Effect of Global Climate Change on Poverty and Inequality in Sub-Saharan Africa

Issoufou SOUMAÏLA MOULEYE[a*] , Adama DIAW[b] , Ahmadou Aly MBAYE[c], Akoété Damien Agbodji[d] and Aklesso Y. G. EGBENDEWE[e]
[a]University Center for Economic and Social Research (CURES), University of Bamako-Mali
[b] Gaston Berger University of Saint-Louis Senegal
[c]Director Of the PhD Climate Change In Economics, West African Science Service Center on Climate Change and Adapted Land Use (WASCAL).
[d,c]Department of Economics and Management Sciences (FASEG) University of Lome, Togo PO Box 1515, Lom e
*E-mail : moulayee@yahoo.fr

Abstract

The purpose of this research is to assess how climate change can impact on poverty and inequality in Sub-Saharan Africa (SSA). To this end, parametric and semi-parametric models of a triangular system of the partially linear functional coefficient model were applied to panel data from 20 Sub-Saharan African countries covering the period from 2000 to 2016. For this purpose, the Generalised Joint Regression Modeling (GJRM) procedure was used to estimate this model. The results of the estimation showed that temperature has a negative and significant nonlinear effect on inequality and positive on poverty by taking the form of inverted "N" when temperatures are between 18°C and 25°C while 'it follows the shape of an' N 'between 25°C and 30°C. In addition, the results showed a positive and significant non-linear relationship between climate change, poverty and inequality in SSA. Finally, the paper recommends that governments integrate the climate dimension into economic programs and policies to reduce poverty and inequality in SSA.

Key words: GJRM, Poverty, Inequality, Climate, Triangular system.

Classification JEL : Q54, Q58, C14

Résumé

L'objectif de cette recherche est d'évaluer comment le changement climatique peut impacter sur la pauvreté et l'inégalité en Afrique subsaharienne. Pour se faire, des modèles paramétriques et semi-paramétriques d'un système triangulaire du modèle de coefficient fonctionnel partiellement linéaire ont été appliqués aux données de panels de 20 pays de l'Afrique subsaharien couvrant la période allant de 2000 à 2016. A cet effet, la procédure « Generalised Joint Regression Modelling (GJRM) » a été utilisée pour estimer ce modèle. Les résultats du modèle ont montré que de la température a un effet non linéaire négative et significative sur les inégalités et positif sur la pauvreté en prenant la forme de « N » inversé lorsque les températures sont comprises entre 18°C et 25°C alors qu'elle suit la forme d'un « N » entre 25°C et 30°. Par ailleurs, les résultats ont montré une relation non linéaire positive et significative entre la pauvreté et les inégalités en Afrique subsaharienne. Enfin, le papier recommande que les gouvernements intègrent la dimension climatique dans les programmes et politiques économiques de réduction de la pauvreté et des inégalités en Afrique subsaharienne.

Mots clés : GJRM, Pauvreté, Inégalités, Climat, Système triangulaire.

Classification JEL : Q54, Q58, C14

Introduction

Climate change is a global and cross-cutting issue that disproportionately affects the world's most vulnerable communities and countries (Mendelsohn, et al., 2006). Poor households are more vulnerable to natural shocks and may also experience greater poverty and inequality than those who are less affected (Fothergill and Peek 2004, Krueger et al., 2010). This is largely due to the fact that these households are more dependent on the natural environment and small-scale agriculture for their subsistence (Bowen, et al., 2012). The causes of increased inequality are sometimes harder to pin down and sometimes they lead to skepticism about our ability to make accurate comparisons of living standards between very different countries such as poor countries in Africa and rich countries. (Deaton 2010). Indeed, the poor communities who live mostly in SSA engaged in subsistence farming are hit hard by climate change, which has a dangerous impact on agricultural crops and access to food. In doing so, food accessibility remains conditional on the income of agriculture, which, because of climate precariousness and declining yields, is leading to a rise in food prices while widening the gap in inequality. This increase in economic inequality has a strong impact on health and economic growth, the very serious consequences of which today lead some economic agents to emigrate to wealthier economic centers or to join terrorist organizations.

However, some authors such as Berthe and Elie, (2015) also raise questions about the role of inequality in worsening climate change. The impact of climate change on agriculture is expected to be more pronounced on the African continent if nothing is done to reduce greenhouse gas (GHG) emissions and define appropriate adaptation strategies (IPCC 2014, Rosenzweig 1994, Egbendewe et al., 2017). A previous study (Rosenzweig, 1994) showed that countries in the northern hemisphere will only be marginally affected by climate change in terms of their ability to produce food from agriculture. At the same time, those in the southern hemisphere, especially those in the tropics, will be affected by climate change on food production from agriculture. While there is evidence that southern countries will be more affected by climate change in terms of weakening their ability to produce food from agriculture (Egbendewe, et al., 2017). Faced with this situation, the risks associated with climate change will lead to increased inequality and poverty and put poor households in Sub-Saharan African countries in a sort of trap of poverty that can annihilate all development efforts.

Fosu (2015) considers that this assertion is technically correct, even if, it does not reflect the heterogeneity of trends in the poverty rate over time. It appears that Sub-Saharan Africa's performance on poverty since 1981 has not been uniform. While the incidence rate of poverty at the level of $ 1.25 increased by approximately 6.6 percentage points between 1981 and 1996, it decreased by 6.0 percentage points between 1996 and 2005 and by , 6 percentage points between 2005 and 2010. According to a UNDP (2017) report, although SSA showed a 3.4 percentage point decrease in the Gini unweighted coefficient between 1991 and 2011, remains one of the regions with the highest levels of global inequality. Inequality and poverty are important factors in social exclusion, whereas conflict, social unrest and instability are the causes, and most countries with a poverty rate of over 60% also experience serious or severe conflict situations. (UNDP, 2017). However, according to AFDB (2018), the shortage in job growth has slowed down the reduction of poverty. Although the proportion of poor people in Africa dropped from 56% in 1990 to 43% in 2012, the numerical incidence of poverty has increased. Inequality has also increased, with the Gini coefficient increasing from 0.52 in 1993 to 0.56 in 2008. The negative effects of climate change have led to interventions aimed at enhancing resilience in drought-prone regions. Youth unemployment requires immediate attention: more than 70% of the population is under 30 years of age. Although in 2013, unemployment was low among 15- to 29-year-old (6.8%), it was higher among urban youth (23.3%) than in the global urban population (AFDB, 2018). Previously an author like (Thorbecke, 2013) thinks that there has been no progress in SSA where half of the population remained below the poverty line in 2005, unlike in other parts of the world.

The objective of this research is to assess how climate change can impact on poverty and inequality in SSA Specifically, our objectives specifically include (1) identifying climatic factors that impact on poverty and (2) those that have an impact on the inequality of the countries of SSA. Because the perception of poverty in SSA has not changed much since the 1980s known as structural adjustment and the people of SSA believe that living conditions continue to deteriorate despite all the efforts of policy against poverty and sustainable development. In our opinion, how can we assess the link between the impact of climate change and poverty and inequality in SSA? And climate change is nowadays the first concern of the IPCC (2017), which has agreed to present a special report for 2018 on the consequences of a global warming of 1.5°C compared to pre-industrial levels and related evolutionary profiles. Global emissions of greenhouse gases, in the context of strengthening the global response to climate change, sustainable development and poverty reduction (IPCC, 2017). This article is intended as an analytical contribution in trying to provide an assessment of the links between climate change and agricultural production on the one hand and on the other hand trying to control the sensitivity of climate change, inequalities and poverty in SSA. To answer these research questions, a rural household model was developed for the countries of SSA. Our research is organized as follows: in Section 2, we give an overview of the literature on the determinants of civil war. In Section 3, we describe in detail the methodological approaches used in the study to answer the above research questions and in Section 4 we discuss the estimation strategy. Section 5 contains empirical results and further analysis of econometric identification and Section 6 presents a conclusion.

