Infrastructure development as a prerequisite for structural change in Africa

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Abstract

Structural change is seen by development economics theorists as a driver of sustained and sustainable economic growth. African countries that have understood this prioritize structural change policies in their national development programs in order to reduce poverty and promote employment through commodity-based industrialization. How does infrastructure development contribute to this process? The purpose of this paper is to answer this question by examining empirically whether the state of infrastructure development in Africa stimulates structural change, understood as the development of the manufacturing sector. After outlining the state of infrastructure quality in the region, and discussing some theoretical channels through which this relationship might pass, we estimate fixed effects models from 52 African countries over the period 2003-2018. Results which are robust to controlling for institutional dynamics and the natural resource curse hypothesis suggest that structural change in Africa is optimized with the development of infrastructure, particularly energy and information and communication technologies. Among other policy implications arising from these findings, the establishment of partnership projects with other developed countries in terms of superstructure for enhanced industrialization is recommended.

Keywords: Infrastructure development, structural change, manufacturing sector, Africa.

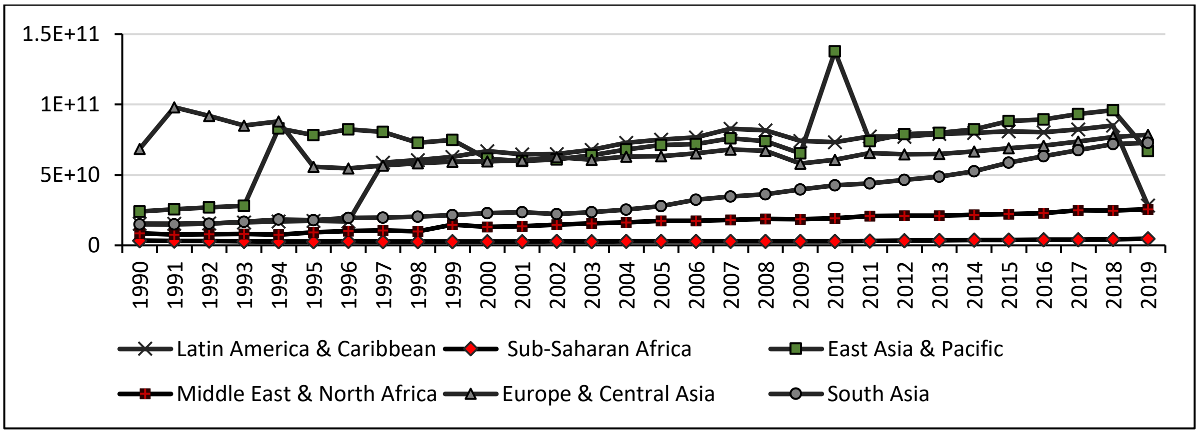
JEL Codes: N67, N77, C23.

1. Introduction

Since the pioneering works of Fisher (1939) and Clark (1940), structural change (hereafter SC) is seen as the key to economic growth and development of modern economies. As Lucas (2004) pointed out, "*the origins of the modern economic world can be seen, in part, as a transition from a traditional agricultural society to a society of sustained growth of opportunities for the accumulation of human and physical capital*" (p.29). In the same light, Jones and Olken (2008) documented that variations surrounding manufacturing-oriented labor force tend to coincide with growth rate accelerations and decelerations. Lin and Monga (2011) note that substantial growth rate accelerations were driven by rapid technological innovation in the era after the industrial revolution as well as the transition to industrialized societies from agrarian economies characterized by a declining share of employment in agriculture employment.

However, despite its advantages, Africa's performance in terms of SC compared to other developing countries has been disappointing. According to UNCTAD (2011), the share of Africa in global manufacturing value added dropped to 1.1% in 2008 from 1.2% in 2000, whereas during the same period that of Asia rose to 25% from 13%. Moreover, as we can observe in Figure 1, SC defined and characterized by the development of the manufacturing sector in terms of value added (Mijiyawa, 2017; Nguimkeu and Zeufack, 2019) is not experiencing a boom such as that observed in other regions. The share of Africa and the Sub-Saharan Africa sub region in particular in manufacturing GDP remains low and has followed a relatively constant trend since the 1990s.

Figure 1: Manufacturing trends in different regions of the world



Source: Authors' construction using data on manufacturing value added (constant 2010 US$) from the World Development Indicators Database.

In this context, the important question to ask is: what are the factors that contribute to SC in Africa? This paper aims to contribute to this reflection by examining the role of infrastructure development within a macroeconomic empirical framework.

The literature on the determinants of the SC process in developing countries in general and in Africa in particular is sparse and mainly consists of micro-level studies. This is the case of the works of Bigsten et al. (2004) and Fafchamps et al. (2008), who analyze the impact of exports on the performance of African manufacturing firms. Other studies look at the factors limiting the success and survival of African manufacturing firms, as well as the constraints they face, such as the size effect, competitiveness and governance (Bigsten et al., 2003). With respect to macroeconomic studies in Africa, most analyze the factors that determine the success and failure of industrial policies (see Marti and Ssenkubuge, 2009; Altenburg, 2011). In this context, the role of infrastructure quality has been only marginally exploited. We can cite the recent work of Danmaraya and Hassan (2016) that has focused on electricity infrastructure as well as those of Asongu and Odhiambo (2020a) and Muller (2021) which have been oriented towards ICT infrastructure.

This paper makes four contributions to the existing literature. First, by recognizing the relevance of the different proxies generally retained in the literature to apprehend the process of SC such as productive diversification (Lectar, 2017), economic complexity (Myriam, 2017), or the sectoral reallocation of workers (Mcmillan and Rodrik, 2011), the paper defines SC in Africa by a deep mutation of the sectors of the economy characterized by the development of the manufacturing sector. On this basis, it uses the share of manufacturing value added in GDP as a measure of SC in Africa. Second, unlike existing works that have attempted to explain MVA through infrastructure development by focusing on a particular type of infrastructure (Asongu and Odhiambo, 2020a; Muller, 2021), this study distinguishes between the four main categories of infrastructure, namely: ICT, electricity, transport, and water and sanitation. To this end, we provide evidence of the positive effect of infrastructure development in general and ICT and electricity in particular on the SC process in African countries. Second, we arrive at this result based on a sample of 52 countries across all sub-regions of Africa, which allows us to draw general and continentally relevant implications. Third, in our empirical analyses, we address the issues of poor institutional quality, the natural resource curse that characterizes the continent given its undisputed natural resource wealth and low economic development. Moreover, in the light of the likely endogeneity bias (i.e. variable omission bias and the unobserved heterogeneity) that exists in most studies conducted in the developing world, thisstudy provides a robust basis for policy formulation and development to promote more effective SC in Africa.

