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Article

Infrastructure and manufacturing in Sub-Saharan Africa: An empirical analysis using dynamic panel data models

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Abstract:

The provisioning of adequate infrastructure may be seen as a key contributing factor in the industrialization process as well as economic development across the globe. While there is a vast empirical literature assessing the impact of infrastructure on economic growth, productivity and income inequality, estimates of the effect on infrastructure on manufacturing sector, in particular, are rather scant. Using dynamic panel data models, we empirically investigate the impact of investments in power, transportation and telecommunication sectors on the manufacturing industry for a sample of 48 Sub-Saharan African countries over the 1980-2012 period. Our findings suggest a positive effect of infrastructure provisioning on industrialization in the region.

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The role of the manufacturing industry in economic development has always been at the center of economic debate. According to Chenery (1960), Kaldor (1960), and Rocha (2018), given that the industrial sector tends to have a higher factor productivity in relation to the other sectors, a change in the sectoral composition of the economy in favor of the manufacturing industry increases aggregate productivity. McMillan and Rodrik (2011) provide empirical evidence supporting this argument by showing that most of the difference in the growth of labor productivity in the recent period between Asian, on the one hand, and Latin America and Africa, on the other hand, can be explained by the differences in the patter of structural change, that is, the labor flow from low- to high-productivity sectors. Szirmai and Verspagen (2015) also tested the impact of manufacturing value added on GDP growth, education, and income gaps for a panel of 88 countries in the period 1950-2005 using fixed effects, random effects, and Hausman-Taylor estimations. Their results convincingly show that manufacturing is the main growth-enhancing sector, especially in developing countries. Thus, there seems to be a close connection between the transformation of the economic structure towards the modern sector and the development process. Identifying and understanding the main drivers of the industrialization process may help policymakers in developing countries to design more effective policy actions with the aim to overcome the obstacles to sustained growth and economic development.

In terms of policy, an adequate provision of infrastructure is a necessary condition for the development of a strong industrial sector. Infrastructure is an essential factor to stimulate the industrialization process as well as productivity, competitiveness, and economic development (Straub, 2011; Calderón and Serven, 2014; Chakamera and Alagidede, 2017; Medeiros, Ribeiro and Amaral, 2019, 2020). Good infrastructure reduces firms' costs, increases supply capacity, and indirectly affects productivity growth (IPEA, 2010). In this sense, investment in infrastructure may constitute an important policy tool with the aim of promoting structural change benefiting proportionally more the modern sector with greater capacity to generate economic surplus than the traditional sector.

In light of the literature on growth and economic development, it can be noted that one of the key issues preventing most African countries from climbing the development ladder lies in their difficulties in promoting the expansion of an infrastructure system capable of stimulating the manufacturing sector in particular, and sustained growth of their economic activity as a whole.

Table 1 presents infrastructure indicators from the Global Competitiveness Index (GCI) (World Economic Forum, 2018) for some Sub-Saharan Africa and other emerging countries. In this comparative analysis, we can see the precarious conditions of African infrastructure across all sectors. To the best of our knowledge, international literature and especially the literature dealing with Sub-Saharan Africa has not yet robustly analyzed the relationship between infrastructure and the degree of industrialization. The present work aims to fill this gap in the empirical literature by analyzing the impact of infrastructure provision on the manufacturing sector in particular.

We estimate here the impact of infrastructure provision in the power, transportation, and telecommunications sectors on the manufacturing industry (as a percentage of GDP) for a sample of 48 Sub-Saharan African countries[1] between 1980 and 2012. To the best of our knowledge, the only work close in spirit to ours is that by Khanna and Sharma (2018) in which the authors find a positive impact of a governance quality index (consisting of measures of infrastructure services among other indicators) on the state-level total factor productivity of Indian manufacturing industry. We contribute to the literature by providing evidence of the heterogeneous impact of different infrastructure sectors, i.e. energy, transportation, and telecommunication, on the manufacturing value added share of GDP for a comprehensive set of developing countries in Sub-Saharan Africa.

In addition to this introduction, the remainder of this article consists of three sections. In the next section, we present a brief literature review on the importance of investment in infrastructure for economic development. Section 2 discusses the methodology and data, and section 3 shows the main results. Lastly, we present some conclusions.

[1] For the complete list, see table A1 in the appendix.

