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Financial development and human capital thresholds for the infrastructure development-industrialization nexus in Africa

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Financial development and human capital thresholds for the infrastructure development-industrialization nexus in Africa

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Abstract

Examining the value-added link between infrastructure and industrialization is fundamental to achieving Sustainable Development Goal (SDG) 9, which consists of building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation. The objectives of this paper are to analyse the effect of infrastructures on industrialisation and how financial development and human capital modulate this effect in 33 African countries during the period 2003-2019 through the system GMM methodology. The results show that infrastructural development has a direct enhancing effect on industrialisation in Africa. When the indirect effect regressions through the modulating effects of financial development and human capital are considered, the net effects are equally positive though the results vary across the different specifications of infrastructure and the specific transmission channel considered. For instance, the indirect effect through the interaction of electricity and transport infrastructures with financial development and human capital produced a negative net effect. The thresholds of financial development and human capital required to nullify these negative effects are provided and practical policy implications are discussed.

Keywords: infrastructures, industrialization, financial development, human capital

JEL Code: H54, L60, O55

I. Introduction

The delay observed in the development process of African economies compared to economies belonging to other regions of the world can be explained by four major paradigms that have marked the history of these developing economies. The first paradigm is revealed by the seminal work of Chenery and Strout (1966) who posit the urgent need of a significant level of investment through capital accumulation which can only be achieve via official development assistance. The second is based on the work of Mckinnon and Shaw (1973) who believe that State intervention constrains private sector development. The authors advocate for financial liberalization and the complete opening of African economies to trade. The third was revealed in the work of Burnside and Dollar (2000) which is a condition for the success of the ideas of the first paradigm. They argue that aid is useful and will likely leads to good results if accompanied with good economic policies. Unlike the first three, the fourth paradigm was not developed on the basis of research work but rather as a plan by the United Nations Congress in 2000. This last paradigm gave birth to the millennium declaration of 20001 that has continued since 2015 as the sustainable development goal. One of the main objectives of these goals is to end poverty through sustainable economic growth. Given that slow economic growth, uncontrolled migration, climate change, and global unemployment are some of the world's major economic problems that will only be solved through Africa's economic prosperity industrial development driven by infrastructure would alleviate the suffering of the people by reducing poverty (Malick, 2017).

Industrialization is a process of structural change which consists of moving from a primary production structure (production of primary goods) to an industrial production structure (Hughes, 1984 and Griffin, 1989). Aid flowing from northern countries favoured the creation of industries in developing countries, which allowed some to integrate into a highly competitive international market in the early 1980s. It was in the light that some African countries like Kenya and Côte d'Ivoire registered a significant share of manufactured products in total exports of 60.8% and 33.6%respectively, during the period 1973-1981.

Unfortunately, with a few exceptions, industrialization strategies were unsuccessful in Africa (Griffin, 1989). The author posit that the causes of this failure can be endogenous or exogenous. Among the main endogenous causes, he further highlights the excessive interference of the State in the economic life of countries, poorly designed investment projects and overprotection of infant industries. As for the exogenous causes the study evokes

the reduction in export earnings and the stagnation of production caused by a disadvantageous environment.

Progress in the manufacturing sector is meaningless without structural change through appropriate infrastructure financing. In terms of definition, infrastructure financing could be defined as an investment in key sectors of the economy through access to electricity, water network, gas, transport and an appropriate telecommunications system, as well as real estate, which has the capacity to improve the quality of life, provide reasonable jobs and reasonably affect the education system, while bridging the gap between rural and urban differentials (World Bank, 2010). One of the key factors preventing Africa from realizing its potential for economic growth and achieving its development goals, including poverty reduction, is the infrastructure deficit. To this end, a majority of the rural population which represents 60% of the population of the continent generally does not have access to modern infrastructure services of transport, distribution of electrical energy, communication, and sanitation as indicated by African Union (2009) and Nchofoung et al. (2022).

In the electricity sector, the World Bank (2017) reveals that the region's electricity capacity fluctuates around 0.04 megawatts per 1000 inhabitants. It is less than a third of that of South Asia and less than a tenth of that of Latin America and the Caribbean. There are variations across countries, with little progress in per capita power generation capacity in low-income and lower-middle-income countries, with more than double capacity among upper-middle income countries. Energy consumption per capita in sub-Saharan Africa (excluding South Africa) is 180 kWh, compared to 13,000 kWh per capita in the United States and 6,500 kWh in Europe. In addition, the African Development Bank (2018a) estimates that electricity costs three times more in Africa than in other developing regions, hence, most industrialists operating in West and East Africa rely on expensive back-up generators as the main source of energy, which negatively impacts their profit margins.

Also, a weak transport network hinders the production capacity of manufacturers to take advantage of regional economies of scale. According to the AfDB (2012), less than a third of the African population has access to an all-season road. Besides, the density of the road network in SSA decreased from 0.11 to 0.09 km per km2 from 1990 to 2011 (AfDB, 2018a). This poor performance makes SSA the only region where road density has decreased during this period compared to other benchmark regions of the world. Likewise, according to the aforementioned study, the recorded rail network density is also very low, with less than 0.002 km per km2 in 2014.Thus, this region recorded a low density of road and rail networks

compared to other reference regions (East Asia and the Pacific, South Asia, Latin America and the Caribbean, and the Middle East and North Africa) between 1990 and 2014 a reference is needed hear because this is a statement of fact.

Regarding the telecommunications sector, its density has increased dramatically in SSA over the past 25 years. The median number of fixed and mobile telephone lines per 1000 inhabitants increased rapidly, from 3 in 1990 to 736 in 2014. In addition, the density of the Internet network, measured as the number of Internet users per 100 inhabitants, was 16.7 in SSA in 2015. This density has increased considerably over the last twenty years for all income groups. For example, the rate of internet users rose from 1.1% per 100 people in 2005 to nearly 11.4 in 2015 in low-income countries and from 7.5% to 50.1% in upper middle-income countries during the same period. A similar trend is observed in other reference regions around the world (East Asia and the Pacific, South Asia, Latin America and the Caribbean, and the Middle East and North Africa). A comparison of telecommunication density in different regions reveals that, despite this surge, SSA is lagging behind other regions (African Development Bank, 2018a).

Thus, this infrastructural deficit poses a serious challenge to industrialization, as industries can only survive in an economy with good infrastructure (Kuete and Asongu, 2021). The insufficient stock of productive infrastructure in transport, telecommunications, water and electricity services is one of the main factors delaying industrialization in sub-Saharan Africa. Closing this deficit would allow companies to prosper in sectors with strong comparative advantages (AfDB, 2018a) and permits Africa to solve its major economic and socio-political problems and to become a major contributor to global demand.