The rest of the paper is organized as follows. Section 2 presents some stylized facts about infrastructure in Africa. Section 3 discusses the theoretical channels. Section 4 presents the data and methodology. Section 5 discusses key findings. Section 6 tests their robustness and section 7 concludes.

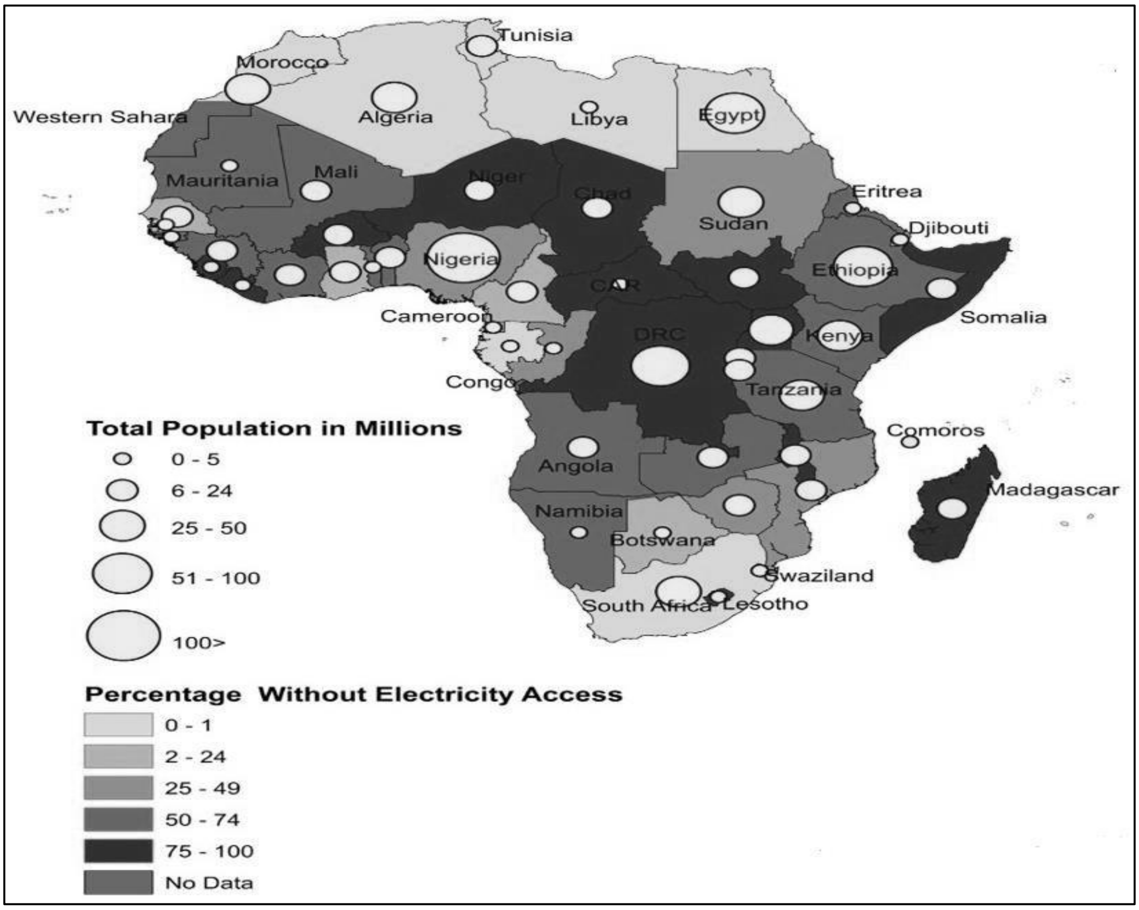
2. Some stylized facts about the state of infrastructure quality in Africa

In practice, there are four main indicators of infrastructure development in an economy: electricity, ICT, transport and water and sanitation infrastructure. We take stock of these different indicators in the context of African countries.

2.1Electricity infrastructure

Commonly, when we talk about electricity infrastructure, we are usually referring to a country's electricity generation, including both private and public power generation. The statistics on electricity infrastructure on the African continent are bleak. According to the International Energy Agency (IEA) in its 2019 report as well as the 2019 World Energy Outlook, Africa faces a significant electricity access challenge. With an estimated population of 1.3 billion in 2018, or 17% of the world's population, it accounted for only 3% of electricity consumption (IAE, 2019). SSA especially, is the most electricity-poor region in the world. More than 600 million people in the subregion do not have access to electricity. Figure 2, where the depth of color on the map reflects the intensity of the energy deficiency and the bubbles reflect the size of the population (in millions), presents the severity of the problem in the subregion. The average rate of population without access to electricity in most countries is over 50%. For example, in countries such as the Central African Republic, Niger, the Democratic Republic of Congo, Chad and Somalia, less than 10% of the population has access to electricity.

Figure 2: Electricity access in Africa

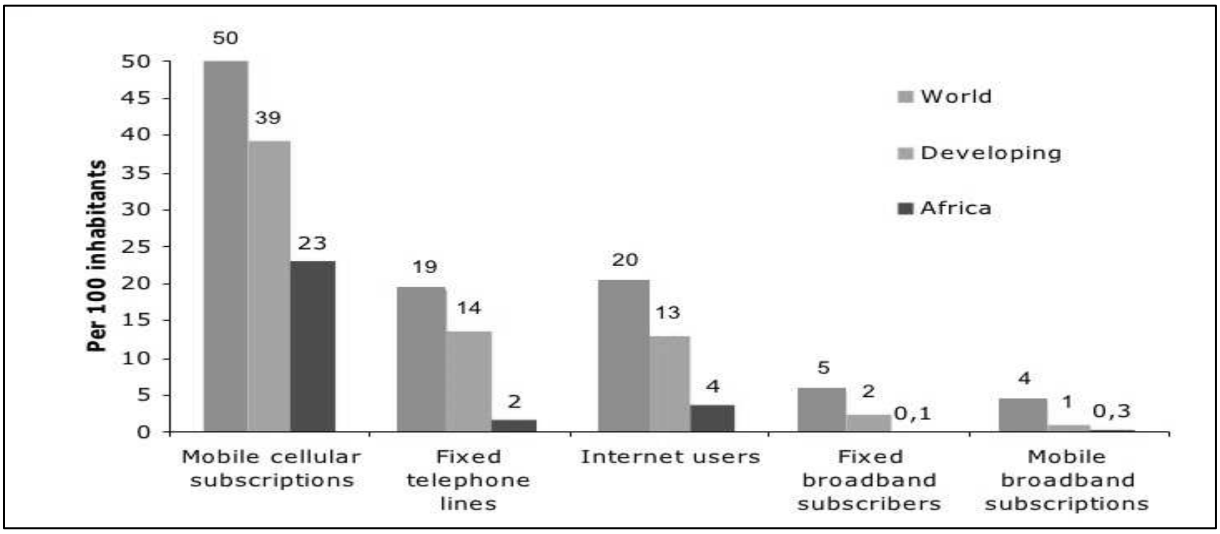


Source: IEA, 2014.