1. Theoretical effects of climate change on poverty and inequality

The world is now confronted with several problems that undermine the development of populations, but two major aspects have important consequences on the well-being of economic agents. These are climate change and economic inequality. Both of these have a very disproportionate impact on poor communities in the world and particularly in the countries of SSA. To fight both of these aspects, it is imperative to involve the reduction of vulnerabilities and inequalities related to poverty. It may then be surprising that a substantial literature examines whether these two objectives are compatible (Berthe and Elie, 2015, 2015; Grunewald, et al. 2017 ; Isaksen, 2017 and Wiedenhofer et al., 2017). This review is based on two streams of research analysis on inequality, poverty and climate change. On the one hand we make a research that evaluates the influence of income inequality on environmental pollution by examining the existence of the Kuznet environmental curve, including Torras and Boyce, (1998) ; Coondoo (2002); Shao et al. (2011), and Golley (2012), on the other hand the research that examines the relationship between income inequality and environmental quality based on the refutation of Kuznet's theory of the environmental curve (Torras and Boyce, 1998 and Boyce 2010). According to Grunewald, et al. (2017) for low- and middle-income economies, higher income inequality is associated with lower carbon emissions, while in middle- and high-income countries; income inequality increases per capita emissions.

1.1. Poverty, inequality and climate, which relations?

The first contributions on the links between climate and poverty, mainly influenced by the research of Udry (1995), and refers to the potential impact of exogenous factors (i.e. climate variability) on vulnerability to poverty. However, the vast literature has not yet assessed the effect of climate on the probability of a household becoming or remaining poor in the foreseeable future, and it is therefore expected that negative impacts on food security will occur. in areas highly dependent on local food production and with fewer opportunities for internal and external insurance (Herrera, et al., 2018). Another approach used to study the impacts of climate variability is to focus on the effect of climate variability on the main rural assets, mainly through land prices and such an analysis is based on the economic rationality according to which farmers maximize their profits, land prices are directly correlated to the (future) income capacity of the land (Mendelsohn, et al., 2006, Masters and McMillan 2001, Herrera, et al., 2018). Thus, climate change can have a very negative impact on incomes, sown areas and household assets. Another approach, which is often used to analyze the link between climate change and poverty, chooses a measure of well-being and examines the impact of climate change directly on household incomes (Herrera, et al., 2018). To this end, Tol (2009) uses a comparative welfare model to show the effects of climate change on income poverty in the different regions affected, and finds that the most important effects are recorded in areas where poverty is high. Since the IPCC (2017), the comprehension on the relationship between climate change, poverty and vulnerability has increased significantly. There is no doubt that the most vulnerable people are already, and will continue to be, the most concerned by climate change, including changing trends and more frequent and extreme events (Tschakert, 2016).

Torras and Boyce, (1998) research has focused on environmental policies and adopted water quality indicators and has empirically proven that income inequality would lead to environmental degradation. They used sulfur dioxide models, smoke and dust as environmental quality indicators, and found that increasing income gaps and environmental quality degradation coexist in low-income countries, opening the way for research on income inequality (Hao, et al, 2016). In similar studies, (Grossman & Krueger 1991; Shafik & Bandyopadhyay, 1992 and Selden & Song, 1994) also found that income inequality would lead to a shift in environmental policies, and that rich communities, who often had more political power, only considered economic costs and benefits, while the terrible environmental cost was mostly borne by poor communities, and such environmental policies would exacerbate pollution (Hao, et al, 2016). Authors like Ravallion et al. (2000) also tried to study the relationship between income inequality and environmental quality by constructing a demand function for individual and income-based carbon emissions. They pose the problem of the supply and demand for environmental goods. For example, Martinez-Alier (1995) has analyzed the influence of income inequality on the quality of the environment from the point of view of supply and demand, and argues that "vulnerable communities sell cheap products. Which means they are more likely to underestimate the value of environmental goods compared to other goods due to the lack of environmental goods in all markets.

1.2. Empirical Elements on the Triptych Poverty, Inequality and Climate Change

To deepen the empirical relationship between the income gap and environmental quality in China, authors such as Hao, et al, (2016) used panel data for 23 provinces from 1995 to 2012, taking carbon emissions as the indirect indicator of environmental pollution and performs GMM regression. They concluded that the rise in per capita CO2 emissions is widening the income gap in 25 provinces of China. Thus, the results of the GMM regression indicate that the influence of regional income inequality on CO2 emissions is more important in the East. Per capita CO2 emissions would increase dramatically with income expansion, while growth would be relatively slow in non-eastern regions (Hao, et al, 2016). Finally, they concluded that the relationship between real GDP per capita and CO2 emissions per capita is likely to be a "U" shaped curve. However, they believe that a relatively high population density would reduce per capita CO2 emissions, but the effect is not significant. The research of Bimonte (2002) used cross-sectional data from 35 European countries as samples, reflecting the distribution of income by Gini coefficient, and measured the condition of environmental protection. The results revealed a negative correlation between income inequality and environmental protection. He added that the more equitable income distribution tilts the CEK to the left, ie in an environment where the distribution of income is relatively equal; the CEK inflection point will be reached at a lower level. The research of Shao et al. (2011) also verified that the inverted N-shaped relationship between energy-related industrial CO2 emissions and GDP per capita in Shanghai City, China.

Another major category of empirical studies has examined the relationship between income inequality and environmental quality based on the refutation of EKC theory. With the increase in the availability of data quality in a group of specific regression equations. However, this relationship was not statistically significant in the other regression equations. Gawande et al. (2001) empirically analyzed the relationship between US household income and toxic waste disposal sites. Research has indicated that under the EKC relationship, wealthy families would live far from sources of pollution. People who became rich were more likely to leave polluted areas than to influence public policies to reduce pollutant emissions. To a certain extent, this confirmed Boyce's (1994) argument that income inequality would affect people's temporal preference for the use of the environment. Studies by Torras &

Boyce, (1998) and Boyce (2010) have shown that the environmental demands of the population must be combined with its purchasing power and purchasing penchant. In this case, purchasing power referred to a realistic restriction of environmental concerns, and the inclination to purchase referred to the subjective restraint of environmental concerns. L'inégalité des revenus différenciait le pouvoir d'achat des personnes de différents groupes de revenus. As the income gap widened, low-income groups were more likely to overexploit natural resources to generate income, which would intensify environmental destruction; whereas high-income groups were inclined to settle in areas where the environmental risks were lower and their wish to pay for the management of the environment was low. As a result, with the widening income gap, the consent to pay for the environment was low for low-income and high-income groups, exacerbating environmental pollution. All of this evidence confirmed that EKC did not exist. However, according to Hao, et al, (2016), very few studies have investigated the relationship between income inequality and the quality of the environment in China, and they believe that many studies use panel data, but only few studies focused on China to empirically examine the relationship between the income gap and environmental performance.