Financial development plays an important role not only in the realization of projects, but also as concern economic prosperity. According to Levine (2005), financial development is a key factor in economic performance. As Levine (2005), Ndikumana (2003) believes that the development of the financial sector contributes to a better allocation of financial resources through the channelling of savings towards productive investment projects without substantial risk of asymmetric information. Conversely, an underdeveloped financial sector is an obstacle to economic development. In view of its importance, financial development could present itself as a mediator between the development of infrastructures and the structural transformation of an economy.

Considering that investing in the construction of the various infrastructures and their maintenance requires a skilled workforce, it is important for policy makers who wish to build

sustainable infrastructures to integrate human capital if poverty must be eradicated. Indeed, Romer's (1990) model incorporate increasing returns by assuming that capital stock has a significant positive effect on output at the industry level. The capital stock considered by Romer (1990) encompasses knowledge and spills over to other firms in the economy, hence industrial development may depend on the rate of investment in knowledge and infrastructure. For example, Anyanwu (2018) in his empirical assessment of the role of human capital in the development of manufacturing value added in Africa indicated that higher education is a driver of the development of manufacturing value added in Africa. At the same time, Francisco and Tanaka (2019) argue that good infrastructures are essential for human capital development. Health infrastructures would improve the health outcome of a population and educational infrastructures on their part will enhance educational quality. At the same time, Squicciarini and Voigtländer (2015) argue that human capital is the main brain for rapid industrial development, as most industrial positions require skilled labour.

In the African context, most of the existing literature focused on the growth effects of infrastructure and the role of infrastructure in manufacturing value added (MVA) has hardly been taken into account. This lacuna will be cover by this study. Examining the value-added link between infrastructure and industrialization is fundamental to achieving Sustainable Development Goal (SDG) 9, which consists of building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation. In addition, Agenda 2063 and the Continental Free Trade Area offer a powerful vision to open up the African region and transform its economy for the betterment of their citizens. In particular the latter, this aims to create a single continental market for goods and services, with the free movement of businessmen and investments. The objectives of this paper are thus to examine the effect of infrastructural development on industrialisation in Africa and how financial development and industrialisation modulate this relationship. The results of the analyses show that infrastructures matter for industrialisation and that a sufficient level of financial development and human development are required for this effect to be effective. Besides, the African Union Commission, the NEPAD Planning and Coordinating Agency and the African Development Bank have put in place financial instruments to address the infrastructure gap on the continent. In addition, the G20 Infrastructure Action Plan, the Consortium for Infrastructure in Africa, the EU-Africa Infrastructure Trust Fund and the Diagnosis of National Infrastructure in Africa all underscore the need for regional infrastructure to boost the growth of Africa.

The contribution of the study is multifaceted. Firstly, past studies on the subject have focus on direct effects. The closest study to this effect is that of Kuete and Asongu (2021), but this study differs from the aforementioned study in that, they focused on natural resources as a modulating mechanism, whereas this study focus on the modulating roles of financial development and human capital. This is particularly imperative given the importance of a developed financial sector in the financing of industrial projects and the undisputable role of human capital for industrial development. Secondly, the paper of Kuete and Asongu (2021) was limited to non-dynamic panels. This study extends the previous study by integrating dynamism of industrialisation in our model which takes into account the importance of initial economic conditions in the industrialisation process. Thirdly, policy thresholds are provided for each modulating variable for complementary policy orientations.

The rest of the paper is organized as follows. Section two provides a review of the literature. Section three describes the data and the methodology used. Section four gives the results and policy implications while section five concludes.

II. Review of related literature

This section is organized around two subsections: the first is furnished with the theoretical foundations of the relationship between infrastructure and industrialization while the second section refers to the empirical evidence between the two variables.

II.1 Theoretical foundations of the relationship between infrastructure and industrialisation

Theoretically, the availability of an adequate and efficient infrastructure not only improves the quality of life of populations but also promotes rapid industrialization. Developing infrastructure in Africa is essential to foster economic growth and improve the standard of living of Africans. It contributes significantly to human development, poverty reduction and the achievement of sustainable development goals (African Development Bank, 2018b). Development economists have viewed physical infrastructure as a prerequisite for industrialization and economic development, where physical infrastructure, in general, consists of two parts as follows: economic infrastructure such as telecommunications, roads, irrigation and electricity, and social infrastructure such as water supply, sewage systems, hospitals and schools (Murphy et al., 1989). Thus, infrastructure and industrialization go hand in hand in the quest for sustainable development in any economy (Umofia et al., 2018).

Erenberg (1993) asserts that national and multinational companies will operate less efficiently, and below their optimal level, if public infrastructure is not extended to them, as they would have to bear an additional cost of building their own, this will lead to the duplication and waste of the scarce resources. In the production process, infrastructure facilities are considered intermediate inputs although they are outputs of their own industry. Their availability in adequate quantity and quality reduces the cost of inputs and increases profitability thus allowing a higher level of production for industries.

Several works on the theory of endogenous growth (Romer, 1986; Lucas, 1988; Barro, 1990) have shown the catalytic role that infrastructures can play on economic growth. According to Eustace and Fay (2007), good infrastructure stimulates economic growth and, conversely, growth promotes increased demand for infrastructure. For example, the transport system facilitates the movement of people and the movement of goods in order to promote trade and production. Likewise, communication systems make it possible to move knowledge and finance across borders for production and trade. As for energy, it is necessary for the production and transport of goods from the points of production to the points of sale.

The existence of efficient transport and trade infrastructure networks has the effect of amplifying trade in the integrated space. The resulting drop in transport costs results in an expansion of the market and the volume of transactions in accordance with the predictions of gravity models (Krugman, 1980). The resulting externalities will provide companies with non-price gains. This dynamic creates centrifugal forces, leading to diffusion effects resulting from positive externalities linked to the reduction of transport costs between territories. This upheaval of the productive system, supported by high demand, induced by a varied range of locally produced products, widens the market and encourages the expansion of inter-regional trade. It creates an effect of attracting companies fascinated by sustainable profits. On the other hand, infrastructures promoting inter-regional trade give rise to centripetal forces to amplify the gaps linked to differences in capital intensity (Abdo, 2014).Adapted infrastructures thus represent the starting point for the success of regionalization. They neutralize the limitations imposed by poor economic geography, stimulate the factors of mobility in the growth cycle, attract efficient agents and facilitate competition between territories through inter-regional exchanges.