2.2 ICT infrastructure

As far as ICT infrastructure is concerned, its diffusion on the continent dates back to the end of the 1990s and has increased significantly in recent years. Indeed, between 2000 and 2005, for example, the number of devices increased from 130 to 900 million on the continent, including 200 million smartphones. In 2016, the Sub-Saharan Africa (SSA) sub-region alone had nearly 420 million subscribers, equivalent to a penetration rate (number of internet users per 100 inhabitants) of 43%. Moreover, with an increasing rate estimated at 6% by the Groupe Spécial Mobile association, mobile telephony is experiencing the strongest growth in Africa (GSMA, 2019). Although this dynamic is not equal across the countries of the continent, it represents a considerable market for the continental economy. By 2020, the GSMA estimates that it will account for nearly 7.7 percent of GDP in SSA; tax revenues generated by the sector are close to $13 billion; and employment was estimated at over 1.1 million in 2016. However, even though these statistics look promising for the continent, it is still ranked low in the world in terms of ICT development and exploitation (see Figure 3). Whether in terms of fixed telephone lines, mobile cellular, mobile and fixed broadband subscriptions, and internet users, the statistics for Africa remain low compared to other developing countries and the global average.

Figure 3: ICT uptake by geographic region, 2016

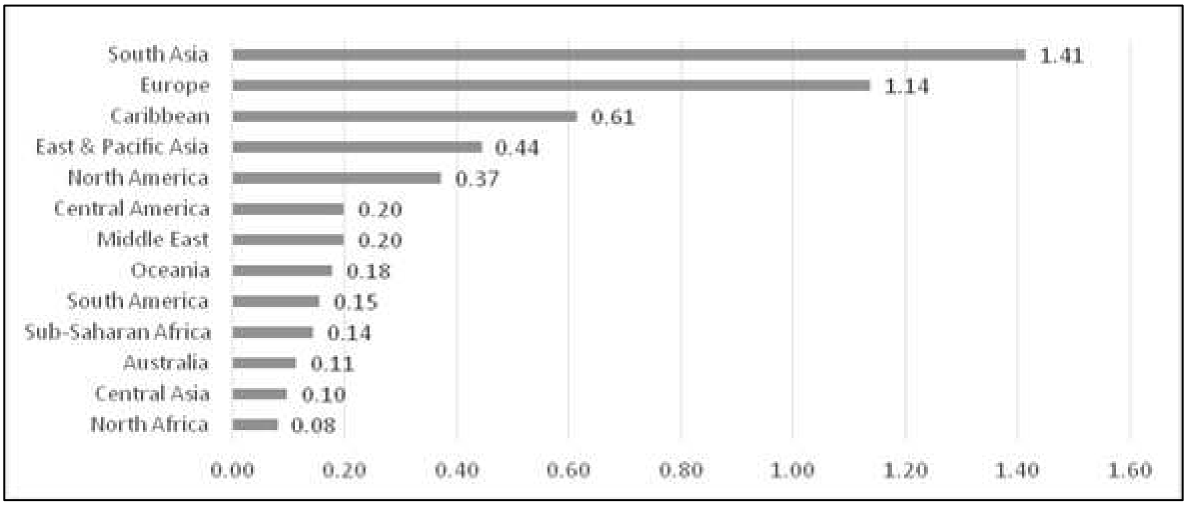


Source: ITU based on ICT indicators database.

2.3 Transport infrastructure

With respect to transportation infrastructure, road networks, which are an important part of a nation's infrastructure, promote the development of various sectors of the economy. For example, reducing the distance between markets, knowledge and people through quality infrastructure induces a cycle of growth opportunities for all sectors. Moreover, connectivity through road networks eradicates poverty by providing access to education, medical facilities, employment and various other social opportunities. According to statistics from the International Road Federation (IRF), African and specifically North African countries have the lowest road density in the world (IRF, 2019). An analysis conducted on the 2019 statistics related to the quality of the road network in different regions of the world, reveals that North Africa, with an estimated road density of 0.08km/km2 ranks last in the regional ranking (Figure 4). Sub-Saharan Africa is not far behind with an average of 0.14 km/km2. On the other hand, the highest road density is observed in South Asia, which has nearly 18% of the world's road network, i.e. the highest regional road density.

Figure 4: Road density (km/km²) by geographic Region, 2019

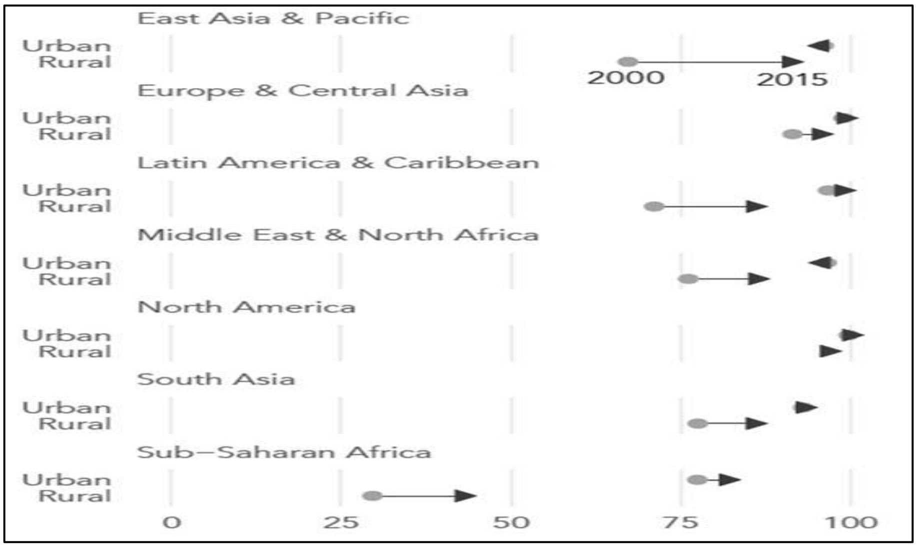


Source: IRF World Road Statistics 2019.

2.4 Water supply and sanitation infrastructure

The Sustainable Development Goals (SDGs) have drawn attention to the problems related to the quality of water supply and sanitation for countries, particularly developing countries. Although many countries are on track to meet this goal, most African countries, particularly those in SSA, are still lagging behind. According to the World Bank report (2011), nearly 2.5 billion people in the world do not have access to improved sanitation. Of these, 22% live in Africa. Statistics from SDG Atlas 2018 (see Figure 5) reveal that only 58% of the population there has access to safe drinking water, with a significant gap between people in urban and rural areas.

