to create a competitive industrial sector and promote greater industrial linkages. In essence, increased investment in stock of transport, particularly in Africa transport infrastructure and services, would strengthen intra-African trade and international markets. The advantages of better infrastructure stock will reduce transaction costs and spur Africa economic growth, which would make African countries more competitive on the world market. Roads, Airways and railways have played an important role in economic history over the past century. Certainly railways were critical in promoting economic progress in the nineteenth century, but their quality and quantity remained insufficient to improve continually the economic growth. Given the long distances and sparse density in Africa, railways have a very significant role to play in facilitating trade and investment and creating an enabling business environment. Airways has become this last decade the most used means of transport to do business on international market. Roadways still under low condition, remain the most used by the African population

3.2.1- Roads

In general, physical links in Africa remain below expectations, and the infrastructure and services network are still unintegrated. Road transport is the dominant mode of transport, accounting for 90% of intercity transport. Only about 20% of the continent's 2,300,000 km of road are tarred, and the density of the road network is low, estimated at 7.6 km /100 km2 in 2006. In 2016 less than 30% of the 2,942,179 km of roads were paved, and the density of the road network was still low, estimated at 9.9 km/100 km2 of land area. See Table3 and Figure1 (Appendix3) for the African road network. Overall, progress is being made in improving the African road network. This progress is generally sufficiently indicated, in part due to the low statistical capacity of many African countries. Ethiopia illustrates the improvement achieved in African countries. Effective implementation of the Road Sector Development Program resulted in an extension of the Ethiopian road network from 26,550 km in 1997 to 85,966 km in 2013 (an increase of 224%). The quality of the country's road network has also improved considerably, with the proportion of roads in good condition rising from 22% in 1997 to 70% in 2013. In particular, nearly 77% of the development of the road sector over the past 16 years has come from domestic resources, including the Government of Ethiopia and the Road Fund.

3.2.2- Railways

The African rail network comprises about 87 000 km covering an area of approximately 29 600 000 km2, representing a network density of almost 2.9 km / 1000 km2 see Table4 (Appendix4). This is to be compared to a density of 40 km / 1000 km2 in Europe. In Africa, the network consists mainly of a single route to the interior of the country from sea ports, with very few interconnections except in South Africa. The average technical speeds of the African railways are about 30-35 km / h. Efforts are under way to renovate the African railways, mainly through Chinese investments. For example, the Ethiopia-Djibouti railway is being built by the China Civil Engineering Construction Corporation. The 485 km long Nairobi-Mombasa Railway is under construction by the Chinese state-owned China Roads and Bridges Corporation. Nigeria is also renovating its rail network with the support of China. The Dakar-Ndjamena-Djibouti road and rail project is part of the Presidential Initiative to promote NEPAD infrastructure. The Senegalese Government, in charge of promoting the project, gave priority to the Dakar-Bamako railway project as the first phase of the overall project.

3.2.3- Air transport

According to the International Air Transport Association (IATA), in 2016, aviation provided nearly 6.9 million jobs in Africa and contributed US $ 80 billion in economic activity. The airlines based in Africa carried 70 million passengers in the same year. The main concerns of the African aviation sector include security, intra-continental and continent-to-world links, as well as high costs and taxation. The International Air Transport Association (IATA) has called on African governments to prioritize the development of aviation nationally and at a pan-African level to bolster economic growth and development. Africa is set to be one of the fastest-growing aviation regions over the next 20 years, with annual expansion averaging nearly 5% (IATA 2015). This opens up incredible economic opportunities for the continent's 54 nations.

Aviation has the potential to be a much greater strategic catalyst for economic growth if governments would stop milking the industry for taxes and enable it with smarter regulations focused on safety and the development of connectivity. The commitments are already there with the Abuja Declaration and the Yamoussoukro Decision. It's time to achieve them in partnership with the industry. Air transport is a facilitator of international business and trade. Improved connectivity means more access to cities, markets, business and people as well as the integration into global supply chains, an important factor to attract inward investment into any country.

3.3- Chinese Investment to Logistics Infrastructure projects in Africa

In recent years, China has shown a great interest by financing African logistics infrastructure. China relationship with Africa improved considerably over the period between 2000 and 2003(MOFCOM 2016). Investments announced by China reached a record level of $20.9bn in 2015[1] see figure3 (appendix5), comparatively to the very low level of announcements of $3.1bn in 2014. In the last five years following 2015, the average annual level of Chinese investments was $13.1bn, as compared to $15bn in 2011. China is strategically investing in ports which eventually fulfill their goal of a Maritime Silk Road (MSR). Chinese investment will put a dent in the $900 billion deficit and benefit local trade as well, with investment supporting the logistics infrastructure at root levels, such as businesses and schools. Specifically, many ports will receive money for construction and improvements. Ports on the West coast will increase capacity significantly with what is expected to be a $99.5 million dollar spending; specifically Nigeria, Congo, Togo, Ivory Coast and Ghana. In addition, Ghana's port has received multiple investments and is under construction by a Chinese company called China Harbor Engineering (CHEC) and estimated to be operational by 2017.

Before 2015, transport was the most invested sector in Africa by China, with $40bn spending plans over the period. Major announcements in the transport sector focused on the East African rail network (some of which must now meet new conditions imposed by the Chinese lenders since the announcement) and the DakarKidira railway in Senegal, where Chinese investment is also promised for two motorways: Blaise to Diagne and Ila to Touba. South Africa's state-owned freight transport and logistics company, Transnet, announced a $1.5bn loan facility agreed with China Development Bank (CDB) in June 2015, with an option to increase the facility to $2.5bn. In the same year, the company signed $952m club loan with five major financial institutions. The company will use the proceeds of the loan to fund its locomotive fleet acquisition program. China appears to be increasingly focused on sustainable infrastructure investments in Africa, transferring skills to the continent and investing in training.

4- Theoretical Framework: An Augmented Solow Model with Infrastructure and Chinese Infrastructure Investment Project

In this section, we introduce a Solow model with infrastructure, Chinese investment infrastructure project and human capital. This model introduces an infrastructure stock (infrastructure index: Inf. Ind) in the production function. The model presented by Solow (1989) is based on cobb-Douglas function with labor augmenting technological progress, human capital, Chinese infrastructure investment project (Kciip) and the infrastructure index.

$$Y(t) = I(t)^{\gamma} K_{pub}(t)^{\alpha} K_{pciip}(t)^{\mu} H(t)^{\beta} (A(t)L(t))^{1-\gamma-\alpha-\mu-\beta}, 0 < \gamma + \alpha + \mu + \beta < 1 \quad \textbf{(1)}$$

Where,
Y is the income,
I *is* the Inf Ind,
$\mathbf{K_{pub}}$ is Public capital,
$\mathbf{K_{pvt}}$ **is** Private Chinese Capital,
H *is* the stock of human capital,
A *is* the technology and L is labor.

$\gamma, \alpha, \mu, and\ \beta\ are$ the infrastructure stock, public capital, private Chinese capita and human's capital shares of income respectively. The parameter constraint $0 < \gamma + \alpha + \mu + \beta < 1$ ensures decreasing returns to capital. We define $y = Y / AL$, $i = I / AL$, $k_{pub} = K_{pub}/ AL$, $k_{pvt} = K_{pciip}/ AL$ and $h = H / AL$ to be the income, stock of infrastructure, stocks of public capital, private Chinese capital and human capital per effective unit of labor. Further, S_i, S_{pub}, S_{pciip}, *and* S_h are the fractions of GDP on infrastructure, physical public capital, physical private Chinese capital and human respectively invested. Labor and technological progress are assumed to grow exogenously at rates *n* and *g*: $L(t) = L(0)\ e^{nt}$ and $A(t)=A(0)e^{gt}$. Therefore the number of effective units of labor, $L(t)A(t)$ grows at rate $g+n$. Finally Capital depreciates at rate δ. In per capita terms,

$$\frac{Y(t)}{A(t)L(t)} = \left[\frac{I(t)}{A(t)L(t)}\right]^{\gamma} \left[\frac{K_{pub}(t)}{A(t)L(t)}\right]^{\alpha} \left[\frac{K_{pvc}(t)}{A(t)L(t)}\right]^{\mu} \left[\frac{H(t)}{A(t)L(t)}\right]^{\beta} \Rightarrow y(t) = i(t)^{\gamma} k_{pub}(t)^{\alpha} k_{pvc}(t)^{\mu} h(t)^{\beta} \quad \textbf{(2)}$$

The evolution of *i*, k_{pub}, *kpciip*, *and h* is governed by

$$\begin{cases} \dot{i} = s_i y(t) - (n+g+\delta) i(t) \\ \dot{k}_{pub} = s_{pub} y(t) - (n+g+\delta) k_{pub}(t) \\ \dot{k}_{pciip} = s_{pciip} y(t) - (n+g+\delta) k_{pciip}(t) \\ \dot{h} = s_h y(t) - (n+g+\delta) h(t) \end{cases} \quad \textbf{(3)}$$