Theoretically, the development of infrastructure in Africa can affect industrialization through a number of channels and mechanisms. For example, there are several mechanisms through which diffusion of ICT impacts industrialization. The first is the channel of creating new

firms. ICT diffusion is always correlated with the emergence of new businesses, in particular in manufacturing and services (Zhou et al., 2019). Start-ups are lunched, generally in the production of useful technologies (using computers and internet). With the introduction of ICT, new services can be offered in the primary sector and affect industrialization via their impact on employment. Beyond efforts to help African manufacturers to better access digital inputs, African Governments can also use digital technologies to enhance public administration's support for industrialization. Digitization can help enhance the efficiency and productivity of services associated with manufacturing (Oulton, 2002), including customs administration, general logistics, etc, thereby enhancing industrial development. In particular, digitization of customs administration can help improve customs efficiency, reduce trade costs and thus promote greater intra-African trade (particularly in the context of the African Continental Free Trade Area (AfCFTA)), which, in turn, would support greater industrial development on the continent. There are a number of digital innovations in customs administration and related trade barriers that can reduce trade costs, including costs of customs clearance and trade document preparation (United Nations, 2017). One such innovation is electronic single windows, which have proven to be a cost-effective intervention to reduce trade costs in Africa as indicated by African Alliance for Electronic Commerce, (2013).

II.2 Empirical evidence for the relationship between infrastructures and industrialization

Empirically, several studies have established the link between infrastructure and industrialization.

Regarding information and communication technologies, Abri and Mohamoudzadeh (2005) found that ICT and industrial productivity were positively correlated. However, the study of Yazdan and Hossein (2013) reveals that ICTs have had an insignificant effect on productivity growth in Middle Eastern countries. The work of Steenkamp and Rooney (2017) reveals that ICT infrastructure has a positive and significant effect on manufacturing output in the case of middle-income countries. This result was found by Anyanwu (2017) in the case of the countries of North Africa. Njagang and Nounamo (2020) examined how information and communication technologies affect the industrialization process in 46 African countries over the period 2000-2015. Two indicators of information and communication technologies (composed of internet and mobile phone penetration), and two industrialization indicators

(involving added manufacturing value and employment in industry) were used. Using Generalized Moments (GMM) methods, the results show that ICTs have a positive and significant effect on the industrialization of African countries.

With regard to energy infrastructure and transport, Canning (1999) finds in a sample of 10 or 20, please you need a number for it to make sense countries that electricity and transport have almost the same marginal impact on manufacturing productivity measured as total capital. In a related study, Hulten and Isaksson (2007) regressed total factor productivity levels on power generation capacity for 112 countries from 1970 to 2000. Countries were divided into five groups according to their income classification by the World Bank. The results revealed that energy infrastructure was positive and significantly related to total factor productivity. The overall result suggests that investment in infrastructure can drive industrialization to the desired level in developing countries. However, Abokyi et al. (2018) conclude that electricity consumption has a negative effect on manufacturing production in Ghana. They justify these results by considering that although electricity supply in Ghana may improve, the share of industrial sector consumption, on average, has steadily plunged.

Other authors used more than two indicators as infrastructure proxies in their study. These are Rietveld et al. (1994), Sahoo et al. (2010) and Azolibe and Okonkwo (2020). Rietveld, Kameo et al. (1994) examined the impact of roads, telecommunications and electricity on the development of manufacturing industries and found a positive and significant impact of infrastructure on the productivity of the manufacturing sector. As for Sahoo et al. (2010), they studied the effect of electricity, energy, telephone, roads, railways and ports on manufacturing output and found that public infrastructure has a positive and significant effect on the growth of manufacturing productivity. Unlike previous authors, the work of Azolibe and Okonkwo (2020) stands out as it takes into account the development index of infrastructure, energy, roads, transport and information and communication technologies in their analysis. To this end, the authors analysed the impact of infrastructure development on industrialization in sub-Saharan Africa during the period 2003-2018.The result of the study indicates that the main factor influencing the productivity of the industrial sector in sub-Saharan Africa is the quantity and quality of telecommunications infrastructure. The analysis shows that the relatively low level of productivity of the industrial sector in sub-Saharan Africa is largely due to the poor quality of their electricity and transport infrastructure; and the underutilization of water supply and sanitation infrastructure. Nnyanzi et al (2022) analyzed the effect of infrastructure on industrialization through trade liberalization and governance in sub-Saharan Africa during the period 2003-2018. Using the PSCE and FGLS

methodology, the authors found that governance and trade liberalization are channels through which infrastructure development impacts industrialization.

Overall, although the central role of infrastructure development in accelerating the performance of the manufacturing sector has been recognized in the literature, some findings suggest that infrastructure has a negative impact on industrialization. It emerges from this literature that the link between infrastructure and industrialization on panel samples in Africa is remarkably poorly provided. Moreover, most of the studies use for the most part, a single index of infrastructure, which does not allow us to appreciate the effect of other disaggregated indices of infrastructure on industrialization. Moreover, none of these studies attempted to analyse an indirect relationship between infrastructure and industrialization through human capital and financial development. The aim of this study is to fill these gaps in the literature relating to the analysis of the effect of infrastructure development on industrialization.

The ability of African countries to create a competitive industrial sector and promote closer industrial linkages is hampered by poor infrastructure (energy, transport, communication, etc.), resulting in higher transaction and production costs. It is therefore imperative to step up investment in infrastructure, including energy. To this end, financial development is a lever through which the various governments can rely to strengthen these investments in order to improve the competitiveness of the industrial sector. In addition, to hope for a long-term effect of infrastructures on industrialization, it would be necessary to highlight human capital capable of maintaining these infrastructures. If, as economists agree, financial development and human capital are among the critical factors explaining the divergence in performance among developing countries, particularly in the industrial sector, it is essential to determine their role in the link between the infrastructure development and industrialization

Therefore, the relationship between infrastructure development and industrialization is given by Figure 1.

