

Climate Change Vulnerability and Sustainable Urbanisation in Sub-Saharan African

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Received: January 1, 2022

Accepted: February 2, 2022

Online Published: February 9, 2022

doi:10.5539/jsd.v15n2p132

URL: <https://doi.org/10.5539/jsd.v15n2p132>

Abstract

This study investigates the role of climate change vulnerability in sustainable urbanisation using a panel of 31 Sub-Saharan African countries over the period 2000-2017. The study employs a dynamic model based on a sequential linear panel data estimator. The results show that the high levels of climate change vulnerability are associated with a decrease in sustainable urbanisation in Sub-Saharan Africa. More specifically, only the adaptive capacity component of climate change vulnerability has a significant negative influence on sustainable urbanization. The role of climate change vulnerability on sustainable urbanization seems to be robust to the sensitivity analysis and the GMM estimator. Otherwise, the results also show that GDP per capita and Foreign Direct Investment positively affect sustainable urbanisation, while industrialisation and migration rate have negative effects on it in Sub-Saharan Africa.

Keywords: climate change, vulnerability, sustainable urbanisation, Africa

1. Introduction

Urbanisation is one of the important structural transformation that Sub-Saharan Africa (SSA) has experienced over time (Glaeser & Xiong, 2017; Potts, 2018). Indeed, according to United Nation forecasts, 56% of SSA population is going to live in the cities by 2050 (United Nations Department of Economic and Social Affairs (UNDESA), 2015). This rapid increase in urban population represents a big opportunity for SSA countries to take advantage of their growing population in urban area to develop their human capital necessary for industrialisation (Hove et al., 2013; Young, 2013). But it also constitutes a big challenge given the fact that a growing urban population implies that government must invest more in basic infrastructures (water, electricity, roads, school, among others) in order to meet increased population needs (Castells-Quintana, 2017). In the case that the government fails to do so, it could increase poverty, diseases, pollution and thus be a real burden for the environment. Urbanisation must therefore be sustainable if it is to be an opportunity for SSA countries (UN, 2015).

Thus, sustainable urbanisation implies uncertainty and risks about people, their life conditions and their environment given the constant increase in city population and in a context of climate change. According to Turok & Borel-Saladin (2014), sustainable urbanisation has three main concerns. The capacity of urban institutions to meet the accelerate demand for basic services. Secondly, the capacity of the economy to fund the huge cost of infrastructures in urban areas and lastly the capacity of labour market to absorb the growing labour force in a context of increasing informality that can exacerbate poverty of the already vulnerable population. All these concerns, if not well managed can lead to irreversible damages of the environment (UN-Habitat, 2014).

One of the well-known consequences of environment damage caused by human activities is climate change. As climate change gives rise to more frequent and more devastating severe storms, droughts, and wildfires, an increasing number of communities around the world are facing existential threat due to continued damage that make them vulnerable (IPPC, 2007). Smit et al. (2000) for example defines vulnerability as the “degree to which a system is susceptible to injury, damage or harm”, whilst Blaikie et al. (1994) describes vulnerability as “the characteristics of a person or group in terms of their capacity to anticipate, cope up with, resist and recover from the impact of a natural hazard”. A third definition by the IPCC conceives vulnerability as the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes” (Parry et al., 2007). The IPCC definition is broader in its scope regarding the subject analysis which can either be an economic sector, a bioregion, the Coupled Human-Environment System (CHES), among others;

but very specific regarding the hazard affecting the system which is climate change (Soares et al., 2012).

The literature recognises that urban problems in most of the SSA Countries are due to government failure in providing essential services and the needed infrastructure like housing, safe water, electricity, sanitation, health infrastructures, transport and communication infrastructures (Ohwo, 2019; Oloke et al., 2021). By analysing urbanisation in developing countries, Lipton (1977) concluded that there is a bias in favour of the city through the over-investment of most national resources in cities. The author goes on to say that the effect of the urban bias is also identified by the disparity between urban and rural areas in consumption, wages and productivity. This disparity is the result of public policies that favour investment in the city at the expense of the countryside and hence the agricultural sector.