Table 1 – *Infrastructure in Sub-Saharan Africa and selected emerging economies, Global Competitiveness Index 2018*

	Overall infrastructure (0-100)	Transportation infrastructure (0-100)	Road infrastructure (0-100)	Power infrastructure (0-100)	Electrification rate (% population)	Mobile subscriptions (per 100 inhabitants)
Côte d'Ivoire	51.18	36.77	56.01	71.77	62.5	100
Cameroon	42.05	27.35	36.69	68.93	63.3	68.27
Dem. Rep. of Congo	33.09	20.92	32.41	51.99	15.2	36.13
Cape Verde	54.66	31.3	38.74	96.58	96.59	93.37
Ethiopia	45.5	33.65	34.9	63.297	40.4	49.71
Ghana	50.25	31.81	50.11	82.99	84.09	100
Angola	40.73	31.64	37.07	63.56	34.7	37.79
Nigeria	42.3	29.3	44.97	73.66	60.6	63.26
South Africa	68.6	57.51	74.38	91.056	86.3	100
Zambia	50.99	44.91	53.4	63.84	33.7	65.51
China	98.29	78.12	67.97	74.02	99.42	100
India	89.84	68.69	63.1	59.65	83.42	82
Brazil	64.55	64.329	43.48	48.73	94.01	99.59
Chile	100	75.23	55.1	80.51	99.52	100

Notes: the higher the value of the index (0-100), the better the infrastructure.
Source: elaboration based on World Economic Forum (2018).

1. Related literature

The importance of investment in infrastructure for economic development has been described by both theoretical and empirical literature. The pioneering study done by Aschauer (1989), which estimated a production function in the period 1949-1985 for the United States, found that public spending on infrastructure was responsible for stimulating productivity gains and fostering economic growth. Regarding the latter aspect, other studies pointed out that: 1) investments in infrastructure reduce production costs, since they decrease spending on intermediary agents (Krugman, 1991); 2) labor productivity is promoted through expanding access to infrastructure (Fourie, 2006); and 3) investments in infrastructure make domestically produced products more competitive (Duranton et al., 2014), which increases exports and decreases imports and public dependence on accumulation of foreign capital, thus improving the prospects for economic growth.

The economic and social development of a nation is linked to its infrastructure provision and quality. Investing in the infrastructure system fosters and enables other investments in the whole economy (Hirschman, 1958; Barro, 1990; Fedderke and Garlick, 2008; Bronzini and Piselli, 2009). Mussolini and Teles (2010) analyze the relationship between both public infrastructure and private capital on productivity in Brazil in the period 1950-2019. The authors estimate a Vector Error Correction (VEC) model and show complementarities between public and private capital: both increase productivity and have a long-term co-integration relationship. In their view, private capital would become more productive due to the greater availability of infrastructure services.

Other studies find a positive relationship between infrastructure and economic growth. Bertussi and Ellery Jr. (2012) investigate the impact of infrastructure spending on economic growth in Brazil in the period 1986-2007. Using static panel data models, they find a positive relationship between infrastructure and economic growth. Applying a quantile regression model, they highlight that expenditures on transport infrastructure is more productive in the less developed regions of the country. Siyan et al. (2015) analyze the impact of road transportation on economic growth in Nigeria. Based on a VEC model, they show that investments in the transportation sector generate positive effects on growth. Similarly, Boopen (2006) analyzes the impact of investment in transport infrastructure on economic growth for a sample of 38 Sub-Saharan African countries. The author uses cross-sectional and panel data econometric models. He finds that the stock of transportation infrastructure contributes to the economic progress of these countries.

From this literature review, it is understood that investment in infrastructure has a positive effect on economic growth, but there is a marked heterogeneity in the results. One can mention, for example, the difference found among analyses that use aggregate data and those that start from disaggregated data. Another strand of literature uses microeconomic variables to analyze the impact of investment in infrastructure on reducing industrial costs. Following this line of research, we can mention the study by Morrison and Schwartz (1996). Their findings indicate that the increase in the infrastructure stock has a significantly positive impact in terms of increased efficiency (cost reduction) of production. According to Ferreira (1994), for a given number of private factors, better road, power, and communication infrastructure raise the productivity of private factors and reduce the cost per unit of input. It is important to note that here there is also a recognition of the heterogeneity of the effect of infrastructural investment on economic growth: it can change from industry to industry, location to location, as well as over time (Straub, 2011; Calderón and Serven, 2014; Asher and Novosad, 2017).

The literature on infrastructure and development indirectly shows how the relationship between infrastructure and manufacturing is subject to change, also when considering the diversification of logistical conditions and the scale of production. It is necessary to think about policies aimed at expanding investments in infrastructure to sustain present and future industrial demands. According to Luger et al. (2013), it is necessary to make investments in specific types of infrastructure to meet the manufacturing requirements. In the same way, not only does the industry require a certain infrastructure, but also the converse is true: the investment decisions in infrastructure itself can be guided by industrial performance. In other words, advances in the manufacturing development stage generate bottlenecks in the production process, thus increasing the need for more investments in infrastructure. Yet, investments in infrastructure relax the supply constraints for capital accumulation and hence enable the manufacturing industry to attain a sustained growth path. This means that the relationship between manufacturing and infrastructure is one of mutual and dynamical dependence over time.