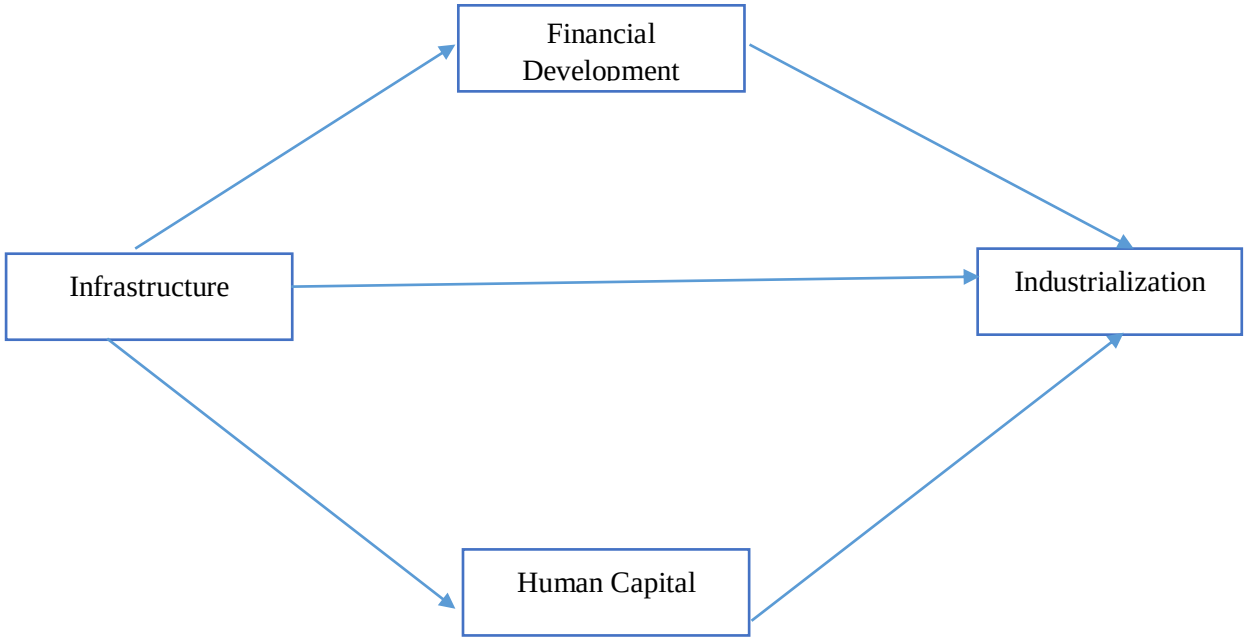


Figure 1: The Relation Between Infrastructure and Industrialization

Source: Authors

III. Econometric Strategy

The following empirical model is adopted based on the works of Gui-Diby and Renard (2015) and Nkoa (2016)

$$INDU_{it} = \beta_0 + \beta_1 INFRA_{it} + \beta_j X_{it} + \varepsilon_{it} \qquad (1)$$

Where INDU is industrialization at time, t for country, i, INFRA is the measure of infrastructures, X is a vector of control variables including economic growth (GDPK), foreign direct investment (FDI) trade openness (trade), human capital (HC), financial development through the size of the financial sector (M2) and through domestic credit accorded to the private sector (domestic_credit), and rule of law in the economy (rule_law). β is the coefficient associated to the explanatory variables and ε is the error term.

III.1 Justification of choices of variables

The dependent variable of the study is industrialization. In this study, this is proxy by manufacturing value added (MVA) and Industrial value added per capita (IVAK). Studies that used similar measures include Gui-Diby and Renard (2015), Nkoa (2016), and Njangang and Nounamo (2020).

The independent variable of interest in this study is infrastructural development. Based on the studies of Kengdo et al. (2020) and Nchofoung et al. (2021), infrastructural development is proxy by the African infrastructural development index (AIDI). This is a composite index of infrastructure that encompasses the transport composite index (Transport), the electricity composite index (Electricity), the information and communication technology composite index (ICT) and the water and sanitation composite index (WSS). Kuete and Asongu (2021) argued that infrastructural development is of importance for structural transformation in Africa. A positive sign is thus expected on this variable.

The control variables used in this study are: financial development proxy by the size of the financial sector [broad money (M2)] and the ability to accord credit to private sectors domestically (domestic_credit). Other control variables are foreign direct investment inflows (FDI), trade openness (trade), economic growth (GDPK), rule of law (rule_law), and human capital(HC) are also used.

Gui-Diby and Renard (2015) argued that FDI inflows did not have a significant effect on industrialisation in Africa. Rather, trade openness, market size (GDP) and financial development explain industrial development in these countries. In this respect, they argue that import trade, economic growth and financial sector development boost industrialisation. Nkoa (2016) on his part argue that industrialisation through value added is boosted by FDI. From this literature, FDI, trade, Domestic_credit, GDPK and M2 are expected to have positive signs in this study.

Also, Totouom et al. (2019) aggregating institutions as a composite index posit that institutional quality has a positive effect on industrialisation in Sub-Saharan Africa. Besides, Samouel and Aram (2016) argued that governance and human capita enhance industrialisation in Africa. Similar results are expected in this study. Human capital and rule of law are expected to have positive signs in this study.

From (1) there could exist an indirect effect through financial development and human capital such that

$$INDU_{it} = \beta_0 + \beta_1 INFRA_{it} + \beta_2 domestic\_credit_{it} + \beta_3 HC_{it} + \beta_j X_{it} + \alpha_1 (INT_{it} \text{ x } INFRA_{it}) + \mu_{it} \qquad (2)$$

Here, α is the coefficient of the indirect effect while β is the coefficient of the direct effect and INT is the modulating variable that takes financial development at first place and human capital at second place. The rest of the variables are as defined above. The interactive regressions could yield a net effect depending on the significance and sign of the direct and

interactive coefficients. Based on attendant literature on interactive regressions (Nchofoung and Asongu, 2022 a, b), the net effect is computed as in (3).

$$Net\ effet = (\alpha_1 * \overline{INT}) + \beta_1 \qquad (3)$$

Where, $\overline{INT}$ is the average of the modulating variable considered and is apparent in the summary statistics table. In such a case, the threshold for the modulating variable is computed by equating the partial derivative of (2) with respect to infrastructures to zero and solving for the modulating variable.