The nexus between climate change and urbanisation is receiving a growing attention in the literature (Barrios et al., 2006; Cardona et al., 2012; He et al., 2019; Henry et al., 2004; Natalie et al., 2015; Nwankwo et al., 2021). The existing studies can be grouped into two blocks. The first analyse urbanisation like a determinant of climate change (Cardona et al., 2012; He et al., 2019; Nwankwo et al., 2021) and the second analyse climate change like determinants of Urbanisation (Barrios et al., 2006; Henry et al., 2004; Natalie et al., 2015). With regard to studies on sustainable urbanisation, it should be noted that few studies have focused on the analysis of the bidirectional relationship with climate change. The studies conducted by Henry et al. (2004), Barrios et al. (2006) and Natalie et al. (2015) on the determinants of sustainable urbanisation have not given enough importance to the effects of climate change vulnerability. Sustainable urbanisation is a loosely defined idea associated with the rural–urban demographic transition in low and middle-income countries (Turok & Borel-Saladin, 2014). One concern is with the capacity of city-level institutions to manage the accelerating demands from the population for essential services (such as access to electricity, water and sanitation and adequate housing) (Collier & Venables, 2017). World Development Report (World Bank, 2011) highlights, access to basic services as fundamental for the well-functioning of large cities.

As climate change gives rise to more frequent and devastating severe storms, droughts, and wildfires, an increasing number of communities around the world are facing existential threat due to continued damage to already vulnerable water and electricity infrastructure (Godart & Hart, 2020). Thus, scholars believe that the climate change vulnerability directly affects the livelihoods of farmers whose activities are highly dependent on natural resources, leading to accelerated rural-urban migration (Barrios et al., 2006). For this purpose, Lonergan (1998) developed the concept of environmental refugees which is a form of the widespread belief that urbanization is strongly influenced by environmental conditions. Repeated droughts and low soil productivity are known to be major factors that can lead people to leave their villages. Since the main source of livelihood in rural Sub-Saharan Africa is agriculture, it is therefore clear that environmental factors such as rainfall and soil degradation may influence socio-economic conditions and then induce people to migrate (Barrios et al., 2006).

Indeed, SSA as a whole is rich in natural resources including forests, wildlife, minerals and a biological diversity in comparison to other continents. However, this wealth is not reflected in the continent's level of development (United Nations Environment Programme [UNEP], 2000). Access to basic services remains a major challenge in SSA. Climate change and its effects have only made the situation worse. According to World Bank (2013), essential urban infrastructure include electricity, safe water and sanitation. They affect viability of and protect ecosystem from pollution and waste.

Regarding access to safe water, SSA countries are still lagging behind. According to Moore et al. (1993) and Calow et al. (2009), the provision of safe water generates benefits in terms of health, agricultural production, food security and poverty reduction. Rainfall is important in that it affects ambient temperature, soil quality, vegetation and even electricity supply (hydroelectric dams). Because of climate change, the level of rainfall has varied greatly since the 1900s and the number of regions affected by severe droughts is increasing significantly (Sheffield & Wood, 2008). Projections from the IPCC's Fourth Assessment Report on the state of Africa show that by 2050, 75 to 250 million people will be affected by water stress and that cereal production will decline by 50% over the same period (Boko et al., 2007).

In the other hand, access to manageable sanitation goes hand in hand with water. In this in this sense that (World Health Organisation [WHO] (2004) argues that improved water and sanitation provision would increase socio-economic benefits in SSA, however for it to have the desired effect it must be available in quantity but also in quality. In the case of SSA countries, WHO and UNICEF (2015) report revealed that 30% of population had access to improved sanitation. It shows the promiscuity in which people live and the need to remedy it.

Access to electricity is another essential element for sustainable urbanisation in that it contributes to greenhouse gas emissions, by increasing energy consumption, and by promoting economic growth (IRENA, 2015). An

increase in rural electrification is associated with higher youth literacy rates by upgrading in-school and domestic learning facilities (Kanagawa & Nakata, 2008). It has been linked to improving ambulant and nursing care (Herrin, 1979), increased rural productivity and the development of farm and non-farm income generating activities (Kirubi et al., 2009). According to World Bank (2015), the standard deviation of rural electrification in SSA has increased by almost 50% between 1990 and 2010. During this period, some countries like Ghana and Senegal have increase rural electrification in order to decrease the urban electrification bias. Although, the nexus climate change and sustainable urbanization in SSA is heavily debate, the studies are essentially theoretical.

The focus on sustainable urbanisation lies on two main reasons: the first one is that according to United Nation (UN-Habitat, 2014), with the growing rate of urbanization (4.5% per annum in SSA) more than 2 billion inhabitants in developing world are going to live in slums lacking access to basic services in 2030. The second is related to the fact that access to basic services can play a key role in industrialisation and development of SSA countries.

The aims of this study is therefore to analyse the effect of the climate change vulnerability on sustainable urbanisation in SSA countries. The contribution of this study is both theoretical and empirical as many studies have focused on the link between climate change and urbanisation, but very few to our knowledge have focused on vulnerability to climate change in SSA.

The rest of this paper is organised as follows. Section 2 present the methodological approach and describe the data, section 3 discusses the results and section 4 concludes.

