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**Linear and non-linear effects of infrastructures on inclusive human development in Africa**

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# Linear and non-linear effects of infrastructures on inclusive human development in Africa

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## Abstract

The objectives of this paper are to verify the linear and the non-linear effects of infrastructural development on inclusive human development in Africa. The results of the system GMM estimations show a positive effect of infrastructural development on inclusive development across all the infrastructural development indexes employed, except the ICT infrastructural composite index which presents an insignificant negative effect. Besides, a non-linear effect of infrastructures on inclusive development was established across all the infrastructure indicators except for the ICT indicator. Negative thresholds for complementary policies are established for the African Infrastructure Development Index (AIDI) and the transport index while positive thresholds are apparent for the electricity index and the water and sanitation infrastructure index (WSS). Accordingly, in order to sustain the positive incidence of the AIDI and transport index on human development, complementary policies should be engaged to avoid an overall negative effect on human development when the indexes are respectively, 31.12% and 25.56%. In the same vein, the electricity index and WSSI should exceed critical levels of respectively 49.79% and 41.92%, to engender an overall positive effect on inclusive human development.

*Keywords*: Infrastructure; Inclusive development: Africa

*JEL Classification*: N67; N77; C23; I00; O55

## 1. Introduction

The motivation of this study on whether an infrastructural development matter for inclusive human development is by three principal factors. Firstly, the African continent is has been established as the least endowed region of the world in infrastructure stocks, even compared to its developing counterparts (Bond, 2016). Secondly, the 2030 agenda for sustainable development highlights sustainable infrastructure as a central target and equally the central role of inclusive human development in this agenda (Tchamyou et al., 2019a; Tchamyou, 2019) and thirdly, the research gap in literature.

To begin with, Africa's economic development path has taken an upward direction since the early 1990s, despite some external disturbances that engender oscillations on this growth path. However, the attendant growth path is not uniformly distributed on per capita bases as the human development of the continent is still a little more to be desired (Asongu and Nwachukwu, 2018). Recently, economists including the Nobel Laureate Amartya Sen have questioned the effectiveness of growth in promoting wellbeing and the quality of life. This has been shown in the sense that some poorer nations do better in wellbeing indicators than some of their richer counterparts. In this respect, economic growth is not a guarantee for human development.

For the African continent, it has been argued that the lag in the quality of life is due to the fact that growth has not been accompanied by economic transformation mostly as a result of low level of investments (Ajakaiye and Ncube, 2010; Tchamyou et al. 2019b). For adequate transformation to be witnessed, sectoral infrastructural development matters. However, Africa lags behind in terms of infrastructures. The combination of low endowment in infrastructure and poor quality infrastructure services in Africa relative to other developing regions means that the continent has additional development hurdles to over-come. These attendant development hurdles include inclusive development. The lack of robust transport linkages between rural and urban markets for instance, reduces opportunities for the advancement of agriculture from subsistence to market-based. Indeed, infrastructural development increases economic productivity (Albala-Bertrand and Mamatzakis, 2004).

In recent years, Africa has improved on its infrastructural development mostly attributed to the progress made in the information and communication technology (ICT) sector as well as water and sanitation (Njamen et al., 2020). Investment in infrastructures that facilitate economic transformation would increase per capita growth. That of social infrastructures such as water and sanitation would increase the health status, while

educational infrastructures would go a long way in improving on educational quality. Conclusively, investment in infrastructures, if properly utilised, would improve inclusive human development. However, studies on the explaining factors of inclusive human development in Africa have been largely limited to: foreign development aid (Asongu and Nwachukwu, 2018); environmental quality (Asongu et al., 2017; Asongu, 2018; Asongu and Odhiambo, 2021); information and communication technology (Asongu and Nwachukwu, 2017); external flows (Asongu and Leke., 2019); social media (Asongu and Odhiambo, 2021) and natural resources rents (Nchofoung et al., 2021)[1]. To the best of knowledge, no study has attempted establishing the effect of infrastructural development on inclusive human development. Accordingly, one of the indicators that have widely been argued as an engine for growth is infrastructures (Ayogu, 2007). Moreover, Carrus (2017) has argued that green infrastructures matter for human health and wellbeing. In fact, infrastructures and inclusive human development seen in the angle of the latter's constitutive variables (health, education, growth and inequality) are highlighted in the 2030 Sustainable Development Agenda of the United Nations Development Programme (UNDP). Looking at statistics on these indicators, following the 2020 UNDP classification, the highest ranked country in Africa in terms of human development, Mauritius with a score of 0.804[2] is only 66$^{th}$ in the World. In fact, the bottom quarter of the classification are mostly occupied by African countries, with majority of them with scores less than 50. Indeed countries like Chad, the Central Africa Republic and Niger are the least classified in the world with scores less than 40. These performances in human development are even worst when adjusted for inequality, with countries like the Central African Republic scoring less than 25. Looking at the infrastructural performances of these countries as reported by the African Development Bank in 2021, the best ranked country in terms of composite infrastructural development is Seychelles with a score of 96.73[3] up from 70.5 in 2010 followed by Egypt (88.39) from 53.1 in 2010. In fact, only 12 of the 54 African countries had scores above 30 in 2020 from 9 in 2010 and less than 10 of these countries have a score above 50, with countries like Niger, Chad, and Somalia with scores of 6.46, 7.84 and 4.53 respectively up from 3.6, 3.9 and 2.5 respectively in 2010. Though the level has almost doubled in most of these countries compared to the 2010 index, there is still a lot to be desired. The objective of this paper is thus to investigate the linear and non-linear effects of infrastructural development on inclusive human development in Africa.