2. Methodology and data

We use panel data models in order to estimate the relationship between infrastructure and industrialization in 48 Sub-Saharan Africa countries during the 1980-2012 period. The model specification goes as follows:

$$y_{it} = \gamma + \lambda y_{i,t-1} + \alpha_1(infrastructure)_{it-1} + \alpha_2(infrastructure)_{it-2} + \beta x_{it} + v_i + \kappa_t + e_{it} \quad (1)$$

where i and t represent the cross-sectional and time units, respectively; $\gamma, \lambda, \alpha_1, \alpha_2$, and β are parameters to be estimated; y_{it} is the dependent variable and denotes deviations of the log of the manufacturing share of GDP from its Hodrick-Prescott (HP) trend; $y_{i,t-1}$ accounts for an autoregressive term; x_{it} is a vector of control variables, in logs; v_i and κ_t are unobserved effects associated with Sub-Saharan African countries and time, respectively; and e_{it} denotes the error term. Infrastructural investments take some time to reach maturity (Medeiros and Ribeiro, 2020; Medeiros et al., 2020). In order to avoid this issue, we have included lagged observations of the infrastructure indicators.

It is observed that the differences in terms of population, income levels, and productive structure across countries in the region can influence the degree of infrastructure investments in each location. More industrialized countries may demand more investments in infrastructure and, at the same time, greater infrastructure can stimulate industrial production. If the issue of possible reverse causality among the dependent and independent variables of the model is not taken into account, the coefficients (α_1 and α_2) measuring the responsiveness of manufacturing to changes in the stock of infrastructure may be biased. To avoid this issue, we use the Generalized Method of Moments (GMM) estimator, which is more suitable for this type of problem as it takes into account the possible endogeneity of one or more regressors, it controls for the unobserved fixed effects related to the cross-sectional units, and it allows a dynamic panel analysis by inserting the lag of the dependent variable into the model. Differences regressions can solve these problems and our suggestion is to use the GMM-Difference or GMM-System methods (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998).

In the presence of endogenous variables, the GMM-Difference, as proposed by Arellano and Bond (1991), has advantages over the static panel models (such as Pooled OLS, Fixed and Random Effects estimators) as it uses lagged observations of the endogenous variables in levels as instruments for the endogenous variables in first differences in order to avoid the bias. However, a problem occurs when endogenous variables show a high degree of persistence over time, which means that lagged observations fail to be a proper instrument for the first differences (Arellano and Bover, 1995; Blundell and Bond, 1998). In this case, the GMM-System method developed by Blundell and Bond (1998) is a more adequate alternative, as it adds to the matrix of instruments the lagged differentials of endogenous variables in levels. The authors show through Monte Carlo simulations that the GMM-System estimator is systematically more robust than the GMM-Difference estimator.

The validity of the instruments can be evaluated through the *J*-statistic of the Hansen test. The null hypothesis implies the joint validity of the instruments. The Arellano and Bond test for AR (2) in the first differences should also be tested. The null hypothesis of this test states that the residuals of the difference regression are serially uncorrelated in the second order. However, the proliferation of instruments may cause over-identification of the endogenous variables. We tried to maintain the number of instruments to the minimum. To do so, we used up to two lags of the endogenous variables and collapsed the instrument matrix in order to limit the proliferation of the instruments.

The model developed here considers manufacturing, infrastructure, trade openness, and GDP per capita as endogenous regressors, and the level of education, and population as exogenous regressors. It is worth noting that in order to satisfy the consistency properties of the GMM estimator we must have a panel structure with a large number of cross-sectional units and a short time span. So, following a standard procedure in this literature we averaged the variables over 4-year window periods, thus resulting in eight time-periods for each country in the sample.

2.1. Data

In order to evaluate the effects of infrastructure provision on industrialization, we utilize a database from the African Development Bank. To account for infrastructure provision, variables representing the transportation, telecommunication, and power sectors are considered. Data related to value added in manufacturing, trade openness, human capital, and GDP per capita are also included.