2. Methodology

2.2 Conceptual framework

In this research, empirical data on the types of interactions between levels of poverty (Y_{it}) and inequality (X_{it}) and the effect of climate change captured by the vector (Z_{it}) on these interactions. As a result, a very general semi-parametric simultaneous system model is proposed using endogenous explanatory variables (Newey et al., 1999, Blundell and Powell 2003, Ai and Chen 2003, Su; and Ullah, 2008 and Martins-Filho and Yao, 2012). The problem of endogeneity of regressors is widely encountered in empirical models in economics, mainly due to measurement error or simultaneity that results from individual choices or market equilibrium (Geng, Martins-Filho and Yao 2015). Thus, the development of estimation procedures that take into account the endogeneity of regressors has permeated much of modern econometrics research. Doing it in the context of fully parametric models can be misleading because of the high probability of poor model specification that can lead to inconsistent estimators and erroneous inference. Therefore, a useful trade-off is to consider partially linear models that take advantage of any known parametric functional form information while retaining the flexibility of non-parametric structures for the other components of the regression (Robinson, 1988, Hardle et al. 2000).

The specification and estimation of non-parametric and semi-parametric regression models using "endogenous" regressors has received considerable attention in econometrics (Newey et al., 1999, Blundell and Powell, 2003). Ai and Chen, 2003, Su Ullah, 2008 and Martins-Filho and Yao, 2012). We start with the basic model of Newey, Powell and Vella (1999) and Ozabac, Henderson and Su (2014). They considered a triangular system of the following partially linear functional coefficient model:

$$Y_{it} = g(X_{it}, Z_{it}) + \theta'_{it}V_{it} + \varepsilon_{it} \qquad (1)$$

$$X_{it} = m(Z_{1,it}, Z_{2,it}) + \Psi_{it}V_{it} + U_{it} \qquad (2)$$

$$E(U_{it}|Z_{1,it}, Z_{2,it}, V_{it}) = 0 \qquad (3)$$

$$E(\varepsilon_{it}|Z_{1,it}, Z_{2,it}, U_{it}, V_{it}) = E(\varepsilon_{it}|U_{it}); \qquad E(\varepsilon_{it}) = 0 \qquad (4)$$

When $X_{it} = (X_{1,it}, \dots, X_{dx,it})$ is a vector $dx \times 1$ of endogenous regressors, $Z_{1,it} = (Z_{1,it}, \dots, Z_{d1,it})$ is a vector $d1 \times 1$ of exogenous regressors "included", $Z_{2,it} = (Z_{2,it}, \dots, Z_{d2,it})$ is a vectror $d2 \times 1$ Exogenous explanatory variables "excluded", g(-, -) indicates the structural function of really unknown interest, $m_{it} = (m_{1,it}, \dots, m_{dx,it})$ is a vector $dx \times 1$ smooth functions of the instruments $Z_{1,it}$, $Z_{2,it}$; et $\varepsilon_{it} = (\varepsilon_{1,it}, \dots, \varepsilon_{dx,it})$ and $U_{it} = (U_{1,it}, \dots, U_{dx,it})$ are error terms . V_{it} , is a vector $k \times 1$ of exogenous variables, θ_{it} is a parameter vector $k \times 1$ and $\Psi_{it} = (\psi'_{1,it}, \dots, \psi'_{dx,it})$ is a matrix $dx \times k$ of parameters in the reduced form regression for X. To avoid the problem of dimensionality, we will suppose that $m(Z_{1,it}, Z_{2,it})$, $g(X_{it}, Z_{1,it})$and $E(\varepsilon_{it}|U_{it})$ have additive forms. Newey, Powell and Vella (1999) are interested in a coherent estimation of $g(X_{it}, Z_{1,it})$. and have shown that $g(X_{it}, Z_{1,it})$ can be identified up to an additive constant under the key identification conditions that $E(U_{it}|Z_{1,it}, Z_{2,it}, V_{it}) = 0$ and $E(\varepsilon_{it}|Z_{1,it}, Z_{2,it}, U_{it}, V_{it}) = E(\varepsilon_{it}|U_{it})$. If these conditions are met, Ozabac, Henderson and Su (2014) notice that the results developed in the previous sections go straight to the specified model which:

$$E(Y_{it}| X_{it}, Z_{1,it}, Z_{2,it}, U_{it}, V_{it}) = g(X_{it}, Z_{it}) = E(\varepsilon_{it}|U_{it}) + \theta'V_{it} = g(X_{it}, Z_{it}, U_{it}) = \theta'V_{it} \qquad (6)$$

$$E(X_{it}|\ Z_{1,it}, Z_{2,it}, V_{it}) = m(Z_{1,it}, Z_{2,it}) + \Psi_{it}V_{it} \qquad (7)$$

Given a random sample $\{(Y_{it}, X_{it}, Z_{1,it}, Z_{2,it}, U_{it}, V_{it}), i = 1, .., n\ et\ t = 1, \dots, T\}$, we can continue to use the Generalised Joint Regression Modeling (GJRM) procedure to estimate the model above. Indeed, the GJRM offers functions to adapt general models of joints in various situations. The estimation approach is based on a very generic framework based on penalized maximum likelihood, where any (parametric) distribution can in principle be used, and the smoothers (representing several types of covariate effects) are implemented using penalized regression curves (Marra and Radice 2018).

2.3 Empirical specification

In this research, it is estimated that the vector of current and future climate variables (Z_{it}) have direct effects on agricultural value added through effects on yields, prices and other sources of income (Sesmero, Ricker-Gilbert and Cook 2017). Previous work has shown that households that tend to be more dependent on cereal production may, in a context of adverse climatic conditions, fall into a climate-induced poverty trap (Dercon and Christiaensen 2011). To estimate the empirical models, we used two models based on two (2) poverty lines of \$ 3.10 and \$ 1.90. Thus, starting from equations (1) and (2) we formulate the following models:

Model (1)

$$\begin{aligned} pov310_{it} = {} & vmi_{it} + vmz_{it} + vsg_{it} + pmi_{it} + pmz_{it} + psg_{it} + dal_{it} + fpc_{it} + mpm_{it} + gdp_{it} \\ & + edp_{it} + sal\_5_{it} + brq_{it} + cur_{it} + gsb_{it} + s(ztp)_{it} + s(zpl)_{it} + s(gini)_{it} \end{aligned} \tag{8a}$$

$$\begin{aligned} gini_{it} = {} & vmi_{it} + vmz_{it} + vsg_{it} + pmi_{it} + pmz_{it} + psg_{it} + dal_{it} + fpc_{it} + mpm_{it} + gdp_{it} + edp_{it} \\ & + sal\_5_{it} + brq_{it} + cur_{it} + gsb_{it} + s(ztp)_{it} + s(zpl)_{it} \end{aligned} \tag{9a}$$

