How to Cite:
Yao Séraphin, P., & Mounoufié Valery, K. (2025). Nonlinear effects of inflation on economic growth in selected Sub-Saharan African Countries: Are the level of economic development, geographical area, and currency zone relevant?. *International Journal of Economic Perspectives*, *19*(9), 102–123. Retrieved from https://ijeponline.org/index.php/journal/article/view/1111

Nonlinear effects of inflation on economic growth in selected Sub-Saharan African Countries: Are the level of economic development, geographical area, and currency zone relevant?

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Abstract---The objective of this paper is to estimate the optimal inflation rate, defined as the rate below and above which inflation differentially affects economic growth in SSA countries. To do so, we apply a Panel Smooth Transition Regression (PSTR) model, developed by González et al. (2005), on data covering the period 2000-2019 for 30 SSA countries. Our results indicate first that the relationship between inflation and growth in SSA is nonlinear. Second, the optimal inflation rate for SSA is around 11.64 percent. Third, the inflation thresholds differ from one zone to another: 10.06 percent for Southern Africa, 4.39 percent for the Central African Economic and Monetary Community (CEMAC) countries, 6.19 percent for East Africa, 11.58 percent for the Economic Community of West African States (ECOWAS) countries, and 3.93 percent for the West African Economic and Monetary Union (WAEMU) countries. Fourth, the estimated optimal thresholds are sensitive to a number of macroeconomic variables such as public investment spending, the level of financial development, and trade openness. Sensitivity analyses and estimation using the GMM method show that these results are robust.

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Submitted: 27 July 2025, Revised: 09 August 2025, Accepted: 18 September 2025

***Keywords*---**Threshold of Inflation, PSTR Model, Monetary Policy, Growth, Welfare.
Jel Classifications: C33, E31.

Introduction

In this paper, we propose to determine the optimal inflation rate in Sub-Saharan Africa (SSA). The stylized facts on macroeconomic developments in SSA over the last two decades have shown that the dynamics of economic growth have been marked by more optimal growth and monetary management policies. Indeed, central banks thus face a real challenge when it comes to reconciling low inflation and high economic growth (Ibarra and Trupkin, 2016). This dilemma is more pronounced in developing countries (DCs) and particularly in African countries, which have recorded positive growth rates over the past two decades. Based on data from the World Bank (2021), we note that the evolution of the inflation rate and the growth rate of real GDP revealed two phases of economic growth. The first phase, from 2000 to 2009, was marked by more moderate growth with relatively high inflation rates, around 7%. The second phase, from 2010 to 2019, was marked by a decline in economic growth with relatively low inflation rates of around 5%. At the sub-regional level, the analysis revealed some regional disparity in terms of growth and inflation rates. In Southern Africa, with an average inflation rate of 13.4%, the region achieved an average growth of 3.7%, while Central Africa achieved an average growth of 3.3% with an average inflation rate of 2.7%. East African countries achieved an average growth of 5.4% with an average inflation rate of 9.8%, while West Africa generated an average growth of 4.5% with an average inflation rate of 4.5%. From these stylized facts, we see a complex relationship between inflation and economic growth in SSA.

At the theoretical level, Sidrauski (1967) finds that there is no relationship between inflation and growth. On the contrary, some authors indicate that inflation has a negative effect on growth, investment and the balance of payments (Stockman, 1981 ; Fisher, 1993 ; Barro, 1995). For others, inflation has a positive effect on economic growth (Mallik and Chowdhury, 2001).

Empirically, Khan and Senhadji (2001) analyze the nature of the relationship between inflation and economic growth in both developed and developing countries. The results indicate that the sensitivity between these two variables depends on the level of development achieved by the different countries and on the evolution of certain macroeconomic variables that can vary considerably from one country to another. For example, in countries with a developed financial sector, inflation exacerbates price variability in goods and money markets. As a result, the negative effects of inflation on growth are more severe for economies with a higher level of financial development (Eggoh and Khan, 2014).

In Africa, Seleteng et al (2013), determine an optimal inflation of 18.96% for the Southern African Development Community countries, 8.08% for the WAEMU countries, according to Combey and Nubukpo (2010) and around 4.3%, for the CEMAC countries (Mondjeli and Tsopmo, 2017). The most recent contribution is that of Sall (2020) on the WAEMU zone, with a threshold around 3.9%. However, the author neglects a number of factors in explaining this relationship, notably, important macroeconomic variables. Thus, our study, which is an extension of the work mentioned above, determines the optimal inflation threshold endogenously. But, to our knowledge, this study is the very first one that takes into account the level of economic development, the geographical area and the monetary area. This is the major contribution of this study.

At the methodological level, we use a smooth transition threshold effect panel model (PSTR) proposed by González et al. (2005) and which Villavicencio and Mignon (2011) argue has at least two advantages. First, the parameter coefficients can take different values that depend on the regime. Second, to the extent that the transition from one regime to another is smooth, the coefficients can change gradually.