[1] https://www.icafrica.org/fileadmin/documents/Annual_Reports/ICA_2015_annual_report.pdf (Infrastructure financing trends in Africa- 2015)

Equating (2) to zero, substituting to Y and we get

$$i^* = \left(\frac{S_i^{1-(\alpha+\mu+\beta)} S_{pub}^{\alpha} S_{pciip}^{\mu} S_h^{\beta}}{n+g+\delta}\right)^{\frac{1}{1-\gamma-\alpha-\mu-\beta}} \quad ; \quad k_{pub}{}^* = \left(\frac{S_{pub}^{1-(\gamma+\mu+\beta)} S_i^{\gamma} S_{pciip}^{\mu} S_h^{\beta}}{n+g+\delta}\right)^{\frac{1}{1-\gamma-\alpha-\mu-\beta}}$$

$$k_{pciip}{}^* = \left(\frac{S_{pciip}^{1-(\gamma+\alpha+\beta)} S_i^{\gamma} S_{pciip}^{\alpha} S_h^{\beta}}{n+g+\delta}\right)^{\frac{1}{1-\gamma-\alpha-\mu-\beta}} \quad and \quad h^* = \left(\frac{S_h^{1-(\gamma+\alpha+\mu)} S_i^{\gamma} S_{pub}^{\alpha} S_{pciip}^{\mu}}{n+g+\delta}\right)^{\frac{1}{1-\gamma-\alpha-\mu-\beta}} \quad \textbf{(4)}$$

Introducing these steady states in $y(t) = i(t)^{\gamma} k_{pub}(t)^{\alpha} k_{pvc}(t)^{\mu} h(t)^{\beta}$ and taking logs we get

$$y^* = ln\left(\frac{Y(t)}{L(t)}\right) = \ln A(0) + gt - \frac{\gamma+\alpha+\mu+\beta}{1-\gamma-\alpha-\mu-\beta}\ln(n+g+\delta) + \frac{\gamma}{1-\gamma-\alpha-\mu-\beta} ln(S_i) + \frac{\alpha}{1-\gamma-\alpha-\mu-\beta}\ln(S_{pub}) + \frac{\mu}{1-\gamma-\alpha-\mu-\beta} ln(S_{pciip}) + \frac{\beta}{1-\gamma-\alpha-\mu-\beta}\ln(S_h) \textbf{(5)}$$

This equation shows how income per capita depends on labor growth, accumulation of physical and human capital, technology and Inf Ind. Following Mankiw, Romer and Weil (MRW 1992), MRW hereafter, this equation may be rewritten in terms of the steady state:

$$y^* = ln\left(\frac{Y(t)}{L(t)}\right) = a + \varepsilon + \frac{\gamma}{1-\gamma-\alpha-\mu-\beta}(ln(S_i) - \ln(n+0{,}05)) + \frac{\alpha}{1-\gamma-\alpha-\mu-\beta}(\ln(S_{pub}) - \ln(n+0{,}05)) + \frac{\mu}{1-\gamma-\alpha-\mu-\beta}(ln(S_{pciip}) - \ln(n+0{,}05)) + \frac{\beta}{1-\gamma-\alpha-\mu-\beta}(\ln(S_h - \ln(n+0{,}05))\textbf{(6)}$$

The growth rate of technology and depreciation rates are assumed to be constant and both sum are equal to 0.05, i.e. g+δ=0.05. The terms ln A(0) + gt reflect the initial technology level of the economy and its progress. The identifying assumption made by MRW is that levels of technology are uncorrected with everything on the right-hand side, hence one writes ln $A(0) + gt = a + \varepsilon$ where *a* is a constant and ε is country specific shock.

5- Econometric Model, Analysis and Result

5.1- *Econometric Model*

There are several possible econometric techniques to estimate our economic models (5) and (6): panel data, pooled regression and cross-section regression (over long time spans). We retain panel data techniques to estimate, because of its advantages over the cross-section and time series in using all the information available, which is not detectable in pure cross-sections, in pooled regression or in pure time series. We therefore specify the following econometric model for the economic model (6)

$$y_{it}{}^* = \mathrm{a} + b_1[ln(S_{I,it}) - \ln(n_{it}+g+\delta)] + b_2[ln(S_{pub,it}) - \ln(n_{it}+g+\delta)] + b_3[ln(S_{pciip,it}) - \ln(n_{it}+g+\delta)] + b_4[ln(S_{h,it}) - \ln(n_{it}+g+\delta)] + \mathcal{E}_{it} \ \textbf{(7)}$$

A few points need to be sorted out to relate the estimated model to our original economic model. The parameters that are estimated are those of the econometric model needed to generate the implicit parameters of the economic model; γ, *α, μ* and *β* are the infrastructure, physical public capital, private Chinese capital and human's capital elasticity in GDP respectively. The infrastructure parameter, the government investment parameter, the Chinese private investment parameter, the education (human capital) parameter can be computed from the estimated model using $\gamma = \frac{b_1}{1+b_1+b_2+b_3+b_4}$; $\alpha = \frac{b_2}{1+b_1+b_2+b_3+b_4}$; $\mu = \frac{b_3}{1+b_1+b_2+b_3+b_4}$; $\beta = \frac{b_4}{1+b_1+b_2+b_3+b_4}$ **(8)** respectively.

Where,

b1, b2, b3 and b4 are the coefficients of ARDL long run estimation results. (See Table7)

In order to achieve suitable and consistence estimates, considering the fact that the GDP is quantitatively very huge compare to the infrastructure index, total Chinese private investment capital and human capital respectively and following Mankiw, Romer and Weil (MRW 1992), MRW approach. We took the option to proxy the following shares of the income capital $S_{I,it}$, $S_{pub,it}$, $S_{pciip,it}$ and $S_{h,it}$ in equation (7) by Infrastructure Index, Public capital, Private Chinese Capital and human capital respectively. Therefore equation (7) may be rewritten as follow:

$$ln\left[\frac{GDP}{\text{labor force}}\right]_{it} = \text{a} + b_1[\ln(Infrastructure(I))_{it} - \ln(n_{it} + 0.5)] + b_2\left[ln\left(Total\ Government\ Investment(k_{pub})\right)_{it} - \ln(n_{it} + 0.5)\right] + b_3\left[ln\left(Total\ chinese\ Private\ Investment(k_{pciip})\right)_{it} - \ln(n_{it} + 0.5)\right] + b_4[ln(Human\ Capital(h))_{it} - \ln(n_{it} + 0.5)] + \mathcal{E}_{it} \quad \textbf{(9)}$$

Where $\mathcal{E}_{it}$ is a set of error terms.
i=1,…N , t = 1,… T; N is the number of countries, $\boldsymbol{T}$ the number of periods.

5.2- *Econometric Analysis*

5.2.1- *Date Source*

Annual data on GDP, per capita GDP, Gross Domestic Capital Formation (public and Private) and Human Capital are taken from various issues of the economic survey, such as World Development. Labor force is taken from the international labor organization (ILO) definition of economically active population that includes both the employed and unemployed. Infrastructure indicators such as air freight transport (million tons per km), roads (total network-km), and rail lines (total route-km) are taken from Africa infrastructure national data from World indicators. Trade data (Exports-Imports) come from UNCTAD (2016), population from IMF (2016). Outwards Chinese foreign direct investment comes from MOFCOM (ministry of commerce).

5.2.2- Methodology of Technical Analysis

In this study, we will show how logistics infrastructure, public capital, Chinese private capital, labor force and human capital matter to growth in Africa from 2000-2015. Firstly we have to compute an index of infrastructure with the three variables of infrastructure stock under this study. The empirical literature examining the impact of infrastructure on growth uses a variety of definitions of infrastructure development or some indicators of physical infrastructures. However, a composite index of major infrastructure indicators has been developed to examine the impact of infrastructure stock on growth.