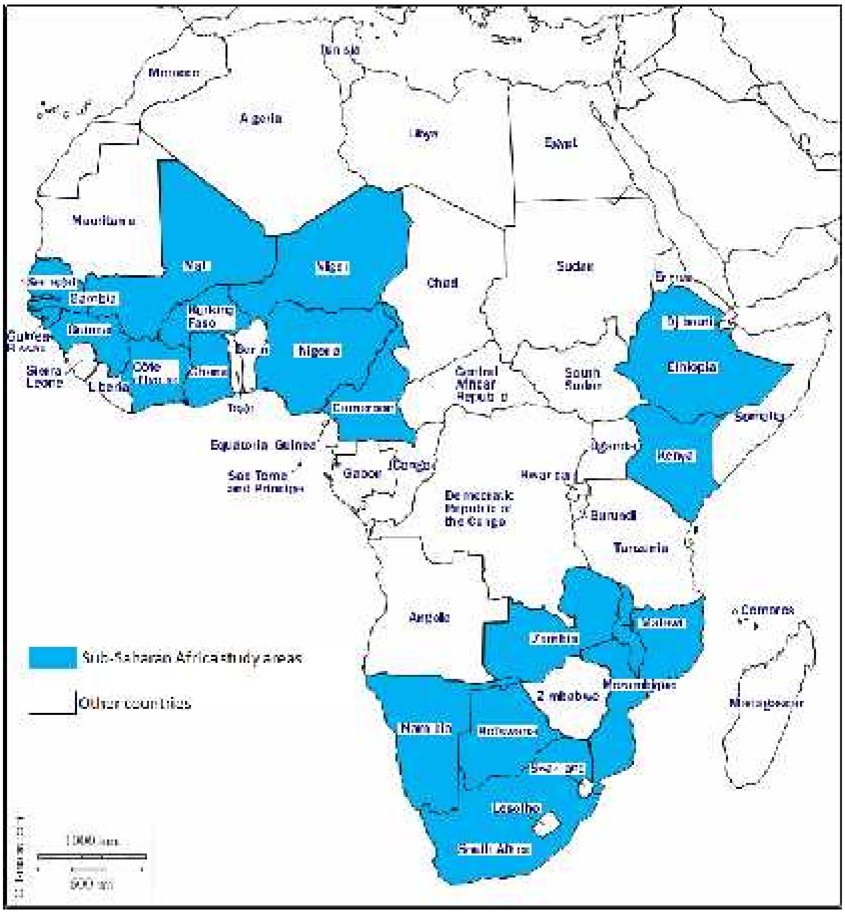
Model (2)

$$\begin{aligned} pov190_{it} = {} & vmi_{it} + vmz_{it} + vsg_{it} + pmi_{it} + pmz_{it} + psg_{it} + dal_{it} + fpc_{it} + mpm_{it} + gdp_{it} \\ & + edp_{it} + sal\_5_{it} + brq_{it} + cur_{it} + gsb_{it} + s(ztp)_{it} + s(zpl)_{it} + s(gini)_{it} \end{aligned} \tag{8b}$$

$$\begin{aligned} gini_{it} = {} & vmi_{it} + vmz_{it} + vsg_{it} + pmi_{it} + pmz_{it} + psg_{it} + dal_{it} + fpc_{it} + mpm_{it} + gdp_{it} + edp_{it} \\ & + sal\_5_{it} + brq_{it} + cor_{it} + gsb_{it} + s(ztp)_{it} + s(zpl)_{it} \end{aligned} \tag{9b}$$

3. Sources of data

As part of this research, the empirical model is estimated using a semi-parametric model of simultaneous equations. It is based on panel-based data on Sub-Saharan African countries through vectors of climatic and non-climate variables and on several indicators of poverty and inequality. The panel data used in this research covers the period 2000-2016 for 20 Sub-Saharan African countries. The data sources and descriptive statistics for the variables are presented in the table (attached). The sources for the Gini Index data were collected from the World Factbook (https://www.cia.gov/library/publications/the-world-factbook). Regarding climate variables such as temperatures (in degrees Celsius) and Precipitation (in mm/m^3) were collected at the World Bank Climate Change Knowledge Portal (http://sdwebx.Worldbank .org/climate portal). These variables are important for understanding the impacts of climate change on poverty and inequality. They matter because, compared to case studies and comparative analyzes of the poor in poor countries, the literature on climate change and debates about the poor in developed countries and their experiences with a changing climate have been surprisingly dumb. Poverty and inequality in SSA have been poorly documented and represented in international poverty indicators and in-depth climate change surveys. We also used other variables including, among others, prices, agricultural value added, etc., from the basis of FAOSTAT 2018 (http://www.fao.org/faostat/en/#home). Descriptive statistics are listed in Table1.



Source: author's construction from www.d-maps.com

Table 1: Overall description of model variables

Variable	Designation	Obs	Mean	Std.Dev.	Min	Max
gdp_{it}	Current GDP per capita (in US $)	340	1597,87	1916,57	111,36	8229,73
$pov310_{it}$	poverty line at US $ 3.10 / pers / day (%)	340	69,36	15,24	34,68	92,04
$pov190_{it}$	poverty line at US $ 1.90 / pers / day (%)	340	45,15	16,97	16,56	80,36
$gini_{it}$	Gini inequality index	340	8,99	2,39	2,90	13,00
dal_{it}	food availability (Kcal / pers / day Average / 3 years)	340	147,65	93,06	24,00	453,00
fpc_{it}	total fertility rate (births / woman)	340	5,16	1,15	2,49	7,68
mpm_{it}	mortality rate (per 1000 inhabitants)	340	11,66	2,76	5,84	18,29
edp_{it}	number of puplis enrolled in elementary school	340	3876,00	5173,23	0,24	26167,50
sal_5_{it}	Prevalence of malnutrition (% of children <5 years old)	340	20,73	11,52	3,60	53,60
vmi_{it}	Value added of millet (in millions of US dollars)	340	93,55	202,83	0,00	1386,95

vmz_{it}	Value added of corn (in millions of US $)	340	198,64	276,90	0,09	1299,95
vsg_{it}	Value added of sorghum (in millions of US $)	340	109,62	229,41	0,57	1203,31
pmi_{it}	100-based index of millet price (in US $)	340	380,75	260,19	64,30	1158,33
pmz_{it}	100-based index of corn price (in US $)	340	296,86	221,30	52,50	1405,90
psg_{it}	100- based index of sorghum price (in US $)	340	334,05	253,62	52,50	2103,10
zpl_{it}	average annual precipitation (in mm / m3)	340	76,86	37,97	12,00	179,30
ztp_{it}	average annual temperature (in ° C)	340	25,49	2,99	17,61	29,75
brq_{it}	Government inefficiency (from 0 = low to 4 = high)	340	1,33	0,74	0,00	2,50
cor_{it}	control of corruption (from 0 = low to 6 = high)	340	2,12	0,63	0,50	4,00
gsb_{it}	government instability (from 0 = low to 12 = high)	340	8,28	1,52	4,46	11,58

Source: Author's construction from 2000-2016 SSA data

4. Results and discussions

The econometric results are presented to gradually achieve the objectives of the research starting with the results of the parametric models to finish with the results of semi-parametric models. The estimated parametric models are derived from equations (8a, 9a) and (8b, 9b) for the $ 3.10 and $ 1.90 thresholds for both inequality and poverty interactions. The estimated nonparametric models were derived from said equation.

4.1. Parametric analysis of the relation between poverty and inequality

The estimated parametric model is that of a structural semi-parametric equation model of partially linear functional coefficient (equations 8a, 9a and 8b, 9b). The estimate was made using the GJRM function (Marra and Radice, 2018). The analysis of the results of the estimation of parametric models at the poverty line of $ 1.90 and $ 3.10 are listed in Tables 2 and 3. The results show that the effects of cereals (millet, corn and sorghum) vary according to poverty lines in both equations (poverty and inequality). As a result, when the poverty line is $ 1.90, only the agricultural value added of sorghum has a significant negative effect on both poverty and inequality, but the effects of maize and sorghum remain only negative and significant in regard to poverty on inequality when the threshold is $ 3.10. As for the agricultural value of millet, it positively and significantly affects poverty if the poverty line remains at $ 1.90 and as soon as this threshold reaches $ 3.10, its effect is no longer significant. The results in relation to the price effect of millet remained positive and significant on inequalities at the $ 1.90 and $ 3.10 levels, as well as on poverty when the threshold was set at $ 3.10. However, the price effect of maize is rather positive and significant for poverty and it is negative for inequality regardless of the poverty line set. Authors such as Harttgen, et al., (2015) found that rising maize and / or staple food prices increase food poverty, particularly among poor and urban populations who cannot change their mode of food consumption in favor of other food products (generally more expensive).