[1] A search of "inclusive human development" on Google Scholar shows that most the contemporary studies have been published by Asongu and co-authors.

[2]UNDP normalizes the values to range between 0 and 1, with 1 representing an ideal human development index desired, while 0 represents the worst human development index score.

[3]These values are normalized to score between 0 and 1. The more the value is closer to 1, the more the country is ready to respond to the infrastructural need necessary for its development (AfDB, 2018).

The contribution of this paper is at least threefold. Firstly, to the best of knowledge, this is the first study to assess the effect of infrastructural development on inclusive human development in Africa. The closest studies focusing on the underlying effect are Carrus (2017) and Asongu and Nwachukwu (2017). But this study substantially departs from the attendant studies for three main reasons. Firstly while the work of Asongu and Nwachukwu (2017) is limited only to ICT development (i.e. which is just a sub-set of the ICT infrastructure considered in this study), the study of Carrus (2017) focuses on green infrastructures only. Besides, the human development indicator considered in his study was limited to health. This study apart from using composite infrastructural development indexes uses the inequality adjusted human development index. Secondly, this study puts into evidence the type of infrastructures that matter most for inclusive human development in Africa. Thirdly, non-linear relationships are established within the remit of quadratic regressions in order to articulate negative policy thresholds for complementary policies as well as positive thresholds. Accordingly, the negative thresholds represent critical infrastructure levels at which complementary policies are worthwhile in order to maintain an enhancing incidence on inclusive human development while positive thresholds denote critical benchmarks of infrastructure development that should be attained in order for the underlying infrastructure to engender a positive incidence on human development.

Away from this introductory section, the rest of this paper is organised as follows: section 2 presents a brief review of literature, section 3 outlines the econometric technique employed, section 4 presents the results and discussions and finally section 5 concludes.

## 2. Brief review of literature

This section highlights two strands of literature. The first strand of literature presents literature on infrastructural development, while the second strand of literature focuses on the determinants of inclusive human development.

In the first strand of literature, Albala-Bertrand and Mamatzakis (2004) posit that public infrastructures reduce production cost and as a result increase productivity in the Chilean economy. Also, Ogun (2010) investigates the effect of infrastructural development on poverty reduction in Nigeria between 1970 and 2015 through the Structural Vector Autoregressive technique. The results indicate that infrastructures reduce poverty and that social infrastructures explain the forecast error in poverty reduction than physical infrastructure. Calderón and Servén (2010) argue that the volume of infrastructure has a positive impact on long-run growth and a negative impact on inequality in Africa between

1960 and 2005. On their part, Blimpo et al. (2013) examine the nexus between marginalisation in politics, public investment in infrastructures and food security in Ghana, Benin, Senegal and Mali. They argue that political factors affect the allocation of road infrastructures and in this respect; politically marginalised areas suffer from food insecurity due to fewer road infrastructures. Besides, Mohanty et al. (2016) argue that infrastructural development is an engine for human development in India. In addition, Germaschewski (2020) examines the distributional incidences and welfare ramifications of a joint fiscal and monetary policy response to the expansion of public infrastructure in emerging market economies. It is apparent from the findings that investment in government infrastructure provides significant gains in welfare to the economy, and the selection of fiscal instruments engenders substantial distributional impacts across agents. Moreover, Njamen et al. (2020) examine the effect of external debts on infrastructural level in Africa between 2003-2018 periods through a Fixed Effects Driscoll and Kraay's and the Lewbel's estimators. The result indicates that external debts negatively affect the level of infrastructure.