5.2.2.1- The aggregate index of infrastructure stock

Our synthetic indices of infrastructure stock and service quality are constructed using the Principal Components Analysis (PCA) method. This takes n specific indicators and yields new indices (principal components) that capture information on the different dimensions of the data. Our aggregate index of infrastructure is the first principal component of the vector of physical indicators of infrastructure stocks (I). Generally speaking, the first principal component is defined by the vector of weights a = (a_1, a_2, …, a_n)' on the set of indicators {X_1, X_2, .., X_n} such that the linear combination

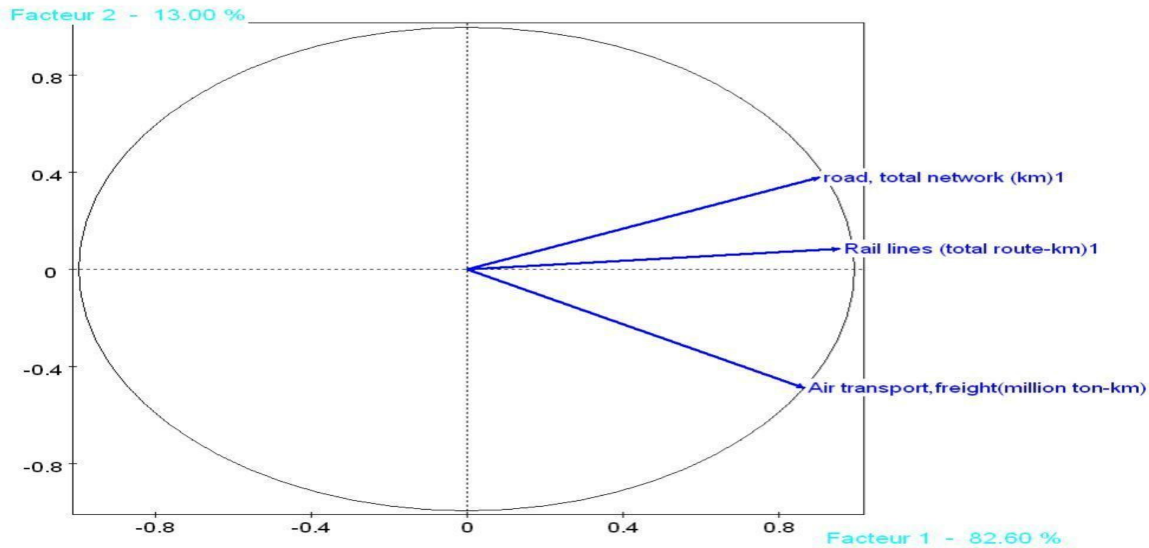
$$P1 = a_1X_1 + a_2X_2 + \dots + a_nX_n$$

has the maximum variance for any possible choice of weights subject to restriction that the sum of squares normalization is equal to 1 (that is, a'a = 1). Using the PCA, we construct an aggregate index of infrastructure stocks (I).

We aggregate individual physical measures of infrastructure in Air transport (freight million tons per kilometer), Rail lines (total route-km), and Roads (total network-km) to compute our index of infrastructure stocks. The first principal component of the three stock variables accounts for 82.60% of their overall variance and, as expected. We observe not only that the weights are similar among aggregate indices, but also that these global alternative indices are highly correlated. Specifically, the correlation between rail lines and road is 0.84, its correlation with air transport (freight million tons per kilometer) is 0.75 and while the correlation between road and its correlation with air transport (freight million tons per kilometer) is 0.62. All three measures of infrastructure stock enter the first principal components with approximately similar weights, just as it can be visualize on Figure1 present the results of the PCA:

$$\text{I} = 0.87 * \text{Air transport} + 0.90 * \text{Roads} + 0.95 * \text{Rail lines}$$

Figure1 Results of the PCA



In addition, panel data estimation provides improved estimates over time-series techniques by increasing the power of the tests if the data span is short, given the fact that we only have 16 observations for each country. The first step is to ascertain the stationary properties of the relevant variables. Multiple methods for unit root tests as well as cointegration analysis have been developed for panel data in the recent past and can be grouped as first generation tests (Levine, Lin, and Chu 2002; Im, Pesaran, and Shin, 2003) based on the assumption of cross-sectional independence between panel units (except for common time effects), and second-generation tests (Smith *et al.* 2004; Pesaran 2007) allowing for cross-sectional dependence. In our analysis, we apply both the Im *et al.* (2003) and Smith *et al.* (2004).

5.2.2.2- Unit root tests

In time series analysis, before running the causality test among the variables, the test of stationarity must be tested. For the purpose in this current study we use the conventional ADF tests, the Phillips-Perron test following Phillips and Perron (1988) and the Dickey-Fuller generalized least square (DF-GLS) de-trending test proposed by Elliot *et al.* (1996). The ARDL bounds test is based on the assumption that the variables are I(0) or I(1). So, before applying this test, we determine the order of integration of all variables using the unit root tests. The objective is to ensure that the variables are not I(2) with a view to avoid spurious results. In the presence of variables integrated of order two, we cannot interpret the values of F statistics provided by Pesaran *et al.* (2001).

5.2.2.3- ARDL Bounds tests for cointegration

In order to do empirically analysis over the long-run relationships and short run dynamic interactions among the variables of interest (GDP, Infrastructure Index, Capital Chinese Infrastructure Investment Project, Public Capital and Human Capital), we apply the autoregressive distributed lag (ARDL) cointegration technique as a general vector autoregressive (VAR) model of order p, in Z_t, where Z_t is a column vector composed of the five variables: $Z_t = (y^*_t , I_t , K_{ciipt} , K_{pubt} , H_t)'$. The ARDL cointegration approach was developed by Pesaran and Shin (1999) and Pesaran *et al.* (2001). It has three advantages in comparison with other previous and traditional cointegration methods. The first one is that the ARDL does not need the fact that all the variables under study must be integrate at the same order and it can be applied when the under-lying variables are integrated of order one, order zero or fractionally integrated. The second advantage is that the ARDL test is relatively more efficient in the case of small and finite sample data sizes. The last and third advantage is that by applying the ARDL technique we obtain unbiased estimates of the long-run model (Harris and Sollis, 2003). The ARDL model used in this study is expressed as follows:

$$D(\ln(y_t^*)) = a_{01} + b_{11}\ln(y_{t-1}^*) + b_{21}[ln(I_{t-i}) - \ln(n_{it-i}+0.5)] + b_{31}[ln(K_{pub,t-i}) - \ln(n_{it-i}+0.5)] + b_{41}[ln(K_{pciip,t-i}) - \ln(n_{it-i}+0.5)] + b_{51}[ln(H_{t-i}) - \ln(n_{it-i}+0.5)] + \sum_{i=1}^{p} a_{1i} D(\ln(y_{t-i}^*)) + \sum_{i=1}^{q} a_{2i} D([ln(I_{t-i}) - \ln(n_{it-i}+0.5)]) + \sum_{i=1}^{q} a_{3i} D([ln(K_{pub,t-i}) - \ln(n_{it-i}+0.5)]) + \sum_{i=1}^{q} a_{4i} D([ln(K_{pciip,t-i}) - \ln(n_{it-i}+0.5)]) + \sum_{i=1}^{q} a_{5i} D([ln(H_{t-i}) - \ln(n_{it-i}+0.5)]) + \mathcal{E}_{1t} \quad (\mathbf{10})$$

$$D(ln(I_t) - \ln(n_t+0.5)) = a_{02} + b_{12}\ln(y_{t-1}^*) + b_{22}[ln(I_{t-i}) - \ln(n_{it-i}+0.5)] + b_{21}[ln(K_{pub,t-i}) - \ln(n_{it-i}+0.5)] + b_{31}[ln(K_{pciip,t-i}) - \ln(n_{it-i}+0.5)] + b_{41}[ln(H_{t-i}) - \ln(n_{it-i}+0.5)] + \sum_{i=1}^{p} a_{1i} D(ln(I_{t-i}) - \ln(n_{it-i}+0.5)) + \sum_{i=1}^{q} a_{2i} D(\ln(y_{t-i}^*)) + \sum_{i=1}^{q} a_{3i} D([ln(K_{pub,t-i}) - \ln(n_{it-i}+0.5)]) + \sum_{i=1}^{q} a_{4i} D([ln(K_{pciip,t-i}) - \ln(n_{it-i}+0.5)]) + \sum_{i=1}^{q} a_{5i} D([ln(H_{t-i}) - \ln(n_{it-i}+0.5)]) + \mathcal{E}_{2t} \quad (\mathbf{11})$$

$$D(ln(K_{pub,t}) - \ln(n_t+0.5)) = a_{03} + b_{13}\ln(y_{t-1}^*) + b_{23}[ln(I_{t-i}) - \ln(n_{it-i}+0.5)] + b_{33}[ln(K_{pub,t-i}) - \ln(n_{it-i}+0.5)] + b_{43}[ln(K_{pciip,t-i}) - \ln(n_{it-i}+0.5)] + b_{53}[ln(H_{t-i}) - \ln(n_{it-i}+0.5)] + \sum_{i=1}^{p} a_{1i} D(ln(K_{pub,t-i}) - \ln(n_{it-i}+0.5)) + \sum_{i=1}^{q} a_{2i} D([ln(I_{t-i}) - \ln(n_{it-i}+0.5)]) + \sum_{i=1}^{q} a_{3i} D(\ln(y_{t-i}^*)) + \sum_{i=1}^{q} a_{4i} D([ln(K_{pciip,t-i}) - \ln(n_{it-i}+0.5)]) + \sum_{i=1}^{q} a_{5i} D([ln(H_{t-i}) - \ln(n_{it-i}+0.5)]) + \mathcal{E}_{3t} \quad (\mathbf{12})$$