The rest of the article is structured as follows. Section 2 is devoted to the literature review. In section 3, we present the methodology of the study and the data. Section 4 is reserved for the results and discussions. Section 5 is devoted to the conclusion of the article.

Review of the Literature

The relationship between inflation and economic growth is multifaceted. Mundell (1963) predicts that in periods of inflation, economic agents accumulate more capital by saving more, because of the uncertainty associated with inflation. This increase in savings will lead to a fall in the real interest rate, which will ultimately stimulate investment and economic growth. Tobin (1965) believes that inflation stimulates capital accumulation at the expense of holding liquid assets. Indeed, what the economics literature calls the Mundell-Tobin effect states that, given the substitutability between money and capital, an increase in inflation erodes the purchasing power of money balances, leading to a substitution between resources in favour of real assets. Ireland (1994) finds that inflation reduces the return to holding real balances, based on a consumption savings decision rather than a portfolio substitution mechanism. In contrast, using a model in which money and capital are complementary, Stockman (1981) shows that a rise in inflation reduces both capital accumulation and the holding of monetary assets. As a result, the steady-state level of output declines, leading to lower economic growth. Moreover, inflation could reduce economic growth through its negative impact on the marginal productivity of physical and human capital by acting as a tax (Greenwood and Huffman 1987 ; Gillman et al., 2002 ; Vaona 2012).

While it is true that inflation has contrasting effects on capital accumulation (both physical and human), and thus on economic growth, there seems to be a consensus that the relationship is non-linear. Akerlof et al (2000) have shown that a moderate increase in the inflation rate can increase the level of capital. In fact, according to them, the continuous increase in inflation will lead to a trade-off between two opposing effects. For less rational agents, the increase in inflation will encourage job creation and thus an increase in capital. Otherwise, higher inflation will induce more agents to adopt fully rational behavior, leading to lower capital, output and employment. Thus, the effect of inflation on economic growth appears to be a function of the level of inflation. Above a certain threshold, higher inflation hurts economic growth. The non-linearity can be theoretically explained by "menu cost" models, in which costly adjustment to demand shocks makes the link between inflation and growth viscous. As an illustration, Ball et al (1988) show that in the presence of a menu cost, the response of different firms will be asymmetric to demand shocks. When the level of inflation is low, the adjustment of prices to shocks is slower and output reacts more strongly than prices. However, when inflation increases, the adjustment process becomes faster and output becomes less responsive to demand shocks. Klump (2003) provides the microeconomic basis for this non-linear relationship between inflation and growth through the effect of inflation on the efficient allocation of resources by firms. Inflation disrupts factor substitution in the production process and imposes a welfare cost. On balance, no school of economic thought has categorically taxed accelerating inflation as having undesirable distributional and welfare effects. The effects of inflation on growth are subject to certain macroeconomic conditions that can vary considerably across countries (Eggoh & Khan, 2014). Thus, in empirical studies, various factors such as money supply, interest rate, potential output, exchange rate, trade openness, and level of development influence the relationship between inflation and economic growth (Bhattacharya, 2014 ; Ghosh, 2014). The optimal inflation thresholds obtained are linked to the level of development of countries. Thus, Espinoza et al (2010) show that inflation above the threshold of 1% and 10% is harmful to economic growth in developed and developing countries respectively. For Kan and Omay (2010), the optimal inflation threshold is 2.52% for developed countries. As for Seleteng et al (2013), they obtain an optimal inflation of 18.96% in the Southern African Development Community countries. Yabu and Kessy (2015) showed for Kenya, Tanzania and Uganda, over the period 1970-2013, that average inflation rates above 8.46% had a negative and significant impact on economic growth in these countries. Using a PTR model, Ndoricimpa (2017) analyzed the relationship between inflation and growth for 47 African countries on a non-cylindrical panel. His results confirmed the existence of a nonlinear relationship between inflation and growth. The estimated inflation threshold is 6.7 percent for the entire sample, 9 percent for the subsample of low-income countries, and, 6.5 percent for middle-income countries. Prao (2019), used the same model to examine the link between inflation and growth in the CFA franc zone and the BRICS (Brazil, Russia, India, China, South Africa), over the period 1990-2016. The results strongly confirm the non-linear relationship between inflation and growth, with a threshold of 3.17% in the CEMAC zone, 11.30% for the WAEMU zone and 7.04% for the BRICS. Furthermore, the study indicates that the 2% target set by the BCEAO for WAEMU countries can be raised without negatively affecting growth. As for the BRICS, they should avoid inflation rates above 7%. Long before, Combey and Nubukpo (2010) showed that the optimal inflation threshold is around 8.08% for WAEMU countries. Recently, a study by Sall (2020) conducted on WAEMU countries, over the period from 1980 to 2016, estimated an optimal inflation threshold of around 3.9%. For CEMAC countries, Ndjokou and Tsopmo (2017), estimated the optimal inflation rate, using data covering the period 1985-2013, and obtained a threshold of 4.3%. Below this threshold, a 1% increase in inflation induces that of growth by 0.28%, however, above the threshold, economic growth is reduced by 0.25% when inflation increases by 1%. After sensitivity analyses and estimation using the GMM method, the authors confirmed the robustness of these results. Khan (2014) analyzed the nonlinearity between inflation and growth for 100 industrialized and developing countries over the period 1963-2012. The results confirm the nonlinearity between inflation and growth for these different groups of countries with a threshold of 3.89% for advanced economies, 4.91% for upper-middle income countries and 16.28% for emerging economies. Furthermore, the study indicates that these differences in thresholds between countries are due to the level of financial development, investment, public spending and trade openness. For a smaller sample of 53 African countries over the period 1980-2013, Djiogap (2018) investigated the nonlinearity of the inflation-growth relationship by conditioning it on the quality of institutions. The study concludes that countries with good institutions suffer less from the effects of inflation than countries with poor quality institutions. Furthermore, the results indicate an optimal inflation rate of 7.85 percent for economies with a floating exchange rate regime and an optimal inflation rate of 9.45 percent for economies with a fixed exchange rate regime. In the end, the thresholds obtained vary according to countries' levels of development, geographical areas, and often, according to monetary arrangements.