In the second strand of literature, Asongu and Nwachukwu (2017) assess the role of governance in mobile phones for inclusive development through the Fixed Effects, GMM and Tobit regressions for Sub-Saharan Africa between 2000 and 2012. The results show that mobile phones enhance inclusive human development and that good governance has a synergy impact on the established effect. Using an IV Tobit regression technique, Asongu and Le Roux (2017) assess if increasing ICTs in Sub-Saharan Africa promote inclusive human development. The results show that ICT enhances inclusive human development, a result that varies according to the specificities of ICT and inclusive human development. In the same line, Asongu and Odhiambo (2019) assess how increasing carbon dioxide ($CO_2$) emission is likely to influence inclusive human development in 44 countries within the sub-Saharan African region. The results through the Fixed Effects and Tobit regressions show consistent decreasing returns and corresponding net effects that are consistently positive. Using simultaneity-robust Fixed Effects regressions, Asongu and Nwachukwu (2018) assess education thresholds in mobile phones for inclusive development in 49 Sub-Saharan African countries for the period 2000–2012. The results show positive net impacts on inclusive development from the interactions between educational quality and mobile phones. Furthermore, Asongu and Odhiambo (2020) assess the impact of environmental degradation on inclusive human development in 44 countries in Sub-Saharan Africa modulated through governance. The results indicate a net negative effect though governance. Recently, Nchofoung et al. (2021) have posited that natural resource rents enhance inclusive human

development in developing countries and that the result varies depending on the income levels, geographical locations, level of development and export structure.

The above literature lacks a coherent link between infrastructural development and inclusive human development especially for Africa which still lags behind in meeting the sustainable development goals (SDGs). Moreover, as we have discussed in the introduction, the non-linear relationship that could possibly exist between the two concepts is totally neglected in literature. There is thus need in filling this research gap. The following section presents the econometrics strategy that can be applied in achieving the attendant objective and by extension, filling the identified research gap.

## 3. Econometric Strategy

### 3.1 Econometric model specification

Inspired by the work of Asongu and Le Roux (2017), the following empirical model can be specified.

$$IHDI_{it} = \beta_0 + \beta_1 IHDI_{i(t-1)} + \beta_2 INFRA_{it} + \delta_h X_{it} + \upsilon_t + \gamma_i + \varepsilon_{it} \qquad (1)$$

Where IHDI is the inequality adjusted human development index, INFRA is infrastructural development, X is the vector of control variables, υ is the time fixed effect and γ is the country fixed effect.

**Dependent variable**

The dependent variable is the inclusive development proxy by the inequality-adjusted human development index. This has been used in earlier works to measure inclusive human development, including the works of Asongu and Le Roux (2017) and that of Nchofoung et al. (2021).

**Independent Variables of Interest**

Our variable of interest is infrastructural development. Following the studies of Njamen et al. (2020), we use the infrastructural development variables developed by the African Development Bank (AfDB). These include the Africa infrastructure development index (AIDI) which is made up of four sub-indicators namely: the transport infrastructure composite index (transport), the electricity infrastructure composite index (electricity), the information and communication technology infrastructure composite index (ICT) and the

water and sanitation infrastructure composite index (WSS). Both the AIDI and its constituent indicators are used for robustness purposes.

**Control variables**

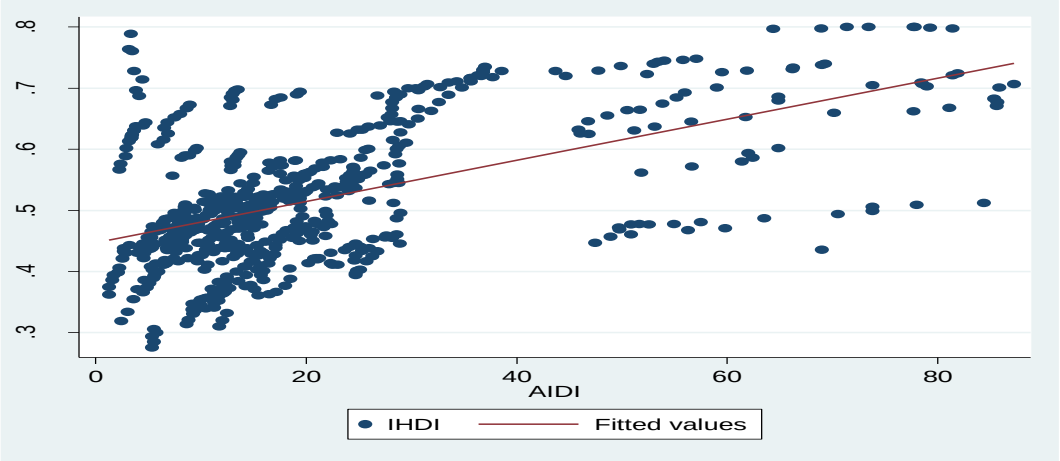
In order to control for omitted variable bias in the model, control variables were included based on contemporary literature on the matter. These include environmental quality (CO2 emission), foreign direct investment inflows (FDI), political stability, inflation, and natural resources rents.