$$D(ln(K_{pciip,t}) - \ln(n_t+0.5)) = a_{04} + b_{14}\ln(y_{t-1}^*) + b_{24}[ln(I_{t-i}) - \ln(n_{it-i}+0.5)] + b_{34}[ln(K_{pub,t-i}) - \ln(n_{it-i}+0.5)] + b_{44}[ln(K_{pciip,t-i}) - \ln(n_{it-i}+0.5)] + b_{54}[ln(H_{t-i}) - \ln(n_{it-i}+0.5)] + \sum_{i=1}^{p} a_{1i} D(ln(K_{pciip,t-i}) - \ln(n_{it-i}+0.5)) + \sum_{i=1}^{q} a_{2i} D([ln(I_{t-i}) - \ln(n_{it-i}+0.5)]) + \sum_{i=1}^{q} a_{3i} D([ln(K_{pub,t-i}) - \ln(n_{it-i}+0.5)]) + \sum_{i=1}^{q} a_{4i} D(\ln(y_{t-i}^*)) + \sum_{i=1}^{q} a_{5i} D([ln(H_{t-i}) - \ln(n_{it-i}+0.5)]) + \mathcal{E}_{4t} \quad (\mathbf{13})$$

$$D(ln(H_t) - \ln(n_t + 0.5)) = \mathrm{a}_{05} + \mathrm{b}_{15}\ln(y^*_{t-1}) + \mathrm{b}_{25}[ln(I_{t-i}) - \ln(n_{it-i} + 0.5)] + b_{35}[ln(K_{pub,t-i}) - \ln(n_{it-i} + 0.5)] + b_{45}[ln(S_{pciip,t-i}) - \ln(n_{it-i} + 0.5)] + b_{55}[ln(H_{t-i}) - \ln(n_{it-i} + 0.5)] + \sum_{i=1}^{p} a_{1i} D(ln(H_{t-i}) - \ln(n_{it-i} + 0.5)) + \sum_{i=1}^{q} a_{2i} D([ln(I_{t-i}) - \ln(n_{it-i} + 0.5)]) + \sum_{i=1}^{q} a_{3i} D([ln(K_{pub,t-i}) - \ln(n_{it-i} + 0.5)]) + \sum_{i=1}^{q} a_{4i} D([ln(K_{pciip,t-i}) - \ln(n_{it-i} + 0.5)]) + \sum_{i=1}^{q} a_{5i} D(\ln(y^*_{t-i})) + \mathcal{E}_{5t} \mathbf{(14)}$$

The bounds test is mainly based on the joint F-statistic which its asymptotic distribution. The first step in the ARDL bounds approach is to estimate the five equations (10, 11, 12, 13 and 14) by ordinary least squares (OLS). The estimation of the five equations tests for the existence of a long-run relationship among the variables by conducting an F-test for the joint significance of the coefficients of the lagged levels of the variables, *i.e.*, : H0: $b_{1i} = b_{2i} = b_{3i} = b_{4i} = b_{5i} = 0$, against the alternative one : H1: $b_{1i} \neq b_{2i} \neq b_{3i} \neq b_{4i} \neq b_{5i} \neq 0$ for i=1,2,3,4 et 5. Two sets of critical values for a given significance level can be determined (Pesaran *et al.*, 2001). The first level is calculated on the assumption that all variables included in the ARDL model are integrated of order zero, while the second one is calculated on the assumption that the variables are integrated of order one. The null hypothesis of no cointegration is rejected when the value of the test statistic exceeds the upper critical bounds value, while it is accepted if the F-statistic is lower than the lower bounds value. Otherwise, the cointegration test is inconclusive.

5.2.2.4- Granger short run and long run causality tests

The cointegration analysis is established. However, we have only the relationship among the variables, which does not provide the direction of the causality. More clearly whether human capital has an impact on the GDP or vice versa is still not established. In order to ascertain the direction of causality, Granger causality test has been employed. As ARDL can be applied irrespective of the order of integration (Pesaran *et al.* 2001), Granger causality tests are applicable irrespective of the orders of integration of the underlying variables if it has been established that there exists a long-run equilibrium relationship between the underlying series (Groenewold and Tang 2007). The conditional ARDL (p, q1,q2,q3,q4,q5) long-run model for $\ln(y^*_t)$ can be estimated as :

$$\ln(y^*_t) = \mathrm{a}_{01} + \sum_{i=1}^{p} a_{1i}\ln(y^*_{t-i}) + \sum_{i=0}^{q_1} a_{2i}\,[ln(I_{t-i}) - \ln(n_{it-i} + g + \delta)] + \sum_{i=0}^{q_2} a_{3i}[ln(K_{pub,t-i}) - \ln(n_{it-i} + g + \delta)] + \sum_{i=0}^{q_3} a_{4i}[ln(K_{pciip,t-i}) - \ln(n_{it-i} + g + \delta)] + \sum_{i=0}^{q_4} a_{5i}[ln(H_{t-i}) - \ln(n_{it-i} + g + \delta)] + \mathcal{E}_t \mathbf{(15)}$$

Where, all variables are as previously defined. The orders of the ARDL (p,q_1,q_2,q_3,q_4,q_5) model in the six variables are selected by using AKAIKE Information Criteria (AIC).

However, in the presence of a long-run relationship, Granger causality test requires the inclusion of a lagged error correction term within a vector error correction model (VECM) in order to capture the short-run deviations of the series from their long-run equilibrium relationship (Narayan and Smyth 2004; Feridun *et al.* 2009). In vector error correction mechanism, the following regression will be specified for the Granger causality analysis:

$$D(\ln(y^*_t)) = \mathrm{a}_0 + \sum_{i=1}^{p} a_{1i} D(\ln(y^*_{t-i})) + \sum_{i=1}^{q} a_{2i} D(ln(I_{t-i}) - \ln(n_{it-i} + 0.5)) + \sum_{i=1}^{q} a_{3i} D(ln(S_{pub,t-i}) - \ln(n_{it-i} + g + \delta)) + \sum_{i=1}^{q} a_{4i} D(ln(S_{pciip,t-i}) - \ln(n_{it-i} + g + \delta)) + \sum_{i=1}^{q} a_{5i} D(ln(H_{t-i}) - \ln(n_{it-i} + g + \delta)) + \varphi \mathrm{ECT}_{t-1} + \mathcal{E}_t \mathbf{(16)}$$

$$D(ln(I_t) - \ln(n_t + 0.5)) = a_0 + \sum_{i=1}^{p} a_{1i}\, D(ln(I_{t-i}) - \ln(n_{it-i} + 0.5)) + \sum_{i=1}^{q} a_{2i}\, D(\ln(y^*_{t-i})) + \sum_{i=1}^{q} a_{3i}\, D\big(ln(K_{pub,t-i}) - \ln(n_{it-i} + 0.5)\big) + \sum_{i=1}^{q} a_{4i}\, D\big(ln(K_{pciip,t-i}) - \ln(n_{it-i} + 0.5)\big) + \sum_{i=1}^{q} a_{5i}\, D(ln(H_{t-i}) - \ln(n_{it-i} + 0.5)) + \mathcal{E}_t \quad (\mathbf{17})$$

$$D\big(ln(K_{pub,t}) - \ln(n_t + 0.5)\big) = a_0 + \sum_{i=1}^{p} a_{1i}\, D\big(ln(K_{pub,t-i}) - \ln(n_{it-i} + 0.5)\big) + \sum_{i=1}^{q} a_{2i}\, D(ln(I_{t-i}) - \ln(n_{it-i} + 0.5)) + \sum_{i=1}^{q} a_{3i}\, D(\ln(y^*_{t-i})) + \sum_{i=1}^{q} a_{4i}\, D\big(ln(K_{pciip,t-i}) - \ln(n_{it-i} + 0.5)\big) + \sum_{i=1}^{q} a_{5i}\, D(ln(H_{t-i}) - \ln(n_{it-i} + 0.5)) + \mathcal{E}_t \quad (\mathbf{18})$$

$$D\big(ln(K_{pciip,t}) - \ln(n_t + 0.5)\big) = a_0 + \sum_{i=1}^{p} a_{1i}\, D\big(ln(K_{pciip,t-i}) - \ln(n_{it-i} + 0.5)\big) + \sum_{i=1}^{q} a_{2i}\, D(ln(I_{t-i}) - \ln(n_{it-i} + 0.5)) + \sum_{i=1}^{q} a_{3i}\, D\big(ln(K_{pub,t-i}) - \ln(n_{it-i} + 0.5)\big) + \sum_{i=1}^{q} a_{4i}\, D(\ln(y^*_{t-i})) + \sum_{i=1}^{q} a_{5i}\, D(ln(H_{t-i}) - \ln(n_{it-i} + 0.5)) + \mathcal{E}_t \quad (\mathbf{19})$$

$$D(ln(H_t) - \ln(n_t + 0.5)) = a_0 + \sum_{i=1}^{p} a_{1i}\, D(ln(H_{t-i}) - \ln(n_{it-i} + 0.5)) + \sum_{i=1}^{q} a_{2i}\, D(ln(I_{t-i}) - \ln(n_{it-i} + 0.5)) + \sum_{i=1}^{q} a_{3i}\, D\big(ln(K_{pub,t-i}) - \ln(n_{it-i} + 0.5)\big) + \sum_{i=1}^{q} a_{4i}\, D\big(ln(K_{pciip,t-i}) - \ln(n_{it-i} + 0.5)\big) + \sum_{i=1}^{q} a_{5i}\, D(\ln(y^*_{t-i})) + \mathcal{E}_t \quad (\mathbf{20})$$