Methodology and Data

The methodology used in this study will be described here. First, we present the specification of the model and second, the estimation procedure. Third, we present the robustness test and fourth, the data sources.

The Model Specification

To examine the nonlinear effect of inflation on economic growth, in sub-Saharan Africa, we use a threshold-effect Panel modeling. Threshold effect models are an instrument for the analysis of non-linear economic phenomena. They allow economic series to have different dynamics depending on the regimes in which they evolve. The transition mechanism for the transition from one regime to another is carried out using an observable transition variable, a threshold and a transition function. There are two main types of panel threshold modeling : the modeling proposed by Hansen (1999) and that of Gonzalez et al. (2005 ; 2017). In that of Hansen [1999], nonlinearity is reflected in the fact that the dependent variable is generated by two distinct processes. We are located in one process or another according to the value taken by a variable called transition variable. The modeling assumes that the transition between the two regimes is abrupt. Indeed, we are located in the dynamics of one process or the other. However, it could very well be that, instead of being abrupt, this transition is rather smooth. The PSTR modeling proposed by Gonzales et al. (2005 ; 2017) thus makes it possible to model situations where the transition from one regime to another takes place gradually. Thus, the transition function will be, not an indicator, but rather a continuous function. The PSTR can also be seen as models in which, there are two extreme regimes between which, there would be a continium of regimes. In the context of this study, the gradual transition models (PSTR) are more appropriate to describe the change in economic behaviors induced by quantitative regime variables. To illustrate the relationship between inflation and economic growth, we assume the simple case of the PSTR with two extreme regimes and a single transition function. In the case of two extreme regimes and a single transition function, the PSTR model can be written as follows :

$$y_{it} = \mu_i + \lambda_t + \beta'_0 x_{it} + \beta'_1 x_{it} G(\mathrm{INFL}_{it}; y, c) + \varepsilon_{it} \quad (1)$$

Where i = 1, 2, …, N is the number of countries and t = 1, 2, …, T is the number of periods. These are the individual dimensions and the temporary dimensions of the panel, respectively. The dependent variable y_{it} is a scalar and represents the growth rate of real GDP (GDPR), x_{it} is a K-dimensional vector of the explanatory variables generally considered in the literature on the supply of bank credit. μ_i and λ_t represent fixed individual effects and time effects, respectively, and ε_{it} is the error term, and β the regression coefficients. Transition function $G(INFL_{it}; \gamma, c)$ is a continuous function and depends on threshold variable ($INFL_{it}$) and normalized to be bounded between 0 and 1, and these extreme values are associated with regression coefficients β_0 and (β_0 + β_1), and on $c = \{c_1, \ldots., c_m\}$ which is a vector of threshold parameters and the parameter γ determines the slope of the transition function and indicates the transition speed from one regime to another (transition parameter). Like Granger and Teräsvirta (1993), González et al. (2005), we consider the following logistic transition function :

$$G(INFL_{it};\, \gamma\,, c) = \left[1 + \exp\left(-\gamma \prod_{j=1}^{m} (INFL_{it}; -c)\right)\right]^{-1} \quad (2)$$

With γ > 0 and $C_1 \leq C_2 \leq \cdots \leq C_m$.