Figure 5: People using at least basic water services (%) by geographic Region, 2017



Source: World Bank, World Development Indicators statistic 2017.

In conclusion, it appears from these statistics that, even though the efforts made by African leaders and international organizations to improve the quality of infrastructure on the African continent have been notable, enormous efforts are still required. These efforts are crucial in view of the implications for the socio-economic development of these countries which is contingent on effective SC.

3. Theoretical discussion of how infrastructure development could affect structural change

The effect of ICTs on the SC in Africa can take place through several channels. Indeed, whether it is agriculture, industry or services, all sectors of an economy are affected by the diffusion of ICT. For example, ICT infrastructures such as telephone, optical fibre and the internet facilitate the flow of transactions notably, by the transfer of money and data to execute transactions. The internet in particular is a crucial tool for the industry sector, as most transaction flows in the latter are directly dependent on the former. Moreover, it helps in the search for the products most likely to please consumers as well as information on the different markets that offer the best prices for their products. As evidenced by the wealth of empirical research on the relationship between ICT infrastructure and economic and inclusive growth (Sassi and Goaied, 2013; Asongu and le Roux, 2018; Cheng and Chien, 2021), which maintains that growth cannot be achieved without effective SC, there is no doubt that ICT is an important factor to be considered.

Concerning electricity infrastructure, it has important effects on sectoral growth, particularly in industry and manufacturing. Indeed, industries operate on a daily basis with equipment and machinery that require a constant power supply to prevent any disruption of the production process. Moreover, production needs energy for the transformation of raw materials into finished or semi-finished products, and the transportation of goods and services. This will ensure the continuity of the flow in production, and thus increase productivity. Similarly, as Kander et al (2014) point out, electricity conditions other energy factors such as ICT, which contributes to making manufacturing and trade more productive. In general, electric power contributes to improving the social, industrial, and economic development of a country (Tang and Tan, 2013; Atems et al., 2018).

Transport infrastructure is essential for the development of trade. Indeed, railroads, ports and roads that are accessible and in good condition help to facilitate the transport of products, improve the productivity of firms and even reduce the price of products. This is consistent with Smith's (1994) argument that any disruption of the transport of people, goods and services has adverse economic consequences for consumers and firms. In the same sense, studies on the relationship between trade, infrastructure and transport costs show that the deterioration of transport facilities significantly increases the cost of transporting goods and thus reduces the volume of trade (Limao and Venables, 2001). In addition, the poor quality of the roads makes it difficult to transport raw materials from the areas where they are harvested to the processing plants and to the markets. This has an impact on investments and the profitability of companies. Several empirical studies in this direction have shown that the quality of transport infrastructure improves investment (Khadaroo and Seetanah, 2010; Samir and Mefteh, 2020; Shahbaz et al., 2021) and hence economic growth (Bosede et al., 2013; Cigu et al., 2019).

Last but not least, the quality of water supply and sanitation infrastructure represent an important necessity for SC in an economy. Specifically, the primary sector, especially agriculture, needs an adequate supply and quality of water to ensure the quality of production and the constant supply of raw materials to the secondary sector, especially industry and manufacturing. The latter, considered as the most productive sector of an economy, need in addition to these raw materials, good quality water supplies to transform them into finished products, before forwarding them to the service sector.

4. Material and methods

4.1 Data and measurements

Our main sample for analysis is an unbalanced panel of 52 African countries[1] over the period 2003 through 2018. The sample size and study period are conditioned by the availability of data on the variables of interest.

In this study, SC is approximated by industrialization.Indeed, despite the multidimensionality and complexity of the concept, this measure seems to be unanimously accepted by researchers. In essence, in the light of the attendant literature, if SC is understood as a reallocation of activities from the less productive sectors to the more productive sectors, it is expected to translate into an increase in the share of the industrial sectors in GDP (Nixson, 1990; Cadot et al., 2016). In this respect, a plethora of industrialization measures are used in the mainstream literature, notably: (i) the share of manufacturing valued added in GDP, and (ii) the share of manufacturing employment in economy-wide employment (Rodrik, 2016; Jeanneney and Hua, 2017; Nguimkeu and Zeufack, 2019). Following these authors and given the availability of data, industrialization is captured in this study by the share of manufacturing value added in GDP at constant prices. The data are extracted from the World Bank's World Development Indicator (WDI) database (2021).

Regarding the measurement of infrastructure quality, we follow Kodongo and Ojah (2016), Azolibe and Okonkwo (2020) and approximate it by the African Infrastructure Development Index (AIDI) of the African Development Bank. Available for all 54 African countries over the period 2000-2018, the AIDI is a composite index which monitors the status and progress of infrastructure development across the African continent. Its major components are electricity which is measured by the production of electricity of a given country, including both public and private energy generated and energy imported from abroad; (i) transport which is measured by total road network in kilometers (km) and total paved roads, (ii) ICT which is measured by the number of internet users per 100 inhabitants and the total number of phone subscriptions; and (iii) water and sanitation which is a proxy for improved sanitation facilities and the percentage of the population with access to water source.

Control variables are introduced into the analysis to account for other factors affecting SC as suggested by the literature. These are GDP per capita, population size, foreign direct

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[1]The list of countries in the study is presented in Table A1 of the appendix.

investment (FDI), urbanization and exchange rate. In his study of "premature deindustrialization," Rodrik (2016) explains manufacturing output by the log of population size and GDP per capita, and their squared value. He finds inverted U-shaped relationships between these variables and industrialization, but with reversal thresholds that differ. As an extension, Nguimkeu and Zeufack (2019) retain these same control variables and arrive at the opposite relationship in the specific case of Sub-Saharan African countries. More specifically, they find that an increase in per capita income as well as in population size would be accompanied by a decrease in the share of manufacturing in GDP up to a threshold, and then would evolve in the same direction. In addition to these two variables, Mijiyawa (2017) also considers the nominal exchange rate variable, under the assumption that countries that maintain undervalued currencies will tend to experience more pro-growth of SC process, which he considers one of the main channels of technology transfer in developing countries. Moreover, studies such as Collier and Venables (2008) have shown that urbanization (measured in this study by the share of the population in the largest city) creates powerful agglomeration economies conducive to industrialization. All these control variables are extracted from the WDI (2021) database.