$$\frac{\partial CO2}{\partial INFRA_{it}} = 0 \qquad (4)$$

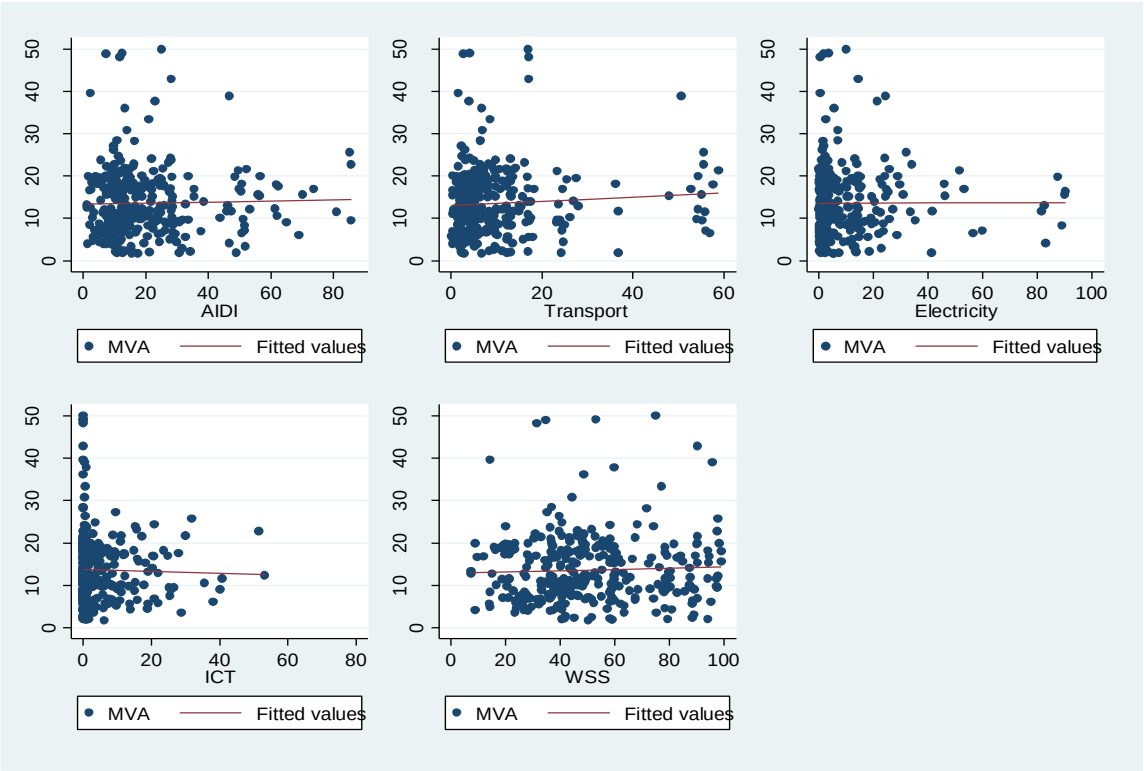
This simply yields the coefficient of the direct effect to that of the indirect effect.

III.2 Data

The infrastructure variables, were obtained from the African Development Bank data base, while the rule of law variable was taken from the Worldwide Governance indicators of the World Bank and the rest of the variables were obtained from the World Development indicators. . The data span from 2003-2019 for 33 African countries[1] mostly based on the availability of data on the variables retained. The summary statistics, the correlation of the variables and their detailed definitions are found in appendices 1, 2 and 3 respectively. Figure 2 presents the two-way fitted scatter plot between infrastructural developments in Africa.

Figure 2 scatter plot

[1]Algeria, Angola, Botswana, Burkina Faso, Cameroon, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Morocco, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, South Africa, Sudan, Togo, Tunisia, Uganda, Zambia, Zimbabwe, Congo, Rep.



Source: Authors computation

The scatter plot in figure 2 shows a similar pattern of an apparent non-significant positive effect of infrastructural development on industrialisation. However, there is co-movement between economic variables both domestically as results of national policy and internally as a result of globalisation and economic integration. The actual relationship is thus worth examining in the presence of other economic control variables. Before the regression, a unit root test is carried out. In this regard, Im-Pesaran-Shin unit root is implemented and the results are presented in appendix 4. The results show that all the variables are stationary at level.

III.3 Estimation method

This study uses the system GMM estimation methodology. The rationale behind the choice of this method is Multiple Following Rodman (2009) the necessary condition for the application of the GMM methodology is that the number of cross-sections should be more than the time dimension. This is exactly the nature of our data as we are disposed of 33 countries and over 17 years. Also, the inclusion of the lagged dependent variable in our model could result in it correlating with the fixed effect in the error term (Nickell, 1981).

The main problem usually associated with this method is that of identification and instruments proliferations. To resolve these, we ensure that the number of instruments is less than the number of cross-sections. Moreover, we ensure that the Hansen and Sargan test of instruments validity are valid (i.e. their P-values are above 10%). Our analyses however focused on Hansen test than Sargan test because the latter is not robust and not weaken by so many instruments. Besides, based on contemporary literature (Asongu and Nwachukwu, 2016; Asongu and Leke, 2019; Nchofoung et al., 2021), all our explanatory variables are considered as potential sources of endogeneity. The second lags of the explanatory variables are used as instruments in both the level and difference equations.

The GMM methodology in level and difference is thus specified as follows

$$INDU_{it} = \beta_0 + \beta_1 INDU_{i(t-\tau)} + \beta_2 INFRA_{it} + \sum_{h=1}^{k} \delta_h W_{h,i(t-\tau)} + \upsilon_t + \gamma_i + \varepsilon_{it} \qquad (4)$$

$$\begin{aligned} INDU_{it} - INDU_{i(t-\tau)} &= \beta_1 \left(INDU_{i(t-\tau)} - INDU_{i(t-2\tau)}\right) + \beta_2 \left(INFRA_{it} - INFRA_{i(t-\tau)}\right) \\ &+ \sum_{h=1}^{k} \delta_h \left(W_{h,i(t-\tau)} - W_{h,i(t-2\tau)}\right) \left(\upsilon_t - \upsilon_{t-\tau}\right) + \varepsilon_{i(t-\tau)} \end{aligned} \qquad (5)$$

The variables are defined as above.

IV. Results and discussion

In this section, tables 1 and 2 present the direct effects while tables 3 and 4 present the indirect effect. Tables 1 and 2 show that infrastructural development have a positive and robust effect on industrialisation. The results present the presence of both first and second order autocorrelation of residuals. Moreover, the instruments employed are valid as both the Sargan and Hansen probabilities are in majority above 10%. Besides the number of instruments are in all cases less than the number of cross-sections.

Looking at other control variables, financial development captured by the size of the financial sector has a positive effect on industrialisation but the effect is rather negative when we consider the amount of domestic credits issued to the private sector. Moreover, human capital, rule of law, and foreign direct investment inflows has enhancing effects on industrialisation while economic growth and trade openness have deleterious effects. Increase in infrastructural development if properly used stimulates economic growth, ease trade transactions thereby stimulating industrial productivities. At the same time, investment in

some specific infrastructures (ICT or electricity for instance) requires qualified human capital for its proper use. Also, most industrial projects require financing for it proper kick-off. Africa is considered as one of the financially least development sub-regions around the club (Asongu and Nchofoung, 2021). Health and education infrastructures contribute in the enhancements of human capital require taking up industrial positions. In addition, telecommunications and road infrastructures are necessary for trade facilitation which in turn will boost industrial productivity. There is thus necessity to investigate the actual transmission channels through which infrastructures can stimulate industrial revolution in Africa.

