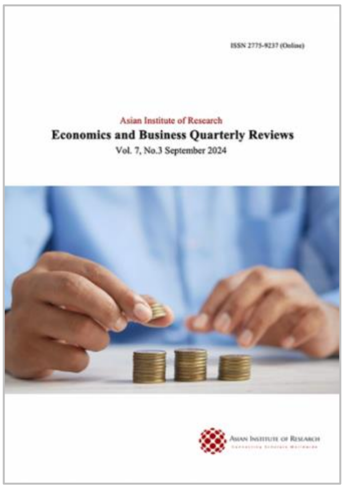

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Re-examining the Link Between Economic Growth and Income Inequality in Sub-Saharan African Countries: Do Natural Resource Endowments Matter?

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Abstract
Do natural resource endowments influence the relationship between economic growth and income inequality in Sub-Saharan African (SSA) countries? This is the main question of this article. To this end, we use polynomial non-linear modeling and non-parametric and semi-parametric modeling applied to a panel of 43 SSA countries between 2000 and 2020. The data used come from World Development Indicators (WDI) and the University of Texas Inequality Project. In order to enrich the empirical literature on the subject, four indices measure income inequality in the econometric tests. All other things being equal, the results show that the growth-inequality link is non-linear, with a positive trend that changes convexity with the level of growth. Rents from non-renewable natural resources (oil, gas and other minerals) accentuate the negative effect of growth on inequality, while income from renewable resources (water and forests) has the effect of reducing inequality. Furthermore, these results show that rents from a single product (a single natural resource) have no impact on inequality. On the other hand, income from the export of several natural resources accentuates the effect of growth on inequality. Consequently, SSA countries need to put in place a general policy to reduce inequalities and a strategy to reduce their dependence on the exploitation of natural resources. This can be achieved through the structural transformation of economies and the development of global value chains.

Keywords: Economic Growth, Income Inequality, Natural Resource Endowments, Sub-Saharan Africa

1. Introduction

1.1. Growth and inequality dynamics in developed and developing countries

The global financial crisis and the recent COVID-19 pandemic have devastated the majority of countries, leading to an increase in income inequality accompanied by a drastic decline in economic growth. As a result, there has been renewed interest in the relationship between poverty, inequality and economic growth (Mary et al. 2023). Income disparity while ensuring higher economic growth is at the heart of the equity exchange shaping policy discussions worldwide (Acheampong et al. 2023; De Dominicis et al. 2008). Furthermore, reducing income inequality and environmental fragility are important factors that can contribute to achieving sustainable development (Khan et al. 2023). Consequently, policies aimed at reducing income inequality, improving the equitable distribution of income and reducing relative poverty rates can help stimulate more inclusive and sustainable economic growth (Iwan et al. 2024).

The issue of inequality is not new to economic literature. It dates back to the pioneering work of Simon Kuznets (1955) and Kaldor (1956). However, their economic, social and political weight has increased markedly in recent years with the rapid growth of globalization. Stiglitz (2012) notes that in the United States, income inequality has returned to the record levels of the 1920s. The richest 1% captured over 65% of the increase in national income between 2002 and 2007.

Reading Piketty (2013), one would be tempted to conclude that the world has never been so unequal since the 18th century. Alvaredo et al. (2018) provided a comprehensive review of income inequality over the 40 years and highlighted a rise in income inequality in China, Russia and India. These alarming voices from researchers and international organizations warn of the damaging consequences of inequality on the macroeconomic and financial stability of developed countries, and on the economic and social development prospects of southern countries such as those in SSA. Furthermore, inequality has been a major challenge in SSA, mainly because several countries in the sub-region have not benefited from increased economic growth over the past 20 years (Menyelim et al. 2021). However, existing work in this dynamic is inconclusive on the variables that determine the link between growth and income inequality. Thus, the relationship between income inequality and economic growth remains an ongoing theme in both theoretical and empirical literature, and continues to enrich research in development economics.

1.2. The importance of natural resource endowments in SSA countries

SSA is endowed with an enormous abundance of natural resources. It has arable land and subsoil for agricultural activities, large-scale forests for timber production and abundant sources of energy such as gas, oil and other minerals. However, despite high rates of economic growth since the early 2000s, SSA's socio-economic performance lags behind that of developing countries in Asia. SSA is struggling to significantly reduce inequality and poverty, the two main targets of the African Union's Sustainable Development Agenda and Agenda 2063. Six of the world's ten most unequal countries are located there, and nine out of the world's ten poorest countries in terms of GDP per capita belong to it (World Bank, 2019). Africa ranks second after the Near and Middle East in terms of the benefits derived from natural resources, with 12.19% of GDP, including 9.25% for SSA (Table 1).

Table 1: Total benefits from natural resources as a % of GDP

regions of the world	**average**	**weighted average**
Africa	12,19	11,30
SSA	9,25	8,39
Central and South America	5,77	3,93
North America	1,69	1,18
eastern Asia	4,71	1,95
Area of the former USSR	7,26	9,91
Europe	0,68	0,37
Oceania	10,03	9,69
Near and Middle East	12,85	9,34

Source: Author, based on World Bank data (2021)

This table highlights the presumed role of natural resource endowments in the growth-income inequality relationship in SSA countries. In other words, it compares the simultaneous evolution of these two variables in resource-rich and resource-poor countries, and distinguishes the particular case of oil-exporting countries from that of countries exporting other minerals.

2. Literature Review

2.1. Growth and income inequality: a review of the theoretical literature

The theoretical literature on the relationship between growth and income inequality shows that there is a positive link and a negative one, which is evidenced through several channels of transmission.

2.1.1. Growth and income inequality: a positive relationship

This positive relationship between growth and income inequality is demonstrated by the inverted U-shaped Kuznets curve and by the channels of savings and investment, incentives and trickle-down theory. Firstly, the relationship between an inequality indicator such as the GINI coefficient and the level of gross domestic product is described by a curve, the inverted-U Kuznets curve. According to Kuznets (1955), inequality increases in the early stages of development, before economic structures are sufficiently solid, and decreases as the economy becomes more developed. Inequality increases until a critical point is reached, where the country experiences a certain level of average income, associated with high income inequality.

Secondly, in a full-employment model, since the richest people have a higher proportion of savings, an increase in inequality and in the richest people's share of national income increases, all other things being equal, savings and consequently investment and growth (Kaldor, 1955). But for this channel to work, (1) the increase in the income of the wealthiest must not be accompanied by an equivalent fall in their savings, (2) the increase in savings must translate into an increase in productive investment, and (3) the increase in investment must translate into an increase in growth (and not just more capital-intensive growth).

