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# Economic Growth and Income Inequality in Sub-Saharan Africa: Does Environmental Policy Matter?

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

The counter-intuitive correlation between economic growth and income inequality in sub-Saharan Africa in recent years and the lack of consensus in the literature on this relationship call for its re-examination, particularly in the context of sustainable development. This article analyses the effect of environmental policies on the relationship between economic growth and income inequality in sub-Saharan Africa. With its suitability for analyzing non-linear relationships, the panel smooth transition regression model (PSTR) of Gonzalès (2005) was applied to data covering the period 1999 to 2021 from the World Bank, the Yale Center for Environmental Law and Policy (YCELP), the World Governance Indicator (WGI) and the World Income Inequality Database (WIID). In the presence of a strict application of environmental policies, the results show a U-inverted relationship

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between economic growth and income inequality in sub-Saharan Africa. The more a relatively wealthy country adopts a rigorous environmental policy, the more economic growth contributes to reduce income inequalities. Thus, the socially virtuous effect of a rigorous environmental policy only occurs in economically dynamic countries. In other words, environmental policies in sub-Saharan African countries can only be promoted in relation to their economic performance. Any standardisation of environmental policies on a continental or sub-regional scale for economically different countries should be reconsidered.

*Keywords: Environmental policy; economic growth; income inequality; sub-Saharan Africa; PSTR.*

JEL Code: *N34, Q51, B22*

## 1. INTRODUCTION

Economic growth and income inequality are concerns for decision-makers in both developed and developing countries. Despite strong economic growth in sub-Saharan Africa in recent years, income inequalities have remained stable in some countries and increased in others. Indeed, despite an economic growth of about 3 percentage points (1.3% to 4%) between 2016 and 2021 (World Bank, 2022), sub-Saharan Africa remains one of the regions most affected by income inequality, with a Gini index of 0.46 compared to 0.48 at the global level (World Bank, 2022; Moers, 2015; OXFAM, 2019). Once again, this raises the question of the relationship between economic growth and income inequality. Unlike Kuznets (1955), who established an inverted U-shaped relationship between economic growth and income inequality, some authors find a linear, positive or negative relationship between the two variables. This lack of consensus makes it worthwhile to look for mechanisms that could provide a clear explanation. Among these potential factors, the environmental protection policy in a context of sustainable development deserves particular attention. Indeed, the environmental resources on which depend most of poor people in developing countries are increasingly subject to access restrictions, notably through the regulation of forest areas, fishing zones, etc. (Doumbe-Billé, 2004).

Such arrangements can exacerbate inequalities, at least in the short term, which in turn affect the quality of the environment (Boyce, 1994; Coondoo and Dinda, 2008; Dinda and Coondoo, 2006; Golley and Meng, 2012; Grunewald et al., 2011; Torras and Boyce, 1998; Wolde-Rufael and Idowu, 2017). The resulting environmental degradation has a negative impact on economic growth as showed by several authors (Azam, 2016; Chatterjee, 2009; Etchie et al., 2017; Gallagher, 2005; Lima et al., 2015; Loizeau et al., 2018; Pao and Tsai, 2010; Reddy and Behera, 2006; Usman et al., 2019). Although an abundant literature exist on these two-way relationships, particularly between economic growth and the environment (Kozluk, T., & Zipperer, V., 2015) on the one hand, and between environmental quality and inequality (Jha et al., 2019; Boyce, 1994; Torras and Boyce, 1998; and Magnani, 2000) on the other, few authors have focused on the relationship between economic growth, income inequality and environmental quality. Those who have done so have favoured the human capital channel (Aloi and Tournemaine, 2013; Constant, 2019).

Unlike the latter, this paper identifies the role of environmental quality in the relationship between economic growth and income inequality. In particular, it analyses the effect of environmental policy on the relationship between economic growth and income inequality in sub-Saharan Africa.

The contribution of this paper is threefold. Firstly, this research makes an empirical contribution insofar as most have adopted a theoretical approach. Then, the paper focuses on the impact of environmental policy on the link between economic growth and income inequality. Finally, the paper focuses on sub-Saharan African countries characterised by weak environmental policies and high level of poverty.

The rest of the paper is structured as follows. The second section specifies the model and deal with the data. The third section presents and discusses the main results of the study. The final section draws out the policy implications and concludes the paper.