Table 1. Direct effect of infrastructures on manufacturing value added

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Dependent variable: manufacturing value added				
L.mva	-0.0808	-0.169	-0.754	-0.251	-0.179
	(0.0756)	(0.0211)	(0.284)	(0.0840)	(0.111)
m2	0.0665**	-0.0545*	-0.208**	0.0587*	0.0645**
	(0.0283)	(0.0304)	(0.0843)	(0.0296)	(0.0286)
Fdi	0.0915***	0.0461***	0.304	0.0995***	0.0948***
	(0.0291)	(0.00883)	(0.267)	(0.0220)	(0.0207)
Trade	-0.00657	-0.00761	-0.116**	-0.00754	-0.00733
	(0.0112)	(0.00576)	(0.0510)	(0.00879)	(0.00945)
GDPK	-0.782	-1.830***	-8.622***	-3.002***	-2.774***
	(0.988)	(0.529)	(2.962)	(0.917)	(0.814)
rule_law	0.781	2.049***	-3.544	1.288	2.277**
	(0.736)	(0.518)	(2.837)	(1.355)	(1.033)
Hc	1.214	4.868***	18.71***	3.341	4.800**
	(1.633)	(0.759)	(4.820)	(2.336)	(1.989)
domestic_credit	-0.0458**	0.0159	-0.0610	-0.0181	-0.0430
	(0.0193)	(0.0136)	(0.0783)	(0.0322)	(0.0291)
Aidi	0.0764**				
	(0.0322)				
Transport		0.0903***			
		(0.0270)			
electricity			0.508***		
			(0.163)		
Ict				0.134	
				(0.107)	
wss					-0.0120
					(0.0260)
Constant	14.46**	20.78***	59.66***	30.14***	27.22***
	(5.572)	(3.785)	(16.72)	(8.598)	(8.028)
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	187	187	137	139	139
Number of countries	33	33	33	33	33
Prop>AR1	0.00548	0.00668	0.0758	0.0406	0.0572
Prop>AR2	0.137	0.0885	0.787	0.389	0.467
instruments	18	27	18	18	18
Prop>sargan	0.144	0.00277	0.838	0.697	0.700
Prop>hansen	0.294	0.494	0.350	0.856	0.843
F	9.433***	6643***	9.639***	25.32***	16.91***

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2. Direct effect of infrastructures on industrial value added

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Dependent variable: Industrial value added per capita				
L.IVAK	0.894***	0.892***	0.921***	0.930***	0.923***
	(0.0180)	(0.0172)	(0.0552)	(0.0569)	(0.0840)
m2	-0.000160	-0.000343	-0.000145	-0.000177	-0.000939*
	(0.000246)	(0.000230)	(0.000401)	(0.000280)	(0.000506)
Fdi	-0.000449	-0.000642	0.000495	0.000122	0.00104
	(0.000326)	(0.000512)	(0.000469)	(0.000639)	(0.00216)
Trade	-0.000375**	-0.000303**	-0.000287*	-0.000338*	-0.00111
	(0.000142)	(0.000131)	(0.000206)	(0.000182)	(0.000747)
GDPK	-0.0157***	-0.00130	0.00424	0.00764	0.00391
	(0.00534)	(0.00644)	(0.0121)	(0.00967)	(0.0142)
rule_law	0.00647	0.000674*	0.00417*	0.00881*	0.0564*
	(0.00793)	(0.00767)	(0.0135)	(0.0115)	(0.0295)
Hc	0.0255**	0.00936	-0.00334	-0.0108	-0.0306
	(0.0103)	(0.0119)	(0.0188)	(0.0167)	(0.0374)
domestic_credit	0.000159*	0.000149*	-9.76e-05*	-7.44e-05*	0.000983*
	(0.000206)	(0.000200)	(0.000404)	(0.000182)	(0.000503)
Aidi	0.000512***				
	(0.000181)				
transport		0.00129***			
		(0.000209)			
electricity			0.000198		
			(0.000582)		
Ict				-0.000698	
				(0.000454)	
Wss					0.00174**
					(0.000669)
Constant	1.048***	0.990***	0.744	0.665	0.773
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	414	414	412	414	414
Number of countries	33	33	33	33	33
Prop>AR1	0.0259	0.0253	0.0256	0.0201	0.0170
Prop>AR2	0.730	0.947	0.712	0.736	0.486
Instruments	27	26	18	18	18
Prop>sargan	0.436	0.349	0.441	0.578	0.631
Prop>hansen	0.468	0.586	0.271	0.357	0.404
Fisher	950.7***	1176***	150.9***	104.9***	69.85***

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Most industries in Africa are multinationals or own by western nationals. Most often than not, they bring in their nationals to head these firms. This has let the question of knowing if human capital or financing has been a problem for Africans to actually develop their industries. In what follows, we test the effectiveness of human capital and financial development in modulating the effect of infrastructures on industrialisation.

From table 3, financial development is interacted with infrastructures producing a negative direct effect and a positive indirect effect. The indirect effect overrides the direct effect producing a positive net effect. However, at a financial development threshold of 138.4615, this positive net effect is nullified. When alternative measures of infrastructures are used, a negative net effect is witnessed for the electricity composite index of infrastructure continue up to a financial development threshold of 131.0256, when this negative effect is nullified. On the other hand, ICT composite index produces a rather negative net effect when interacted with financial development, up to a financial development threshold of 27.13 when this effect becomes nullified. Kuete and Asongu (2021) argue that there is an indirect effect from infrastructures to industrialisation through natural resources. However, increase in the stock of infrastructures stimulates trade transactions leading to more use of financial institutions for both national and international transactions. More loans are given out to economic operators and enterprises to boost productivity and expansion of private business leading to increase in industrial output. The negative net effects of ICT infrastructures is consistent with the study of Nchofoung and Asongu (2022 a) who argue that ICT has a negative effect on sustainable development below a certain trade openness threshold. This shows that the infrastructures should be able to stimulate trade and consequently financial development for the desired effects to be felt within the economy.