2. Methodology and Data

2.1 Empirical Strategies

The empirical strategy is mainly based on two methods. The Principal Component Analysis (PCA) and the Sequential Linear Panel Data (SLPD) estimator. The PCA allows the construction of the sustainable urbanisation index, while SLPE enable the estimation of linear relationship between climate change vulnerability and sustainable urbanisation.

Index of sustainable urbanisation

According to UN-Habitat (2016) sustainable urbanisation raises three issues: (i) the government’s capacity to provide the public services needed to meet the growing demand in urban areas (Water, electricity, health infrastructure, schools, sanitation, etc.); (ii) the government’s capacity to finance the construction of the necessary infrastructure in terms of housing, roads, pollution reduction; (iii) the capacity of the labour market to absorb the abundant low-skilled workforce. Failure to consider these different aspects constitutes a real risk for the economy. Our analysis follows. The Trotter (2016) approach to electrification in SSA, and Liddle (2017) approach to sustainable urbanisation, focussing on rural-urban inequality in terms of access to water, electricity, the proportion of the poor and the population living in individual slums. Unlike the latter, we construct a composite index based on three basic services namely, access to drinking water, electricity and sanitation. The list of sustainable indicators select in this study is not exhaustive due to the availability of data on SSA countries.

In the first step, we apply PCA in order to estimate each of three dimensions (water, electricity and sanitation) formulated as follow:

$$D_i = \sum d_{j,k} = 1\lambda_j^d d_{ki}^d \sum d_j = 1\lambda_j^d \tag{1}$$

With $D_k = X\lambda_j \cdot \lambda_j$ the variance of the k^{th} principal components (weights), D_i the index of dimensions and X the indicators. Subsequently, weights are assigned to each indicator according to their respective contributions.

In the second step, we run the PCA again to calculate the sustainable urbanisation index using the same procedure as in the first step, given by:

$$SUI_i = \sum d_{j,k} = 1\lambda_j D_{ki} \sum D_j = 1\lambda_j \tag{2}$$

Where SUI_i is the sustainable urbanisation index of country i . The SUI obtained was normalised using the Min-Max method. Therefore, any SUI_i^t of country i at the date t is transformed in:

$$NSUI_i^t = \frac{SUI_i^t - \min_i(SUI_i^t)}{\max_i(SUI_i^t) - \min_i(SUI_i^t)} \tag{3}$$

Where $\min_i(SUIS_i^t)$ and $\max_i(SUIS_i^t)$ are the minimum and the maximum values of SUI_i^t between countries i at the date t respectively. The normalised indicator $NSUI_i^t$ obtained after standardisation is between 0 and 1.

This indicator is then multiplied by 100 to be between 0 and 100. A value close to 100 reflects a high level of sustainable urbanisation while a value close to 0 reflects a low level of sustainable urbanisation.

The Sequential Linear Panel Data Estimator

In order to estimate panel data models, the Ordinary Least Squares (OLS) method with fixed effect or random effect is often used, depending on the relationship between the explanatory variables and the unobserved individual effects (Keneck-Massil et al., 2021). This method remains limited in that it does not address the problem of heterogeneity and endogeneity. To address these limitations, we use the two-stage linear panel data (SLDP) estimator to identify the coefficients of the time-invariant regressors (Kripfganz & Schwarz, 2019). The first step consists of estimating the coefficients of the time-varying regressors while the second step uses the residuals from the first step to estimate the coefficients of the time-invariant regressors. This estimator has an advantage over traditional techniques because it performs the identification using the instrumental variables as suggested by Hausman and Taylor (1981). Furthermore, it adjusts the standard errors of the second stage to account for any estimation error in the first stage (Kripfganz & Schwarz, 2019).

The difficulty raised by the presence of time invariant regressors is simply presented in the following equation:

$$Y_{it} = \alpha Y_{it-1} + X'_{it}\beta + f'_i\gamma + \varepsilon_{it}, \text{ with } \varepsilon_{it} = \alpha_i + \mu_i \quad (4)$$

Where i is the number of units, t is a fixed number of time periods, Y_{it} represents sustainable urbanisation index X_{it} is a vector of time-varying regressors (gross domestic production, industrialisation, migration rate, foreign direct investment and political stability), f_i is a vector of time invariant regressors (vulnerability index and its components) that incorporates and intercept, and α_i is the unobserved unit-specific effect. Equation (4) assumes that some regressors are correlated with unobserved unit-specific effect. The technique of Kripfganz and Schwars (2019) is used for identification as follows:

$$Y_i = Y_{i-1} + X_i\beta + F_i\gamma + \varepsilon_i, \text{ with } \varepsilon_i = \alpha_i\iota_T + \mu_i \quad (5)$$

Where $Y_i = (Y_{i1}, Y_{i2}, \dots, Y_{iT})$, ι_T is a $(T, 1)$ vector of ones. With this hand two matrices are defined: $W_{yxi} = (X_i)$ the matrix of time-varying regressors, where coefficients $\theta = \beta'$ are estimated in the first step and $W_{xyfi} = W_{xyi}, F_i$ is the full regressor matrix.