## 2. METHODOLOGY

### 2.1 Model Specification

To analyse the effect of environmental policy on the relationship between economic growth and income inequality, we use a panel threshold effect model. As a tool adapted to the analysis of non-linear phenomena (Belguith et al., 2017), this model considers context heterogeneity. The panel smooth threshold regression (PSTR) model proposed by Gonzales et al (2005) and revised in 2017 is the one used in this paper. It used for modelling situations where the transition from one regime to another is gradual.

The PSTR model takes the following form:

$$y_{it} = \mu_i + \beta_0 X_{it} + \beta_1 X_{it} G(q_{it}, \gamma, C) + e_{it} \quad (1)$$

Where $y_{it}$ represents the dependent variable (in our case it is the Gini index), $\mu_i$ is the vector of individual fixed effects and $G(q_{it}, \gamma, C)$ denotes the transition function associated with a transition variable $q_{it}$, a threshold parameter C and a smoothing parameter γ. $X_{it} = (X_{it}^1, \dots, X_{it}^k)$ is the matrix of k explanatory variables (the control variables) containing no lagged endogenous variables, $\beta = (\beta_1, \dots, \beta_k)$ is the vector of coefficients and $\varepsilon_{it}$ is the independent and identically distributed iid $(0, \sigma_i^2)$ error term. The index $i = 1 \dots N$ indicates the individual dimension corresponding to the countries and the index $t = 1 \dots T$, the temporal dimension. Theoretically, a smooth transition mechanism between regimes can be modelled using various transition functions if they are continuous and integrable on the interval [0,1].

González et al (2005) proposed a logistic transition function of order m:

$$G(q_{it}, \gamma, C) = [1 + \exp(-\gamma \prod_{j=1}^{m} (q_{it} - C_j))]^{-1} \epsilon [0; 1] \quad (2)$$

With $\gamma > 0, C_1 < \cdots < C_m$ where ( $C_1;\ C_2; \dots; C_m$) is an m-dimensional vector of the threshold parameters. When $\gamma \to \infty$ , the transition becomes abrupt and the PSTR model converges to a PTR with two regimes (left, respectively right of $C$). On the other hand, for $\gamma \to 0,\ G(.) \to 1/2$, and the PSTR estimate joins that of a panel with individual fixed effects. For γ values between these two extremes, the transition is smooth between the two regimes.

The empirical specification is as follows:

$$Gini_{it} = \delta_i + \alpha_1 pole_{it} + \alpha_2 lnpibh_{it} + \alpha_3 lnpibh_{it}^2 + \alpha_4 Corrup_{it} + \alpha_5 lnouvcom_{it} + [\alpha_6 pole_{it} + \alpha_7 lnpibh_{it} + \alpha_8 lnpibh_{it}^2 + \alpha_9 Corrup_{it} + \alpha_{10} lnouvcom_{it}] G(q_{it}, \gamma, C) + e_{it} \quad (3)$$

With:

$Gini_{it}$: Gini inequality index for country i at period t;

$Lnpibh_{it}$: neperian logarithm of the gross domestic product per capita of country i in period t;

$Pole_{it}$: index of the state of environmental policy in country i at period t (transition variable $q_{it}$).

We use the sub-indicators of the Environmental Performance Index (EPI) as environmental policy variables. These are a) the adjusted carbon dioxide performance index (IPCO2) which assesses the performance of countries in complying with policies related to the reduction of CO2 emissions ; b) the animal and plant species protection performance index (IPPEAV), which assesses countries‘ performance in complying with policies relating to the protection of animal and plant resources; and c) the ozone layer protection performance index (IPPCO), which indicates countries’ level of performance in complying with policies relating to the protection of the ozone layer. $lnouvcom_{it}$ is the natural logarithm of the degree of trade openness of country i at date t. $Corrup_{it}$ is the indicator of corruption in country i at period t. This indicator belongs to the interval [-2.5, +2.5]. To facilitate its interpretation, we re-parameterise so that a high score indicates a strong perception of corruption. Thus, we define the variable $corrup_{it}$ = - WGI corruption indicator.

The PSTR method has several advantages. The main one being that the coefficients represent elasticities of income inequality in relation to environmental policies and economic growth and vary over time and by country. Despite its interest and flexibility, the estimation of a PSTR model requires prior tests, in particular the verification of the existence of non-linearity and the determination of the number of transitions.

### 2.2 Data Sources and Description

We use a panel of 26 sub-Saharan African countries covering the period from 1999 to 2021.