Asongu and Odhiambo (2019) have argued for an environmental Kuznets curve and consistent positive net effect of environment quality on inclusive human development in Sub-Saharan Africa. The expected sign associated with CO2 emission is thus positive. Asongu and Leke (2019) posit that FDI has an enhancing effect on inclusive human development in Africa. A positive sign is expected to be associated with this variable. Political instability is expected to have a negative sign in accordance to Asongu and Nwachukwu (2017). Musahet al. (2019) on their part argue that inflation inhibits economic growth in Ghana. A negative sign is expected to be associated with this variable. Nchofoung et al. (2021) found a positive direct effect of natural resource rents on inclusive human development in developing countries. This variable is thus expected to have a positive sign.

The data for our dependent variable is collected from the UNDP database, that of our variables of interest from the African Development Bank while the rest of the variables are from the World Bank, notably: World Development Indicators and World Governance Indicators. The data is collected between 2003 and 2019 for 36 African countries[4]. Details of data sources and definition of variables are found in Appendix 1 while the summary statistics is presented in Appendix 2. The corresponding correlation matrix is provided in Appendix 3.

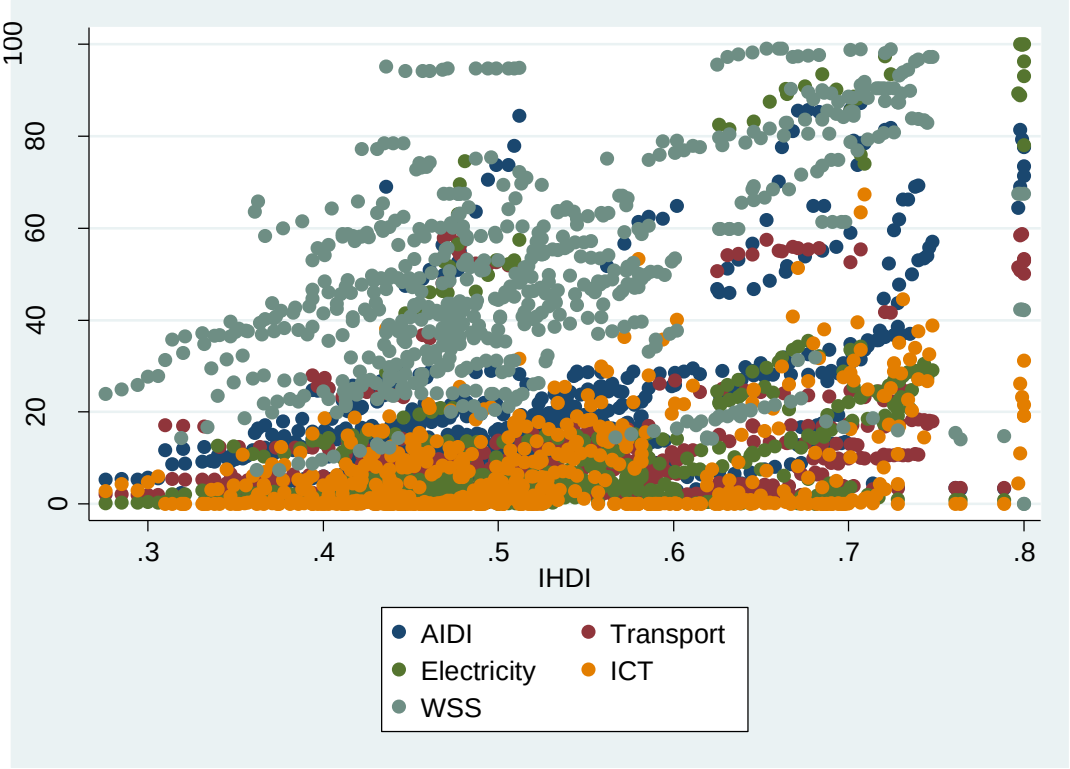
[4]Algeria, Angola, Botswana, Burkina Faso, Cameroon, Congo Democratic Republic, Congo Republic, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Libya, Madagascar, Malawi, Mali, Morocco, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, South Africa, Sudan, Tanzania (United Republic of), Togo, Tunisia, Uganda, Zambia, Zimbabwe

Figure 1. Relationship between AIDI and IHDI in Africa




Source: Authors' computation

Figure 2. Dispersion of the different infrastructural indices in explaining IHDI in Africa




Source: Authors' computation

From Figure 1, there is a perceived positive relationship between infrastructure and inclusive human development in Africa. Figure 2 shows that the share of ICT infrastructures and that of water and sanitation dominate in infrastructural development in Africa.