These results on the correlation between poverty and inequality have been associated with changes in the socio-economic variables that have been the subject of several studies, such as those of Beteille, (2003), who state that poverty and inequality do not evolve at the same pace, and they can even evolve in opposite directions. Indeed, a decrease (increase) in poverty is not always accompanied by a decrease (increase) of inequality, it can actually be accompanied by an overall increase (decrease) of inequality.

Table 2: Results of parametric model estimation at the $ 3.10 poverty line

Variables	pov310		Gini310		Pov310		Gini310	
	coef(1)	prob(1)	coef(1)	prob(1)	coef(2)	prob(2)	coef(2)	prob(2)
Constant	-17,240	0,118	13,730	0,000	-11,340	0,148	13,770	0,000
vmi_{it}	0,006	0,298	0,000	0,390	0,006	0,233	0,000	0,470
vmz_{it}	-0,006	0,171	0,000	0,646	-0,007	0,014		
vsg_{it}	0,003	0,771	-0,004	0,000			-0,004	0,000
pmi_{it}	0,008	0,140	0,001	0,000	0,009	0,028	0,001	0,000
pmz_{it}	0,015	0,014	-0,001	0,046	0,013	0,018	-0,001	0,025
psg_{it}	-0,009	0,003	0,000	0,637	-0,009	0,003	0,000	0,572
dal_{it}	-0,141	0,072	0,027	0,000	-0,102	0,069	0,027	0,000
sal_5_{it}	1,443	0,032	-0,248	0,000	1,105	0,022	-0,243	0,000
fpc_{it}	11,570	0,000	-0,470	0,000	11,120	0,000	-0,456	0,000
mpm_{it}	0,387	0,468	-0,053	0,000			-0,054	0,000
gdp_{it}	-0,001	0,009	0,000	0,003	-0,001	0,005	0,000	0,001
edp_{it}	0,000	0,810	0,000	0,000			0,000	0,000
brq_{it}	-2,910	0,023	0,666	0,000	-2,244	0,014	0,670	0,000
cor_{it}	6,054	0,000	0,027	0,746	6,108	0,000		
gsb_{it}	-1,114	0,012	0,120	0,000	-1,000	0,021	0,127	0,000
n	340		340		340		340	
σ	53.3(46.1,61.2)		0.372(0.317,0.429)		53.6(45.7,62.8)		0.372(0.326,0.439)	
ι		-0.0069(-0.183,0.183)				0.0464(-0.0465,0.147)		
θ		-0.0108(-0.283,0.283)				0.0728(-0.073,0.229)		
Total edf		70.3				65.7		

Source: Author's construction from 2000-2016 SSA data

On the other hand, the magnitude of food availability has an inverse effect on the level of poverty while it significantly and positively affects inequality at both $ 1.90 and $ 3.10 level. Indeed, when the scale of food availability increases by 1%, it negatively affects the level of poverty by -0.10% but leads to an increase of about + 0.03% of inequalities in SSA. As a result, the prevalence of under-five malnutrition positively affects poverty with a very high significance at the $ 3.10 level. In terms of inequality, the effects remain negative at both the $ 3.10 and $ 1.90 thresholds. At the socio-economic level, the results highlight the relationship, negative (positive) and significant, between the domestic product per individual and the level of poverty (inequality). In doing so, it is understood that the decline in per capita income is one of the economic causes that exacerbates poverty and at the same time its rise causes an increase in inequalities in SSA. It is often assumed that people in developed countries enjoy universal food security, the main conditions being economic prosperity and the ability to produce abundant food (Richards, et al., 2016), thus economic inequalities increase worldwide, including in economically developed countries (Jaumotte et al., 2013, Piketty, 2015). It has been argued that increasing social inequality, especially poverty, leads to food insecurity and that food security is primarily a question of unequal distribution of resources (Carolan, 2013, Sen, 1981).

Table 3: Results of parametric model estimation at the $ 1.90 poverty line

Variables	pov190		Gini190		Pov190		Gini190	
	coef(1)	prob(1)	coef(1)	prob(1)	coef(2)	prob(2)	coef(2)	prob(2)
Constant	-42,300	0,000	13,730	0,000	-42,790	0,000	13,820	0,000
vmi_{it}	0,026	0,000	0,000	0,418	0,027	0,000		
vmz_{it}	-0,004	0,425	0,000	0,672				
vsg_{it}	-0,026	0,016	-0,004	0,000	-0,029	0,000	-0,004	0,000
pmi_{it}	0,006	0,324	0,001	0,000			0,001	0,000
pmz_{it}	0,016	0,019	-0,001	0,045	0,018	0,000	-0,001	0,036
psg_{it}	-0,003	0,352	0,000	0,621				
dal_{it}	-0,060	0,488	0,027	0,000	-0,077	0,240	0,027	0,000
sal_5_{it}	14,120	0,000	-0,470	0,000	0,768	0,179	-0,248	0,000
fpc_{it}	-0,283	0,619	-0,053	0,000	13,820	0,000	-0,451	0,000
mpm_{it}	-0,002	0,008	0,000	0,003			-0,054	0,000
gdp_{it}	0,000	0,117	0,000	0,000	-0,002	0,013	0,000	0,000
edp_{it}	0,636	0,394	-0,248	0,000	0,000	0,032	0,000	0,000
brq_{it}	-2,554	0,074	0,667	0,000	-2,978	0,005	0,671	0,000
cur_{it}	5,403	0,000	0,027	0,745	5,373	0,000		
gsb_{it}	-0,441	0,387	0,121	0,000	-0,533	0,287	0,127	0,000
n	340		340		340		340	
σ	76.6(65.2,86.1)		0.372(0.33,0.438)		76.5(65.7,87.9)		0.373(0.323,0.43)	
τ		0.102(-0.0693,0.251)				0.0834(-0.0156,0.222)		
θ		0.16(-0.109,0.385)				0.131(-0.0245,0.342)		
Total edf		68.1				60.5		