And thirdly, inequality can increase growth by providing incentives for effort, innovation and entrepreneurship. Despite the fact that some authors consider Stiglitz's (2012) argument to be “qualified as a moral fable”, for authors such as Ostry et al. (2014), a lower level of income inequality is robustly correlated with faster and sustainable growth for a given level of redistribution.

2.1.2. Growth and income inequality: the hypothesis of a negative relationship

The hypothesis of a negative relationship between the unequal distribution of resources and economic development can be seen through three channels. We will discuss in turn the political economy channel, the social cohesion or political instability channel, and the credit market imperfections channel. For Alesina & Perotti (1996), inequality produces socio-political instability that threatens property rights. Barro (2000) stresses that redistribution reduces crime and anti-social activity.

Another theoretical channel is that of under-investment linked to capital market imperfections. According to Piketty (1997), the initial distribution of wealth affects the equilibrium interest rate in the presence of credit market imperfections. If wealth is very unevenly distributed, demand for capital will be greater than supply, and the interest rate will be higher. From the above, we note that the literature on the growth-income inequality relationship highlights a theoretical controversy.

2.2. Growth and inequality: controversial results in the empirical literature

Since the 2010s, recent studies have once again contradicted this positive relationship. Empirical studies have been the most abundant and the results the most controversial. For example, Marrero & Servén (2022) revealed that the impact of economic growth on inequality can be positive or negative. On the other hand, there is no strong relationship between income inequality and growth (Gao & Fan, 2023). Brueckner & Lederman (2018) concluded that inequality hinders growth in high-income countries. Madsen et al. (2018) found that inequality hinders growth at low levels of financial development. Hailemariam & Dzhumashev (2020) conclude that low levels of inequality can have a positive effect on growth. However, they can be grouped into consensual, alternative and skeptical approaches.

2.2.1. Inequality reduces growth: the consensus approach

Inequality negatively affects growth (Table 2).

Table 2: Inequality negatively affects growth

Authors	Country/Period	Measure of income inequality.	estimation methods used	results
Royuela et al. (2019)	15 OECD countries, 2003-2013	Gini coefficient	Pooled OLS RE IV	-
Cingano (2014)	OECD countries, 1980-2012	Gini coefficient	GMM	-
Lyke & Ho(2017)	Italy, 1967-2012	Gini coefficient	ARDL	-
Braun et al. (2019)	150 countries, 1978-2012	Gini coefficient	- pooled OLS - Dynamic panel	-
Royuela et al. (2019)	15 OECD countries, 2003-2013	Gini coefficient	Pooled OLS RE and IV	-
Breunig & Majeedc(2020)	152 countries, 1956-2011	Gini coefficient	GMM	-
Malinen (2008)	60 countries, 1971–2000	Gini Index	Panel dynamic OLS Panel dynamic SUR	-

Source: author's compilation. Note: - indicates a negative value.

2.2.2. Inequality contributes to higher growth: the alternative thesis

A number of studies have concluded that inequality has a positive impact on growth (Table 3).

Table 3: Inequality has a positive impact on growth

Authors	Country/Period	Measure of income inequality.	estimation methods used	results
Forbes (2000)	45 middle and high-income countries, 1966-1995	Gini coefficient	GMM first difference	+
Rangel et al. (2002)	Brazil, 1991-2000	Gini coefficient	Various estimated regressions	+
Shahbaz (2010)	Pakistan, 1971-2005	Gini coefficient	ARDL	+
Majeed (2016)	Pakistan, 1975-2013	Gini coefficient	ARDL	+
Scholl & Klasen (2019)	122 countries, 1961-2012	Gini coefficient	FE GMM and IV	+

Source: author's compilation. Note: + indicates a negative value.

2.2.3. The skeptical thesis: the growth-inequality relationship is non-existent

Some studies conclude that the relationship between inequality and growth is ambiguous.

Table 4: The non-existence of a stable relationship between inequality and growth

Authors	Country/Period	Measure of income inequality.	estimation methods used	results
Halter et al. (2014)	106 countries, 1965-2005	Gini coefficient	System GMM First-difference GMM	short term + long term -
Ostry et al. (2014)	90 countries, 1960-2010	Gini coefficient	System GMM	Early stage + stage of maturity -

Brueckner & Lederman (2018)	144 countries, 1970-2010	Gini coefficient	2SLS GMM	Middle-income countries + high-income countries -
Niyinbamira (2017)	Mpumalanga (18 municipalities), 1996-2014	Gini coefficient	FE Pooled regression	0
Benos & Laragiannis (2018)	Data at the level of the American states, 1929-2013	Gini coefficient	2SLS GMM	0
Gao & Fan, (2023)	Belt and Road Initiative countries 1999-2018	Gini coefficient	GMM in two steps	0

Source : compilation de l'auteur. Note: - denotes negative; + denotes positive; 0 denotes no relationship.

3. Methodology

We will present a methodology based on two (02) stages: Firstly, we use parametric and semi-parametric models. Before doing so, however, it is important to carry out a critical analysis of income inequality measures in order to select the most appropriate indicators for the context of the study (geographical setting and data constraints).

3.1. Critical analysis and choice of income inequality indicators

A wide variety of measures can be used to account for income distribution.

3.1.1. The inter-decile ratio

This ratio establishes the link between the 9th decile and the first income decile. The first decile defines the 10% of households with the highest incomes, and the 9th the 90% of households with the lowest incomes. This is the ratio of decile limits. This indicator has the merit of clarity, but does not reflect inequality in the income distribution as a whole.

3.1.2. The GINI index

This indicator is designed to summarize the Lorenz curve, which is defined on the x-axis by the percentage of households with the lowest incomes, and on the y-axis by the mass of income shared by these households. The GINI index is equal to 2 times the area bounded by the Lorenz curve and the first bisector. By construction, the GINI index lies between 0 (uniform distribution: all households have the same income) and 1 (distribution where all households except one have zero income). The closer the GINI index is to 1, the greater the inequality measured.

$$\mathbf{G(x)} = \frac{\mathbf{2}}{\bar{\mathbf{x}}}\frac{\mathbf{1}}{\mathbf{n^2}}\sum_{\mathbf{i}}(\bar{\mathbf{x}} - \sum_{\mathbf{i=0}}\bar{\mathbf{x}}_{\mathbf{i}}) \quad (1)$$

A second formulation of the index corresponds to an indicator of satisfaction: here, it is a linear social welfare function U(x) assigning weights (2n-1), (2n-3), ..., 1 to individuals ranked in ascending order of welfare!

$$\mathbf{U(x)} = \frac{\mathbf{1}}{\mathbf{n^2}}(\sum_{\mathbf{i}}(\mathbf{2(n-1)+1})\bar{\mathbf{x}}_{\mathbf{i}}) \quad (2)$$

From which we deduce :

$$\mathbf{G(x)} = \mathbf{1} - \frac{\mathbf{U(x)}}{\mathbf{x}} \quad (3)$$

Either again:

$$\mathbf{U(x)} = \bar{\mathbf{x}}[\mathbf{1} - \mathbf{G(x)}] \quad (4)$$

The social welfare indicator is therefore the average standard of living x corrected by the coefficient 1-G(x), which is between 0 and 1, and decreases when inequality increases.