**Table 1. Definition of variables and units of measurement**

| Variables | Definition | Units of measurement | Data sources |
|---|---|---|---|
| PIBH | Gross domestic product per capita | US Dollar ($) | WDI 2023 |
| IPPEAV | Animal and plant species protection index | Score rated on 100 | EPI 2023 |
| IPPCO | Ozone layer protection index | Score rated on 100 | EPI 2023 |
| $IPCO_2$ | CO2 emissions control index | Score rated on 100 | EPI 2023 |
| Gini | Income inequality index | Score rated on 1 | WIID 2023 |
| Corrup | Level of corruption | score belongs to the interval $[-2{,}5;+2{,}5]$ | WGI 2023 |
| Ouvcom | $\frac{(X+M)}{(2PIB)}$*100 is the degree of commercial openness | % | WDI 2023 |

**Table 2. Descriptive statistics of variables**

| Variables | Number of obs | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Gini | 598 | 0.615048 | 0. 058282 | 0 .4945792 | 0.7765049 |
| PIBH | 598 | 1391.988 | 1709.417 | 102.598 | 8810.931 |
| IPPCO | 598 | 42.8871 | 12.32301 | 21.70335 | 82.66817 |
| $IPCO_2$ | 598 | 29.60408 | 20.77485 | 0 | 85.03919 |
| IPPEAV | 598 | 81.48642 | 12.56834 | 41.47988 | 99.63895 |

*Source: Author, based on data WIID (2023); WDI (2023); WGI (2023) and EPI (2023)*

This limited number of countries is due to the unavailability of data from other countries in the region. The data comes from the World Bank's World Development Indicator (WDI). For environmental policy, we use the Environmental Performance Index (EPI) published by the Yale Center for Environmental Law and Policy (YCELP) (Wendling et al, 2023). For the democracy indicator, the 2023 World Governance Indicator (WGI) is used. For income inequality, we use the Gini index from the 2023 World Income Inequality Database (WIID).

Table 1 describes all the variables used in the model. Descriptive statistics are presented in Table 2.

Table 2 shows that income inequality remains high in sub-Saharan Africa, with a less dispersed Gini index, averaging around 0.62 and sometimes reaching 0.78 in some countries. As for GDP per capita, it is widely dispersed around an average of US$1,392, with some countries achieving just US$102 billion (the minimum) and others as high as US$8,800 billion (the maximum). The first group includes countries such as Chad, the Democratic Republic of Congo, Mali and Madagascar, with a low GDP per capita.

In terms of environmental protection, Sub-Saharan Africa has, on average, a low level of protection. However, protection of animal and plant species is high, with an average index of 81.49. In fact, animal and plant species are better protected than atmospheric air, in particular the ozone layer with a protection index of 42.89 and CO2 emissions with a control index of only 29.60. This performance in terms of protecting flora and fauna could be explained by several initiatives in the form of financial or technical support from international institutions and NGOs in favour of nature.

## 3. RESULTS AND DISCUSSION

### 3.1 Preliminary Tests

The application of the PSTR model requires the verification of some hypotheses based on statistical tests, in particular tests of linearity and determination of the number of regimes. Tables 3 and 4 show the results of these tests. The null hypothesis of linearity is rejected at the 1% significant level, indicating the existence of a non-linear relationship between environmental policies and income inequality. This result led to the determination of the number of regimes in the process, which is two (2), since the null hypothesis of the test could not be rejected at the 1% significant level. There is a single threshold allowing the transition from one environmental policy regime (extreme regime 1) to another (extreme regime 2). These thresholds are 42.5027, 75.9979 and 33.8038 respectively for the IPPCO, IPPEAV and IPCO2. Table 3 shows that non-linearity holds for all transition variables.

**Table 3. Non-linearity test with ippeav, ippco and ipco2 as transition variables**

| **Test assumptions** | **H0: Linear Model**<br>**H1: PSTR model with at least one threshold** | | |
|---|---|---|---|
| **Transition variables** | **IPPCO** | **IPPEAV** | **$IPCO_2$** |
| **Tests** | | | |
| Wald test (LM) | W=34.83***<br>(0.000) | W=104.78***<br>(0.000) | W=53.96***<br>(0.000) |
| Fisher Tests (LMF) | F=3.475***<br>(0.000) | F=11.94***<br>(0.000) | D=5.574***<br>(0.000) |
| LRT Tests (LRT) | LRT= 35.88***<br>(0.000) | LRT=115.2***<br>(0.000) | LRT= 56.55***<br>(0.000) |

*Source: Author's calculation using Matlab2021a; ***, ** and * indicate the significance of the variables at the 1%, 5% and 10% level respectively*