Note that m is the number of location parameters and $C_1 \leq C_2 \leq \cdots \leq C_m$. For m = 1, the model has the two extreme regimes separating low and high values of $INFL_{it}$ with a single monotonic transition of the coefficients from β_0 and (β_0 + β_1), as $INFL_{it}$ increases. For a higher value, the transition becomes rougher and transition function G ($INFL_{it}$, γ, c) becomes the indicator function G ($INFL_{it}$, c). When tends towards infinite, indicator function G ($INFL_{it}$, c) = 1 if event $INFL_{it}$, > c occurs, and indicator function G ($INFL_{it}$, c) = 0 otherwise. When is close to 0, the transition function G ($INFL_{it}$, γ, c) is constant. In that case, the PSTR converges towards the two regime panel threshold regression (PTR) of Hansen (1999). In general, for any value of m, the transition function G ($INFL_{it}$, γ, c) is constant when is close to 0. In which case, the model in equation (1) becomes a linear panel regression model with fixed effects. The empirical model to be estimated is presented as follow :

$$GDPR_{it} = \mu_i + \alpha GDPR_{it-1} + \theta_1 COR_{it} + \theta_2 OUV_{it} + \theta_3 INVEST_{it} + \theta_4 DEPPUB_{it} + \theta_5 FIND_{it} + \theta_6 DEMC_{it} + \theta_7 INFL_{it} + (\theta'_1 COR_{it} + \theta'_2 OUV_{it} + \theta'_3 INVEST_{it} + \theta'_4 DEPPUB_{it} + \theta'_5 FIND_{it} + \theta'_6 DEMC_{it} + \theta'_7 INFL_{it}) * G(INFL_{it}; y, c) + \varepsilon_{it} \quad (3)$$

Where θ_i represents the regression coefficients. The selected dependent variable is economic growth. This variable is measured by the growth rate of real GDP ($GDPR_{it}$) for each country at time t. The explanatory variable of interest is the inflation rate ($INFL_{it}$) measured by the growth rate of the consumer price index (CPI), at time t for each country. In addition to inflation a set of variables was selected as a control variable. This is the investment rate ($INVEST_{it}$) of a country defined by gross fixed capital formation to real GDP, at time t. The degree of trade openness (OUV_{it}) is measured by the ratio of the sum of exports and imports over

2 times real GDP, at time t for each country. Government consumption expenditure ($DEPPUB_{it}$) is used as a proxy for government expenditure, at time t for each country. Financial development ($FIND_{it}$) is measured by broad money to GDP (M3), for each country at time t. The literature shows that the quality of institutions is necessary for economic growth (Sall 2020). In our analysis, we will focus on the institutions responsible for controlling corruption (COR_{it}), for each country at time t. Population growth for each country at tme t ($DEMC_{it}$) is also used.

The estimation procedure

The econometric approach is based on three steps. In the first one, the stationarity of each variable is examined by performing the unit roots tests of Pesaran (2007). In the second one, we test both the linearity against the PSTR model and the number of transition function. Finlay, in the third one, we apply the non-linear least squares methods to estimate our PSTR model. It's the estimation procedure for obtaining the coefficients.

- **The Pesaran test (2007)**

Indeed, Pesaran's (2007) second generation test assumes possible correlations between individuals (inter-individual dependencies) of the panel. The CIPS (Cross-sectionally Augmented IPS) test takes into account the cross-sectional dependence (inter-individual dependence) of the observations. In general, the objective is to test the null hypothesis of the presence of unit root against the alternative hypothesis of the absence of unit root. The principle of the test is as follows :

$$H_0\text{: } presence\ of\ unit\ root\ or\ \ H_1\text{: } absence\ of\ unit\ root$$

The presence of a unit root means that the series are non-stationary. The absence of a unit root means that the series studied are stationary. If the p-value associated with the test statistic is less than 5%, then the null hypothesis is rejected and the hypothesis of no unit root is accepted.

- **Linearity test**

The estimation of the PSTR model begins with the elimination of the fixed individual effects μ_i by removing the mean of the specific individual effects and thus applying the nonlinear least squares on the transformed model. Gonzàlez et al. (2005) proposes a test procedure according to the following order :

i) The linearity test against the PSTR model,

ii) Determination of the number r of the transition functions

The linearity test in the PSTR model (equation 1) can be done by testing :

$$H_0\text{: }\gamma = 0\ \ or\ \ H_0\text{: }\beta_1 = \beta_0$$

However, under the null hypothesis, the test will not be the same in both cases, and the PSTR model contains unidentified nuisance parameters. One possible solution is to replace the transition function $G(z_{it}; y, c)$ with the Taylor expression at order 1 around $\gamma = 0$ and test an equivalent hypothesis in an auxiliary regression. We then get the following :

$$GDPR_{it} = \mu_i + \alpha GDPR_{it-1} + \theta_1^* COR_{it} + \theta_2^* OUV_{it} + \theta_3^* INVEST_{it} + \theta_4^* DEPPUB_{it} + \theta_5^* FIND_{it} + \theta_6^* DEMC_{it} + \theta_7^* INFL_{it} + (\theta^{*\prime}{}_1 COR_{it} + \theta^{*\prime}{}_2 OUV_{it} + \theta^{*\prime}{}_3 INVEST_{it} + \theta^{*\prime}{}_4 DEPPUB_{it} + \theta^{*\prime}{}_5 FIND_{it} + \theta^{*\prime}{}_6 DEMC_{it} + \theta^{*\prime}{}_7 INFL_{it}) * G(INFL_{it}; \gamma, c) + \varepsilon_{it}^* \qquad (4)$$