3.1.3. The THEIL indicator

$$\mathbf{T(x)} = \frac{1}{N}\sum_i \frac{x_i}{\bar{x}} \mathbf{Ln} \frac{x_i}{\bar{x}} \quad (5)$$

Inspired by the measure of entropy, the THEIL index measures the gap between the equal distribution.

3.1.4. The ATKINSON indicator [1]

These indices are defined by the value given to a parameter (e):

$$\mathbf{A_e(x)} = \mathbf{1} - \frac{1}{\bar{x}}\left[\frac{1}{N}\sum (x_i)^{1-e}\right]^{\frac{1}{1-e}} \quad (6)$$

For parameter (e) belonging to $[0,1)\mathrm{U}(1, \rightarrow]$

Et $A_e(x) = 1 - \frac{1}{\bar{x}}[\pi_i \, x_i]^{\frac{1}{\bar{x}}}$ for e = 1. Where x_i is the individual's income i (i =1,2,….N) and $\bar{x}$ is the average income. Each of these indices reflects the population's aversion to inequality: an Atkinson index worth x% means that the population would agree to lose x% of its current income so that the distribution becomes egalitarian. If e =0 then the social utility function is simply the sum of the income.

3.1.5. The variance of logarithms

For income distributions that roughly follow a normal log distribution, this indicator seems to be appropriate. Like the Theil index, it can be broken down and allows for multi-criteria variance and regression analyses.

$$\mathbf{VL(x)} = \frac{1}{n}\sum_i \left(\mathbf{Lnx_i} - \left(\frac{1}{n}\sum_i \mathbf{Lnx_i}\right)\right)^2 \quad (7)$$

3.1.6. The Palma index

The Palma ratio is defined as the share of national income held by the richest 10% divided by the share of the poorest 40%. This ratio is based on research that has shown that middle-class incomes (deciles 5 to 9) almost always represent half of gross national income, while the other half of income is distributed between the richest 10% and the poorest 40%, with the share of these two groups varying considerably from country to country (Palma, 2011).

In this work we will use the Gini coefficient, which is the most popular measure for capturing inequality, to which we compare the results of other indicators in order to enrich the empirical literature on income inequality in SSA.

3.2. Presentation of theoretical models

We will present the non-parametric and semi-parametric models in panel data, the linar polynomial model and finally the variables of the study.

3.2.1. Non-parametric and semi-parametric models in panel data

In this paper, we retain the non-parametric and semi-parametric specification of panel data proposed by Zhou & Li (2011) because it is best suited to the nature of our data (unrolled panel). We place in the general multi-variate case where z designates a vector of dimension 'p'. The formulation for the single-variate case is inferred by assuming "p=1". This more flexible methodological framework allows testing the non-linearity of the relationship

[1] The Atkinson index, named after Anthony ATKINSON, is an income inequality index based on the economic theory of well-being. It can be interpreted as follows: Let Y* be the income which, if all individuals had this amount, would give the same level of social utility as the existing one (ū).

and evaluating the effect of natural resource endowments while benefiting from both the interest of panel data and the advantage of non-parametric and semi-parametric models.

$$\mathbf{y_{it}} = \mathbf{g(z_{it}) + u_i + \varepsilon_{it}} \qquad \mathbf{t = 1, 2, \ldots, m_i}; \quad \mathbf{i = 1, 2, \ldots n}. \qquad (8)$$
$$\mathbf{y_{it}} = \mathbf{g(z_{it}) + x'_{it}\gamma + u_i + \varepsilon_{it}} \qquad \mathbf{t = 1, 2, \ldots, m_i}; \quad \mathbf{i = 1, 2, \ldots n}. \qquad (9)$$

The specifications (8) and (9) represent respectively the non-parametric and semi-parametric models on fixed-effect panel data. We refer to the dependent variable as y and to the vector of explanatory variables as z where the link function g(.) that links the vector z with the variable y is an unspecified function to be estimated defined $\Re^p \Re$.. For the case of semi-parametric model, «q» other control variables «x» are considered of which γ is a dimension vector «p» parameters to be estimated. We consider the case of an unrolled panel where each country «i» has half observations. The individual effects u_i are considered fixed and correlated with z and where the form of this correlation is unspecified. The error terms ε_itare assumed to be i.i.d, averaging zero and of equal variance σ_ε^2 where $E(\varepsilon_{it}/z_{it}) = 0$.. Note that I_k is the matrix of identity dimension k and $e_k$is a unit vector kx1. If $\tilde{\varepsilon_i} = (\widetilde{\varepsilon_{i2}}, \ldots, \widetilde{\varepsilon_{im_i}})$' where $\widetilde{\varepsilon_{it}} = \varepsilon_{it} - \varepsilon_{i1}$, the covariance matrix of $\tilde{\varepsilon_i}$ « $\sum_i$ » and its inverse « $\sum_i^{-1}$ » can be expressed σ_ε^2 as follows:

$$\mathbf{\textstyle\sum_i = \sigma_\varepsilon^2(I_{mi-1} + e_{mi-1}e'_{mi-1})}$$
$$\mathbf{\textstyle\sum_i^{-1} = \sigma_\varepsilon^2(I_{mi-1} - e_{mi-1}e'_{mi-1}/m_i)} \qquad (10)$$