Where a_{1i}, a_{2i}, a_{3i}, a_{2i}, a_{1i}, a_{2i} are short-run dynamic coefficients of the model's convergence to equilibrium and ECT_{t-1} denotes the one-period lagged error correction term. ECT_{t-1} captures the speed of adjustment (φ) of the variables in response to a deviation from their long-run equilibrium path just as mentioned in equation (16). The significance of the differenced explanatory variables based on F statistics indicates the existence of short-term causal effects, whereas the significance of ECT_{t-1} based on t statistics indicates the existence of a long-term relationship.

5.3- Results and Interpretation

Table1 shows the values of variables in more detail. Precisely, the different means of dependent and independent variables followed by the standard derivation during the period 2000 to 2015 with the minimum and maximum. To understand whether the variables have causality relationship among them or whether mean and variance of the series does not depend on time, several test must be applied.

Table1 Description of variables

	N	Mean	Median	Std. Deviation	Minimum	Maximum
GDP (constant LCU)	***864***	***3 865 331 833 213***	***777 168 425 650***	***9 015 408 148 210***	***394 676 000***	***69 780 692 720 000***
Index of Infra	***864***	***39 333***	***17 821***	***56 877***	***288***	***349 969***
Labor force, total	***864***	***6 685 209***	***3 477 537***	***9 338 344***	***43 880***	***57 140 119***
Population, total	***864***	***17 782 210***	***9 872 877***	***26 251 673***	***81 131***	***181 181 744***
Gross fixed capital formation (% of GDP)	***864***	***21,73***	***20,80***	***11,44***	***1,10***	***145,70***
Chinese FDI in Africa data1.xlsx	***864***	***38,65***	***4,03***	***183,40***	***- 814,91***	***4 807,86***
School enrollment, secondary (gross), gender parity index (GPI)	***864***	***0,84***	***0,80***	***0,22***	***0,30***	***1,40***

Before starting off with the Granger causality test among the variables, one must make that only stationary series are involvement as highlighter by Granger (Granger C. W. J. 1969). Secondly, there is also the issue of long rung relationship between the variables. To address these issues, two tests namely the panel unit root and panel cointegration test are performed. The first step is to run a panel unit root test to check whether the variables used are stationary. A series is said to be stationary if the mean and variance of the series does not depend on time. The results of the panel unit root are provided in Table 2 and Table 3 as follow.

Unit root on log level of variable

This study employs two Tests of Im, Pesaran and Shin (IPS), 2003; and ADF - Fisher which are among the first generation unit root tests because these tests have a more realistic assumption of heterogeneity.

Table2 Unit root tests on log levels of variables

	Im, Pesaran and Shin W-stat			**ADF - Fisher Chi-square**		
	τ_u	τ_T	τ	τ_u	τ_T	τ
LN_(GDP/LABOR)	-17.23***	-13.72***	-	469***	361.815***	70.5455
LN_(IndexIn)- Ln(n+g+δ)	-18.55***	-14.57***	-	496.302***	380.904***	102.696
LN_(KPUB)- Ln(n+g+δ)	-18.35***	-15.0185***	-	496.316***	392.624***	60.0148
LN_(K_{CIIP}) - Ln(n+g+δ)	-3.43***	-9.723***	-	182***	301.913***	123.810
LN(SCHOOL_ENROL) Ln(n+g+δ)	-0.4345	0.273	-	170.511***	150.479***	312.768***

τ_u is the model with an intercept and without trend ; τ_T represents with an intercept and trend: and τ is without an intercept and trend. ***, **, * indicates significance at 1%, 5% and 10% respectively

Table3 Unit root tests on first differences of log levels of variables

	Im, Pesaran and Shin W-stat			ADF - Fisher Chi-square			Decision
	τ_u	τ_T	τ	τ_u	τ_T	τ	
D(LN_(GDP/LABOR))	-25.25***	-18.7138***	-	485.818***	674.088***	1015***	I(1)
D(LN_(IndexIn)- Ln(n+g+δ))	-28.75***	-21.315***		756.115***	54.587***	1097***	I(1)
D(LN_(KPUB)- Ln(n+g+δ))	-30.09***	-24.02***	-	782.274***	595.201***	1062.79***	I(1)
D(LN_(K_{CIIP}) - Ln(n+g+δ))	-24.65***	-19.58***	-	663.501***	503.167***	984.819***	I(1)
D(LN(SCHOOL_ENROL) Ln(n+g+δ))	-13.83***	-12.30***	-	415.301***	347.526***	577.542***	I(1)

τ_u is the model with an intercept and without trend ; τ_T represents with an intercept and trend: and τ is without an intercept and trend. ***, **, * indicates significance at 1%, 5% and 10% respectively

The results of the stationarity tests were estimated using Eviews 9.5 to show that all variables are non-stationary at level; these results are given in Table2. The Im, Pesaran and Shin W-stat and ADF - Fisher Chi-square tests applied to the first difference of the data series reject the null hypothesis of non stationarity for all the variables used in this study (Table3). It is, therefore, worth concluding that all the variables are integrated of order one. The figure1 above shows that all the variables are integrated I(1).

Once the existence of panel unit root has been confirmed at level, the second step is to find whether there exists a long run equilibrium relationship between infrastructure, public capital, Chinese private capital, school enrollment and economic growth. We can easily apply Johansen cointegration tests. Before cointegration test, we must determine the approximate lag structure for the model.

Determination of the approximate lag structure for the model

The ranges of summation in the various terms in (11) are from 1 to p, 0 to q1, 0 to q2, 0 to q3, and 0 to q4 respectively. We need to select the appropriate values for the maximum lags, p, q1, q2, q3 and q4. Usually, these maximum lags (see Table4) are determined by using one or more of the "information criteria" - AIC, SC, HQ, etc. These criteria are based on a high log-likelihood value, with a "penalty" for including more lags to achieve this. The form of the penalty varies from one criterion to another. Each criterion starts with -2log (L), and then penalizes, so the smaller value of an information criterion is the better result.

In general we use the Schwarz (Bayes) criterion (SC), as it's a consistent model-selector. Care must be taken not to "over-select" the maximum lags, and we usually also pay some attention to the (apparent) significance of the coefficients in the model.

Table4 Approximate lag structure for the model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-897.1579	NA	7.075357	4.794486	4.888174*	4.831669
1	-897.1579	9.92e-07	7.112916	4.799777	4.903875	4.841092
2	-897.0313	0.245758	7.145893	4.804398	4.918906	4.849845
3	-896.4737	1.079788	7.162674	4.806739	4.931656	4.856317
4	-895.2953	2.275733	7.155958	4.805795	4.941122	4.859504
5	-891.2517	7.787718	7.041691	4.789691	4.935428	4.847532
6	-886.5700	8.991812*	6.905901	4.770212	4.926358	4.832184
7	-884.6610	3.656305	6.872830*	4.765402*	4.931959	4.831506*
8	-884.5475	0.216850	6.905211	4.770093	4.947059	4.840328

Looking at the AIC values in Table4, we see that a maximum lag of 7 is suggested for $D(LN\_GDP\_LABOR)_t$. We can also notice that, lag7 is suggested as far as Hannan-Quinn Information Criterion (HQ) is concern but SC criterion lead to a maximum lag of 0. Anyway we will adopt 7 as maximum lag but while performing the analysis we will probably meet up with a significant model with lag less than 7.

Cointegration test

Once the existence of panel unit root test has been confirmed at level, the unit root test is important to ensure that there will not be I (2) variables integrated at that level. We can easily apply Johansen cointegration (Table5). However, due to the contradiction among Im, Pesaran and Shin W-stat and ADF results in the case of ln (SCHOOL_ENROLLMENT/ GDP) and ln(n+g+δ), we prefer ARDL approach over Johansen cointegration approach for detailed analysis of long-run relationship. However, we shall start with Johansen cointegration for testing estimating equation 11.