4.2 The empirical model

The empirical model chosen to estimate the effect of infrastructure quality on SC in Africa, is a modified version of the original Chenery (1960) model, and augmented by those of Rodrik (2016) and Mijiyawa (2017). It is specified as follows:

$$SC_{it} = \alpha + \beta INFRAS_{it} + \gamma_1 Y_{it} + \gamma_2 Y_{it}^2 + \gamma_3 P_{it} + \delta X_{it} + u_i + v_t + \varepsilon_{it} \quad (1)$$

With SC_{it}, the measure of structural change;$INFRAS_{it}$, the measure of infrastructure, and β, the parameter to be estimated;P_{it}, Y_{it} and Y_{it}^2 respectively, the size of the population, income per capita, and its squared (log) value, and γ_1, γ_2, γ_3 the associated parameters; X the vector of the other control variables, and δ the vector of its parameters and ;u_i, v_t and ε_{it} are respectively, the country-specific effects and timefixed effects, and the error term.

4.3 The estimation technique

To estimate the model, we use panel data that allow us to control for country fixed effects. Indeed, by controlling for country fixed effects, we take into account factors that could simultaneously affect the conduct over time of certain industrial policies that are specific to countries. Accordingly country fixed effects allow us to control for country-specific factors that might influence industrialization, such as a country's landlocked position. In practice, two possibilities are generally used to estimate panel data in the literature. These are the random-effects model, which assumes an absence of correlation between the countries fixed effects and the explanatory variables, and the fixedeffects model, which assumes the existence of such a relationship. The choice between these two models is dictated by the Hausman specification test. To this end, the results of this test summarized in Table A3 in the Appendix lead us to choose the fixed effects model, given that the probability value associated with Chi^2 is below the 1% threshold. However, the model could suffer from an endogeneity problem that could result either from measurement errors, which are very common in studies conducted in developing countries. The fixed effects model does not account for this concern, and in order to ensure the robustness of our results, other aspects of endogeneity are accounted for. For the measurement errors and variable omission bias aspects of endogeneity, the specifications are tailored to respectively, employ proxies that have used in the attendant literature and account for a plethora of factors that affect SC in the conditioning information set.

4.4 Descriptive analysis

The descriptive statistics of the data and corresponding correlation matrix are disclosed in Table 1. Insights into the mean and standard deviation enable the study to draw two major conclusions. First, their SC (MVA) and the infrastructure measures are relatively less dispersed as it pertains to the proportionality between the mean and standard deviation. Hence, the level of MVA as well as infrastructure quality would therefore be relatively grouped around their averages of 11.28 and 20.77, respectively. This observation is valid for all the control variables, except for FDI which is relatively volatile.

With regard to the correlation matrix, we observe that the AIDI, GDP per capita, population size and urban share of the population arepositively linked to MVA. On the other hand, MVA would be a negative function of FDI and exchange rate. Furthermore, the low values of these coefficients suggest that the model does not seem to suffer from strong correlations between the variables. However, since these correlations are purely descriptive, only an in-depth analysis based on the econometric results will enable us to robustly establish the meaning of these correlations.

Table 1: Descriptive statistics

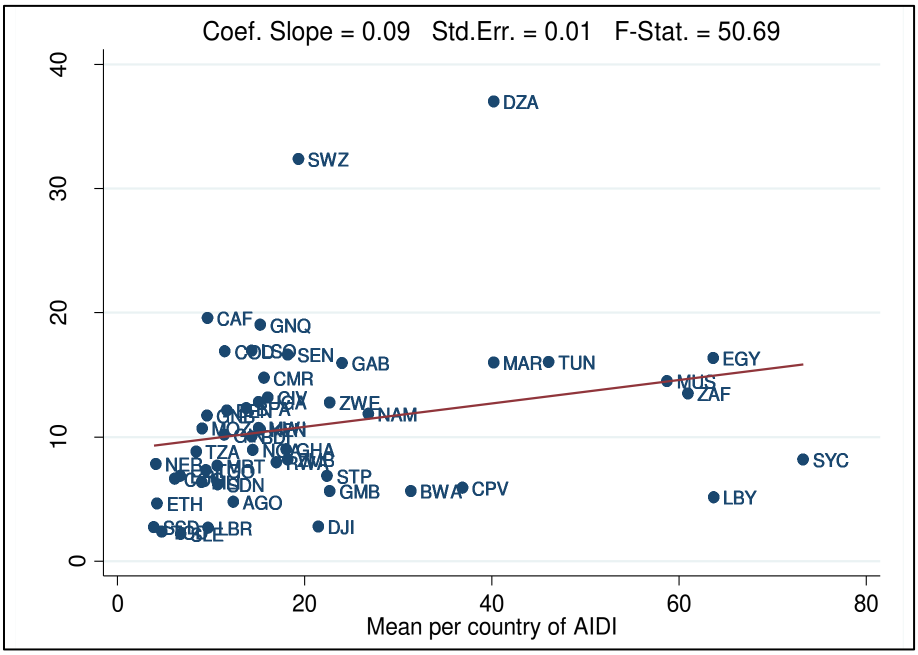
Variables	Obs	Mean	SD	Min	Max	MAN	AIDI	ln_GDP	ln_GDP2	ln_POP	FDI	ln_NER	urban
MVA	734	11.28	7.12	0.23	50.04	1							
AIDI	832	20.77	18.20	0.37	94.32	0.38	1						
Log (GDP)	809	7.18	1.08	4.73	10.04	0.33	0.58	1					
Log (GDP Squared)	809	52.68	16.13	22.40	100.82	0.34	0.57	1.00	1				
Log (Population)	825	15.84	1.60	11.32	19.09	0.15	0.21	-0.12	-0.14	1			
FDI (% GDP)	809	4.79	8.35	-6.37	103.34	-0.19	-0.13	-0.05	-0.06	-0.16	1		
Log (Nominal ER)	814	4.75	2.35	-0.36	22.63	-0.04	-0.47	-0.34	-0.34	-0.11	-0.04	1	
Share of Urban Pop.	697	37.14	15.34	8.78	90.71	-0.31	-0.27	-0.24	-0.23	-0.60	0.16	0.30	1

Source: Authors' calculations.

5. Results and discussions

We first observe the graphical correlation between the infrastructure quality index and MVA (Figure 6). From the latter, a positive correlation between infrastructure development and the level of MVA emerges. This means that, on average, African countries with good infrastructures seem to be countries where the process of SC, especially the development of the manufacture is high.