*Since non-linearity is verified for each of the transition environmental policy variables (IPPEAV, IPPCO, IPCO2), we will determine the number of regimes*

**Table 4. Number of schemes by transition variable**

| **Test assumptions** | **H0: PSTR model with one regime(r=1)**<br>**H1: PSTR model with at least two regimes(r=2)** | | |
|---|---|---|---|
| **transition variables** | **IPPCO** | **IPPEAV** | **$IPCO_2$** |
| **Tests** | | | |
| Wald Test (LM) | W = 27.508***<br>(0.002) | W=83.26***<br>(0.000) | W=59.31***<br>(0.000) |
| Fisher Tests (LMF) | F = 2.66***<br>(0.004) | F=8.93***<br>(0.000) | F=6.07***<br>(0.000) |
| LRT Tests (LRT) | LRT= 28.16***<br>(0.002) | LRT=89.66***<br>(0.000) | LRT= 62.37***<br>(0.000) |

*Source: Author's calculation using Matlab2021a; ***, ** and * indicate the significance of the variables at the 1%, 5% and 10% thresholds respectively*

## 3.2 Interpretation and Discussion of the Results of the Econometric Estimates

These results show two regimes in each case. After these preliminary tests, the PSTR model is estimated, and the results are presented in Table 5.

The high values of the gamma smoothing parameters (3.8798, 8.849 and 2.3518) indicate an abrupt transition. According to Yueying (2017) the transition is abrupt and the PSTR model converges to a Hansen (1999) threshold effect model (PTR). This abrupt transition at different environmental policy thresholds indicates that SSA countries cannot be divided into an infinite number of classes, suggesting a degree of homogeneity of these countries with a similar level of inequality. It is therefore possible to clearly identify sub-groups of SSA countries on which homogenous estimates involving the three variables can be made. This result confirms the two extreme regimes. The model is globally significant and most of the variables are significant at the 1% level.

The results validate Kuznets' inverted-U relationship only in the context of strict application of environmental standards. Specifically, the results show that strict application of environmental standards reduces income inequality in sub-Saharan Africa above a wealth threshold. Indeed, the more a relatively wealthy country adopts a rigorous environmental policy, the more economic growth contributes to reduce income inequalities. In other words, economic growth can only reduce income inequality in a context of strict compliance with environmental standards. Authors such as Magnani (2000), Aloi & Tournemaine (2013) and Constant (2019) have reached the same conclusion. Magnani (2000) shows that in rich countries, economic growth improves the quality of the environment through income inequalities reduction. According to this view, a fair distribution of economic growth generated in the form of public goods (environmental quality, education, health) improves the human capital of the population, which in turn increases productivity; thereby raising the mean willingness to pay for environmental protection.

**Table 5. Results for the PSTR model with ippeav, ippco and ipco2 as transition variables**

| **Specification** | **Model 1** | | **Model 2** | | **Model 3** | |
|---|---|---|---|---|---|---|
| **TransitionVariable** | **IPPCO** | | **IPPEAV** | | **IPCO2** | |
| **Extreme regimes** | **r1** | **r2** | **r1** | **r2** | **r1** | **r2** |
| **Coef** | $\boldsymbol{\beta_0}$ | $\boldsymbol{\beta_1}$ | $\boldsymbol{\beta_0}$ | $\boldsymbol{\beta_1}$ | $\boldsymbol{\beta_0}$ | $\boldsymbol{\beta_1}$ |
| **Explanatory Variables** | | | **Gini** | | | |
| IPPCO | 0.019*** (2.82) | -0.02*** (-2.91) | - | - | - | - |
| IPPEAV | - | - | -0.002 (-1.11) | 0.0034** (2.60) | - | - |
| $IPCO_2$ | - | - | - | - | 0.02*** (2.82) | -0.02*** (-2.91) |
| lnpibh | -0.36*** (-5.85) | 0.35*** (4.75) | -0.10** (-2.61) | 0.04 (1.16) | -0.36*** (-5.85) | 0.35*** (4.76) |
| $Lnpibh^2$ | 0.026*** (6.38) | -0.03*** (-5.39) | 0.01** (2.73) | -0.005*** (-2.00) | 0.026*** (6.38) | -0.03*** (-5.39) |
| Corrup | 0.196*** (13.90) | -0.20*** (-14.00) | -0.013 (-1.38) | 0.03*** (2.81) | 0.20*** (13.91) | -0.20*** (-14.00) |
| lnouvcom | 0.01 (0.24) | -0.02 (-0.81) | 0.04*** (6.69) | -0.09*** (-10.96) | 0.005 (0.24) | -0.02 (-0.81) |
| Smoothing Para.$\gamma$ | 3.88*** (0.00) | | 8.89*** (0.00) | | 2.35*** (0.00) | |
| Threshold Para. $C$ | 42.50*** (0.00) | | 75.99*** (0.00) | | 33.80*** (0.00) | |
| AIC criterion | -7.49 | | -7.59 | | -7.39 | |
| Schwarz criterion | -7.40 | | -7.49 | | -7.39 | |
| No observation | 598 | | 598 | | 598 | |