Source: Author's construction from 2000-2016 SSA data

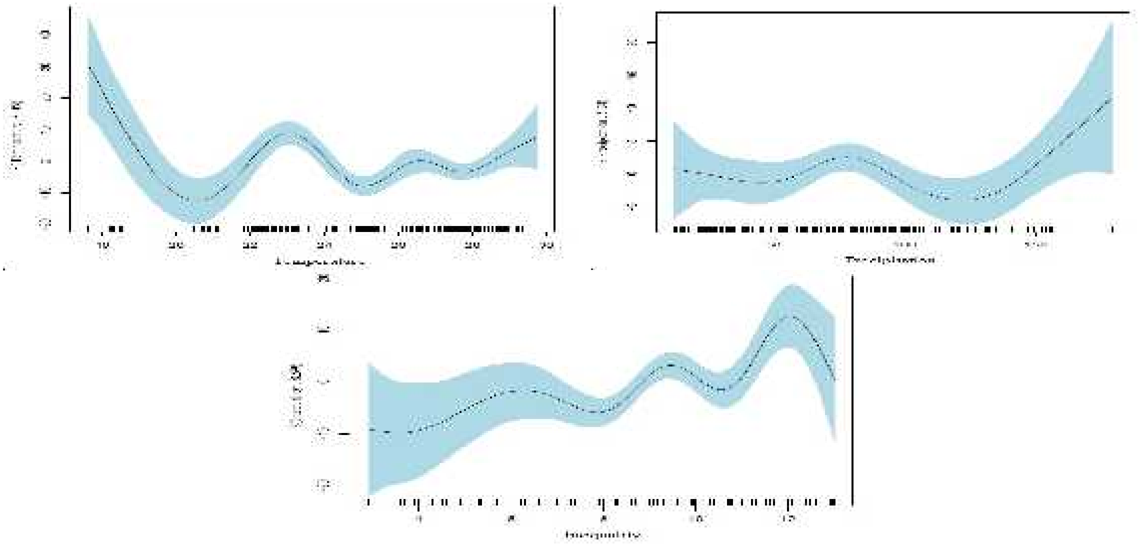
The results of the parametric estimate, at the thresholds of $ 1.90 and $ 3.10, show that the total fertility rate has a very significant positive effect on the increase in poverty respectively for both 13.82 % and 11, 12% thresholds. On the other hand, total fertility and mortality rates have a negative inverse effect on inequalities. Indeed, the research of Flegg, (1982); Rodgers, (1979) and Waldmann, (1992) have shown that countries with high inequalities have higher infant mortality rates than countries where the national product per capita is similar but the income distribution is more equal. However, another very significant negative effect at the parametric model level is captured by one of the very important institutional variables that is the control of corruption on poverty at the thresholds of $ 1.90 and $ 3.10. In other words, the lack of control over corruption is a factor that aggravates poverty and increases inequalities by about 6.10% and 0.67% respectively. However, variables such as the stability of government and the efficiency of bureaucracy contribute negatively and significantly to the increase of poverty respectively to -2.24% and -1.00% in SSA. At the same time, the results of the inequality equation show an effect of the stability of the government is positive and significant of + 0.02% against a significant negative effect of the efficiency of the bureaucracy of -0.24%. Indeed, the research of Gupta, et al., (2002) provided evidence that high and rising corruption increases income inequality and poverty, and came to an important conclusion that good control of corruption will most likely also reduce income inequality and poverty.

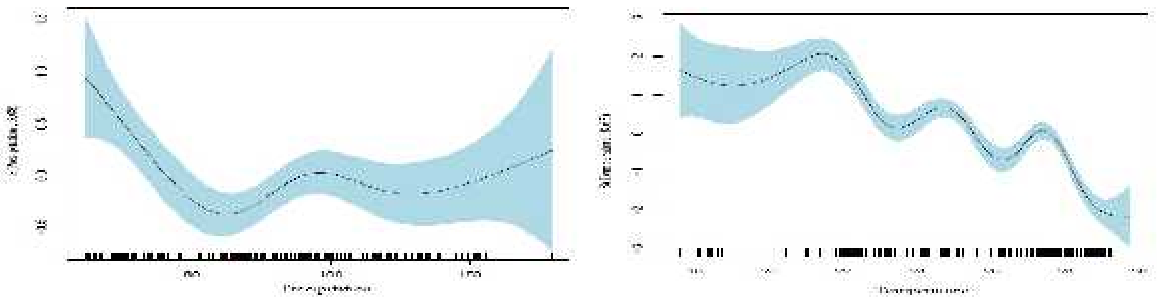
4.2 Semi-parametric analysis of the poverty-inequality relationship and climate change

The results of the semi-parametric analysis show that the relationship between climate variables (temperature and rainfall), poverty and inequalities in SSA is rather a complex relationship that is very often in the form of a non-linear relationship. To do this we have estimated a semi-parametric model in a triangular system of partially linear functional coefficient (equations 8a, 9a and 8b, 9b) and the estimated coefficients of the non-parametric model, on which our interest is mainly focused, reveal the relation nonlinear between inequalities, poverty and climate change through temperature and rainfall variables, with several thresholds (See Figure 1). The total degrees of freedom (edf) of the estimated bi-varied model are 70.3 and 65.7 for models (1) and (2) at the $ 3.10 threshold. By modifying the threshold at $ 190, the total edf are respectively 68.1 and 60.5 for both models (1 and 2). Indeed, Marra and Radice (2017) recall that when the edf is equal to 1, the respective estimated effect is linear, so that the covariate can enter the model parametrically, but when the edf is higher , the estimated curve is more complex. In addition, our estimates of the specific distribution parameters for the poverty and inequality equations are respectively $\upsilon_{2.1}$ =53.6(45.7$\leq \upsilon_{2.1} \leq$62.8) et $\upsilon_{2.2}$ =0.372(0.326$\leq \upsilon_{2.2} \leq$0.439) for model (2) at the level of 3,10$ et de $\upsilon_{2.1}$ = 0.0464(-0.0465$\leq \upsilon_{2.1} \leq$0.147) et $\upsilon_{2.2}$ =0.0728(-0.073$\leq \upsilon_{2.2} \leq$0.229) at the level of 1,90$. The value of Kendall's τ is 76.5 (65.7$\leq \tau \leq$87.9) and 0.373 (0.323$\leq \tau \leq$0.43) for the two respective thresholds and the results show positive and very significant degrees of dependence, between poverty and inequality, given by the parameter θ that is $0.0834\,(-0.0156 \leq \theta \leq 0.222)$ at the level of 310 $ and $0.131(-0.0245 \leq \theta \leq 0.342)$ at the level of 1,90$.

The results of temperature, rainfall, and the Gini inequality coefficient in the poverty and inequality equations show different degrees of non-linearity. Figure 1 shows the effects of temperature, rainfall, and inequality on poverty and inequality. The graphs show a nonlinear effect with maximum and minimum peaks and show that on average, poverty (at $ 3.10 and $ 190 thresholds) takes the form of inverted "N" when temperatures are between 18°C and 25°C while it follows the form of an "N" between 25°C and 30°C. At the same time, rainfall has more complex effects on poverty and inequality in that it tends to cyclically affect them. Regarding the endogenous effect of inequalities on poverty, the results show a positive and significant non-linear relationship between them. Indeed, the results show that the probability of remaining in poverty increases inequalities regardless of the thresholds of $ 3.10 and $ 1.90 in SSA. On the other hand, in terms of the inequality equation, the results highlight a negative and significant nonlinear effect of temperature on inequalities at both poverty lines of $ 3.10 and $ 1.90. In previous research, the results of Herrera, et al., (2018) also showed a negative impact of fluctuations in precipitation and temperature on household income and the level of poverty. Indeed, according to the argument of Heshmati, et al., (2015), despite the fact that an increase in rainfall is expected to increase agricultural value added the overall negative impact of rising temperatures is more than compensate for the limited positive impact due to increased rainfall.

Figure 1: Estimation of the smooth effects of temperature, precipitation, and inequality index on poverty and inequality with 95% confidence intervals