Since the parameters $\theta^{*1} \ldots\ldots\ldots.\theta^{*m}$ are proportional to the slope parameters of the transition function, and ε_{it}^* is ε_{it} plus the residue of Taylors development. The

null hypothesis of the linearity test becomes H0 : $\theta^{*1} = \cdots = \theta^{*m} = 0$ and the linearity is tested with standard tests.
We use Wald test expressed as follows :

$$LM_w = \frac{NT(SCR_0 - SCR_1)}{SCR_0}$$

where SCR_0 is the sum of the squares of the panel residuals under the hypothesis H_0 and SCR_1 is the sum of the squares of the panel residuals in the PSTR model with m regimes. Then the corresponding statistic F is then defined as follows :

$$LM_F = \frac{(SCR_0 - SCR_1)/mK}{SCR_0/(TN - N - mK)} \sim F(mK, TN - N - mK) \quad (5)$$

Where T, N and K are the number of years, the number of countries and the number of exogenous variables respectively. After applying the linearity test, the problem is to identify the number of transition functions. LMF follows a Fisher distribution with mK and $(TN - N - mK)$degrees of freedom (F(mK,$TN - N - mK$)). All these linearity tests are distributed $\chi^2(k)$ under the null hypothesis.

Test de robustesse

To test the robustness of the PSTR model results, we estimate a growth equation that is expressed as follows :

$$y_{it} = \theta y_{it-1} + \mu_i + \beta_0' x_{it} + \beta_1' \pi_{it}^2 + \varepsilon_{it} \quad (6)$$

Thus to estimate equation 6, we use the dynamic panel generalized method of moments (GMM) (Arellano and Bond, 1991 ; Arellano and Bover, 1995 and Blundell et al. 2000). By specifying our GMM in quadratic form (the π_{it}^2 term in equation 6), we postulate the existence of a nonlinear relationship between inflation and economic growth. One advantage of the GMM method is that it controls for endogeneity between variables. The instrumentation method differs according to the nature of the explanatory variables : (a) for purely exogenous variables, current variables are used as instruments ; (b) for weakly exogenous variables, values lagged by at least one period are used as instruments ; (c) for endogenous variables, values lagged by two or more periods can be used as valid instruments.

Data sources

For this study on the relationship between inflation and economic growth in SSA, we selected 30 sub-Saharan African countries, based on data availability. Thus, the 30 countries selected are : Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Côte d'Ivoire, Eswatini (Swaziland), Gabon, Gambia, Ghana, Guinea Bissau, Kenya, Madagascar, Mali, South Africa, Mauritius, Niger, Nigeria, Uganda, Central African Republic, Democratic Republic of Congo (DRC), Republic of Congo, Rwanda, Senegal, Seychelles, Sudan, Tanzania, Chad, and Togo. The data are annual and come from the World Development Index (WDI 2021) and

WGI (2021). The study covers the period 2000-2019. The choice of this period is due to the availability of data for a large number of countries over this period. All selected variables are summarized in the table 1.

Table 1. Variables and Data Sources

Type of variables	Variables	Definitions	Sources
Dependent variable	GDPR	Economic Growth	WDI(2021)
Variable of interest	INFL	consumer Price Index	WDI(2021)
Control variables	COR	Control of Corruption	WGI(2021)
	OUV	Commercial Opening	WDI(2021)
	INVEST	Investment	WDI(2021)
	DEPPUB	Public Expenditure	WDI(2021)
	FIND	Financial Development	WDI(2021)
	DEMC	Population Growth	WDI(2021)

Source : Authors, based on literature

After the description and presentation of the sources of the variables of the study, we can proceed to a step, that of providing the main results.

Results and Discussion

The preliminary tests will be analyzed on the one hand, and on the other hand, the interpretation and discussion of the estimation parameters.

Analysis of preliminary test results

We present the results of the descriptive analysis, stationarity tests, and linearity tests in turn. At the descriptive analysis level, Table 2 presents the descriptive statistics for the SSA data set for the period 2000-2019.