If we note$g_{it} = g(z_{it})$, The model (1) becomes $y_{it} = g_{it} + u_i + \varepsilon_{it}$. In the event that « t=1 » we have $y_{i1} = g_{i1} + u_i + \varepsilon_{i1}$. If more is noted $\tilde{y_i} = (\widetilde{y_{i2}}, \ldots, \widetilde{y_{im_i}})'$ and $g_i = (g_{i2}, \ldots, g_{imi})'$ where $\widetilde{y_{it}} = y_{it} - y_{i1}$, can be expressed $\tilde{\varepsilon_i}$ depending on $\tilde{y_i}$, g_i and g_{i1} as follows :

$$\mathbf{y_{it} = g(z_{it}) + u_i + \varepsilon_{it} = g_{it} + u_i + \varepsilon_{it}}$$
$$\mathbf{\widetilde{y_{it}} + y_{it} = g_{it} + u_i + \widetilde{\varepsilon_{it}} + \varepsilon_{it}}$$
$$\mathbf{\widetilde{y_{it}} = g_{it} - u_i + \widetilde{\varepsilon_{it}} + \varepsilon_{it}}$$
$$\mathbf{\widetilde{y_{it}} = g_{it} - g_{il} + \widetilde{\varepsilon_{it}}}$$
$$\mathbf{\tilde{y_i} = g_i - g_{i1} + e_{mi-1} + \tilde{\varepsilon_i}}$$

from where $\mathbf{\tilde{\varepsilon_i} = \tilde{y_i} - g_i + g_{i1}e_{mi-1}}$ (11)

Thus, individual likelihood can be developed from the formulation of $(\tilde{\varepsilon_i})$ as follows:

$L_i(.) = -\frac{1}{2}\widetilde{\varepsilon_i}' \sum_i^{-1} \tilde{\varepsilon_i}$, i = 1, 2…n.

$\mathbf{L_i(.) = -\frac{1}{2}(\tilde{y_i} - g_i + g_{it}e_{mi-1})' \textstyle\sum_i^{-1} \tilde{y_i} - g_i + g_{it}e_{mi-1}(\tilde{y_i} - g_i + g_{it}e_{mi-1})}$, i = 1, 2… n.

$$\mathbf{L_{it}^g = \frac{\partial L_i(.)}{\partial g_{it}} = \begin{cases} -e'_{mi-1} \sum_i^{-1}(\tilde{y_i} - g_i + g_{it}e_{mi-1}), t = 1 \\ c'_{i,t-1} \sum_i^{-1}(\tilde{y_i} - g_i + g_{it}e_{mi-1}), t \geq 2 \end{cases}} \qquad (12)$$

Where $c'_{i,t-1}$ is a dimension vector $(m_i - 1)$x1 whose all elements are null except the $(t - 1^{ème})$ element which is equal to 1. If one defines $\binom{\alpha_0}{\alpha_1} = \binom{g(z)}{\partial g(z/\partial z)} = \binom{g(z)}{g^1(z)}$ and $G_{it} = \binom{1}{(z_{it} - z)/h}$.. The estimation of $\binom{\alpha_0}{\alpha_1}$ is done by solving the first order condition of the profiled likelihood in an iterative way as follows:

$$\mathbf{\textstyle\sum_{i=1}^n \frac{1}{m_i} \sum_{t=1}^{m_i} K_h(z_{it} - z) G_{it} L_{it}^g\left(\hat{g}_{[l-1]}(z_{i1}), \ldots, G_{it}(\alpha_0, \alpha_1)', \ldots, \hat{g}_{[l-1]}(z_{imi})\right) = 0} \qquad \textbf{(13)}$$

Where $\hat{g}_{[l-1]}(z_{is})$ is the estimate of $g(z_{is})$ for $(l-1)^{ème}$ iteration and $k_h(v) = h^{-1}k(v/h)$ and $k(.)$ is the kernel function. We can then define the estimate for the l'st iteration according to the $(l-1)^{ème}$ iteration:

$\binom{\alpha_0}{\alpha_1} = \binom{\hat{g}_{[l]}(z)}{\hat{g}_l^1(z)} = \frac{(A_1 + A_2)}{A_3}$ such as:

$$\begin{cases} \mathbf{A_1} = \sum_{i=1}^{n} \frac{1}{m_1}\left(e'_{mi-1}\sum_i^{-1} e_{mi-1}K_h(z_{i1}-z)G_{i1}\hat{g}_{[l-1]}(z_{i1}) + \sum_{t=2}^{m_i} c'_{i,t-1}K_h(z_{i1}-z)G_{i1}\hat{g}_{[l-1]}(z_{i1})\right) \\ \mathbf{A_2} = \sum_{i=1}^{n} \frac{1}{m_1}\left(K_h(z_{i1}-z)G_{i1}e'_{mi-1}\sum_i^{-1} H_{i,[l-1]} + \sum_{t=2}^{m_i} K_h(z_{il}-z)G_{it}c'_{i,t-1}\sum_i^{-1} H_{i,[l-1]}\right) \\ \mathbf{A_1} = \sum_{i=1}^{n} \frac{1}{m_1}\left(e'_{mi-1}\sum_i^{-1} e_{mi-1}K_h(z_{i1}-z)G_{i1}G'_{i1} + \sum_{t=2}^{m_i} c'_{i,t-1}\sum_i^{-1} c_{i,t-1}K_h(z_{i1}-z)G_{i1}G'_{it}\right) \end{cases}$$

Where $H_{i,[l-1]}$ is a dimension vector $(m_1-1)x\ 1$ of which the elements noted « $h_{i,[l-1]}$ » are as $h_{i,[l-1]} = \left(\widetilde{y_{it}} - \left(\hat{g}_{[l-1]}(z_{it}) - \hat{g}_{[l-1]}(z_{it})\right)\right), t = 1,2,\ldots, m_i$.. The initial estimator of g(.) is obtained based on the time series while the last iteration is selected when the convergence criterion is checked:

$$\sum_{i=1}^{n}\frac{1}{m_i}\sum_{t=2}^{m_i}\left(\hat{g}_{[1]}(z_{it}) - \hat{g}_{[1]}(z_{it})\right)^2 / \sum_{i=1}^{n}\frac{1}{m_i}\sum_{t=2}^{m_i}\hat{g}^2{}_{[l-1]}(z_{it}) \le 0.01 \qquad \textbf{(14)}$$

In addition, the variance σ_ε^2 is estimated by:

$$\sigma_\varepsilon^2 = \frac{1}{2n}\sum_{i=1}^{n}\frac{1}{m_i-1}\sum_{t=2}^{m_i}\left(y_{it} - y_{i1} - \left(\hat{g}_{[1]}(z_{it}) - \hat{g}_{[l-1]}(z_{it})\right)\right)^2 \qquad \textbf{(15)}$$

The variance of the estimator $\hat{g}(z)$ is calculated by: $k\left(nh\widehat{\Omega}(z)\right)^{-1}$

where $k = \int k^2(v)dv$ n and $\widehat{\Omega}(z) = \sum_{i=1}^{n}\frac{m_i-1}{m_i}\sum_{t=2}^{m_i}K_h(z_{i1}-z)/\widehat{\sigma_\varepsilon^2}$