Infrastructure stocks are the first group of variables we consider. Following the literature (Medeiros et al., 2020; Calderón and Serven, 2014; Straub, 2011), these variables capture the provision of a given infrastructural sector, such as power, transportation, and telecommunications, for a given country, of which the services are offered for general use by the population. As a proxy for the transportation sector, the natural logarithm of the total length of paved roads in kilometers divided by the total area of the country in squared kilometers is used. It should be noted that the infrastructure provision measures used in our estimates do not capture infrastructure quality and access, which constitutes a limitation of our work. Due to the unavailability of access and quality data for a longer time period, we only use provision measurements. Also due to data availability problems, we cannot include other transportation sectors that could be important to explain the infrastructure-industrialization nexus.

We utilize the natural logarithm of the installed electricity generation capacity (in kilowatts) divided by the number of inhabitants to represent the power infrastructure provision, which is the power supply variable more commonly used in the literature. In order to represent the telecommunication sector, we take the natural logarithm of the number of mobile phone subscribers per 1000 inhabitants. The choice of these measures follows the existing literature in order to enhance comparability (Calderón and Chong, 2004; Calderón and Servén, 2004, 2010).

The variable to be explained is the manufacturing industry share in value added (in percentage of GDP). We, then, use the Hodrick-Prescott (1997) filter to detrend this series and isolate its cyclical component by country. The idea here is to reduce the possibility of capturing spurious statistical relationships between the regressors and the stochastic trends of the dependent variable in the whole sample or in particular countries. By so doing, we also increase the robustness of the autoregressive term in the estimates below.

Trade openness is the sum of exports and imports, in percentage of GDP. Trade openness might increase market size, boosting productivity and facilitating integration between the world's economies. Another control variable that we consider is GDP per capita. The objective of this variable is to control for the level of development and possible differences in institutional quality of the countries. The gross percentage of secondary school enrollment is considered as a measure of human capital, which plays a fundamental role in economic growth models. Finally, we use population as a proxy for labor supply.

Table 2 presents more details on the variables used in the econometric analysis and the sources of data.

Table 2 – *Variables description*

Variable	**Description**	**Source**
Population	Number of inhabitants (in log)	AfDB dataset
Transportation infrastructure	Roads (km) per area in km^2 (in log)	AfDB dataset
Power infrastructure	Installed electricity generation capacity (kW) per capita (in log)	AfDB dataset
Telecommunication infrastructure	Number of mobile phone subscribers per capita (in log)	AfDB dataset
Manufacturing	Industrial share of value added (% GDP) (in log)	AfDB dataset
Manufacturing cycle	Deviation of manufacturing from the Hodrick-Prescott filter trend, with smooth parameter equal to 1600	Authors' elaboration
Trade openness	Sum of exports and imports (in % GDP) (in log)	AfDB dataset
Human capital	Gross enrollment percentage in secondary school (in log)	AfDB dataset
GDP per capita	Gross Domestic Product per capita (constant 2000 US$) (in log)	AfDB dataset

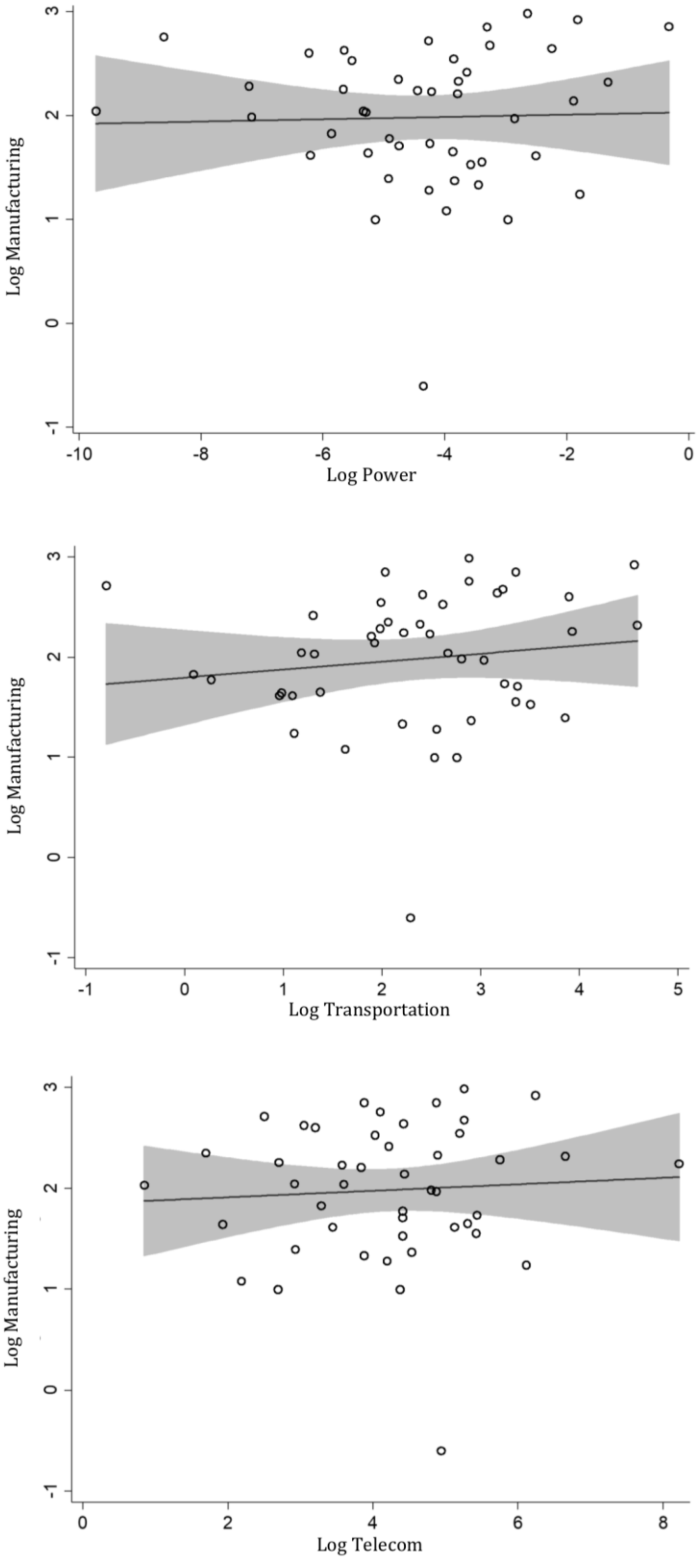
Source: African Development Bank Group (AfDB), https://dataportal.opendataforafrica.org/