Table5 Pedroni cointegration results

	τ_u	τ_T	τ
Within Dimension			
Panel v-	-3.178806	-6.653727	-1.251580
Panel rho	1.559466	4.163946	-0.882619
Panel PP	-15.16149***	-17.37763***	-15.34831***
Panel ADF	-5.524666***	-5.154812***	-6.988432***
Between Dimension			
Group rho	4.531108	6.841935	2.142826
Group PP	-23.25159***	-25.68061***	-25.85365***
Group ADF	-6.106062***	-4.900154***	-9.156148***

τ_u is the model with an intercept and without trend ; τ_T represents with an intercept and trend: and τ is without an intercept and trend. ***, **, * indicates significance at 1%, 5% and 10% respectively.

Pedroni developed seven main statistical analyses which are divided into two main parts; panel statistics (within dimension) and group mean co-integration (between dimensions). The results in Table5 generally show that, in all three groups, at least two tests for each specification (an intercept and without trend; with an intercept and trend; without an intercept and trend) reject the null hypothesis of no co-integration. Although other tests display mixed results, both panel ADF and group ADF statistics reject null hypothesis of no co-integration in most cases at either one or five or ten percent level of significance. Thus, we can conclude that ln(GDP/LABOR), ln(K_{CIIP}/GDP), ln(IndexIn/GDP), ln(KPUB/GDP) , ln(SCHOOL_ENROLLMENT_INDEX_/GDP), Ln(n+g+δ) are cointegrated. Therefore, there is a long-run relationship between real GDP and real infrastructure, public capital, private Chinese capital and human capital.

Furthermore, as mentioned earlier for the robustness purposes we also use ARDL cointegration technique. The use of this approach is guided by the short data span. The calculated F-statistics are reported in Table6 when each variable is considered as a dependent variable (normalized) in the ARDL-OLS regressions. Their values are: for equation (11), F_{Y*} (y*, I, k_{pub}, k_{ciip}, h) = 11.69 ; for equation (12), F_i(i /y*, k_{pub}, k_{ciip},h) =13.09; for equation (13), F_{pub}(k_{pub}/y*,k_{ciip},i,h)= 12.22; for equation (14), F_h(h/y, i, k_{pub}, k_{ciip})= 0.7268 and for equation (15), F_h(h/y, i,k_{pub},k_{ciip})= 0.9504. From these results, it is clear that there is a long run relationship amongst the variables when GDP, infrastructure Index and Public capital are considered dependent variable respectively because their corresponding F-values are higher than the upper-bound critical value (5.122) at the 1% level. This implies that the null hypothesis of no cointegration among the variables in equations (11), (12) and (13) is rejected.

Table6 Results from bound tests

Dependant Variables	F-statistic	Decision
$F_{y*}(y*/I, k_{pub}, k_{ciip}, h)$	11.69	Cointegration
$F_i(i/y*, k_{pub}, k_{ciip}, h)$	13.09	Cointegration
$F_{pub}(k_{pub}/y*, k_{ciip}, i, h)$	9.7873	Cointegration
$F_{ciip}(k_{ciip}/y*, k_{pub}, i, h)$	0.5838	No cointegration
$F_h(h/y, i, k_{pub}, k_{ciip})$	1.6267	No cointegration
Lower-bound critical value at 1%	3.817	
Upper-bound critical value at 1%	5.122	

Granger short run and long run causality tests

After establishing a long-run relationship, the next task is to estimate the error correction model for the long-run elasticity and error correction term. For this purpose, we use the ARDL estimators to run equation (11). (Table7)

Table7 ARDL long run estimation Results

Dependent Variable: LN_GDP_LABOR

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-14.71230	4.345679	-3.385502	0.0007
LN_INDEXINF_LN_N_G_D	0.073491	0.028885	2.544242	0.0111
LN_KPUB__LN_N_G_D	0.128607	0.036916	3.483722	0.0005
LN_GDP_LABOR (-1)	0.142719	0.034884	4.091264	0.0000
LN_SCHOOL_ENROLLMENT__LN (-1)	1.043422	0.325881	3.201851	0.0014
LN_KCIIP__LN_N_G_D(-1)	6.083382	0.961936	6.324100	0.0000

R-squared	0.176606	Mean dependent var	12.10189
Adjusted R-squared	0.171479	S.D. dependent var	2.852071
S.E. of regression	2.596045	Akaike info criterion	4.753244
Sum squared resid	5411.779	Schwarz criterion	4.788071
Log likelihood	-1916.687	Hannan-Quinn criter.	4.766616
F-statistic	34.44624	Durbin-Watson stat	2.067656
Prob (F-statistic)	0.000000		

We know that in the long run $\forall i \in \mathbb{N}$; LN_GDP_LABOR (t-i)= LN_GDP_LABOR(t)

$$\mathrm{LN\_KCIIP\_\_LN\_N\_G\_D}(t-i) = \mathrm{LN\_KCIIP\_\_LN\_N\_G\_D}(t)$$

From the previous Table we obtain the coefficients dividing by one minus the dependant variable term. Once this is done while returning to equation (**8**), we have the following value of $\gamma = 0{,}008977; \alpha = 0{,}01571; \mu = 0{,}743128;$ $\beta = 0{,}127461$; with the sum of the expected sign equal to 0.895277 respecting the condition of equation (1) ($0 < \gamma + \alpha + \mu + \beta < 1$).

Furthermore, the output elasticity of infrastructure and private Chinese capital are positive and significant. The output elasticity of public capital is positive (0.015) and very low than Aschauer (ranking to 0.38 to 0.56) in 1989; with 0.12 of human capital. The low output elasticity of public capital is due by the fact that several African leaders give priority to public project that will enable them to reach their personal interest via corrupt system. All of these lead to a poor educational system, cause of growing unemployment problem and low productivity of labor in Africa.

The long run relationship between the variables indicates that there is Granger Causality in at least one direction which is determined by the F-statistic and the lagged error-correction that we are going to discuss below. For the short run, we have the following: (see Table8)

Table8 ARDL short run estimation Results (equation (12))

Dependent Variable: LN_GDP_L

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.027210	0.122027	0.222983	0.8236
D(LN_GDP_LABOR(-1))	-0.254698	0.096252	-2.646160	0.0084
D(LN_KCIIP__LN_N_G_D(-1))	0.402816	1.365424	0.295012	0.7681
D(LN_GDP_LABOR(-2))	-0.391368	0.080047	-4.889221	0.0000
D(LN_SCHOOL_ENROLLMENT__LN(-2))	-3.164203	3.198204	-0.989369	0.3230
D(LN_GDP_LABOR(-3))	-0.347566	0.073836	-4.707299	0.0000
D(LN_KPUB__LN_N_G_D(-3))	-0.064625	0.032292	-2.001297	0.0459
D(LN_KCIIP__LN_N_G_D(-3))	-1.831389	1.399025	-1.309047	0.1912
D(LN_GDP_LABOR(-4))	-0.322022	0.067309	-4.784250	0.0000
D(LN_INDEXINF_LN_N_G_D(-4))	-0.051080	0.025759	-1.982988	0.0479
D(LN_GDP_LABOR(-5))	-0.260253	0.058882	-4.419876	0.0000
D(LN_KPUB__LN_N_G_D(-5))	-0.084974	0.032565	-2.609388	0.0094
D(LN_GDP_LABOR(-6))	-0.165731	0.045107	-3.674168	0.0003
ECT(-1)	-0.618455	0.099914	-6.189903	0.0000

R-squared	0.464744	Mean dependent var	0.093809
Adjusted R-squared	0.450002	S.D. dependent var	3.354435
S.E. of regression	2.487712	Akaike info criterion	4.688987
Sum squared resid	2921.070	Schwarz criterion	4.809577
Log likelihood	-1125.424	Hannan-Quinn criter.	4.736364
F-statistic	31.52470	Durbin-Watson stat	2.083588
Prob(F-statistic)	0.000000		

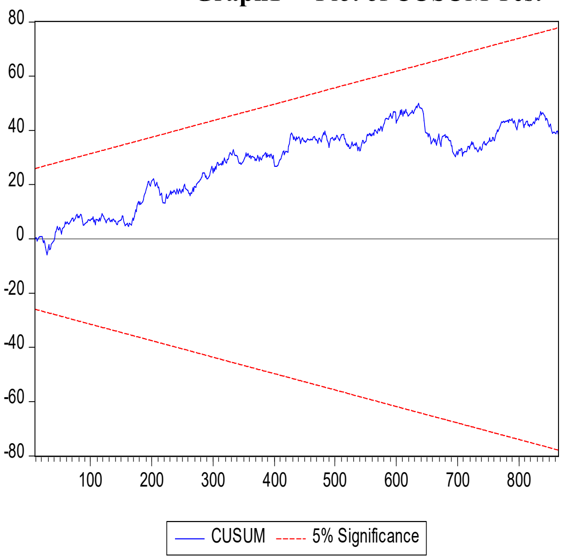
Table 9 Results of of model validation tests