For the estimation of the semi-parametric model, the nonparametric estimator of the non-parametric estimator of the 'q' control variables $\hat{g}_x(.) = (\hat{g}_{x,1}(.),\ldots,\hat{g}_{x,q}(.))'$ and the dependent variable $\hat{g}_y(.)$ defines the estimator is defined. Thus the estimate of γ which is of dimension qx1 is:

$$\hat{\boldsymbol{\gamma}} = \left(\sum_{i=1}^{n}\frac{\widetilde{\widetilde{x_{i\cdot}}}\Sigma_i^{-1}\widetilde{x_{i\cdot}}}{m_i}\right)^{-1}\left(\left(\sum_{i=1}^{n}\frac{\widetilde{\widetilde{x_{i\cdot}}}\Sigma_i^{-1}\widetilde{y_{i\cdot}}}{m_i}\right)\right) \qquad \textbf{(16)}$$

Where $\widetilde{x_{i\cdot}}$ and $\widetilde{y_{i\cdot}}$ are respectively dimension matrices (m_i-1) x q and (m_i-1) x 1 such that the second line is defined by: $\widetilde{\widetilde{x_{it\cdot}}} = \widetilde{x_{it}} - \left(\hat{g}_x(z_{it}) - \hat{g}_x(z_{i1})\right)$ et $\widetilde{\widetilde{y_{it\cdot}}} = \widetilde{y_{it}} - \left(\hat{g}_y(z_{is}) - \hat{g}_y(z_{i1})\right)$. The non-parametric component of the semi-parametric model is deduced by replacing $\widetilde{y_{it}}$ by $\widetilde{y_{it}} - x'_{it}\widehat{\widehat{\gamma}}$.

3.3.2. Polynomial nonlinear model

In order to empirically verify the existence of a non-linear relationship between income inequality and economic growth, we first test a parametric model integrating powers of higher order than the base model {model (M1)}. This is equivalent to introducing a quadratic or cubic polynomial function of gross domestic product (GDP) which provides comprehensive information on the behaviour to be observed in relation to different levels of per capita GDP. We first propose to test a more complex nonlinear behavior that lends itself to an unambiguous interpretation of the form of the relation. This approach allows to capture the proper relation on a wide range of commonly recognized forms (U curve, inverted U curve, inverted N curve...).

The polynomial model of degree k as follows:

$$\begin{cases} \boldsymbol{IncomeIneqv_{it}} = \sum_{k=0}^{k+1}\boldsymbol{\beta_k(GPD_{it})^k + \lambda X_{it} + \mu_i + \varepsilon_{it}} \\ \boldsymbol{where\ t = 2000, 2001, 2002, \ldots 2020,\ \ i = 1, 2, \ldots 43} \end{cases} \qquad (M_1)$$

We consider below three (03) parametric models derived from the polynomial model (M1) that we note models (1), (2) and (3). These models concern respectively the linear model taken as benchmark and the quadratic and cubic polynomial models.

$$\boldsymbol{IncomeIneqv_{it}} = \boldsymbol{\beta_0 + \beta_1 GPD + \lambda X_{it} + \mu_i + \varepsilon_{it}} \qquad \textbf{\textit{(1)}}$$

$$IncomeIneqv_{it} = \beta_0 + \beta_1 GPD + \beta_2 GPD^2 + \lambda X_{it} + \mu_i + \varepsilon_{it} \quad (2)$$
$$IncomeIneqv_{it} = \beta_0 + \beta_1 GPD + \beta_2 GPD^2 + \beta_3 GPD^3 + \lambda X_{it} + \mu_i + \varepsilon_{it} \quad (3)$$
where $X_{it} = (Ts/Sup_{it}, Ts/Sec_{it}, FiDev_{it}, TradeOp_{it}, FDI_{it})$ *and t = 2000, 2001, …, 2020 ; i = 1, 2,3,… 43*

Where i represents a country and t indicates time; IncomeIneq represents the income inequality captured by the Gini index, the Theil index, the Atkinson index or the Palma index; GPD is the gross domestic product per capita at the beginning of the reference period; Ts/sup, Higher education enrolment rate; Ts/sec, Secondary education enrolment rate; FiDev, financial development; TradeOp, commercial openness and FDI, foreign direct investment. The coefficients β_k are parameters to be estimated; μ_i are individual characteristics and ε_{it} stochastic errors.

3.2.3. Definition of study variables

This section presents the dependent variable and the explanatory variables used in this study.

Income inequality: To measure income inequality, we used mainly the GINI coefficient, as is the case for many authors (Hafezali et al. 2023; Menyelim et al. 2021), because it is a relative measure recommended by the European Union and Eurostat (Langel, 2012) and easy to interpret. This index varies between 0 and 1, i.e., the further it is from zero, the greater the inequality. This variable is obtained from the University of Texas Inequality Project.

There are two variables of interest: GPD/cap and natural resource endowments. The impact of natural resource endowments on the growth-income inequality relationship is measured by the interaction variable between growth and natural resource rent (GDP/cap*Natural Resource Rent). GDP/cap is the logarithm of GDP per capita in constant 2005 PPP $ taken from WDI (2021). In line with recent work by Mignamissi & Kuete (2021), we use total resource rent as a percentage of GPD as a measure of natural resource endowments (Rents). This variable is obtained from the WDI (2021) database.

Trade openness: Does trade contribute to improving national well-being? Classical and neoclassical theory answers this question in the affirmative, but some authors, like Bhagwati (1958), speak of "impoverishing growth". When a country opens up to the outside world, this tends to improve the nation's well-being, but the terms of trade may deteriorate to such an extent that they lead to a net decline in well-being. This variable is obtained from the WDI database (2021).

Financial development: The literature explains the effects of financial development on income inequality from models using educational investment and physical capital investment respectively. We follow Zakari &Tawiah (2019), Haseeb et al. (2018), Ali et al. (2019) in the use of domestic credit to the private sector in % of GDP as a proxy for financial development. This variable is obtained from the WDI (2021) database.

School enrolment (secondary and tertiary): Some authors express this in terms of years of schooling (Barro & Lee, 1996). Economic theory had long held that human capital positively affected growth, but other authors challenged this hypothesis in the 1990s (Pritchet, 2001). As in the case of certain authors such as Joseph & Woulkam (2018), we use the number of people enrolled in secondary and tertiary education as a percentage of the total number of people enrolled in school. This variable is obtained from the WDI (2021) database.