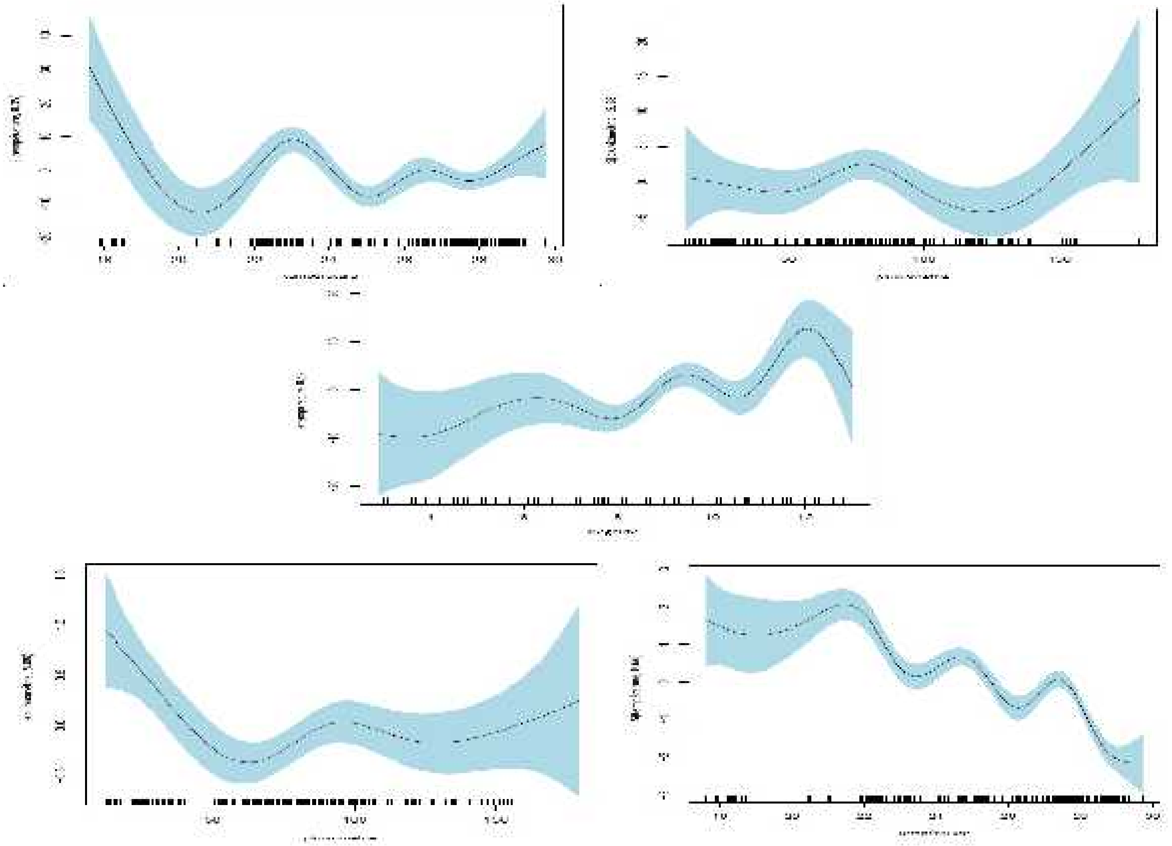




Source: Author's construction from 2000-2016 SSA data

Figure 1: Estimation of the smooth effects of temperature, precipitation, and inequality index on poverty and inequality with 95% confidence intervals obtained by fitting a Gaussian copula model with normal margins to panel data on inequality and the poverty line at $ 3.10 in SSA. The treadmill layout at the bottom of each graph shows the covariate values. The number in parentheses in the legend of the y-axis represents the effective degrees of freedom (edf) of the smooth curves; the higher the value, the more complex the estimated curve.

Figure 2: Estimation of the smooth effects of temperature, precipitation, and inequality index on poverty and inequality with 95% confidence intervals



Source: Author's construction from 2000-2016 SSA data

Estimation of the smooth effects of temperature, precipitation, and inequality index on poverty and inequality with 95% confidence intervals obtained by fitting a Gaussian copula model with normal margins to panel data on inequality and the poverty line at $ 3.10 in SSA. The treadmill layout at the bottom of each graph shows the covariate values. The number in parentheses in the legend of the y-axis represents the effective degrees of freedom (edf) of the smooth curves; the higher the value, the more complex the estimated curve.

Conclusion

This paper is an attempt to provide an answer to the following basic research question: how to assess the relationship between the impact of climate change on poverty and inequality in SSA? Results at the parametric model have shown the negative effects of some agricultural value added (sorghum and maize) on poverty and inequality while millet has a positive effect on poverty. It also appears that cereal prices significantly increase levels of poverty and inequality. At the level of availability when the scale increases by 1%, then it affects poverty by -0.10% but leads to an increase of about + 0.03% of inequality in SSA. In addition, the results also showed that the total fertility rate has a very significant positive effect on the increase of poverty a negative inverse effect on inequalities. Finally, the control of corruption is a factor that aggravates poverty and increases inequalities by about 6.10% and 0.67% respectively, while the stability of the government and the efficiency of the bureaucracy reduce -2.24 % and -1.00% poverty in SSA.

The results of the nonparametric model showed that temperature has a negative and significant nonlinear effect on inequality and positive on poverty by taking the form of inverted "N" when temperatures are between 18°C and 25°C while it follows the shape of an "N" between 25°C and 30°C. Rainfall has also been shown to have more complex effects on poverty and inequality. Finally, results have shown a positive and significant nonlinear relationship between poverty and inequality in SSA. In order to fight poverty and inequality it is imperative that governments integrate the climate dimension into economic programs and policies to reduce poverty and inequality in SSA. Future research that assesses the relationships between parametric models and semi-parametric models using, for example, Monte Carlo simulations, may improve the results of such searches.

Appendix

Table A1 : Countries Sample

South Africa, Botswana, Burkina Faso, Cameroon, Ivory Coast, Ethiopia, Gambia, Ghana, Guinea-Bissau, Guinea, Kenya, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Senegal, Togo, Zambia

Références

AFDB, (2018). *Perspectives Economiques en Afrique*, s.l.: Banque africaine de développement.

Ai, C. & Chen, X., (2003). Efficient Estimation of Models With Conditional Moment Restrictions Containing Unknown Functions. 71(6), pp. 795-1843.

Berthe, A. & Elie, L., (2015) Mechanisms explaining the impact of economic inequality on environmental deterioration. *Ecological Economics,* p. 191–200.

Beteille, A.,(2003). Poverty and Inequality. *Economic and Political Weekly,* 38(4), pp. 4455-4463.

Bimonte, S., (2002). Information access, income distribution, and the Environmental Kuznets Curve. *Ecological Economics,* 41(1), pp. 145-156.

Blundell, R. & Powell, J. L., (2003). *Endogeneity in nonparametric and Ssemiparametric regression models.* Cambridge: Econometric society monographs.

Bowen, A., . Cochrane, S. & Fankhauser, S., (2012). Climate change, adaptation and economic growth. *Climatic Change,* 113(2), p. 95–106.

Boyce, J., (1994). Inequality as a cause of environmental degradation.. *Ecologial Economics,* 11(3), p. 69–178.

Boyce, J., (2010). Economic Inequality and Environmental Quality: Evidence of Pol-lution Shifting in Russia. *PERI Working Papers*, p. 189..

Carolan, M. S., (2013). *Reclaiming Food Security.* 1st Edition éd. London: Routledge.

Deaton, A., (2010). Price Indexes, Inequality, and the Measurement of World Poverty. *American Economic Review,* pp. 5-14.

Dercon, S. & Christiaensen, L., (2011). Consumption Risk, Technology Adoption and Poverty Traps: Evidence from Ethiopia. *Journal of Development Economics,* 96(2), p. 159–173.

Egbendewe, et al., (2017). Can intra-regional food trade increase food availability in the context of global climatic change inWest Africa?. *Climatic Change.*

Flegg, A., (1982). Inequality of Income, Illiteracy, and Medical Care as Determinants of Infant Mortality in Developing Countries. *Population Studies,* 36(3), pp. 441-458.

Fosu, A. K., (2015). Growth, Inequality and Poverty in Sub-Saharan Africa: Recent Progress in a Global Context. *Oxford Development Studies,* 43(1), pp. 44-50.

Fothergill, A. & Peek, L. A., (2004). Poverty and Disasters in the United States: A Review of Recent Sociological Findings. *Natural Hazards,* 32(1), p. 89–110.