3. Results

Figure 1 shows the correlations among manufacturing and the infrastructure provision measures by country, averaged over the 1980-2012 period. In general, we observe a slightly upward sloping trend line, which indicates that infrastructure provisioning and the performance of the manufacturing sector in the Sub-Saharan African case may be positively correlated. There are some countries with similar infrastructure endowments, but at quite different stages in the industrialization process. Those correlations appear to reveal substantial heterogeneity in terms of productive structure and infrastructure provision within the region.

The estimates of the effects of power infrastructure on manufacturing are described in table 3. The estimations were conducted using four techniques: Pooled OLS, Fixed Effects, GMM-Difference, and GMM-System. Since the Pooled OLS and FE models yield inconsistent estimates for either lagged observations of the dependent variable as a regressor or endogenous variables (or both), we focus our discussion here on the GMM System estimates ("GMM-Sys" columns), since they yield the results most robust to reverse causality. The Hansen test indicates that the set of instruments used in the model are valid, and the model is statistically suitable.

Figure 1 – *Correlation between manufacturing and infrastructure, by country, data averaged over the 1980-2012 period (grey area accounts for 95% confidence interval)*



Source: see table 2.

Regarding the variables of interest, we find a positive and statistically significant relationship between an increase in the power infrastructure stock and the participation of the manufacturing sector in GDP (see table 3). Our findings suggest that an increase by 10% in the power stock per capita leads to an average increase of 0.06% in the deviation from the trend of the manufacturing share of GDP after one period. This positive relationship is consistent with the reports by Foster and Briceno-Garmendia (2010), according to which, in recent years, the continent has invested more in power infrastructure, causing an increase in GDP.

Table 3 – *Power infrastructure effects on manufacturing in Sub-Saharan Africa, 1980-2012*

	Pooled OLS	**Fixed Effects**	**GMM-Diff**	**GMM-Sys**
Manufacturing cycle at $t-1$			0.0530	0.1119
			(0.14)	(0.13)
Power infrastructure at $t-1$	0.0037	0.0049*	0.0045	0.0064*
	(0.00)	(0.00)	(0.00)	(0.00)
Power infrastructure at $t-2$	−0.0013	−0.0033	−0.0076	−0.0009
	(0.00)	(0.00)	(0.01)	(0.00)
GDP per capita at t	−0.1503	−1.0015***	−2.3983	−0.1267
	(0.09)	(0.31)	(1.61)	(0.38)
Trade openness at t	0.0045	0.0407	−0.1736	0.1381
	(0.02)	(0.06)	(0.31)	(0.18)
Human capital at t	0.0273	0.0440	0.0889	−0.0233
	(0.02)	(0.04)	(0.10)	(0.08)
Constant	0.1752	1.5146**		−0.2425
	(0.12)	(0.60)		(0.62)
Observations	211	211	148	210
Instruments			14	20
R^2 Adjusted	0.0010	−0.2065		
Arellano-Bond test for AR(2) in first difference (p-value)			0.3230	0.2310
Hansen test of joint validity of instruments (p-value)			0.2271	0.1703