Foreign Direct Investment: The relationship between FDI and income inequality is often explained by neoclassical and dependency theories. FDI represents inward foreign direct investment as a percentage of GDP, as in Khan & Ozturk (2020). This variable is obtained from the WDI database (2021).

4. Results and Interpretations

Table 5 below presents the results of three parametric specifications applied to a panel of 43 SSA countries between 2000 and 2020. Columns (1, 4, 7 and 10) of Table 5 show the results of the reference linear model. The parameter β_1 is positive and significant for all four income inequality indices. This shows that economic growth is not distributive, or conversely, income redistribution does not facilitate economic growth.

The parameters λ_1, λ_2, λ_3, λ_4 and λ_5 corresponding respectively to the five control variables (Higher education enrolment ratio, secondary education enrolment ratio, financial development, trade openness and foreign direct investment) are all statistically significant for at least one income inequality index. These results are in line with those obtained by Lemieux (2006) on the link between rising wage inequality and the profitability of higher education.

The positive and significant coefficient on financial development shows that in most SSA countries, the low level of financial inclusion and the limited diversity of financial institutions keep SMEs and small individual entrepreneurs unable to access the financing they need to develop their activities. Only large companies with collateral can access financing (Bassirou & Ramde, 2019). This may explain the rise in inequality. This result is similar to those obtained by Mansour & Wendel (2015). This result invalidates the hypothesis of Greenwood and Jovanovic (1990) and contrasts with those obtained by Jauch & Watzka (2015). The degree of openness of the economy has no effect on income inequality, as its coefficient appears insignificant for all four (04) income inequality indices. This result contradicts theory. These effects could lead to an increase in per capita income. This result contrasts with that obtained by El Ghak & Zarrouk (2010) and Boukhatem & Mokrani (2012).

The FDI result corroborates the neoclassical theory that FDI promotes economic growth and reduces inequality in recipient countries (Mundell, 1957). The latter assert that, as well as filling resource gaps, FDI promotes greater economic growth and development through technology diffusion, the development of human capital and management skills, and access to export markets (Li & Liu, 2004).

Columns (2, 5, 8 and 11) of Table 5 present the results of the quadratic polynomial model (Model 2) of the four (04) income inequality indices. The positive and significant coefficients of three indices highlight the existence of a "U"-shaped curve. Columns (3, 6, 9 and 12) of Table 5 present the results of the cubic polynomial models (model 3). Estimates of these models using the Gini index, the Theil index or the Palma index as measures of income inequality are still significant for the cubic specification, which implies that, for these three indices, the relationship is likely to withstand further non-linear adjustment. We also note that for all four inequality indices, the explanatory power is greater when the polynomial model is of higher degree. Thus, the "R² Within" of the quadratic model is higher than that of the linear model, and the "R² Within" of the cubic model is higher than that of the quadratic model.

Table 5: Fixed-effects parametric estimation of the linear, quadratic and cubic panel model for SSA countries

Dependent variables : Income inequality indices (Gini, Theil, Atkinson and Palma)												
explanatory	linear	quadratic	cubic	linear	Quadratic	Cubic	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic
variables	(1) a	(2) a	(3) a	(4) b	(5) b	(6) b	(7) c	(8) c	(9) c	(10) d	(11) d	(12) d
constant	44,33	39,04	39,16	42,76	45,02	44,97	45,03	99,59	39,99	0,99	69,57	69,73
	(129,89)***	(70,87)***	(70,83)***	(36,74)***	(122,02)***	(121,9)***	(291,4)***	(0,000019)***	(0,00001)***	(0,004)***	(139,8)***	(139,5)***
GPD/cap	0,015	-	-	0,188	-	-	0,0011	-	-	0,005	-	-
	(1,64)**			(5,74)***			(3,99)**			(2,5)*		
(GDP /cap) ^{2}	0,005	0,045	-	0,26	0,026	-	0,00012	0,009	-	0,059	0,005	-
	(2,49)**	(2,48)**		(1,54)*	(5,83)**		(0,81)	(8,53)*		(2,35)**	(3,27)***	
(GDP /cap) ^{3}	-0,0056	0,0066	-0,0058	0,26	0,0026	-0,0018	-0,00012	-0,00002	-0,0037	-0,057	0,0056	-0,0069
	(0,1)	(2,49)**	(1,1)*	(7,7)***	(1,54)	(1,48)***	(2,49)**	(1,81)	(7,7)	(1,22)**	(2,35)**	(2,49)**
Enrolment/ higher rate	0,035	0,038	0,042	0,211	0,12	0,13	0,0014	0,0016	0,0015	0,014	0,144	0,146
	(2,43)**	(1,00)	(1,10)	(4,21)***	(4,91)***	(5,00)***	(3,87)***	(4,39)***	(4,29)***	(1,26)*	(4,12)***	(4,14)***
Enrolment/sec ondary rate	-0,0042	-0,098	-0,096	-0,0046	-0,015	-0 ,015	-0,0084	-0,0088	-0,0083	-0,0059	-0,118	-0,116
	(0,74)	(6,55)***	(6,4)***	(0,24)	(1,52)	(1,53)	(5,95)***	(6,2)***	(6,15)***	(1,38)	(8,71)***	(8,54)***
Financial Development	0,062	0,017	0,017	0,081	0,022	0,023	0,0066	0,064	0,0065	0,0041	0,023	0,022
	(0,67)**	(0,87)*	(0,89)	(0,26)*	(1,72)	(1,78)*	(3,53)***	(3,43)***	(3,45)***	(0,06)	(1 ,28)	(1,22)
Trade	0,0021	0,0011	0,0011	0,0043	0,0015	0,0015	0,0025	0,0018	0,0017	0,0048	0,0075	0,0077
openness	(0,15)	(1,61)	(1,64)	(0,92)	(0,34)	(0,33)	(0,4)	(0,28)	(0,27)	(4,66)	(1,22)	(1,26)
FDI	-0,01	-0,031	-0,015	-0,014	-0,059	-0,057	-0,0081	-0,0055	-0,0066	-0,0027	-0,053	-0,042
	(1,21)*	(0,81)**	(0,38)	(0,48)**	(1,97)*	(2,19)**	(2,28)**	(1,51)	(1,79)*	(0,41)	(1,5)*	(1,19)
Observations	903	903	903	903	903	903	903	903	903	903	903	903
Number of countries	43	43	43	43	43	43	43	43	43	43	43	43
R^2 Within	0,30	0,31	0,33	0,51	0,55	0,57	0,13	0,12	0,18	0,47	0,39	0,49

*Source: Author. Numbers in parentheses correspond to Student statistics ***, ** and * indicate that the variables are significant at 1%, 5% and 10% respectively. a Income Ineq corresponds to the Gini index of income, b Income Ineq corresponds to the Theil index of income, d*

Income Ineq corresponds to the Atkinson index of order 1: A(1) of income, c Income Ineq corresponds to the Palma index of income..