2.2 Data and Variable Description

This study covers a sample 31 Sub-Saharan Africa countries over the period 2000-2017. The choice of this sample is based on the quality and availability of data. The data come from different sources, namely ND-GAIN Vulnerability Index, World Governance Indicator (WGI) and World Development Indicator (WDI). The countries in our sample are: Angola, Botswana, Burkina Faso, Cameroon, Congo, Congo Democratic Republic, Ivory Coast, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Nigeria, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

Our dependant variable is the sustainable urbanisation index (NSUI) as measured by a composite index based on three dimensions (drinking water access, electricity access and sanitation access) (Liddle, 2017; Trotter, 2016). Using an aggregate measure of sustainable urbanisation allows us to take into account the maximum amount information related to urbanisation. The distribution of sustainable urbanisation index of SSA countries over study period shows that on average it ranges between 15.48% to 84, 39%. The most sustainably urbanised countries are South Africa, Cameroon, Ghana, Botswana, Angola, Gabon and Congo with an index value between 49.68% et 84.39% (figure 1).

Then, the main independent variable is the aggregate climate change vulnerability index. This index was constructed by the Nostras Damus Foundation from 36 indicators. These indicators are divided into three dimensions of vulnerability to climate change, namely exposure, sensitivity, and adaptative capacity. The Overall vulnerability index is the simple arithmetic mean of each of these dimensions. It takes values between 0 and 1, with 0 being the lowest level of vulnerability and 1 the highest level of vulnerability. The analysis of vulnerability to climate change over the study period shows that all the countries in the region have a fairly high vulnerability index. Indeed, the vulnerability index for SSA countries is between 0.40 and 0.68, which confirms the assertion that SSA is one the most vulnerable regions in the world (Figure 1).

To make our analysis informative, we include some control variables that are economic, demographic and institutional variables that can affect sustainable urbanisation. These variables are as follows: Gross Domestic

Product (GDP) per capita measures the income level. According to Todaro and Smith (2008) GDP per capita plays a key role in the urbanisation process in this way that the more developed country is in terms of per capita income, the larger the population living in urban areas. In our case, high GDP per capita would improve the provision of basic services in urban areas but also in rural areas. Industrialisation measures by the value added of the manufacturing sector as a percentage of GDP. This factor can explain urbanisation insofar as, according to Lewis (1954) theory, during the development process the surplus of agricultural labour is transferred to the expanding industrial sector (Chandra, 1992; Echaudemaison et al., 1989). Inflow Foreign Direct Investment (FDI) as a percentage of GDP. According to Kang and Lee (2011) FDI can influence urbanisation as it tends to be directed to areas with a high concentration of population, a potential market for products. FDI is a springboard for entrepreneurship and a source of employment for the surplus labour force. Political Stability represents our institutional variable as used by (Gwartney et al. (2012)). The literature highlights the role of the public sector in the urbanisation processes of many countries. Stable and dynamic institutions have been identified as prerequisites for economic development, as well as a means to create an ideal climate for private sector. Migration rate according to Bairoch (1985) and Beauchemin and Bocquier (2004) migration is condemned as the primary contribution to the uncontrolled expansion of urban areas. Migration affects sustainable urbanisation in two ways. First, new infrastructure is required by the migrants and amenities are more expensive in cities or towns than in rural areas or simply not needed there (housing, transport, garbage and sewage disposal, among others) (Gugler, 1982). Secondly, urban job creation is generally more costly than rural job creation because most jobs in the industrial sector require substantial complementary resource inputs (Todaro, 1997).

Table 1 provides the descriptive statistics. The table shows that from 2000-2017 the average level of sustainable development index in our sample is 23.88%. For the climate change vulnerability index, we note an average of 0.559, with average value of 0.49, 0.475 and 0.707 found for exposure, sensitivity and adaptive capacity components. The standard deviation of these variables has a value of about, 0.06, 0.05, 0.0082, and 0.0085 respectively. This shows that the evolution of climate change vulnerability index and its components is relatively stable in our sample. Concerning the rest of the variables, there is an average of 1629.103, 23.815, -0.631, 218.426 and -0.712 for GDP per capita, industrialisation, migration rate, foreign direct investment and political stability respectively.