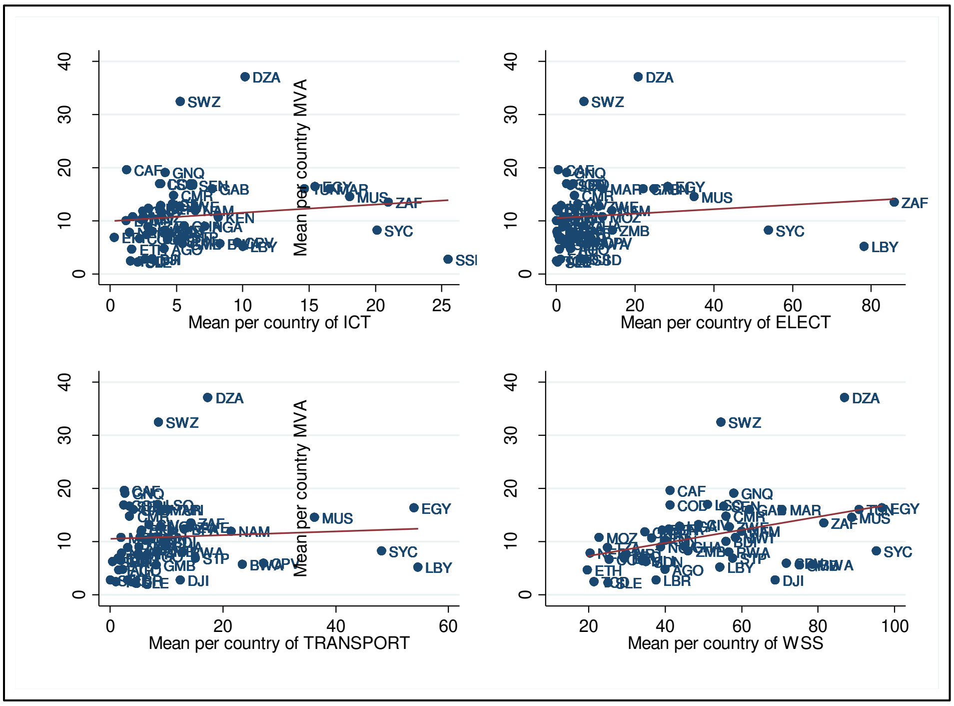
Figure 6: Scatterplots between the infrastructure index and the MVA



Source: Authors' constructions.

This positive correlation between the composite infrastructure index and the MVA is also observed with the disaggregated indicators (Figure 7). Specifically, whether it is the development of ICT, transport, electricity or water and sanitation, all seem to contribute to the development of MVA.

Figure 7: Scatterplots between infrastructure types and MVA



Source: Authors' constructions.

The empirical results summarized in Table 2 confirm these positive correlations. The table gives the results from estimating Equation 1 by the fixed effects model. While Column (1) shows the results of the effect of the composite index of infrastructure quality on MVA, and Columns (2-5) are concerned with the effects of different types of infrastructure. We find an evidence of a positive effect of infrastructure development on MVA, and this effect is significant at the 1% level. Specifically, the coefficient associated with AIDI is positive with a magnitude suggesting that a 10-unit increase in infrastructure quality leads to an increase of the share of MVA in GDP of 0.02 unit. This corroborates the descriptive result obtained previously and means that the improvement in the quality of infrastructure on average on the African continent also induces an improvement of the manufacturing sector, thus contributing to a more effective SC.

Regarding the specific effect of types of infrastructure, although all have positive coefficients, corroborating the graphical correlations observed previously, only electricity and ICTs are statistically significant. Indeed, with the modernization of the world, access to energy in general and electricity in particular has become a global geopolitical issue. This turmoil at the country level has a definite impact on the economic development and particularly the industrialization of a country. Likewise, and as discussed in Section 3, ICT today is essential in all sectors of the economy, and is an important factor in the process of SC.

Finally, concerning the control variables retained, the results show that GDP per capita and its squared value are negative and positive on the MVA, suggesting a U-shaped relationship between economic development and SC in Africa. However, the significance of these variables differs depending on the model estimated. Indeed, the negative effect of GDP per capita is significant only in the model presented in Column 3. Similarly, the positive effect of GDP squared is significant only in the models in Columns 1-3. In order to avoid pitfalls in quadratic regressions documents in contemporary literature (Asongu and Odhiambo, 2020b, 2020c), net effects and corresponding thresholds of GDP per capita are provided. For instance in the Column (3) of Table 2 where both the unconditional and marginal effects of GDP per capita are significant, the corresponding net effect is -0.199 (2×[0.343 × 7.180] + [-5.125]). In this calculation, -5.125 is the unconditional effect of GDP per capita on MVA, 7.180 is the average value of GDP per capita, 0.343 is the marginal impact of GDP per capita while the leading "2" corresponds to the quadratic derivation. Building on the established net effect, the corresponding threshold at which the net effect of GDP per capita changes from negative to positive 7.470 = 5.125/ (2×0.343). It is qualified as a positive threshold because of the associated positive marginal effect. Moreover, given the positive marginal effect, when GDP per capita reaches a critical mass of 7.470 (in log terms), the net effect is on MVA is zero or 0 (2×[0.343 × 7.470] + [-5.125]). Hence, GDP per capita in log terms should reach a threshold of 7.470 before the improvement of GDP per capita should engender a positive incidence on the MVA.Overall this U-shaped effect between economic development and SC, already highlighted by the work of authors such as Mijiyawa (2017), suggests that in the first phase of a country's SC process, economic development is counterproductive up to a certain threshold at which both begin to move in the same direction. Moreover, the coefficients associated with the population variable, a proxy for market size, overall have a positive effect on MVA, although only significant in Models (1) and (2). A 1% increase in population size induces an increase of 0.035 and 0.03 in the manufacturing share of GDP of the countries considered, respectively in Models (1) and (2). Similarly, our results also show that a 100% appreciation of the local currency of these countries, relative to the dollar, is associated with a 0.005 decrease in the manufacturing share in Models (2) and (3).

Table 2.Baseline: infrastructure development and MVA (fixed effects model)

	Dependent Variable : MVA (% GDP)				
	(1)	(2)	(3)	(4)	(5)
AIDI	**0.105***** **(0.022)**				
ICT		**0.053***** **(0.017)**			
Electricity			**0.370***** **(0.066)**		
Transport				**0.029** **(0.073)**	
WSS					**0.035** **(0.037)**
Log (GDP)	-4.043 (2.785)	-2.828 (2.808)	-5.125* (2.787)	-0.539 (2.751)	-0.943 (2.761)
Log (GDP Squared)	0.111*** (0.022)	0.089*** (0.022)	0.343* (0.196)	0.011 (0.192)	0.006 (0.192)
Log (Population)	3.491** (1.478)	3.029* (1.583)	0.088*** (0.023)	0.365 (1.350)	0.077 (1.434)
FDI (% GDP)	-0.007 (0.016)	-0.007 (0.016)	-0.003 (0.016)	-0.004 (0.016)	-0.006 (0.016)
Log (Nominal ER)	-0.051 (0.250)	-0.545** (0.258)	-0.528** (0.263)	-0.152 (0.280)	-0.290 (0.238)
Share of Urban Pop.	0.031 (0.047)	0.032 (0.047)	0.042 (0.047)	0.029 (0.048)	0.029 (0.048)
Net effect of GDP	na	Na	-0.199	na	na
GDP threshold	na	Na	7.470	na	na
Observations	611	611	611	611	611
Within R-squared	0.460	0.250	0.600	0.678	0.509
F-Stat	56.96***	60.47***	63.25***	56.62***	42.65***

Source: Authors estimate. **Note:** MVA, AIDI, ICT and WSS refer respectively, to manufacturing value added, the Africa Infrastructure Development Index, Information and Telecommunication Technology (ICT), and water and sanitation. Standard errors in parentheses. ∗p < 0.10, ∗∗p < 0.05, ∗∗∗p < 0.010. na: not applicable because at least one estimated coefficient needed for the computation of net effect and/or threshold is not significant. The mean value of log (GDP) is 7.18.