4.1. Modèles non-paramétrique et semi-paramétrique

The use of non-parametric or semi-parametric modeling is less restrictive, as it does not require a predetermined functional form. This approach makes it possible to fine-tune the relationship's point cloud while benefiting from smooth, flexible non-parametric functions instead of predefined polynomial functions.

We propose to study the relationship using non-parametric and semi-parametric models for panel data. Thus, if we replace the polynomial function $\sum_{k=0}^{k+1} \beta_k (GDP_{it})^k$ in the polynomial model (M1) by the function $g(GPD_{it})$ to be estimated, our model to be estimated becomes a semi-parametric model. Furthermore, when we eliminate the parametric part λX_it containing the other control variables, the model then becomes a non-parametric model. We thus note the following non-parametric (M2) and semi-parametric (M3) models:

$$\begin{cases} IncomeIneqit = g(GDP_{it}) + \mu_i + \varepsilon_{it} \\ where\ t = 2000, 2001, 2002, \ldots 2020, \quad i = 1,2, \ldots 43 \end{cases} \quad (M_2)$$

$$\begin{cases} IncomeIneqit = g(GDP_{it}) + \lambda X_{it} + \mu_i + \varepsilon_{it} \\ where\ t = 2000, 2001, 2002, \ldots 2020, \quad i = 1,2, \ldots 43 \end{cases} \quad (M_3)$$

Table 6 below shows the parameters of the control variables derived from the semi-parametric estimation {model (M3)}. The coefficients of these variables have the same signs as those obtained in the estimation of the linear parametric model. However, the coefficient of trade openness in this semi-parametric estimation is significant for the Gini index, and that of the tertiary enrolment ratio is not significant for this Gini index either. These results are in line with those found in the polynomial model.

Table 6: Results of the semi-parametric estimation of control variables (Model M 3)

explanatory variables	Dependent variables: Indices of income inequality (1) [a]	(2) [b]	(3) [c]	(4) [d]
Higher education enrolment rate	0,041 (1,05)	0,11 (4,33)***	0,016 (4,55)***	0,13 (3,87)***
Secondary school enrolment rate	-0,09 (6,42)***	-0,001 (1,09)	-0,009 (6,32)***	-0,12 (8,77)***
Financial Development	0,019 (0,98)*	0,016 (1,22)	0,0059 (3,14)***	0,015 (0,82)
Trade openness	0,0011 (1,65)*	0,0016 (0,37)	0,0016 (0,25)	0,008 (1,31)
FDI	-0,007 (0,21)*	-0,031 (1,26)**	-0,0051 (1,45)	-0,035 (1,04)
Observations	903	903	903	903
number of countries	43	43	43	43
R^2 Within	0,31	0,38	0,60	0,52

*Source: Author. Notes: The numbers in brackets are for Student ***, ** and * statistics, indicating that the variables are significant at 1%, 5% and 10% respectively. a Income_Ineq corresponds to the Gini index of income, b Income_Ineq corresponds to the Theil index of income, d Income_Ineq corresponds to the Atkinson index of order 1: A (1) of income, c Income_Ineq corresponds to the Palma index*

4.2. Empirical evaluation of the effects of natural resource endowments on the relationship between growth and income inequality in SSA countries.

By introducing the interaction variable (GPD/cap*Rents from natural resources) into the semi-parametric model (M3) above, we highlight the effects of endowments in natural resources on the growth-income inequality relationship in SSA countries. Thus, the model (M3) becomes:

$$\begin{cases} \text{IncomeIneqit} = g(GDP_{it}) * Rentes_{it} + \mu_i + \varepsilon_{it} \\ where\ t = 2000, 2001, 2002, \ldots 2020, \quad i = 1,2, \ldots 43 \end{cases} \text{(M}_4$$

Table 7 below presents the results of the semi-parametric model (M4) estimation. Like the coefficient of the growth rate of GDP per capita in the previous models, the coefficient of the interaction variable (GPD*RENTS of the NRs) is positive and significant but a value lower than that obtained from the estimation of the linear model; This is evidence that rents from natural resources overall have a moderating effect on income inequality because the results of the previous linear model estimate show that an increase of 10 percentage points in per capita GDP is associated with an increase of 0,15 percentage points of the Gini index, 1.88 percentage points of the Theil index, 0.011 of the Atkinson index and 0.05 of the Palma index whereas this increase is only respectively (0.017), (0.24), (0.0011) and (0.007) for an increase of 10 percentage points in this same interaction variable (GDP/head*Natural resources rent). This suggests that total rents from renewable and non-renewable natural resources mitigate the negative impact of growth on income inequality. The results (table 7) highlight the effects of different types of natural resources. Higher education, financial development and trade opening increase income inequality while secondary school enrolment and FDI reduce income inequality.

Table 7: Results of the semi-parametric model estimation (M4) highlighting the effect of the importance or volume of natural resources

explanatory variables	Dependent variables: Indices of income inequality			
	Gini	Theil	Atkinson	Palma
Constante	44,37 (130,15)***	43,22 (36,6)***	0,99 (0,19)***	75,04 (292,16)
GPD/cap	0,015 (1,64)**	0,188 (5,74)***	0,0011 (3,99)**	0,005 (2,5)*
GPD / cap * Rents from RN	0,0017 (0,51)*	0,024 (1,96)***	0,00011 (0,7)	0,0007 (0,27)**
Higher education enrolment rate	0,034 (2,36)**	0,22 (4,31)***	0,015 (4,16)***	0,14 (1,34)
Secondary school enrolment rate	-0,0042 (0,75)*	-0,004 (0,22)	-0,0086 (6,06)***	-0,0058 (1,36)
Financial Development	0,0045 (0,49)*	0,012 (0,38)	0,0065 (3,47)***	0,0011 (0,17)
Trade openness	0,0033 (0,24)	0,0028 (0,61)*	0,0017 (0,27)	0,0048 (4,7)***
FDI	-0,0083 (0,94)*	-0,039 (1,29)**	-0,0068 (1,88)	-0,0014 (0,21)
Observations	903	903	903	903
Number of countries	43	43	43	43
R^2 Within	0,78	0,48	0,52	0,29

*Source : Author, Figures in brackets correspond to the statistics of Student ***, ** and * indicate that variables are significant at 1%, 5% and 10% respectively*

Table 8 below presents the results of the breakdown of the natural resource endowment effect to highlight the impact of different types of natural resources. This suggests that the benefits from oil, gas and other minerals are accentuating the negative impact of growth on income inequality, confirming our first hypothesis.