Table 1. Descriptive statistic

Variables	Labels	Obs	Mean	Std. Dev.	Min	Max
Sustainable Urbanisation Index	NSUI	433	23.886	12.653	0	100
Vulnerability index	Vulne_index	558	0.559	0.06	0.398	0.709
Exposure index	Exposure	558	0.49	0.05	0.356	0.633
Sensitivity index	Sensitivity	558	0.475	0.082	0.296	0.653
Capacity index	Adat_Capa	558	0.707	0.085	0.488	0.918
GDP per capita	GDP	540	1629.102	2172.091	194.873	10160.344
Industrialisation (% GDP)	Indust	536	23.815	14.232	0.559	77.414
Migration rate	Migra_Rate	558	-0.631	3.763	-11.651	19.55
Foreign Direct Investment	FDI	545	218.426	1168.78	-6.057	7864.253
Political Stability	Pol_stab	526	-0.712	0.891	-3.315	1

Source: Author's Calculation

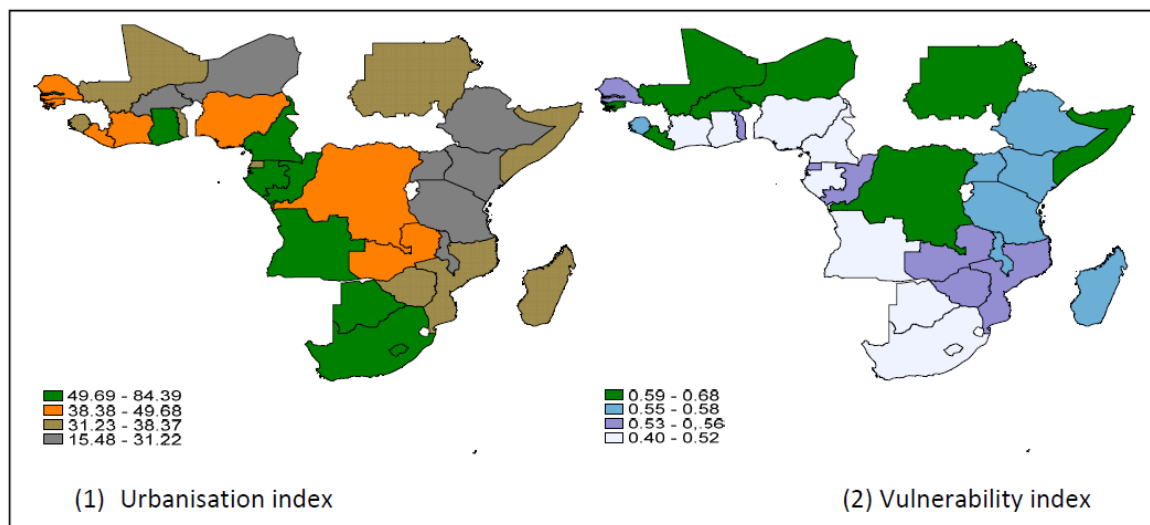


Figure 1. Sustainable urbanization index and climate change vulnerability across SSA countries

Source: Authors construction based on V-dem project database.

3. Results and Discussions

3.1 Primary Results

This subsection presents results of the estimation of equation (6). This equation represents the regression of climate change vulnerability on the sustainable urbanisation. Table 2 presents the results of the estimation of this equation by the OLS while in Table 3, the estimator used is the SLPD. Each of these tables is composed of 8 columns analysing: the impact of climate change vulnerability index (1), the impact of three components of climate change vulnerability index, namely exposure, sensitivity and adaptive capacity (2), the impact of the exposure component only (3), the impact of the sensitivity component only (4), the impact of the adaptive capacity component only (5), the impact of the exposure and sensitivity components (6), the impact of the exposure and adaptive capacity components (7), and the impact of sensitivity and adaptive capacity components (8).

The results, displayed in table 1, show that climate change vulnerability negatively affects sustainable urbanisation. This inverse relationship is shown in figure 2 presenting the correlation between these two variables. In column 2, the results show that the exposure and adaptive capacity components negatively affect sustainable urbanisation. These results are robust to the sensitivity analysis performed in columns 3 to 8. Interpretation of the control variables shows that GDP per capita and Foreign Direct Investment positively affect sustainable urbanisation, while industrialisation, migration rate and political stability have negative effects. It should be noted that these OLS estimates are not robust because the method remains limited in that it does not address the problem of heterogeneity and endogeneity.