Table 3. Indirect effect of infrastructures on industrialisation through financial development

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Dependent variable: Manufacturing value added				
L.mva	-0.0719	0.225***	-0.0904	0.357***	-0.105
	(0.0740)	(0.0242)	(0.0604)	(0.111)	(0.0952)
m2	0.0986**	-0.0328*	0.136***	-0.125**	0.0596
	(0.0380)	(0.0188)	(0.0468)	(0.0481)	(0.0401)
Fdi	0.144***	0.0576***	0.256***	0.0765	0.110***
	(0.0213)	(0.0128)	(0.0555)	(0.142)	(0.0204)
Trade	0.00488	0.000421	0.00249	-0.0974***	-0.00845
	(0.00846)	(0.00797)	(0.00962)	(0.0285)	(0.00921)
GDPK	-3.444**	-1.921***	-1.430	-3.249***	-2.138***
	(1.517)	(0.368)	(1.270)	(1.160)	(0.758)
rule_law	2.850**	1.055***	0.154	1.162	2.649**
	(1.162)	(0.368)	(1.004)	(1.815)	(0.972)
Hc	7.008***	5.043***	6.750***	18.42***	4.122*
	(1.671)	(0.670)	(1.745)	(3.314)	(2.121)
domestic_credit	-0.0562	0.00623	-0.118**	-0.0400	-0.0785
	(0.0448)	(0.0103)	(0.0461)	(0.0361)	(0.0724)
Aidi	-0.180***				
	(0.0621)				
domestic_credit*aidi	0.00130*				
	(0.000710)				
Transport		0.0206			
		(0.0375)			
domestic_credit*transport		0.000371			
		(0.000800)			
Electricity			-0.511***		
			(0.159)		
domestic_credit*electricity			0.00390***		
			(0.00126)		
Ict				-0.605***	
				(0.173)	
domestic_credit*ict				0.0223***	
				(0.00642)	
Wss					-0.0272
					(0.0461)
domestic_credit*wss					0.000549
					(0.000890)
Constant	26.49**	21.60***	12.03	20.05***	23.90***
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Net effect	0.01288	--	-0.41836	0.46921	----
threshold	138.4615	---	131.0256	27.13	--
Observations	187	139	137	187	139
Number of countries	33	33	33	33	33
Prop>AR1	0.0216	0.00780	0.00757	0.0344	0.0223
Prop>AR2	0.584	0.0923	0.591	0.143	0.359
Instruments	20	30	20	20	20
Prop>sargan	0.458	1.44e-05	0.882	0.872	0.391
Prop>hansen	0.579	0.317	0.699	0.588	0.750
Fisher	41.99***	216.2***	10.79***	18.13***	19.86***

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1; NB: in column 2, the value 0.01288=0.00130* 23.754 + (-0.180), where 23.754 is the average of financial development (modulating) variable presented in the summary statistics.

Table 4. Indirect effect of infrastructures on industrialisation through human capital

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Dependent variable: manufacturing value added				
L.mva	0.222*	-0.0674	-0.123	0.280**	-0.0205
	(0.117)	(0.0677)	(0.113)	(0.105)	(0.0714)
m2	0.0317	0.133***	0.0639**	-0.125**	0.104***
	(0.0750)	(0.0307)	(0.0308)	(0.0500)	(0.0241)
Fdi	0.300**	0.108***	0.121***	0.180**	0.0918**
	(0.146)	(0.0345)	(0.0292)	(0.0841)	(0.0346)
trade	-0.101**	-0.00902	-0.0113	-0.0701***	0.00144
	(0.0417)	(0.0107)	(0.00885)	(0.0211)	(0.0102)
GDPK	-4.001***	-1.514*	-2.148**	-2.555***	-0.310
	(0.872)	(0.773)	(1.029)	(0.912)	(0.940)
rule_law	1.958	1.611***	2.229*	2.287	1.688**
	(1.844)	(0.561)	(1.095)	(1.557)	(0.655)
Hc	15.44***	5.561***	3.576*	12.17***	8.444
	(4.051)	(1.888)	(2.078)	(3.641)	(5.930)
domestic_credit	0.0339	-0.0734***	-0.0584	0.0106	-0.0507**
	(0.0263)	(0.0208)	(0.0379)	(0.0274)	(0.0199)
Aidi	0.5335689*				
	(0.300)				
Aidi*hc	-0.2793481*				
	(0.157)				
transport		0.391**			
		(0.150)			
Transport*hc		-0.232**			
		(0.0852)			
electricity			-0.137		
			(0.187)		
Electricity*hc			0.0695		
			(0.0920)		
Ict				-1.202*	
				(0.608)	
Ict*hc				0.563*	
				(0.313)	
Wss					0.226
					(0.183)
Wss*hc					-0.134
					(0.103)
Constant	20.20596**	12.71**	24.11**	22.42***	-1.061
Time fixed effect	Yes	Yes	Yes	Yes	Yes
Net effect	0.0148	-0.03982	--	-0.15651	----
Threshold	1.90406	1.685344	----	2.13499	----
Observations	187	187	137	187	187
Number of countries	33	33	33	33	33
Prop>AR1	0.00864	0.0139	0.0245	0.0674	0.0127
Prop>AR2	0.186	0.229	0.343	0.366	0.247
Instrument	20	20	20	20	20
Prop>sarganp	0.107	0.514	0.766	0.243	0.453
Prop>hansenp	0.353	0.313	0.887	0.362	0.551
Fisher	29.43***	7.027***	12.74***	24.56***	6.999***

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

When human capital is considered as modulating variable, it interaction with infrastructures produces a positive direct effect and a negative indirect effect. The total effect is positive up to a human capital index of 1.90406, when this positive effect is nullified. When alternative measures of infrastructures are used, it produces rather a negative net effect for transport index and a positive net effect for ICT index up to a human development index threshold of 1.685344 and 2.13499 respectively for transport and ICT. These results have policy significance as the thresholds are within the range of values of the modulating variables apparent in the summary statistics. Francisco and Tanaka (2019) argue that good infrastructures are essential for human capital development. Health infrastructures would improve on the health outcome of the population and educational infrastructures on their part will enhance educational quality. While, Romer's (1990) model allows for increasing returns by assuming that the human capital has a significant positive effect on output at the industry level. Skilled and healthy individuals are required to operate manufacturing and other industrial operations. Besides, some specific infrastructures like the ICT infrastructures require high skilled labour for the operation of these infrastructures for proper functioning towards industrial operations.

V. Conclusion and Policy implications

This study aimed at verifying on the one hand, the effect of infrastructural development on industrialisation in Africa and on the other hand, the mechanisms through which financial development and human capital help in modulating this effect. The system GMM methodology was adopted in investigating these objectives with data collected for 33 African countries between 2003 and 2019. Industrialisation was measured through industrial value added per capita and manufacturing value added. Infrastructures were measured through composite indexes. The results of the analyses show that infrastructural development had a positive effect on industrialisation in Africa. When the modulating variables of financial development and human capital were introduced, the results show that positive net effects were apparent for the infrastructural development index and the ICT composite index up to a financial development thresholds of 138.4615 and 27.13 respective when these effects are nullified. The interaction with electricity infrastructure produced a negative net effect. This was up to a financial development threshold of 131.0256 when this negative effect was nullified. When human capital was considered as modulating variable, it interaction with infrastructures produced a positive direct effect and a negative indirect effect. The total effect was positive up to a human capital index of 1.90406, when this positive effect is nullified.