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Notes:
1. Below the coefficients we report the standard errors.
2. Two-step standard errors are robust to the Windmeijer (2005) heteroscedasticity correction, which greatly reduces the downward bias of the one-step standard error.
3. Unobserved individual effects are removed by first differencing in the Fixed-Effects model and in the GMM-Diff and GMM-System.
4. In both GMM-Difference and GMM-system, only human capital is considered as strictly exogenous.
5. The first, the second and the third lags of the endogenous variables were used as instruments for the endogenous variables in the GMM-Difference and GMM-System.
6. We collapsed the instruments in order to restrict the number of instruments (Roodman, 2009).
7. Hansen test: the null hypothesis is that the instruments are not correlated with the residuals.
8. Arellano-Bond test for AR(2) in first difference: the null hypothesis is that the errors in the first difference regression have no second order serial correlation. See table A2 in the appendix for additional estimates for the power sector using GMM-System.

Chakamera and Alagidede (2017) too point out a positive relationship between power infrastructure and economic growth in Sub-Saharan Africa. In the same perspective, Rocha (2013) points out that the investments made in the power sector had a positive effect on the performance of industry and the economy in general. We, thus, provide new evidence on the role of power infrastructure on manufacturing; this finding was expected, given that industrial activity is deeply dependent on power supply to serve capital-based activities.

Table 4 – *Transportation infrastructure effects on manufacturing in Sub-Saharan Africa, 1980-2012*

	Pooled OLS	**Fixed Effects**	**GMM-Diff**	**GMM-Sys**
Manufacturing cycle at *t* – 1			–0.1271	–0.1010
			(0.24)	(0.15)
Transportation infrastructure at *t* – 1	–0.0027	–0.1407	–0.3775	0.3025***
	(0.13)	(0.19)	(0.33)	(0.11)
Transportation infrastructure at *t* – 2	0.0086	–0.0854	–0.4844*	–0.1531
	(0.12)	(0.18)	(0.28)	(0.09)
GDP per capita at *t*	–0.1857	0.7045	1.4426	–1.0260
	(0.14)	(0.87)	(1.42)	(0.63)
Trade openness at *t*	0.0136	0.2360	0.3964*	0.0090
	(0.04)	(0.16)	(0.22)	(0.21)
Human capital at *t*	0.0197	0.0135	0.0157	0.0684
	(0.03)	(0.09)	(0.14)	(0.07)
Constant	0.1803	–1.8629		1.2102**
	(0.18)	(1.57)		(0.58)
Observations	103	103	62	102
Instruments			23	29
R^2 Adjusted	–0.0294	–0.6081		
Arellano-Bond test for AR(2) in first difference (*p*-value)			0.5896	0.4715
Hansen test of joint validity of instruments (*p*-value)			0.2235	0.3853

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Notes:
1. Below the coefficients we report the standard errors.
2. Two-step standard errors are robust to the Windmeijer (2005) heteroscedasticity correction, which greatly reduces the downward bias of the one-step standard error.
3. Unobserved individual effects are removed by first differencing in the fixed-effects model and in the GMM-Diff and GMM-System.
4. In both GMM-Difference and GMM-System, only human capital is considered as strictly exogenous.
5. The first, the second and the third lags of the endogenous variables were used as instruments for the endogenous variables in the GMM-Difference and GMM-System.
6. We collapsed the instruments in order to restrict the number of instruments (Roodman, 2009).
7. Hansen test: the null hypothesis is that the instruments are not correlated with the residuals.
8. Arellano-Bond test for AR(2) in first difference: the null hypothesis is that the errors in the first difference regression have no second order serial correlation. See table A2 in the appendix for additional estimates for the transportation sector using GMM-System.

Table 5 – *Telecommunication infrastructure effects on manufacturing in Sub-Saharan Africa, 1980-2012*

	Pooled OLS	**Fixed Effects**	**GMM-Diff**	**GMM-Sys**
Manufacturing cycle at $t-1$			0.4456	–0.5092
			(1.60)	(1.45)
Telecommunication infrastructure at $t-1$	–0.0475*	0.0625	0.0091	–0.0771
	(0.03)	(0.08)	(0.44)	(0.05)
Telecommunication infrastructure at $t-2$	0.0272	–0.0225	–0.0153	0.0403*
	(0.02)	(0.05)	(0.31)	(0.02)
GDP per capita at t	0.1928	–4.8688	–8.1578	0.3664
	(0.12)	(3.18)	(7.91)	(0.36)
Trade openness at t	–0.0161	0.2381	1.0508	–0.1225
	(0.03)	(0.39)	(1.31)	(0.39)
Human capital at t	–0.0558	0.1524	0.2819	–0.0470
	(0.04)	(0.26)	(0.38)	(0.10)
Constant	0.0552	7.1217		0.2562
	(0.22)	(4.64)		(1.12)
Observations	48	48	8	48
Instruments			8	15
R^2 Adjusted	0.0647	–0.4399		
Arellano-Bond test for AR(2) in first difference (p-value)			1.0000	0.5647
Hansen test of joint validity of instruments (p-value)			1.0000	0.3630