Table 2. Descriptive Statistics for SSA Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
GDPR	600	4.192704	4.224436	-36.392	33.6294
INFL	600	8.732381	30.38124	-8.97474	513.907
DEPPUB	600	13.91175	5.521743	0.951747	39.4506
OUV	600	33.20201	18.06184	0.6094225	112.5115
INVEST	600	21.55316	8.555074	2.78114	81.021
FIND	600	29.09177	20.23407	2.85741	120.817
COR	600	-0.6418867	0.6244097	-1.55852	1.21674
DEMC	600	2.524444	0.8839065	-2.62866	5.60499

Source : Authors' calculations based on WDI(2021) and WGI(2021) data

Table 2 shows the average of the different variables, the minimum and maximum values, and their standard deviation. Economic growth is on average 4.2% with a standard deviation of 4.22. The high level of standard deviation shows that there is heterogeneity at the country level. The average inflation rate is about 8.7 percent over the same period with a standard deviation of 30.38, also reflecting high heterogeneity. However, it should be noted that over the study period, the inflation rate was more volatile than economic growth. Over the same period, the average level of public expenditure is estimated at 13.9%, and 33.2% for trade openness. The average investment rate is 21.5% and 29.1% for financial development. The average level of corruption control is -0.64% with a standard deviation of 0.624, indicating that corruption control is almost similar across the 30 countries in the sample. The average population growth rate is about 2.52% with a standard deviation of 0.88, indicating that the population structure does not vary too much across countries. Furthermore, the minimum and maximum of the different variables give very high ranges. This reveals great heterogeneity in the data and justifies the use of the PSTR model.

In terms of the analysis of correlations between our variables, the results are reported in Table 3. The correlation between inflation and real GDP growth is negative and significant with a small coefficient which shows that the linear relationship between inflation and growth is weak. The correlation between real GDP growth and financial development is negative and significant. There is also a weak negative and significant correlation between real GDP growth and government spending. These low correlation coefficients also indicate a weak negative linear relationship between real GDP growth and its variables. There is also a significant and positive correlation between real GDP growth, investment and population growth with low correlation coefficients, reflecting a weak linear relationship.

Table 3. Correlation matrix of model variables for SSA countries

Variables	GDPR	INFL	DEPPUB	OUV	INVEST	FIND	COR	DEMC
GDPR	1							
INFL	-0.1187*	1						
DEPPUB	-0.1682*	-0.0408	1					
OUV	-0.0072	0.0053	0.4298*	1				
INVEST	0.0889*	-0.0029	0.1294*	0.3973*	1			
FIND	-0.1038*	-0.092*	0.4428*	0.4768*	0.0971*	1		
COR	0.0512	-0.127*	0.4273*	0.3558*	0.0918*	0.5762*	1	
DEMC	0.1998*	0.0353	-0.332*	-0.405*	0.0903*	-0.623*	-0.4991*	1

Source: Authors' calculations based on WDI(2021) and WGI(2021) data

However, the relationship between real GDP growth rate and trade openness and control of corruption is not significant. On the other hand, there is a positive and significant linear correlation between government spending, trade openness, investment, financial development and control of corruption. There is also a weak positive and significant linear correlation between trade openness, investment, financial development and control of corruption. From Table 3, we note that the correlation coefficients between the explanatory variables are low, indicating a weak linear relationship between the variables.

The analysis of the stationarity of the series is presented in Table 4. According to the Pesaran (2007) test, we find that the real GDP growth rate, the inflation rate, trade openness and the population growth rate are stationary at the 1%

threshold. However, corruption control, financial development and investment are stationary at the 5% threshold and public expenditure at the 10% threshold.

Table 4: Test de Pesaran (2007)

VARIABLES	Critical values and decisions		
	CIPS	**Critical Value**	**RESULTS**
GDPR	CIPS* = -3.87***	-2.32	Stationary
INFL	CIPS* = -3.57***	-2.32	Stationary
DEPPUB	CIPS = -1.54*	-1.47	Stationary
OUV	CIPS* = -2.89***	-2.67	Stationary
COR	CIPS = -1.64**	-1.58	Stationary
INVEST	CIPS = -1.63 **	-1.58	Stationary
FIND	CIPS = -2.19**	-2.15	Stationary
DEMC	CIPS* = -2.682 ***	-2.32	Stationary

Source : Authors' calculations based on WDI(2021) and WGI(2021) data
Note : Significance levels (***) means a p-value < 0.01, (**) a p-value < 0.05, and (*) a p-value < 0.1

After these statistical precautions, we can now present the results of the tests of linearity, residual non-linearity and the optimal number of transition functions. The results of the linearity tests reported in Table 5, reject the null hypothesis of linearity of the model with respect to a PSTR specification. Indeed, the linearity tests, based on the Wald (LM), Fisher (LMF) and LRT statistics, unanimously reject the null hypothesis (H0) of a linear relationship between inflation and economic growth in SSA countries at the 1% threshold.