6. Robustness checks

To ensure the robustness of our analyses, we perform a series of robustness tests based on (i) the natural resource curse hypothesis and the control of institutional dynamics and (ii) the use of alternative measures of the dependent variable and the variable of interest.

6.1 Controlling for Resource curse hypothesis and institutional dynamic

The first test that we carry out consists in testing the natural resource curse hypothesis in our results. Indeed, we assume that the abundance of natural resources in Africa could undermine the development of the manufacturing sector by reducing its competitiveness through Dutch disease. Similarly, this abundance of natural resources could lead to the deterioration of institutions, in particular by generating corruption, which could harm the development of the manufacturing sector. To test these arguments, we introduce in our regressions, the variable total rents of natural resources expressed as a percentage of GDP.

Table 3: Robustness check: controlling for institutional dynamic and Dutch diseases hypothesis

	Dependent Variable : MVA (% GDP)									
	Natural resource curse hypothesis					Dynamic of institutions				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AIDI	**0.112*** **					**0.105*** **				
	(0.022)					**(0.022)**				
ICT		**0.057*** **					**0.052*** **			
		(0.017)					**(0.017)**			
Electricity			**0.418*** **					**0.370*** **		
			(0.067)					**(0.066)**		
Transport				**-0.039**					**-0.028**	
				(0.073)					**(0.074)**	
WSS					**0.038**					**0.035**
					(0.037)					**(0.037)**
Log (GDP)	-4.817*	-3.544	-6.436**	-0.939	-1.409	-3.901	-2.702	-4.983*	-0.400	-0.797
	(2.789)	(2.815)	(2.793)	(2.752)	(2.765)	(2.802)	(2.828)	(2.804)	(2.768)	(2.779)
Log (GDP Squared)	0.332*	0.210	0.473**	0.038	0.059	0.424**	0.334*	0.424**	-0.018	-0.001
	(0.197)	(0.197)	(0.199)	(0.193)	(0.193)	(0.187)	(0.185)	(0.193)	(0.192)	(0.192)
Log (Population)	2.506	2.172	0.498	-0.555	-1.050	3.409**	2.952*	1.776	0.284	-0.159
	(1.523)	(1.621)	(1.392)	(1.431)	(1.517)	(1.489)	(1.597)	(1.351)	(1.361)	(1.444)
FDI (% GDP)	-0.005	-0.006	-0.001	-0.003	-0.005	-0.007	-0.007	-0.003	-0.004	-0.006
	(0.016)	(0.016)	(0.015)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Log (Nominal ER)	-0.060***	-0.058***	-0.052***	-0.096	-0.103	-0.041**	-0.038*	-0.122	-0.072	-0.076
	(0.019)	(0.020)	(0.019)	(0.140)	(0.139)	(0.019)	(0.019)	(0.135)	(0.140)	(0.139)
Share of Urban Pop.	0.011	0.013	0.017	0.013	0.013	0.027	0.028	0.038	0.024	0.025
	(0.047)	(0.048)	(0.047)	(0.048)	(0.048)	(0.048)	(0.048)	(0.047)	(0.049)	(0.049)
Total natural resources (%GDP)	**-0.051** **	**-0.047** **	**-0.067*** **	**-0.039* **	**-0.040* **					
	(0.020)	**(0.021)**	**(0.021)**	**(0.021)**	**(0.021)**					
Control of Corruption						**0.060*** **	**0.058*** **	**0.052*** **	**0.041** **	**0.038* **
						(0.019)	**(0.020)**	**(0.019)**	**(0.019)**	**(0.019)**
Net effect of GDP	-0.049	**na**	0.356	**na**	Na	na	na	1.105	na	na
GDP threshold	7.254	na	6.803	na	Na	na	na	5.876	na	na
Observations	611	611	611	611	611	611	611	611	611	611
Within R-squared	0.560	0.341	0.780	0.144	0.169	0.461	0.253	0.600	0.208	0.510
F-Stat	57.51***	59.70***	63.28***	55.95***	42.86***	56.80***	60.22***	63.01***	56.53***	42.12***

Source: Authors estimate using the fixed-effects model. **Note:** MVA, AIDI, ICT, WSS and ER refer respectively to manufacturing value added, the Africa Infrastructure Development Index, Information and Telecommunication Technology (ICT), water and sanitation, and Exchange Rate. Standard errors in parentheses. ∗p < 0.10, ∗∗p < 0.05, ∗∗∗p < 0.010.na: not applicable because at least one estimated coefficient needed for the computation of net effect and/or threshold is not significant. The mean value of log (GDP) is 7.18.

The results obtained, summarized in Table 3 (columns 1-5). We continue to find a positive effect of infrastructure on MVA, indicating that infrastructure development is favorable to the SC process.Similarly, the negative and significant effect of the natural resource variable on MVA confirms the hypothesis of a natural resource curse in the context of African countries.

We also control the effect of infrastructure development on the MVA by the quality of institutions. Indeed, institutions are an important determinant of SC process as documented by Henrekson and Johansson (2011) and Pariboni and Tridico (2019). We use the control of corruption indicator of the World Bank to control for the institutional dynamic of African countries. We observe in Table 3 that even by controlling by the institutions, the results remain sustainable, namely that an improvement of the infrastructures, particularly those of ICT and energy, favors the SC. Likewise, we find that good governance, particularly in terms of corruption control, improves this SC.

6.2 Others proxies of infrastructure and SC

In this robustness test, we test whether the results obtained previously are robust to the use of alternative measures of MVA and infrastructure. Indeed, we have mainly used the share of manufacturing value added in % of GDP as a proxy for manufacturing so far. This time we use this variable expressed in current U.S. dollars. In the same sense, the previous results strongly suggest that among the types of infrastructure, only ICT and electricity have significant effects on MVA. We arrived at this result using the AfDB indices. We use other proxies of ICT and electricity commonly employed in the literature, namely fixed telephone subscriptions and individuals using the Internet (Niebel, 2018; Asongu et al., 2018; Avom et al., 2020), and the percentage of the population with access to electricity (Kanagawa and Nakata, 2008). The data for these new variables are taken from the WDI.