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Notes:

1. Below the coefficients we report the standard errors.
2. Two-step standard errors are robust to the Windmeijer (2005) heteroscedasticity correction, which greatly reduces the downward bias of the one-step standard error.
3. Unobserved individual effects are removed by first differencing in the fixed-effects model and in the GMM-Difference and GMM-System.
4. In both GMM-Difference and GMM-System, only human capital is considered as strictly exogenous.
5. The first, the second and the third lags of the endogenous variables were used as instruments for the endogenous variables in the GMM-Difference and GMM-System.
6. We collapsed the instruments in order to restrict the number of instruments (Roodman, 2009).
7. Hansen test: the null hypothesis is that the instruments are not correlated with the residuals.
8. Arellano-Bond test for AR(2) in first difference: the null hypothesis is that the errors in the first difference regression have no second order serial correlation. See table A2 in the appendix for additional estimates for the telecommunication sector using GMM-System.

Lastly, we present our findings on the impact of telecommunication infrastructure on manufacturing (see table 5). Our results suggest that an expansion of 10% in the digital infrastructure such as mobile lines, broadband and internet services has led to an increase of roughly 0.4% in the share of manufacturing in total GDP above its trend after two periods in sub-Saharan African countries. Digital infrastructure facilitates the distribution of information and the exchange of ideas, which tends to favor technology- and knowledge-intensive industries by cutting transaction and organization costs and by increasing the possibilities for the development of new products and services. Thus, our findings show that not only physical, but digital infrastructure too may play a key role in promoting the growth of the manufacturing sector in the region.

4. Concluding remarks

Infrastructure is essential in the industrialization process as well as for economic and social development. Investments in the sector reduce firms' costs, increase supply capacity and production flows, indirectly influencing productivity growth. Institutional reforms are needed to encourage both public and private investment in infrastructure. A series of reforms from the 1990s paved the way to encourage private sector participation in infrastructure investment. However, those investments undertaken following the reforms were not sufficient to overcome the African infrastructure gap.

Our results show that the impact of all infrastructure sectors on manufacturing is positive and statistically significant. In other word, expanding investments in transportation, telecommunication, and power infrastructure is expected to be an important policy tool in order to develop the industrial sector in Africa. Our findings shed some light on a key issue affecting the productive structure in Sub-Saharan Africa countries – the infrastructure –, which has not received much attention by the existing literature on infrastructure and economic development.

Our results imply that it is necessary to strengthen both national and local infrastructure policies in order to foster a developmental impulse in the Sub-Saharan Africa industrial sector. Furthermore, there is a need for greater integration between the Sub-Saharan Africa countries, which might require wider and better coordination among governments of different countries.

Lastly, it is worth noting that our empirical assessment does not take into account the differences in the quality and access of infrastructure coverage across the Sub-Saharan African territory. Unfortunately, indicators about these are not available for the entire time span of our sample. When available, indicators of access and quality of infrastructure should be included in the model; we leave these possible extensions for future work.

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Appendix

Table A1 – *List of countries*

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

Table A2 – *Power infrastructure effects on manufacturing in Sub-Saharan Africa, 1980-2012*

	(1)	**(2)**	**(3)**
Manufacturing cycle at $t-1$	0.1185	0.1258	0.1119
	(0.07)	(0.08)	(0.13)
Power infrastructure at $t-1$	0.0021	0.0016	0.0064*
	(0.00)	(0.00)	(0.00)
Power infrastructure at $t-2$	0.0009	0.0002	−0.0009
	(0.00)	(0.00)	(0.00)
GDP per capita at t	−0.1199	−0.1572	−0.1267
	(0.16)	(0.19)	(0.38)
Trade openness at t		0.0013	0.1381
		(0.09)	(0.18)
Human capital at t			−0.0233
			(0.08)
Constant	0.2346	0.2867	−0.2425
	(0.29)	(0.31)	(0.62)
Observations	263	258	210
Instruments	15	19	20
Arellano-Bond test for AR(2) in first difference (p-value)	0.0390	0.0427	0.2310
Hansen test of joint validity of instruments (p-value)	0.3875	0.2617	0.1703

$^{***}\ p < 0.01$, $^{**}\ p < 0.05$, $^{*}\ p < 0.10$

Notes:

1. Below the coefficients we report the standard errors.
2. Two-step standard errors are robust to the Windmeijer (2005) heteroscedasticity correction, which greatly reduces the downward bias of the one-step standard error.
3. Unobserved individual effects are removed by first differencing.
4. Only human capital is considered as strictly exogenous.