### 3.2. Estimation method

The generalized method of moments (GMM) is used in this study. The motivation behind this method includes: firstly, the number of cross-sections (36) is greater than the time period which is one of the preliminary requirements for the application of the GMM regression (Tchamyou, 2020). Secondly, the IHDI variable is highly correlated with its past values. In fact, the coefficient of correlation with its first period lag stands at 99.89%. This motivated the inclusion of the lagged dependent variable in our model (Tchamyou, 2021). Thirdly, the method controls for unobserved heterogeneity and simultaneity biases which are two of the four dimensions of endogeneity that could arise as a result of the inclusion of the lagged dependent variable in the model. Fourthly, cross-country dependence in the regressions is controlled.

Roodman (2009) as an extension of the Arellano and Bover (1995) adopted the forward orthogonal deviation to limit instruments proliferation. We employ a similar technique to limit instrument proliferation and restrict over-identification. Besides, we use the two-step instead of the one-step procedure in order to control for heteroscedasticity as the one-step procedure is consistent with homoscedasticity.

The following equations summarises the GMM estimation procedure.

$$IHDI_{it} = \beta_0 + \beta_1 IHDI_{i(t-\tau)} + \beta_2 INFRA_{it} + \sum_{h=1}^{k} \delta_h W_{h,i(t-\tau)} + \upsilon_t + \gamma_i + \varepsilon_{it} \qquad (2)$$

$$IHDI_{it} - IHDI_{i(t-\tau)} = \beta_1\left(IHDI_{i(t-\tau)} - IHDI_{i(t-2\tau)}\right) + \beta_2\left(INFRA_{it} - INFRA_{i(t-\tau)}\right) + \sum_{h=1}^{k} \delta_h\left(W_{h,i(t-\tau)} - W_{h,i(t-2\tau)}\right)\left(\upsilon_t - \upsilon_{t-\tau}\right) + \varepsilon_{i(t-\tau)} \qquad (3)$$

The variables are defined as above.

Dealing with the problem of identification, simultaneity and restrictions, all explanatory variables are suspected of endogeneity in accordance with existing literature on GMM estimation (Asongu and Nwachukwu, 2016; Asongu and Leke, 2019). Accordingly, to maintain our instruments to be strictly exogenous, the period dummies are used as instruments in the regression, in accordance with the attendant GMM-centric literature.

## 4. Presentation and discussion of results

Tables 1 and 2 present the regression results. Whereas Table 1 presents the linear effect of infrastructure on inclusive human development, Table 2 discloses the non-linear effect. In Table 1, a positive effect of infrastructural development on inclusive human development is apparent across all the infrastructural development indexes, except ICT for the infrastructural composite index which presents a negative insignificant effect. Four information criteria are employed to test the validity of our model. Firstly, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR (2)) which is a position for the absence of autocorrelation in the residuals should not be rejected (that is P-value should be >10%). Secondly, the null hypothesis of the Fisher statistics should be rejected for the overall significance of the model to be valid (that is P-value should be<10%). Thirdly, the null hypothesis of the Sargan and Hansen over-identification restrictions tests of validity of instruments should not be rejected (that is P-value should be >10%). Fourthly, the Difference in Hansen Test (DHT) for exogeneity of instruments is also employed to assess the validity of results from the Hansen over-identification restriction test[5]. Besides, to limit the problem of instruments proliferation, we ensured that the number of instruments in each regression is less than the number of cross-sections.

In Table 2, the squared of the infrastructural variables, like the infrastructural variables themselves are in majority of the cases significant. Moreover, their signs are opposing to that of the main variables. This indicates that a non-linear relationship is apparent. This also implies that there is an established threshold for this to be realised. In accordance with contemporary literature on the matter (Njamen et al., 2020), this threshold can be calculated as:

$$threshold = \frac{Coefficient\ INFRA}{2 \times coefficcient\ INFRA\ squared} \times 100 \qquad (4)$$

[5]The results of this test are not reported here because of the good value of both and Hansen and Sargan tests obtained in most of the regressions. The values of the DHT was however one of our decision criterion.