Table 4. Robustness check: alternative measures

	Log of MVA expressed in current U.S. dollars.					**Other ICT and electricity proxies**		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
AIDI	**0.005*** (0.002)**							
ICT		**0.004** (0.002)**						
Electricity			**0.050*** (0.019)**					
Transport				**0.002 (0.007)**				
WSS					**0.003 (0.003)**			
Log Fixed telephone subscriptions						**0.447* (0.256)**		
Individuals using the Internet (% of population)							**0.028* (0.015)**	
Access to electricity (% of population)								**1.377*** (0.331)**
Log (GDP)	0.076 (0.261)	0.051 (0.261)	0.014 (0.264)	0.095 (0.254)	0.127 (0.255)	3.070 (2.640)	3.064 (2.567)	4.086* (2.307)
Log (GDP Squared)	0.065*** (0.018)	0.062*** (0.018)	0.061*** (0.019)	0.052*** (0.018)	0.051*** (0.018)	0.042* (0.026)	0.209 (0.183)	0.447* (0.256)
Log (Population)	1.608*** (0.139)	1.631*** (0.147)	1.484*** (0.127)	1.447*** (0.125)	1.482*** (0.133)	0.070 (0.713)	0.689 (0.706)	0.179 (0.629)
FDI (% GDP)	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.009 (0.016)	0.011 (0.016)	0.007 (0.014)
Log (Nominal ER)	0.092*** (0.021)	0.090*** (0.022)	0.063*** (0.017)	0.050*** (0.019)	0.088*** (0.018)	0.011 (0.016)	0.007 (0.014)	0.744** (0.360)
Share of Urban Pop.	0.012*** (0.004)	0.012*** (0.004)	0.012*** (0.004)	0.012*** (0.004)	0.012*** (0.004)	0.030 (0.041)	0.032 (0.040)	0.071 (0.044)
Net effect of GDP	na	na	na	na	na	na	na	10.504
GDP threshold	na	na	na	na	na	na	na	nsa
Observations	611	611	611	611	611	589	611	591
Within R-squared	0.728	0.728	0.726	0.725	0.725	0.715	0.725	0.724
F-Stat	67.34***	72.60***	72.20***	69.78***	56.59***	63.34***	70.74***	60.97***

Source: Authors estimate using the fixed-effects model. **Note:** MVA, AIDI, ICT, WSS and ER refer respectively to manufacturing value added, the Africa Infrastructure Development Index, Information and Telecommunication Technology, water and sanitation, and Exchange Rate. Standard errors in parentheses. *p < 0.10, **p < 0.05, ***p < 0.010. na: not applicable because at least one estimated coefficient needed for the computation of net effect and/or threshold is not significant. The mean value of log (GDP) is 7.18. nsa: not specifically applicable because a synergy effect is instead apparent.

Table 4 presents the corresponding results. Columns (1-5) show the effect of the different infrastructure indicators on the log of MVA expressed in current dollars. Overall, we find positive and significant effects of the composite infrastructure index and the ICT and electricity indices on the MVA. However, the magnitude of the coefficients is reduced compared to the results obtained with the MVA (% GDP). Columns (6-8) present the effect of other measures of ICT and electricity on MVA expressed in % of GDP. Overall we find a positive and significant effect of access to electricity, fixed cell phone use and internet use on MVA. Thus, even using alternative measures, we find that infrastructure development is important for SC in Africa.

6. Concluding implication and future research direction

This study used data on 52 African countries over the period 2003-2018 to examine the effect of infrastructure development on the Structural Change (SC) process in Africa. The empirical analysis was based on estimating fixed effects model, taking into account the institutional dynamics of the countries and the natural resource curse hypothesis.The main conclusion of our analysis is that policies designed to promote structural change on the continent, especially those focused on the development of the manufacturing sector, require the enhancement of the development of infrastructure, especially electricity and ICT.To achieve this ambition, an important policy implication of our analysis isthe establishment of partnership projects with other developed countries in terms of superstructure for enhanced industrialization.Indeed, as noted in the IMF report (2014), in SSA in general, infrastructure projects are mainly financed from domestic sources such as loans, tax revenues, and other revenues, and very little from development partners. The promotion of partnerships, such as public-private partnerships (PPPs), could be of great benefit to these countries, provided that the associated fiscal risks are carefully considered and appropriate institutional and legal frameworks are established.

As a perspective for future research, it should be noted that this study only covered the economic dimension of the SC process, approximated by the development of the manufacturing sector. Future work could: (i) look at other measures and dimensions of this process (e.g. social and/or political perspectives) and (ii) use alternative methodologies to assess whether the links established stand up to further empirical scrutiny.

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Appendices

Table A1: list of countries of the study

Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi,Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Djibouti, Egypt, Arab Rep., Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe.

Source: Authors' construction.

Table A2: Definitions of variables and data sources

Variables	Definitions	Sources
MVA	Manufacturing refers to industries belonging to ISIC divisions 15-37. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Note: For VAB countries, gross value added at factor cost is used as the denominator.	WDI (2021)
Infrastructure	Composite index of infrastructure quality, including electricity, transport, ICT and water and sanitation.	AfDB (2018)
Population size	Total population based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.	WDI (2021)
GDP per capita	The sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products, divided by midyear population. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars.	WDI (2021)
Share of Urban Pop.	Percentage of a country's urban population living in that country's largest metropolitan area.	WDI (2021)
Nominal exchange rate	The value of a currency against a weighted average of several foreign currencies divided by a price deflator or index of costs.	WGI (2021)
Control of corruption	Perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. Estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, i.e. ranging from approximately -2.5 to 2.5.	WGI (2021)
Total natural resources	The sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents, expressed as a percentage of GDP.	WDI (2021)

Source: Authors' construction.

Table A3: Results of the Hausman test

	(b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
AIDI	-0.0055	-0.0023	-0.0032	0.0008
Log (GDP)	-0.0843	0.0450	-0.1294	0.0959
Log (GDP Squared)	0.0659	0.0635	0.0024	0.0057
Log (Population)	1.6084	1.2236	0.3848	0.1192
FDI (% GDP)	0.0007	0.0003	0.0004	0.0002
Log (Nominal ER)	0.0041	0.0071	-0.0029	0.0039
Share of Urban Pop.	0.0118	0.0056	0.0062	0.0022

Source: Authors.
Note: b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test: Ho: difference in coefficients not systematic
chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 107.63
Prob>chi2 = 0.0000