Table 8: Highlighting the effects of different types of natural resources in the growth-income inequality relationship

explanatory variables	Dependent variables: Indices of income inequality			
	Gini	Theil	Atkinson	Palma
Constant	46,6 (5,11)***	44,4 (17,56)***	0,99 (0,27)***	78,03 (22,8)***
GPD/cap	0,072	0,11	0,0014	0,061

	(1,55)	$(3,48)^{***}$	$(3,11)^{***}$	(1,44)
GDP*Minerals	0,43 $(9,83)^{***}$	0,058 $(1,97)^{**}$	0,0017 $(4,12)^{***}$	0,46 $(11,68)^{***}$
GDP*Gas	0,33 $(3,68)^{***}$	0,32 $(1,33)^{*}$	0,037 (0,11)	0,18 $(3,61)^{***}$
GDP*Oil	0,034 $(1,49)^{*}$	0,042 $(2,76)^{***}$	0,037 $(1,68)^{*}$	0,002 (0,14)
GDP*Fresh water	-0,022 $(5,11)^{***}$	-0,096 $(0,32)^{***}$	-0,007 $(1,77)^{***}$	-0,013 $(3,47)^{***}$
GDP*Forest	-1,33 $(5,6)^{***}$	-0,58 $(2,97)^{**}$	-0,45 (5,21)*	-1,18 $(4,78)^{***}$
Financial Development	0,0048 $(0,41)^{*}$	0,015 (0,48)	0,0069 $(4,47)^{***}$	0,0017 (0,27)
Trade openness	0,0039 (0,24)*	0,0018 (0,65)	0,0037 (0,29)	0,0043 $(5,7)^{***}$
FDI	-0,0087 $(0,94)^{*}$	-0,031 $(1,59)^{**}$	-0,0068 (2,88)	-0,0017 (0,22)
Observation	840	840	840	840
Number of countries	40	40	40	40
R^2 Within	0,38	0,22	0,40	0,27

*Source : Author, Figures in brackets correspond to the statistics of Student ***, ** and * indicate that variables are significant at 1%, 5% and 10% respectively*

However, the coefficients associated with the interaction variables (GDP*Freshwater) and (GDP*Forest) show negative and highly significant signs for all four income inequality indices; This suggests that the benefits of freshwater and forest are reducing the negative effects of growth on income inequality. This result justifies the first showing that rents moderate the negative effect of growth on income inequality because the second effect has outweighed the first, that is to say, the dominant positive effect of renewable resources (fresh water and forests) dissimilated the negative effect of non-renewable resources (minerals, gas and oil) hence the result of the estimation of our first interaction variable (GDP* Total Natural Resource Rents).

Table 9 below presents the results of highlighting the diversity effect of natural resources. We divided our sample into two (02) groups of countries according to the composition of their exports. On the one hand, we have countries for which exports consist of 75% of a single product (from a natural resource) and countries whose exports are composed of at least two (02) natural products or resources. According to the Statistics Division of the African Development Bank, our sample includes thirteen (13) SSA countries in the first category and thirty (30) countries in the second category. Thus, a country is considered as an exporter of a single product when the latter accounts for more than 75% of its exports and products are taken into account if they account for more than 4% of the total exports of the country. The coefficient associated with the interaction variable (GDP*Rent) of countries exporting a single product is not significant for the 04 indices of income inequality. This suggests that rents from a single natural resource do not have an impact on income inequality in SSA countries. On the other hand, the coefficient associated with the interaction variable (GDP*Rent) of countries exporting several products (from two) is positive and statistically significant for the three (03) indices of income inequality out of four (04) ; this shows that for countries exporting several natural resources, the resulting rents increase income inequality. It is also interesting to note that the coefficients associated with our control variables retain the expected signs.

Table 9: Highlighting the diversity effect of natural resources in the growth-income inequality relationship

explanatory variables	Dependent variables: Indices of income inequality			
	Gini	Theil	Atkinson	Palma
constant	43,13 (74,55)***	38,35 (21,02)***	0,99 (0,11)***	75,92 (71,54)***
GDP*Rents (Single product exporting countries)	0,011 (0,69)	0,079 (1,57)	0,013 (0,02)	0,009 (0,77)
GDP*Rents (Countries exporting more than one product)	0,02 (1,66)*	0,24 (5,82)***	0,016 (2,87)***	0,007 (0,76)
Higher education enrolment rate	0,025 (1,53)	0,065 (1,15)	0,004 (0,91)	0,007 (0,58)
Secondary school enrolment rate	-0,003 (0,59)	-0,11 (5,13)***	-0,001 (5,9)***	-0,01 (2,17)**
Financial Development	0,01 (1,1)	0,08 (2,41)**	0,001 (4,69)***	0,013 (1,76)*
Trade openness	0,002 (0,53)	0,047 (3,04)***	0,002 (2,77)***	0,002 (0,69)
FDI	-0,001 (0,88)	-0,085 (1,89)*	-0,001 (2,11)**	-0,004 (0,43)
observations	903	903	903	903
Number of countries	43	43	43	43
R^2 Within	0,45	0,59	0,21	0,32

*Source: Author. Figures in brackets correspond to the statistics of Student ***, ** and * indicate that variables are significant at 1%, 5% and 10% respectively*

5. Conclusions and Economic policy recommendations

Ultimately, this paper examined the effect of natural resource endowments on the relationship between growth and income inequality. The SSA countries provided the framework for analysis. First, it was examined whether there is a non-linear relationship between growth and income inequality from a wide panel of SSA countries between 2000 and 2020. For this, we used non-parametric and semi-parametric models in panel data.

In a second step, to estimate the effects of natural resources on growth-income inequality. To this end, it focused on the methodological framework which is mainly based on econometric analyses relating to the panel data method. After the econometric tests, the results of the regression confirmed that the relationship is non-linear with a positive trend between growth and income inequality, changing convexity according to the level of growth and that the rents from non-renewable resources (oil, gas and other minerals) accentuate the negative effect of growth on income inequality while revenues from renewable resources (water and forests) have the effect of reducing inequalities.

Therefore, given the abundance of renewable and non-renewable natural resources in SSA, it is essential that governments encourage and support the exploitation and development of these sectors. This can be achieved through structural transformation of SSA economies and development of global value chains.

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