Table 1: effect on infrastructures on inclusive human development

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Variables | Dependent variable: inclusive human development(IHDI) | | | | |
| IHDI(-1) | 0.952*** | 0.971*** | 0.960*** | 0.992*** | 1.001*** |
| | (0.0495) | (0.0511) | (0.0376) | (0.0555) | (0.0566) |
| AIDI | 0.0000194* | | | | |
| | (1.96e-05) | | | | |
| Environmental quality | 0.000557 | 0.00170 | 0.000914 | 0.00170 | 0.000996 |
| | (0.00113) | (0.00130) | (0.000840) | (0.00151) | (0.00131) |
| FDI | 5.48e-05** | 6.59e-05*** | 6.36e-05*** | 5.43e-05** | 3.96e-05* |
| | (2.46e-05) | (2.29e-05) | (2.24e-05) | (2.42e-05) | (2.12e-05) |
| Political stability | 0.00187** | 0.00166 | 0.00151 | 0.00188** | 0.00205** |
| | (0.000915) | (0.00100) | (0.00102) | (0.000911) | (0.000899) |
| Inflation | 7.48e-05* | 6.58e-05* | 6.15e-05 | 7.18e-05* | 8.56e-05** |
| | (3.78e-05) | (3.64e-05) | (3.93e-05) | (3.77e-05) | (3.72e-05) |
| Resource rents | 2.29e-05 | 7.59e-05 | 4.92e-05 | 7.82e-05 | 1.35e-05 |
| | (7.19e-05) | (8.26e-05) | (7.09e-05) | (9.18e-05) | (7.65e-05) |
| | (0.000711) | (0.000743) | (0.000716) | (0.000716) | (0.000747) |
| Transport | | 0.0000544** | | | |
| | | (2.20e-05) | | | |
| Electricity | | | 0.0000398** | | |
| | | | (1.56e-05) | | |
| ICT | | | | -3.65e-05 | |
| | | | | (2.56e-05) | |
| WSS | | | | | 0.0000158* |
| | | | | | (2.03e-05) |
| Constant | 0.0303 | 0.0175 | 0.0245 | 0.00696 | 0.00323 |
| | (0.0284) | (0.0300) | (0.0210) | (0.0327) | (0.0332) |
| Time fixed effects | Yes | Yes | yes | Yes | yes |
| Observations | 444 | 444 | 444 | 444 | 444 |
| Countries | 36 | 36 | 36 | 36 | 36 |
| Prop>AR(1) | 0.0695 | 0.0539 | 0.0555 | 0.0586 | 0.0677 |
| Prop>AR(2) | 0.228 | 0.201 | 0.211 | 0.215 | 0.226 |
| Instruments | 26 | 26 | 26 | 26 | 26 |
| Prop>sargan | 0.955 | 0.537 | 0.521 | 0.408 | 0.966 |
| Prop>Hansen | 0.505 | 0.656 | 0.637 | 0.508 | 0.201 |
| Fisher | 1581*** | 1743*** | 1557*** | 2423*** | 1419*** |

Standard errors in parentheses

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

NB: AIDI is the African infrastructure development index, ICT is the ICT infrastructure index, WSS is the water and sanitation infrastructure index and FDI is foreign direct investment inflows