When alternative measures of infrastructures were used, it produced rather a negative net effect for transport index and a positive net effect for ICT index up to a human development index threshold of 1.685344 and 2.13499 respectively for transport and ICT when these effects are nullified.

Based on the results obtained, the policymakers in Africa in their quest for industrialisation should invest in infrastructures. However, caution should be taken in this process. There is necessity in the development of the financial sector and human capital to take up industrial jobs. When infrastructural policies are focused on the ICT sector, policymakers should be careful with the 27.13 threshold of financial development. At this threshold, they are advice to use other economic policy tools. Moreover, there is necessity for financial development to exceed the 131.0256 threshold for the electricity infrastructures to have a positive effect on industrialisation. Caution should also be taken when this development of the financial sector reaches 138.4615 as the total infrastructures in the economy can rather harm industrialisation if other policies are not put in place. Furthermore, there is need for the development of human capital in the sub-region, capable of taking industrial jobs. However, at a human capital threshold of 1.90406, caution should be applied. This human capital development is particularly necessary in the ICT sector that requires highly skilled labour for its functioning. This human capital development includes investments in education with the curriculum designed to suit the industrial need of the country. Also, infrastructural development should be enhanced in the health sector which is a key aspect of human capital for all economies.

Future research on the subject could consider country level analyses for a better policy orientation on the subject. Moreover, other policy modulating variables could be used to see the policy outcomes in future studies. Besides, industrial sectoral studies could further enhance understanding of policy makers on the subject.

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Appendix

A 1. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Manufacturing value added	326	13.593	7.941	1.686	50.037
Industrial value added	551	8.936	1.247	4.877	12.595
Broad money	537	35.609	24.213	3.161	163.325
Foreign direct investment	561	4.38	8.485	-6.37	103.337
Trade openness	552	67.889	30.043	16.669	311.354
GDP per capita	561	7.134	.952	5.272	9.196
Role of law	561	-0.649	.551	-1.852	.731
Human capital	527	1.857	.463	1.098	2.939
Fincial development	488	23.754	28.658	.738	160.125
African infrastructural development index	561	21.248	17.459	1.244	87.23
Transport infrastructure	561	10.003	11.859	0	58.756
Electricity infrastructure	559	10.135	16.747	.054	93.559
ICT infrastructure	561	7.065	10.174	0	67.391
Water and sanitation infrastructure	561	51.656	22.151	7.393	99.014

A2. Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) IVAK	1.000													
(2) mva	0.029	1.000												
	(0.601)													
(3) aidi	0.039	0.026	1.000											
	(0.360)	(0.641)												
(4) transport	0.052	0.072	0.748	1.000										
	(0.223)	(0.195)	(0.000)											
(5) electricity	0.066	0.003	0.763	0.572	1.000									
	(0.125)	(0.953)	(0.000)	(0.000)										
(6) ict	-0.037	-0.023	0.628	0.201	0.269	1.000								
	(0.385)	(0.684)	(0.000)	(0.000)	(0.000)									
(7) wss	0.032	0.045	0.840	0.621	0.590	0.453	1.000							
	(0.459)	(0.422)	(0.000)	(0.000)	(0.000)	(0.000)								
(8) m2	0.017	0.028	0.482	0.280	0.383	0.325	0.362	1.000						
	(0.695)	(0.614)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)							
(9) fdi	-0.050	0.074	0.019	0.207	0.096	-0.102	-0.040	-0.108	1.000					
	(0.238)	(0.182)	(0.657)	(0.000)	(0.024)	(0.015)	(0.340)	(0.013)						
(10) hc	-0.034	0.033	0.406	0.226	0.347	0.316	0.451	0.338	-0.093	1.000				
	(0.438)	(0.572)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.032)					
(11) trade	-0.015	-0.047	0.054	0.074	0.087	-0.024	0.040	0.099	0.275	0.147	1.000			
	(0.735)	(0.404)	(0.204)	(0.083)	(0.042)	(0.571)	(0.354)	(0.022)	(0.000)	(0.001)				
(12) rule_law	0.060	-0.002	0.337	0.258	0.283	0.195	0.301	0.400	-0.053	0.313	0.059	1.000		
	(0.159)	(0.964)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.210)	(0.000)	(0.169)			
(13) GDPK	0.038	0.009	0.457	0.206	0.414	0.327	0.509	0.511	-0.175	0.632	0.128	0.446	1.000	
	(0.374)	(0.876)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)		
(14) domestic_credit	0.040	-0.038	0.429	0.142	0.644	0.225	0.279	0.701	-0.103	0.378	0.075	0.466	0.535	1.000
	(0.387)	(0.532)	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.022)	(0.000)	(0.103)	(0.000)	(0.000)	

A3. Definition and sources of variables

Variable	Definition	Source
mva	Manufacturing value added (% of GDP)	WDI
IVAK	Industry (including construction), value added per worker (constant 2010 US$)	WDI
m2	Broad money (% of GDP)	WDI
fdi	Foreign direct investment inflows (%GDP)	WDI
trade	Sum of exports and exports (%GDP)	WDI
GDPK	Logarithm of per capita growth	WDI
rule law	Rule of law	WGI
hc	Human capita composite index	Penn World Table
domestic credit	Domestic credit provided by the private sector (% GDP)	WDI
aidi	African infrastructural development index	African Development Bank
transport	transport composite index	African Development Bank
electricity	electricity composite index	African Development Bank
ict	information and communication technology composite index	African Development Bank
wss	water and sanitation composite index	African Development Bank

A 4. Unit root test

Variable	IPS at level	Decision on stationarity
Manufacturing value added	0.0163	I(0)
Industrial value added	0.0917	I(0)
Broad money	0.0300	I(0)
Foreign direct investment	0.0000	I(0)
Trade openness	0.0000	I(0)
GDP per capita	0.0013	I(0)
Role of law	0.0068	I(0)
Human capital	0.0000	I(0)
Fincial development	0.0248	I(0)
African infrastructural development index	0.0035	I(0)
Transport infrastructure	0.0199	I(0)
Electricity infrastructure	0.0018	I(0)
ICT infrastructure	0.0008	I(0)
Water and sanitation infrastructure	0.0083	I(0)