	Statistic	Probability
Breusch-Godfrey Serial Correlation LM Test:	2.789	0.0625
Heteroskedasticity Test: White	1.1595	0.1616
Jacque-Bera	5.3529	0.0688

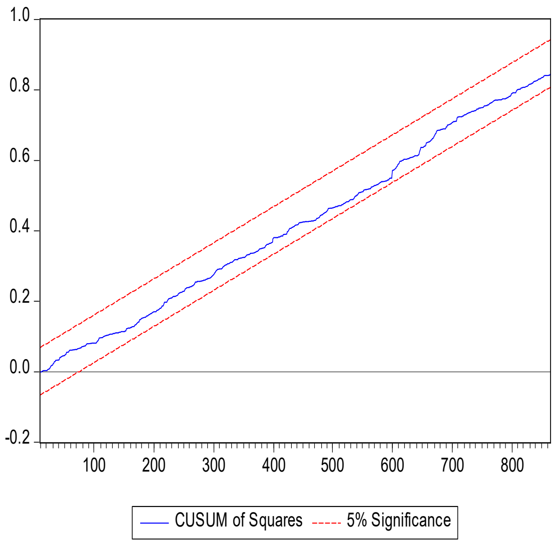
The ECM term of the model is presented in Table8 which is negative and significant. The negative sign implies that any disequilibrium in the short run will be converging to the long run equilibrium (ECM = 0.6184). So there is approximately 61.84% of cases of disequilibrium from the previous year's shock converge back to the long run equilibrium in the current year.

Figure2 Plot of CUSUM Test and CUSUMSQ for equation (11)

Graph1 Plot of CUSUM Test



Graph2 Plot of CUSUMSQ



Further to test the health of our estimation model we pass our model through various statistical tests. In order to find out if our regression, the null hypotheses of correct function form, normal distribution of error, homoscedastic error and, no serial correlation are accepted. In addition, we test the stability of the model by using

Brown *et al.* (1975) stability test as suggested by Pesaran *et al.* (2001). The regression for the ARDL equation (11) fits very well and the model is globally significant at 5% level see Table9. It also passes all the diagnostic tests against serial correlation (Breusch-Godfrey test), Heteroskedasticity (White Heteroskedasticity Test), and normality of errors (Jarque-Bera test).

The stability of the long-run coefficient is tested by the short-run dynamics. Once the ECM model given by equation (11) has been estimated, the cumulative sum of recursive residuals (CUSUM) and the CUSUM of square (CUSUMSQ) tests are applied to assess the parameter stability (Pesaran and Pesaran (1997)). Graphs1 and 2 (see Figure2) show the results for CUSUM and CUSUMSQ tests. The results indicate the absence of any instability of the coefficients because the plot of the CUSUM and CUSUMSQ statistic fall inside the critical bands of the 5% confidence interval of parameter stability.

Short Run Granger Causality Test

Table10 below shows the results of short run causal relationship between dependent and independent variables. In the short-run, the F-statistics on the explanatory variables suggest that at the 10% level or better there is unidirectional Granger causality between infrastructure index (roadways, railways and airways) and economic growth in Africa and between the cost of replacement of human resources and GDP; and from stock of human capital to GDP; Chinese private capital to public capital. There is a bidirectional Granger causality running from Private Chinese Capital and public capital to GDP.

Table10 Results of short run Granger causality

Dependent variable	F-statistics					
	ln(GDP/….	**ln(IndexInf)**	**ln(KPUB)**	**ln(K_{CIIP})**	**ln(SCHOOL_.....)**	**Direction of Causality**
ln(GDP/LABOR)	-	2.12*	1.60*	16.51***	5.46*	Index Inf→GDP ; KCIIP →GDP ; **KPUB**→GDP ; SCHOOL →GDP ;
ln(IndexIn)	0.19	-	1.1864	1.48	0.3059	
ln(KPUB)	4.16***	1.18	-	4.27***	2.38*	GDP → ln(KPUB/GDP) KCIIP → ln(KPUB/GDP) SCHOOL → ln(KPUB/GDP)
(K_{CIIP})	2.572**	1.48	1.68	-	0.4304	KCIIP → GDP;
ln(SCHOOL_ENROLLMENT)	1.011	0.305	1.3038	0.6868	-	

Moreover, there is a significant relationship between private Chinese capital and infrastructure, between private Chinese capital and economic growth in Africa. We also note that there is a significant relationship between infrastructure and economic growth in Africa with for example one unit of increasing of infrastructure leads to an increase of 2.1 percent of GDP. Thus, as follow, one unit of increase of private Chinese capital leads to an increase of 1.5 percent of infrastructure.

Furthermore, there is a significant relationship between human capital and economic growth in Africa. Human capital theorists are of the opinion that improving on social infrastructure, particularly educational facilities improve on the knowledge and skill stock of the population whose benefit to the society eventually exceeds the private benefit. As Lucas (1988) argues that human is an alternative to technological process to improve economic growth in a country. Education is essential to promote better utilization of physical infrastructure and human resources, thereby leading to higher economic growth and improving quality of life (Hall and Jones, 1999). The result confirms that there is a unidirectional relationship between school enrollment and GDP.

6- Concluding remarks and policy implications

In this study, the causal relationship between economic development and infrastructure, Chinese private capital, public capital and human capital has been examined using unit root test, cointegration and Granger causality over the panel data for African countries from the period 2000 to 2015. To bring out the results, the ARDL with ECM model is used to analyze the data. The sign of ECM is negative and significant and conducts to the assumption of return to equilibrium if economy faced a shock.

First in all we used an aggregate of infrastructure to proxy the three main infrastructure stock retained in our study using the principal component analysis (PCA). For testing the causal relationship among the variable, the panel unit root (Table2 and Table3) and panel cointegration (Table5) are performed. Results show that the series has unit root at level, the null hypothesis cannot be reject mean that the series is non-stationary. At the level1, the series has not unit root; null hypothesis is rejected. In this case cointegration test needs to be testing and result it is clear that there is a long run relationship among the variables with its F-statistic (48.61) higher than the upper-bound critical value (4.15) at the 5 percent level.

Moreover, the coefficients of long run elasticity are significant for all the variables with an expected sign (Table7). Result also indicates that there is a short run relationship among the variables (Table8). There is a bidirectional relationship between Private Chinese capital, public capital and economic growth in Africa. The results also assume that there are a unidirectional relationship between index of infrastructure and GDP; private Chinese capital investment and public capital; school enrollment and GDP and between school enrollment and public capital.

To assert that better access of logistics infrastructure (roads, rails and air-transport) has a significant effect on the growth of per capital income; government should improve the quality and quantity of infrastructure which is critical for the regional and international intensification of trade, structural transformation and sustainable economic growth.

The improvement of investment of physical capital and human capital generate significant increase in the growth rate of GDP per capita in Africa; hence the necessity of policy maker to improve the infrastructure services in terms of quality and price. These intangible dimensions of infrastructure could be improved only through effective regulation at both national and regional levels.

In definitively, it will be worthwhile for the African government and policymakers to implement policies geared towards the development of infrastructure. This would result in increasing economic efficiency, productivity and also attract potential FDI inflow into the African continent

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Appendix1 Gross Fixed Capital Formation for some major region

	1960	1970	1980	1990	2000	2005	2010	2015
High Income	23.2	25.3	25.3	24.1.	23.1	22.3	20.7	20.9
Low and Middle Income	--	21.0	25.3	23.1	23.8	27.1	29.9	29.4
Low Income	--	--	--	17.1	17.5	19.4	22.6	26.0
Sub-Saharan Africa	--	--	--	16.2	15	15.3	19.8	20.3
Sub-Asia	12.7	13.8	22.7	22.7	22.3	28.5	30.7	27.6
Euro area	--	27.0	25.2	24.0	22.8.	22.0	20.7	19.6
North America	22.0	21.2	23.5	21.3	22.7	22.7	18.5	20.2
Middle East and North Africa(excluding high income)	--	27.3	32.3	24.7	22.2	23.1	25.7	---

Source from World Bank Indicator (2016)