Table 2: Threshold regression

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Variables | Dependent variable: inclusive human development (IHDI) | | | | |
| IHDI (-1) | 0.907*** | 0.957*** | 0.975*** | 0.968*** | 0.968*** |
| | (0.0159) | (0.00722) | (0.00684) | (0.00602) | (0.00530) |
| Environmental quality | 0.0181*** | 0.0124*** | 0.00804*** | 0.00256*** | 0.00268*** |
| | (0.00170) | (0.00168) | (0.000821) | (0.000467) | (0.000472) |
| FDI | 7.72e-05** | 0.000111*** | 0.000102*** | 9.33e-05*** | 8.50e-05*** |
| | (3.44e-05) | (1.18e-05) | (1.43e-05) | (1.17e-05) | (1.03e-05) |
| Political stability | -0.000683 | 0.00274** | 0.00566*** | 0.00196*** | 0.00192*** |
| | (0.00247) | (0.00106) | (0.00124) | (0.000572) | (0.000590) |
| Inflation | 8.70e-05 | 0.000184 | 0.000204 | 0.000101 | 9.24e-05 |
| | (4.42e-05) | (4.41e-05) | (3.90e-05) | (1.55e-05) | (1.43e-05) |
| Resource rents | 0.000434*** | 0.000338*** | 0.000287*** | 0.000149*** | 0.000111** |
| | (9.87e-05) | (6.56e-05) | (6.34e-05) | (4.95e-05) | (4.25e-05) |
| AIDI | 0.000539** | | | | |
| | (0.000208) | | | | |
| $AIDI^2$ | -8.66e-06*** | | | | |
| | (2.97e-06) | | | | |
| Transport | | 0.000685*** | | | |
| | | (0.000222) | | | |
| $Transport^2$ | | -1.34e-05*** | | | |
| | | (3.99e-06) | | | |
| Electricity | | | -0.000489*** | | |
| | | | (9.10e-05) | | |
| $Electricity^2$ | | | 4.91e-06*** | | |
| | | | (8.30e-07) | | |
| ICT | | | | -3.29e-05 | |
| | | | | (3.32e-05) | |
| $ICT^2$ | | | | 1.44e-07 | |
| | | | | (7.61e-07) | |
| WSS | | | | | -7.42e-05* |
| | | | | | (4.34e-05) |
| $WSS^2$ | | | | | 8.85e-07* |
| | | | | | (4.83e-07) |
| Constant | 0.0251*** | 0.00838** | 0.0126*** | 0.0185*** | 0.0200*** |
| | (0.00776) | (0.00382) | (0.00341) | (0.00352) | (0.00333) |
| Thresholds | 31.12009 | 25.5597 | 49.7963 | --- | 41.9209 |
| Negative versus Positive thresholds | Negative thresholds for complementary policies | | Positive thresholds | | |
| Time fixed effects | yes | yes | yes | Yes | yes |
| Countries | 36 | 36 | 36 | 36 | 36 |
| Prop>AR(1) | 0.00186 | 0.00156 | 0.00462 | 0.0365 | 0.0374 |
| Prop>AR(2) | 0.710 | 0.410 | 0.556 | 0.157 | 0.158 |
| Instruments | 28 | 28 | 28 | 28 | 28 |
| Prop>Sargan | 0.1121 | 0.0211 | 0.000214 | 0.263 | 0.106 |
| Prop>Hansen | 0.184 | 0.253 | 0.392 | 0.360 | 0.334 |
| Fisher | 859.1*** | 6703*** | 13120*** | 4949*** | 6135*** |

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

NB: AIDI is the African infrastructure development index, ICT is the ICT infrastructure index, WSS is the water and sanitation infrastructure index and FDI is foreign direct investment inflows.

The values of these thresholds are computed and presented in Table 2. The results show that the infrastructure thresholds obtained for the various infrastructure indicators are within the infrastructure ranges reported in the summary statistics. These thresholds thus have policy meaning, confirming a non-linear effect of infrastructures on inclusive human development. In essence, enhancing infrastructures increases human development up to this threshold. Above the 25.5597% threshold, transport infrastructures exert negative externalities on the economy which turn to harm human development. Hence, complementary policies are needed at the established thresholds to avoid the negative externalities. Looking at the reality, less than one-third of roads in Africa are paved compared to over three-fifth for low- and middle-income countries (Bond, 2016). Railway networks outside South Africa are under-developed and poorly maintained. Indeed, transport costs in Africa are twice the level of other developing economies (Bond, 2016). The high cost of transport services significantly reduces African competitiveness and exports and constrains economic per capita growth.

Nonetheless, this result is not uniform for all the infrastructural indicators. Above the thresholds of 49.7963% and 41.9209 % for electricity and water and sanitation composite infrastructure indexes respectively, their effects on human development is rather positive. Adequate water and sanitation infrastructures lead to improvements in the health status in the long-run. At the same time, increase in electricity infrastructures boost economic productivity and the per capita growth of the economy and as a result enhances the human development index.

## 5. Concluding implications and future research directions

This paper aimed to verify the linear and non-linear effects of infrastructural development on inclusive human development in Africa. The paper contributed to literature in that: Firstly, this is the first study to empirically verify the effect of infrastructural development on inclusive human development in Africa. The results of the system GMM estimation presented a positive effect of infrastructural development on inclusive development across all the infrastructural development indexes, except for the ICT infrastructural composite index which presents an insignificant negative effect. Besides, a non-linear effect of infrastructures on inclusive development was established across all the infrastructure indicators except for the ICT indicator.