Table 5. Linearity test

H_0 : Linear model	H_1 : PSTR model with at least one threshold variable (r=1)		
Transition variable	Tests	Statistics	P-value
INFL.	Wald Tests (LM)	29.63	0.000
	Fisher Tests (LMF)	4.17	0.000
	LRT Tests (LRT)	30.43	0.000

Source : Authors' calculations based on WDI(2021) and WGI(2021) data

With the linearity hypothesis rejected, the second step is to determine the optimal number of transition functions. The results of these tests based on the same statistics (LM, LMF and LRT), reported in Table 6, show that the hypothesis that there are at least two thresholds is rejected. It follows that the optimal number of transition functions is less than two. Note that in a PSTR model, a single threshold or two extreme regimes are sufficient to account for the nonlinearity. This means that in the context of SSA countries, the relationship between inflation and economic growth has only one threshold or two regimes.

Table 6. Residual non-linearity test

H_0 : PSTR with r= 1 versus H_1 : PSTR with at least r=2			
Transition variable	Tests	Statistics	P-value
INFL	Wald Tests (LM)	9.55	0.216
	Fisher Tests (LMF)	1.26	0.267
	LRT Tests (LRT)	9.63	0.211

Source : Authors' calculations based on WDI(2021) and WGI(2021) data

Given the evidence of nonlinearity, we estimate the PSTR by applying the nonlinear least squares technique.

Interpretation of estimated parameters

The results of the PSTR estimates are presented in Table 7. The columns show the parameters of the transition variables used, and the rows show the parameters of β_0 and β_1 of each control variable.The third row of Table 7, presents the results, of the threshold parameter C, the interest variable, the inflation rate and the parameter γ. The estimated threshold is 11.64% with $\gamma =$ 16733. The coefficient on the variable of interest is significant at the 1% threshold. The inflation rate has a negative and significant parameter β_0 and a positive and significant parameter β_1. From these figures, it follows that in SSA, when the inflation rate is below 11.64%, inflation has a significant negative effect on growth. However, when the inflation rate is above 11.64 percent, it has a significant positive effect on growth.

Table 7. Parameter estimation using PSTR, 2000-2019

Dependent variables : real GDP growth rate (GDPR)								
$G(q_{it};\gamma,c)$	**INFL**		**FIND**		**DEPPUB**		**OUV**	
γ	**16733**		**20.02**		**10628**		**0.54**	
C	**11.64**		**23.61**		**11.14**		**44.5**	
Param.	β_0	β_1	β_0	β_1	β_0	β_1	β_0	β_1
INFL	-0.14*** (-2.55)	0.11** (2.04)	-0.02*** (-3.9)	-0.09*** (-2.8)	-0.24*** (-5.91	0.21*** (5.33)	-0.10* (-1.85)	- 0.03*** (-3.96)
DEPPUB	-0.20** (-2.27)	0.32*** (3.7)	-0.13 (-1.18)	-0.03 (-0.35	-1.73*** (-6.81)	1.63*** (6.19)	-0.06 (-0.37)	-0.16 (0.62)
INVEST	0.04 (0.67)	-0.06 (-1.12)	0.09*** (2.77)	-0.03 (-0.85)	-0.24*** (-4.44)	0.33*** (6.48)	0.42* (1.91)	-0.37 (-1.71)
OUV	0.10*** (2.66)	-0.01 (-0.18)	0.08 (1.21)	-0.06 (-0.76)	-0.19 (-1.30)	0.18 (1.38)	-0.13 (-1.77)	0.21*** (2.8)
FIND	-0.04 (-1.55)	-0.26*** (-4.85)	-0.44*** (-4.54)	0.44*** (4.35)	0.16 (1.77)	-0.20** (2.24)	0.47*** (4.55)	-0.5*** (-4.8)
COR	0.44 (0.50)	-0.23 (-0.19)	1.11 (1.23)	-0.03 (-0.03)	9.20*** (3.62)	-7.92** (-2.24)	-3.76** (-2.02)	-5.4*** (-2.84)

DEMC	1.92** (2.16)	0.58 (0.92)	3.05*** (2.3)	-2.10* (-1.88)	13.13*** (13.35)	-12.03*** (-14.39)	-4.54** (-1.97)	4.2* (1.83)

Source : Authors' calculations based on WDI(2021) and WGI(2021) data
Note : Significance levels (***) means a p-value < 0.01, (**) a p-value < 0.05, and (*) a p-value < 0.1

The gamma parameter of the transition function ($\gamma = 16733$) is very high, reflecting according to Gonzalez et al (2005), a sharp transition in both regimes (low and high). According to Ibarra and Trupkin (2011) and Sall (2020), when the transition is abrupt, the direct effect of inflation on real GDP growth is given by $\beta 0$ for countries with inflation less than or equal to C and by (β_0 + β_1) for countries with inflation greater than C. In other words, when countries with inflation rates below 11.64%, experience an increase in the inflation rate of 1%, economic growth decreases by 0.14% (β_0 = -0,14) while for countries with inflation rates above 11.64%, an increase in the inflation rate of 1%, reduces economic growth by 0.03% (β_1= 0,11 et $\beta 0 + \beta 1$= -0,03).