5. The first, the second and the third lags of the endogenous variables were used as instruments for the endogenous variables.
6. We have collapsed the instruments in order to restrict the number of instruments (Roodman, 2009).
7. Hansen test: the null hypothesis is that the instruments are not correlated with the residuals.
8. Arellano-Bond test for AR(2) in first difference: the null hypothesis is that the errors in the first difference regression have no second order serial correlation.

Table A3 – *Transportation infrastructure effects on manufacturing in Sub-Saharan Africa, 1980-2012*

	(1)	**(2)**	**(3)**
Manufacturing cycle at $t - 1$	–0.1289	–0.0166	–0.1010
	(0.10)	(0.13)	(0.15)
Transportation infrastructure at $t - 1$	–0.0268	–0.0134	0.3025***
	(0.24)	(0.36)	(0.11)
Transportation infrastructure at $t - 2$	–0.0845	–0.0891	–0.1531
	(0.16)	(0.18)	(0.09)
GDP per capita at t	–1.7268***	–0.9288	–1.0260
	(0.59)	(0.59)	(0.63)
Trade openness at t		–0.1723	0.0090
		(0.19)	(0.21)
Human capital at t			0.0684
			(0.07)
Constant	3.4092***	2.6646**	1.2102**
	(1.10)	(1.27)	(0.58)
Observations	123	121	102
Instruments	21	28	29
Arellano-Bond test for AR(2) in first difference (p-value)	0.9231	0.9024	0.4715
Hansen test of joint validity of instruments (p-value)	0.4414	0.5187	0.3853

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Notes:
1. Below the coefficients we report the standard errors.
2. Two-step standard errors are robust to the Windmeijer (2005) heteroscedasticity correction, which greatly reduces the downward bias of the one-step standard error.
3. Unobserved individual effects are removed by first differencing.
4. Only human capital is considered as strictly exogenous.
5. Lags from one to six of the endogenous variables were used as instruments for the endogenous variables.
6. We have collapsed the instruments in order to restrict the number of instruments (Roodman, 2009).
7. Hansen test: the null hypothesis is that the instruments are not correlated with the residuals.
8. Arellano-Bond test for AR(2) in first difference: the null hypothesis is that the errors in the first difference regression have no second order serial correlation.

Table A4 – *Telecommunication infrastructure effects on manufacturing in Sub-Saharan Africa, 1980-2012*

	(1)	**(2)**	**(3)**
Manufacturing cycle at *t* – 1	–0.7221***	–0.5301	–0.5092
	(0.21)	(0.36)	(1.45)
Telecommunication infrastructure at *t* – 1	0.0176	–0.0295	–0.0771
	(0.03)	(0.05)	(0.05)
Telecommunication infrastructure at *t* – 2	–0.0171	0.0090	0.0403*
	(0.03)	(0.04)	(0.02)
GDP per capita at *t*	0.1739	–0.3418	0.3664
	(0.28)	(0.54)	(0.36)
Trade openness at *t*		0.1721	–0.1225
		(0.30)	(0.39)
Human capital at *t*			–0.0470
			(0.10)
Constant	–0.3633	–0.0175	0.2562
	(0.56)	(0.88)	(1.12)
Observations	58	58	48
Instruments	15	19	15
Arellano-Bond test for AR(2) in first difference (*p*-value)	0.3679	0.3384	0.5647
Hansen test of joint validity of instruments (*p*-value)	0.1134	0.5306	0.3630

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Notes:
1. Below the coefficients we report the standard errors.
2. Two-step standard errors are robust to the Windmeijer (2005) heteroscedasticity correction, which greatly reduces the downward bias of the one-step standard error.
3. Unobserved individual effects are removed by first differencing.
4. Only human capital is considered as strictly exogenous.
5. Lags from one to three of the endogenous variables were used as instruments for the endogenous variables.
6. We have collapsed the instruments in order to restrict the number of instruments (Roodman, 2009).
7. Hansen test: the null hypothesis is that the instruments are not correlated with the residuals.
8. Arellano-Bond test for AR(2) in first difference: the null hypothesis is that the errors in the first difference regression have no second order serial correlation.