Table 2. Results of the panel model with OLS

		Dependant variable: Sustainable Urbanisation index							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Vulne_index	-72.36*** (6.990)								
Exposure		-25.24*** (9.319)	-40.86*** (8.129)			-49.53*** (10.87)	-19.15*** (6.445)		
Sensitivity		9.254 (6.473)		-5.137 (6.000)		13.54* (7.147)		0.0558 (4.622)	
Adapt_Capa		-63.96*** (5.520)			-68.12*** (5.394)		-64.45*** (5.540)	-68.13*** (5.516)	
GDP	0.001*** (0.000)	0.001*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.001*** (0.000)	0.002*** (0.000)	0.001*** (0.000)	0.00117*** (0.000)	
Indust	-0.263*** (0.019)	-0.163*** (0.022)	-0.234*** (0.019)	-0.266*** (0.019)	-0.188*** (0.021)	-0.208*** (0.022)	-0.180*** (0.020)	-0.188*** (0.0229)	
Migra_rate	-0.551*** (0.081)	-0.176** (0.078)	-0.632*** (0.085)	-0.589*** (0.087)	-0.147* (0.076)	-0.593*** (0.084)	-0.199*** (0.076)	-0.146* (0.0818)	
FDI	0.004*** (0.000)	0.004*** (0.000)	0.003*** (0.000)	0.004*** (0.000)	0.005*** (0.000)	0.003*** (0.000)	0.004*** (0.000)	0.00519*** (0.000)	
Pol_Stab	-0.923** (0.462)	-1.955*** (0.426)	-0.540 (0.491)	-0.318 (0.510)	-1.887*** (0.434)	-0.641 (0.466)	-1.897*** (0.434)	-1.887*** (0.427)	
Constant	65.93*** (4.363)	76.01*** (3.578)	43.89*** (4.399)	26.81*** (3.026)	71.67*** (3.972)	40.76*** (4.063)	78.41*** (4.167)	71.64*** (3.762)	
Observations	397	397	397	397	397	397	397	397	
R-squared	0.686	0.733	0.655	0.637	0.728	0.658	0.732	0.728	

Note: author’s construction. Robust standard errors are shown in parentheses. (***, **, *) indicate statistical significance and rejection of the null hypothesis at 1%, 5% and 10% level, respectively.

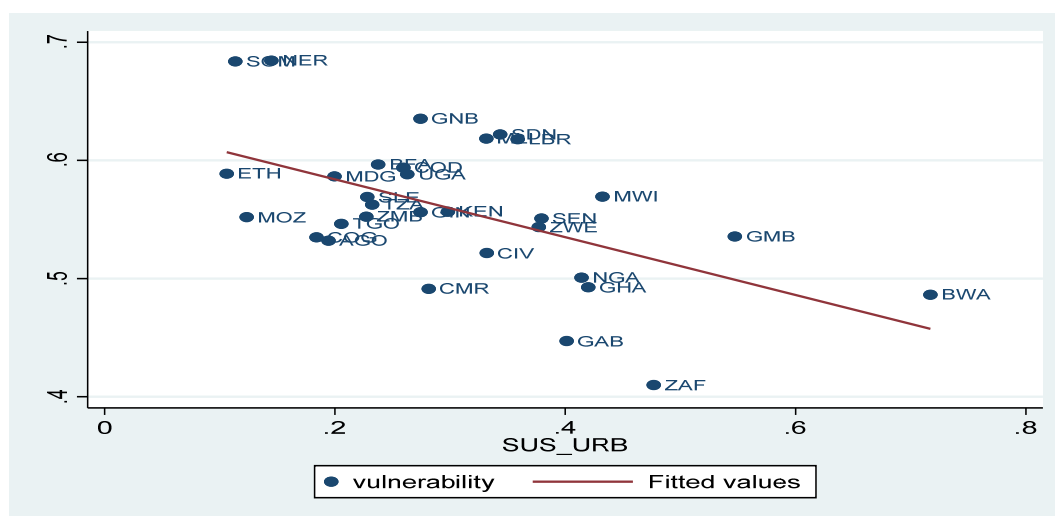


Figure 2. Correlation between sustainable urbanisation index and climate change vulnerability index

Note: Authors construction. The relation between climate change vulnerability and sustainable urbanisation is negative as shown in figure 2. This implies that the more vulnerable a country is, the less disparity in terms of access to basic services between rural and urban areas. Countries such as Niger and Somalia which are among the most vulnerable SSA countries have the lowest disparity index. This could also be explained by Kuznets (1955) inverted U theory which argues that an inverted U-shaped relationship between economic development and inequality is described, so the least developed economies are the least unequal.