Gawande, K., Robert, P. & Alok, K., (2001). A consumption-based theory of the environmental Kuznets curve. *Ecological Economics,* 37(1), pp. 101-112.

Geng, X., Martins-Filho, C. & Yao, F., (2015). *Estimation of a Partially Linear Regression in Triangular Systems,* West Virginia University: Department of Economics.

Golley, J. & Meng, X., (2012). Income inequality and carbon dioxide emissions: The case of Chinese urban households. *Energy Economics,,* 34(6), p. 1864–1872.

Grossman, G. & Krueger, A., (1991). Environmental Impacts of a North American Free Trade Agreement. *NBER Working Paper No. 3914,* p. 57.

Grunewald, N., Klasen, S., Martınez-Zarzoso, I. & Muris, C., (2017). The trade-off between income inequality and carbon dioxide emissions. *Ecological Economics,* p. 249–256.

Gupta, S., Davoodi, H. & Alonso-Terme, R., (2002). Does corruption affect income inequality and poverty?. *Economics of Governance,* 3(1), p. 23–45.

Hao, Y., Chenb, H. & Zhang, Q., (2016). Will income inequality affect environmental quality? Analysis basedon basedon China’s provincial panel data. *Ecological Indicators,* p. 533–542.

Hardle, W., Liang, H. & Gao, J., (2000). *Partially Linear Models.*. Berlin: Springer-Verlag.

Harttgen, K., Klasen, S. & Rischke, R., (2015). Analyzing nutritional impacts of price and income related shocks in Malawi: Simulating household entitlements to food. *Food Policy.*

Herrera, C., Ruben, R. & Dijkstra, G., (2018). Climate variability and vulnerability to poverty in Nicaragua. *Journal of Environmental Economics and Policy,* 7(3), pp. 324-344.

Heshmati, A., Maasoumi, E. & Wan, G., (2015). *Poverty Reduction Policies and Practices in Developing Asia: Economic Studies in Inequality, Social Exclusion and Well-Being.* Springer International Publishing AG éd. s.l.:Asian Development Bank.

IPCC, (2014). *Climate change impacts, adaptations and vulnerability, contribution of working group 2 to the fifth assessment report of the Intergovernmental Panel on Climate Change.,* Cambridge: Cambridge University Press,.

IPCC. (2017). *Le GIEC définit les grandes lignes de son sixième Rapport d’évaluation,* Suisse: Secrétariat du GIEC.

Isaksen, E. T. & Narbel, P. A., (2017). A carbon footprint proportional to expenditure—A case for Norway?. *Ecological Economics,,* p. 152–165..

Jaumotte, F., Lall, S. & Papageorgiou, C., (2013). Rising Income Inequality: Technology, or Trade and Financial Globalization?. *MF Economic Review,* 6(2), p. 271–309.

Krueger, D., Perri, F., Pistaferri, L. & Violante, G. L., (2010). Cross sectional facts for macroeconomists. *Review of Economic Dynamics,* 13(1), pp. 1-14.

Marra, G. & Radice, R., (2017). Bivariate copula additive models for location, scale and shape. *Computational Statistics and Data Analysis,* Volume 112, pp. 99-113.

Marra, G. & Radice, R., (2018). Generalised Joint Regression Modelling. *CRAN packages "GJRM",* 14 novembre.p. 112.

Martinez-Alier, J., (1995). Political Ecology, Distributional Conflicts, and Economic Incommensurability. *New Left Review,* p. 70–88..

Martins-Filho, C. & Yao, F., (2012). Kernel-based estimation of semiparametric regression in triangular systems. *Economics Letters,* 115(1), pp. 24-27.

Masters, W. & McMillan, M., (2001). Climate and Scale in Economic Growth. *Journal of Economic Growth,* 6(3), p. 167–186.

Mendelsohn, R., Dinar, A. & Williams, L., (2006). The distributional impact of climate change on rich and poor countries. *Environment and Development Economics,* 11 (2), pp. 159-178.

Newey, W., Powell, J. L. & Vella, F., (1999). Nonparametric estimation of triangular simultaneous equations models. *Econometrica,* 67(3), pp. 565-603.

Ozabac, D., Henderson, D. J. & Su, L., (2014). Additive Nonparametric Regression in the Presence of Endogenous Regressors. *Journal of Business & Economic Statistics,* 32(4), pp. 555-575.

Piketty, T., (2015). About Capital in the Twenty-First Century. *American Economic Review,* 105(5), pp. 48-53.

Ravallion, M., Heil, M. & Jalan, J., (2000). Carbon emissions and income inequality. *Oxford Economic Papers,* pp. 651-669.

Richards, C., Kjærnes, U. & Vik, J., (2016). Food security in welfare capitalism: Comparing socialentitlements to food in Australia and Norway. *Journal of Rural Studies,,* pp. 61-70..

Robinson, P. M., (1988). Root-n consistent semiparametric regression. *Econometrica,* 56(4), p. 931–954.

Rodgers, G. B., (1979). Income and inequality as determinants of mortality: An international cross-section analysis. *Population Studies* , 33(2), pp. 343-352..

Rosenzweig, C. & Parry, M., (1994). Potential impact of climate change on world food supply.. *Nature,* p. 133–138.

Selden, M. T. & Song, D., (1994). Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions?. *Journal of Environmental Economics and Management,* 27(2), pp. 147-162.

Sen, A., (1981). *Poverty and famines: An Essay on Entitlement and Deprivation.* Oxford, UK: Clarendon Press, Oxford University Press.

Sesmero, J., Ricker-Gilbert, J. & Cook, A., (2017). How do African farm households respond to changes in current and past Weather patterns? A structural panel Data analysis from Malawi. *American Journal of Agricultural Economic,* 100(1), pp. 115-144.

Shafik, N. & Bandyopadhyay, S., (1992). *Economic Growth and Environmental Quality: Time-series and Cross-country Evidence,* s.l.: World Bank Raport.

Shao, S., Yang, L., Yu, M. & Yu, M., (2011). Estimation, characteristics, and determinants of energy-related industrial CO2 emissions in Shanghai (China), 1994–2009. *Energy Policy,* 39(10), pp. 6476-6494.

Su, L. & Ullah, A., (2008). Local Polynomial Estimation of Nonparametric Simultaneous Equations Models. *Journal of Econometrics, 144,,* 14(1), p. 193–218..

Thorbecke, E., (2013). The interrelationship linking growth, inequality and poverty in sub-Saharan Africa. *Journal of African Economies,* p. i15–i48..

Tol, R., (2009). The Economic Effects of Climate Change. *Journal of Economic Perspective* , 23(2), p. 29–51.

Torras, M. & Boyce, J. K., (1998). Income, inequality, and pollution: a reassessment of the environmental Kuznets Curve. *Ecological Economics,* 25(2), pp. 147-160.

Tschakert, P., (2016). Shock Waves: Managing the Impacts of Climate Change on Poverty: The Role of Inequality in Climate-Poverty Debates. *Development Economics; Policy Research Working Paper,* Issue WPS7677, pp. 1-54.

Udry, C., (1995). Risk and Saving in Northern Nigeria. *The American Economic Review,* 85(5), p. 1287–1300..

UNDP, (2017). *Inégalités de revenus en Afrique subsaharienne: Tendances divergentes, déterminants et conséquences,* Nexw York: s.n.

Waldmann, R. J., (1992). Income Distribution and Infant Mortality. *Quarterly Journal of Economics,* 107(4), p. 1283–1302.

Wiedenhofer, D. et al., (2017). Unequal household carbon footprints in China.. *Nature Climate Change,* p. 75–80.

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