Appendix2 African Gross fixed capital formation

Country Name	1997	2000	2005	2010	2014	2015
Algeria	22.95159	20.67661	22.37032	36.28319	36.68579	..
Angola	25.55985	12.75503	36.39284	14.43259	15.34002	10.34062
Benin	17.22596	24.55172	19.7411	23.29529	24.43285	26.00934
Burkina Faso	24.22602	21.17812	19.68779	24.5018	31.95251	31.19662
Cabo Verde	..	..	..	45.19421	..	..
Cameroon	14.33716	16.00221	17.67957	18.97368	20.51497	20.98139
Central African Republic	7.838584	11.0723	9.770292	14.26578	12.73841	11.41031
Chad	16.33064	20.94155	20.59184	33.62211	33.17319	27.96106
Burundi	6.096849	2.781138	22.37271	30.51985	27.81258	21.66025
Botswana	26.17335	25.14248	25.33981	33.61616	29.57618	29.5321
Comoros	13.37053	10.34171	10.3166	10.99743	20.37592	..
Congo, Rep.	21.59903	20.91167	19.72304	20.27095	41.00857	40.87291
Cote d'Ivoire	13.90484	10.27247	9.166938	12.31654	16.1216	16.09567
Congo, Dem. Rep.	2.5	14.41831	11.67535	18.91557	22.33197	16.14737
Djibouti	9.571729	8.79097	18.97744	..	..	..
Egypt, Arab Rep.	17.93907	18.93561	17.91205	19.21326	12.61198	13.73405
Equatorial Guinea	148.2947	125.4979	38.80482	63.60068	47.10515	54.64358
Ethiopia	..	..	..	..	37.99373	39.28981
Eritrea	31.28073	21.99676	20.33944	9.299206	..	..
Gambia, The	5.17517	4.562497	29.45945	18.37583	21.17108	..
Guinea	19.63335	19.59367	18.55461	10.56629	14.01644	13.20737
Guinea-Bissau	23.99925	4.375466	4.279829	6.481664	6.384617	..
Ghana	23.8355	23.09813	29.00214	24.65981	26.23981	23.61362
Gabon	30.1502	21.90206	19.78251	31.40719	35.6952	29.33862
Kenya	15.3879	16.70881	18.69911	20.3218	22.92693	21.51847
Lesotho	61.96626	41.06051	21.11719	27.55689	..	..
Libya	11.90897	11.63657	15.16795	..	..	..
Liberia	..	7.499991	19.45455	19.45454	19.4932	19.97077
Malawi	9.315435	12.3221	15.20796	21.01531	12.01272	12.78605
Mauritania	15.13975	16.21112	58.95761	36.54842	42.92976	..
Mauritius	25.78257	22.94053	21.4359	24.86747	19.15677	17.67029
Mali	22.1121	17.66767	20.24107	20.77445	16.85737	16.68275
Madagascar	12.81397	15.04496	22.19498	20.7749	14.87609	14.81185
Morocco	22.75863	26.97292	28.48692	30.65621	29.42292	..
Niger	10.58103	11.19994	21.41406	38.89546	37.736	38.75877
Namibia	17.54417	16.58277	18.61316	25.28354	32.84562	33.41946
Mozambique	15.39175	22.06102	13.20906	17.86314	42.52038	38.12394
Nigeria	8.356764	7.017881	5.458996	16.5552	15.08125	..
Rwanda	13.80978	13.37598	15.76389	22.50978	25.26413	25.69813
Sao Tome and Principe	..	..	..	..	..	..
Senegal	19.49379	22.39466	23.32771	22.19276	26.39444	27.02714
Seychelles	28.05344	25.17861	..	36.62537	37.3187	33.72809
Somalia	..	..	..	..	7.850009	8.046363
South Sudan	..	..	..	10.28966	10.36144	11.23023
South Africa	17.5557	15.61612	17.24644	19.26599	20.25853	20.04807
Sierra Leone	-2.42436	1.09681	11.4568	30.26292	12.18039	13.3048
Sudan	8.974589	18.56907	23.13625	20.09096	17.28977	17.88149
Tanzania	14.72108	16.35467	25.15302	28.68008	32.65745	31.26144
Swaziland	16.53614	18.11677	15.03925	14.12014	..	..
Tunisia	23.67173	25.16673	21.33052	24.65096	19.56333	..
Togo	12.97279	14.46376	15.82593	18.0243	23.76095	21.32935
Zambia	..	..	..	25.89515	..	..
Zimbabwe	18.04965	11.79798	2.000441	21.74123	13.1957	13.19713
Uganda	16.89416	19.23396	22.20172	25.23988	26.99832	24.91128

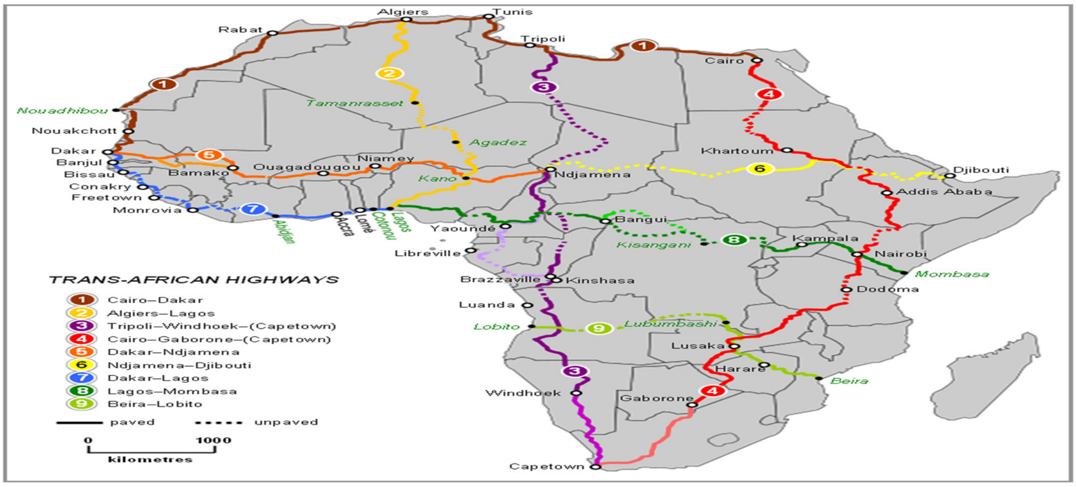
Source from World Development Indicator (2016)

Appendix3 Regional distribution of road networks

Region	Length (km)		Density (km/100km2)
	2015	%	
Southern Region	1.018.284	34.6	3.4
East Africa	585.916	19.91	1.9
North Africa	435.791	14.81	1.5
West Africa	568.735	19.33	1.9
Center Africa	333.453	11.35	1.2
Total	2.942.179	100%	9.9

Sources author's calculation (data from World Bank 2015) and https://en.wikipedia.org/wiki/List_of_countries_by_road_network_size

African road network



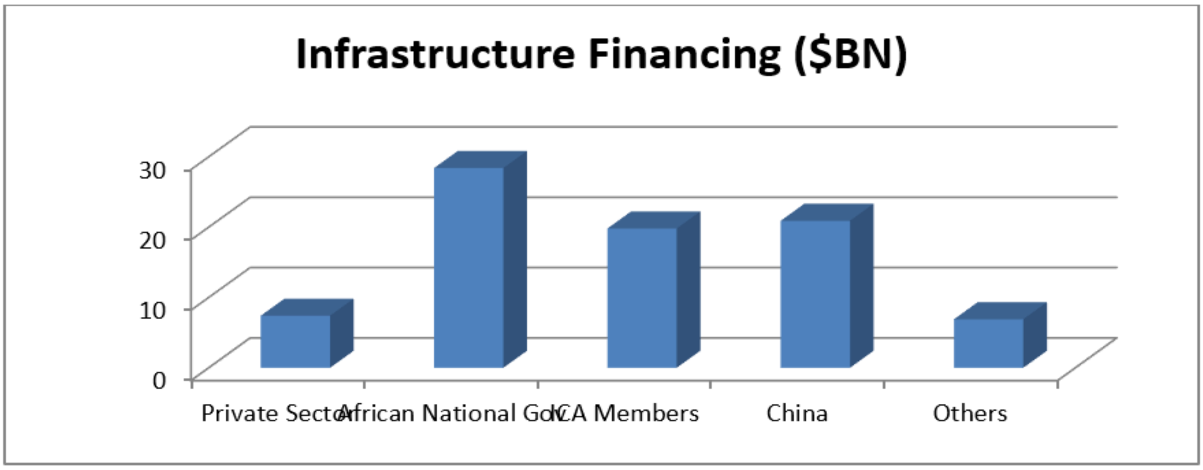
Source https://upload.wikimedia.org/wikipedia/commons/0/03/Map_of_Trans-African_Highways.PNG

Appendix 4 Regional distribution of Railways networks and comparative densities

Region	Total network (km)	Density(km/1000km2)
Southern Africa	34572.6	1.17
East Africa	12568	0.42
North Africa	19061	0.64
West Africa	10846	0.37
Center Africa	9349	0.31
Total of Africa	86.396.6	2.9

Source author's calculation (data from World Bank 2015) andhttps://en.wikipedia.org/wiki/List_of_countries_by_rail_transport_network_size

Appendix 5 Infrastructure Financing in Africa



Source Data from Africa Infrastructure Country Diagnostic, 2015