As presented in the methodology, in order to address the problems of heterogeneity and endogeneity that may exist in the relationship between climate change vulnerability and sustainable urbanisation, we have used the sequential linear estimator to address these problems. As a result, the first column of table 3 shows that high levels of climate change vulnerability are associated with a decrease in sustainable urbanisation. This result would imply that climate change negatively affects the essential components for achieving sustainable urbanisation, namely access to water, sanitation and electricity. Indeed, this negative relationship is explained by the fact that vulnerability to climate change contributes strongly to rural-urban migration, which leads to overpopulation of cities and reduces access to basic infrastructure. Furthermore, the consequences of climate change such as increased temperatures and reduced rainfall negatively affect the availability of basic infrastructure that guarantees the sustainability of cities such as running water and electricity. This results confirm the finding of Henderson et al.(2017) that climate change has negative impact on urbanisation. In column 2, the results show that only the adaptative capacity component has a significant negative influence on sustainable urbanisation. These results are robust to the sensitivity analysis performed in columns 3 to 8.

Let us consider a general comment relating to the control variables. The results shows that GDP per capita and Foreign Direct Investment positively affect sustainable urbanisation, while industrialisation and migration rate have negative effects. Indeed, the positive sign of GDP per capita means that increase of per capita income increases sustainable urbanisation (Trotter, 2016). The positive sign of Foreign Direct Investment means that an increase of external funding increase sustainable urbanisation (Trotter, 2016). Industrialisation have a negative sign meaning that an increase in the share of industrial sector in GDP decrease sustainable urbanisation. This result is contrary to those obtained by Kang & Lee (2011) who finds that the development of the industrial sector will favour sustainable urbanisation. Migration rate have also a negative sign meaning that an increase in the migration rate decreases sustainable urbanisation (Beauchemin & Bocquier, 2004).

Table 3. Results of the panel model with Sequential linear estimator

Dependant variable: Sustainable Urbanisation index									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
<i>Time variant/ First stage</i>									
GDP	0.002*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.002*** (0.000)	0.00294*** (0.000)	
Indust	-0.258*** (0.051)	-0.232*** (0.066)	-0.244*** (0.072)	-0.249*** (0.050)	-0.214*** (0.068)	-0.234*** (0.071)	-0.241*** (0.063)	-0.255*** (0.057)	
Migra_rate	-0.569*** (0.153)	-0.569*** (0.153)	-0.569*** (0.153)	-0.569*** (0.153)	-0.569*** (0.153)	-0.569*** (0.153)	-0.569*** (0.153)	-0.569*** (0.153)	
FDI	0.004*** (0.000)	0.004*** (0.000)	0.004*** (0.000)	0.004*** (0.000)	0.004*** (0.000)	0.004*** (0.000)	0.004*** (0.000)	0.00424*** (0.000)	
Pol_Stab	-0.341 (1.734)	-0.341 (1.734)	-0.341 (1.734)	-0.341 (1.734)	-0.341 (1.734)	-0.341 (1.734)	-0.341 (1.734)	-0.341 (1.734)	
Constant	24.03*** (3.195)	24.03*** (3.195)	24.03*** (3.195)	24.03*** (3.195)	24.03*** (3.195)	24.03*** (3.195)	24.03*** (3.195)	24.03*** (3.195)	
<i>Time invariant / second stage</i>									
Vulne_index	-33.86** (14.55)								
Exposure	-12.37 (24.30)		-26.84 (20.58)		-30.39 (25.00)		-6.130 (20.20)		
Sensitivity	11.76 (10.45)			-2.275 (8.730)		5.506 (9.738)		9.330 (9.253)	
Adapt_Capa	-38.01*** (13.16)				-37.39*** (12.51)		-35.70*** (13.34)		-40.59*** (13.07)
Constant	18.66** (8.101)	26.80** (10.80)	13.12 (10.23)	1.075 (4.125)	25.89*** (8.775)	12.25 (9.971)	27.71** (10.91)	23.69*** (8.389)	
Observations	397	397	397	397	397	397	397	397	

Note: author’s construction. Robust standard errors are shown in parentheses. (***, **, *) indicate statistical significance and rejection of the null hypothesis at 1%, 5% and 10% level, respectively.

3.2 Robustness Check

In order to demonstrate the robustness of the previous results, we estimates a two-stage system GMM model of Roodman (2009). This method uses identification techniques to deal with possible endogeneity problems resulting from reverse causality between the variables of interest. The empirical model can be specified as follows:

$$Urba_{it} = \beta_0 + \beta_1 Urba_{t-1} + \beta_1 Vuln_{it} + \alpha' X_{it} + \gamma_i + \mu_t + \varepsilon_{it} \tag{6}$$

Where X_{it} is the matrix of control variables, γ_i and μ_t indicate unobserved individual and temporal effects, respectively. β_i and α_i are the vectors of coefficients to be estimated; and ε_{it} is the error term. Table 4 below presents the results of our estimates, based on an appropriate set lagged variables as instruments. The arrangement of the columns is the same as in the previous results tables. The regressions satisfy the specification tests (AR(1), AR(2), and Hansen test). There is no evidence of a second serial correlation, but there is strong evidence of a first correlation. Moreover, the regressions pass the Hansen test and confirm the validity of the instruments. Across all estimations, we find the same results as those presented in the table 3 using sequential linear estimator. This demonstrates that our results are robust and that a negative relationship between climate change vulnerability and sustainable urbanisation in Sub-Saharan African countries can be affirmed.