Negative thresholds for complementary policies are established for the African Infrastructure Development Index (AIDI) and the transport index while positive thresholds are apparent for the electricity index and the water and sanitation infrastructure index (WSS). Accordingly, in order to sustain the positive incidence of the AIDI and transport index on human development, complementary policies should be engaged to avoid an overall negative effect on human development when the indexes are respectively, 31.12% and 25.56%. In the same vein, the electricity index and WSS should exceed critical levels of respectively 49.79% and 41.92%, to engender overall positive effects on inclusive human development.

As policy options from the findings of this research, African policy makers in the quest for inclusive development should invest in sustainable infrastructures. In this respect, the efforts towards the trend in infrastructural development need to be further enhanced. Water and sanitation and electricity infrastructures which are basic for efficient development should be taken up at local as well as national levels. These efforts are especially essential in rural Africa which still has localities with no practical roads, no electricity connections and no source of potable water. Hence, in the light of the established findings, the policy makers should complement infrastructure dynamics for which negative thresholds have been established at the attendant thresholds. In the same vein, for infrastructure dynamics for which positive thresholds are apparent, policy makers should implement policies that could consolidate the said infrastructure to reach the critical levels in order for these infrastructures to positively affect inclusive human development.

The findings in this study leave room for further research, especially as it concerns assessing what policy variables can be interacted with the infrastructure dynamics for which negative thresholds have been established in order to engender favourable incidences on inclusive human development. The suggested space for future research is also relevant for country-specific policies for which, more targeted country-oriented policies could be derived in order to better inform policy makers of measures that are not panel-specific but adapted to initial development conditions of sampled countries.

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## References

## A1. Description of variables

| Variables | Description | | Justified study and expected sign |
|---|---|---|---|
| AIDI | Africa Infrastructure Development Index is calculated on the basis of a weighted average of the sub-indexes obtained on four sectors: transport, electricity, ICT and WSS | + | Njamen et al.(2020) |
| Transportindex | Transport composite Index | | |
| ElectricityIndex | Electricity composite Index | | |
| ICTindex | ICT composite Index | | |
| WSSindex | WSS composite Index | | |
| Inflation | Inflation consumer prices in percent | - | Musah et al. (2019) |
| Resource_rents | Total natural resources rents are the sum of oil rents, natural gas rents, coal rents (hard and soft), mineral rents, and forest rents, as percentage of GDP | + | Nchofoung et al. (2021) |
| Political_Stabty | Political Stability and Absence of Violence/Terrorism | + | Asongu and Nwachukwu (2017) |
| CO2 | CO2 emissions (metric tons per capita) | + | Asongu and Odhiambo (2019) |
| FDI | Foreign direct investment inflow (% GDP) | + | Asongu and Leke (2019) |

## A2. Summary statistics

| Variables | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| IHDI | 610 | 0.518892 | 0.110861 | 0.276 | 0.8 |
| Transport | 612 | 10.16781 | 12.69121 | 0 | 58.756 |
| Electricity | 610 | 10.97183 | 19.38695 | 0.054 | 100 |
| ICT | 612 | 7.017524 | 10.06054 | 0 | 67.39113 |
| WSS | 612 | 50.00262 | 22.60066 | 0 | 99.014 |
| AIDI | 612 | 21.20653 | 18.4987 | 1.244 | 87.23024 |
| co2 | 495 | 1.191985 | 2.101967 | 0.020822 | 9.997526 |
| FDI | 611 | 4.576166 | 8.581878 | -6.36988 | 103.3374 |
| political stability | 612 | -0.62347 | 0.823286 | -2.66528 | 1.200234 |
| Inflation | 584 | 7.440785 | 8.349916 | -3.50259 | 98.22414 |
| resource rents | 576 | 14.77101 | 12.67537 | 0.489758 | 68.79008 |

A3. Correlation matrix

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| IHDI(A) | 1 | | | | | | | |
| IHDI (-1) (B) | 0.9989 | 1 | | | | | | |
| AIDI(C ) | 0.5493 | 0.5498 | 1 | | | | | |
| co2 (D) | 0.7183 | 0.7206 | 0.5369 | 1 | | | | |
| fdi (E) | -0.1334 | -0.1326 | 0.0277 | -0.1223 | 1 | | | |
| political stability ( F) | 0.1895 | 0.185 | 0.1515 | 0.215 | 0.0671 | 1 | | |
| inflation (G) | -0.1023 | -0.1065 | -0.1539 | -0.1377 | 0.0237 | -0.1992 | 1 | |
| resource rents (H) | 0.1282 | 0.1299 | 0.0152 | 0.2408 | 0.1456 | -0.1134 | 0.0424 | 1 |