*Source: Author's calculation using Matlab2021a; ***, ** and * indicate the significance of the variables at the 1%, 5% and 10% thresholds respectively. Model1, model2 and model3 are PSTR models using respectively ippeav, ippco and ipco2 as transition variables. r1 and r2 are respectively the first and second extreme regime for each transition variable. $\beta_0$ and $\beta_1$ represent the vector of coefficients of the first and second extreme regime respectively*

This idea is in line with that of Zerbo and Hien (2023), who find that economic growth will only reduce income inequalities if it greatly strengthens the capabilities of the poor.

The quality of the environment resulting from a rigorous environmental policy could constitute this channel, as a healthy environment increases life expectancy, which in turn favours investment in human capital (Harrison and Rubinfeld, 1978; Su et al., 2011; Bell et al., 2006).

This result shows that Kuznets' inverted-U relationship is not independent of environmental policy. According to the environmental Kuznets curve (EKC) highlighted by Grossman and Krueger (1995), the environment is a luxury good, as confirmed by Magnani (2000). The underlying assumption is that environmental standards become more stringent as the economy grows, due to an increasing demand for environmental quality as per capita income rises (Antle and Heidebrink, 1995; Broad, 1994, Grunewald et al., 2017). Economic growth is a prerequisite for the application of strict environmental standards. So the socially virtuous effect (reducing inequalities) of a rigorous environmental policy only appears in economically dynamic countries. On the other hand, strict environmental standards in poor countries lead to an increase in income inequalities. Given that the poor are heavily dependent on environmental resources, any restriction on access to these resources (strict environmental regulation) leads to a deterioration in their economic conditions (Martinez-Alier, 2002; Olsson et al., 2014). Similarly, the results show that, in low-income countries, weak environmental policies are not socially inefficient because they do not increase income inequalities. This result validates the polluter's haven hypothesis, according to which developing countries adopt permissive environmental policies to attract industries favouring job creation, which lead to income inequalities reduction.

A kind of a segmentation of environmental policy is emerging. This segmentation consists, on the one hand, in the strict application of environmental standards in developed countries (Magnani, 2000) and, on the other hand, in a permissive environmental policy in developing countries. Consequently, environmental policy design should consider a country's level of development. Any standardisation of environmental policy within a group of economically different countries would be socially inefficient because it would accentuate income inequalities.

These results contribute to the current debate on environmental policy in general, and climate policy in particular, where all the countries in the world are invited to make some commitments about greenhouse gas emissions reduction.

## 4. CONCLUSION

The persistence of income inequality in a context of economic growth has prompted interest in re-examining the relationship between these two phenomena, particularly in the context of sustainable development. The aim of this paper is to analyse the effect of environmental policies on the relationship between economic growth and income inequality in sub-Saharan Africa. The Panel Smooth Transition Threshold Effect (PSTR) model of Gonzalès (2005) has been used to test data from the World Bank (2023), the Yale Center for Environmental Law and Policy (YCELP) (2023), WGI (2023) and WIID (2023). Two major results were obtained. The first reveals an inverted-U relationship between economic growth and income inequality in sub-Saharan Africa when environmental standards are respected. Indeed, the more a relatively wealthy country adopts a rigorous environmental policy, the more economic growth contributes to reduce income inequalities. Thus, the socially virtuous effect of a strict environmental policy only occurs in economically dynamic countries. The second result validates the polluter haven hypothesis by indicating that weak environmental policies are not socially inefficient because they do not increase income inequalities. Consequently, the promotion of environmental policies in sub-Saharan African countries should consider the level of economic performance. Any standardisation of environmental policies on a continental or sub-regional scale for economically different countries should be reconsidered. To ensure compatibility between economic growth and income equality, these two main results call for a segmentation of environmental policy. This involves strict application of environmental standards in developed countries and a permissive environmental policy in developing countries.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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