Table 4. Result of the panel model with System GMM estimator

	Dependant variable: Sustainable Urbanisation index							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Urba lagged	-0.302*** (0.002)	-0.365*** (0.015)	-0.290*** (0.024)	-0.288*** (0.026)	-0.360*** (0.010)	-0.253*** (0.025)	-0.361*** (0.009)	-0.361 (0.012)
Vulne_index	-87.79*** (21.91)							
Exposure		-32.39 (32.64)	-37.04 (32.35)			-31.45 (44.23)	-25.36 (27.49)	
Sensitivity		-12.57 (17.12)		-5.378 (18.69)		4.433 (24.85)		2.864 (13.41)
Capacity		-84.98*** (16.62)			-91.73*** (15.35)		-87.78*** (16.20)	-92.08** (15.31)
GDP	0.002*** (0.000)	0.001*** (0.000)	0.003*** (0.000)	0.003*** (0.000)	0.001* (0.000)	0.003*** (0.000)	0.001* (0.000)	0.001** (0.000)
Indust	-0.310*** (0.059)	-0.230*** (0.053)	-0.344*** (0.063)	-0.377*** (0.065)	-0.238*** (0.069)	-0.362*** (0.091)	-0.234*** (0.062)	-0.2237** (0.064)
Migra_rate	-0.532*** (0.131)	-0.071 (0.107)	-0.485*** (0.149)	-0.465*** (0.179)	-0.065 (0.097)	-0.262 (0.193)	-0.122 (0.091)	-0.053 (0.112)
FDI	0.006*** (0.000)	0.006*** (0.000)	0.005*** (0.000)	0.006*** (0.000)	0.007*** (0.000)	0.006*** (0.001)	0.007*** (0.000)	0.007*** (0.000)
Pol_Stab	-2.337 (1.481)	-2.486* (1.271)	-2.323 (1.302)	-1.573 (1.428)	-2.162 (1.140)	-6.677 (4.060)	-2.336* (1.370)	-2.142 (1.332)
Constant	81.03*** (14.39)	102.1*** (10.83)	49.79*** (16.01)	35.13** (7.75)	97.31*** (12.31)	45.06** (18.26)	107.0*** (14.33)	96.18*** (11.23)
Observations	349	322	347	347	322	347	322	322
Countries	27	27	27	27	27	27	27	27
instruments	23	25	23	23	23	24	24	23
AR(1)	0.025	0.004	0.036	0.003	0.001	0.010	0.011	0.009
AR(2)	0.296	0.259	0.294	0.296	0.263	0.283	0.264	0.259
Hansen	0.713	0.826	0.666	0.748	0.850	0.600	0.843	0.852

Note: author’s construction. Robust standard errors are shown in parentheses. (***, **, *) indicate statistical significance and rejection of the null hypothesis at 1%, 5% and 10% level, respectively.

4. Conclusion

Climate change vulnerability plays a key role in the process of sustainable urbanization as shown in the present results. Sustainable urbanization is an important process with social, economic and environmental implications for SSA countries despite the heterogeneity that exists across countries. The data used in this paper indeed show important differences across countries in term of access to basic services, which are water, electricity and sanitation, but also in term of vulnerability. To address the heterogeneity and to estimate the relationship between climate change vulnerability and sustainable urbanization, the sequential linear estimator has been used. The econometrics results show that high levels of climate change vulnerability are associated with a decrease in sustainable urbanisation. More specifically, only the adaptive capacity component has a significant negative influence on sustainable urbanization. The role of climate change vulnerability on sustainable urbanization seems to be robust to the sensitivity analysis and the GMM estimator. That maybe because in SSA, the most vulnerable countries have poor basic services both in urban and rural area, climate change vulnerability and his consequences may worsen the situation by reducing access to basic services in both areas. The results also show that FDI have a positive effect on sustainable urbanisation, which suggests that investments that raise access to safe water, electricity and manageable sanitation have to be encouraged in this context of climate change. To mitigate the effects of climate vulnerability on sustainable urbanisation, it is up to the various governments to reduce the rural-urban gap in terms of access to basic services. In addition, the entire population of SSA must adopt responsible behaviour in order to preserve the environment in which they live.

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