The effect of inflation on economic growth in SSA countries is not identical, reflecting the existence of heterogeneous subgroups. To identify the source of this heterogeneity, we split our sample into several subgroups (Southern Africa, Central Africa, West Africa, East Africa and the WAEMU zone). Table 8 presents the results of the parameter estimates of the PSTR model for Southern Africa. The results indicate an optimal threshold of 10.06% with a sharp transition for this group of countries. The negative parameter β_0 shows that for Southern Africa, low inflation rates have a negative effect on economic growth. While the positive parameter β_1 indicates a positive effect of inflation on growth, when the inflation rate is above 10.06%. In contrast to the 12.77% threshold estimated by Ndoricimpa (2017) for SADC, this 10.06% threshold is low. In this part of Africa, inflation rates are high, in large part, due to increased inflationary pressures in Angola and Zimbabwe. For example, in 2019, average annual inflation exceeded the subregional inflation target range of 3 to 7 percent. The economic structure of these countries allows them to have inflation rates around 10% without affecting economic growth. The effect of inflation on growth is low with the increase in public spending, above 24.11% of GDP, and with trade openness, above the 77.98 threshold.

Table 8. Results of PSTR model parameter estimates for Southern Africa

SOUTHERN AFRICA					
Variable of interest	**Param.**	**INFL**	**FIND**	**DEPPB**	**OUV**
Inflation	β_0	-0.199*** (-3.51)	-0.08*** (-2.67)	0.07*** (-2.97)	0.35** (2,16)
	β_1	0.152*** (2.60)	-0.19*** (-2.81)	-0.11** (-2.18)	-0.23*** (-3.19)
Parameter of the transition function.	γ	113.8	44.04	1.18	74.27
	C	10.06	40	24.11	77.98

Source : Authors' calculations based on WDI(2021) and WGI(2021) data
Note : Significance levels (***) means a p-value < 0.01, (**) a p-value < 0.05, and (*) a p-value < 0.1

For the Central African countries (CEMAC), the results in Table 9 reveal an optimal threshold of 4.39% with a smooth transition. Compared to the threshold estimated for SSA (11.64%) and for Southern Africa (10.06%), this threshold of 4.39% is low and above the 3.17% estimated by Prao (2019). However, this threshold confirms the 4.3% threshold found by N'Djokou and Tsopmo (2017). For this estimate, 0 is positive and statistically significant, and 1 is negative. This shows that at low levels, the increase in the inflation rate has a positive effect on growth in CEMAC countries. However, above the 4.39 percent threshold, any increase in the inflation rate of 1 percent, all other things being equal, reduces growth by 0.38 percent. In this part of Africa, the money supply and imported inflation explain most of the price evolution according to Bikai et al (2016). The effect of inflation on economic growth is weak with the increase in public spending, above 7.53% of GDP. On the contrary, too much trade openness amplifies the effect of inflation on economic growth in CEMAC countries (above the threshold of 46.56). Indeed, these are countries that import a great deal to satisfy the consumption of their populations.

Table 9. Results of PSTR model parameter estimates for Central Africa (CEMAC)

CENTRAL AFRICA (CEMAC)					
Variable of interest	**Param.**	**INFL**	**FIND**	**DEPPB**	**OUV**
Inflation	β_0	1.33* (1.86)	-0.53*** (-2.51)	0.58** (2.15)	-3.34*** (-7.15)
	β_1	-1.71*** (-4.25)	0.47 (1.45)	-0.66*** (-2.51)	0.94*** (2.92)
Parameter of the transition function	γ	3.06	0.36	651.8	1.53
	C	4.39	16.77	7.53	46.56

Source : Authors' calculations based on WDI(2021) and WGI(2021) data
Note : Significance levels (***) means a p-value < 0.01, (**) a p-value < 0.05, and (*) a p-value < 0.1

Table 10 presents the results of the estimates for the East African countries. The estimated threshold is 6.19%, well below 8.46%, found by Yabu and Kessy (2015), for the founding countries of the East African Community (Kenya, Tanzania, and Uganda). This estimate yields a positive and statistically significant β_0 and a negative β_1. This shows that in East Africa, at low levels of inflation, an increase in the inflation rate has a positive effect on growth up to the 6.19 percent threshold. Above this threshold, a 1% increase in the inflation rate reduces growth by 0.13%. We also see that the negative effect of inflation on economic growth is amplified with an increase in public spending (above 11.01% of GDP) and trade openness (above the threshold of 15.78).

Table 10. Results of PSTR model parameter estimates for East Africa

EAST AFRICA					
Variable of interest	**Param.**	**INFL**	**FIND**	**DEPPB**	**OUV**
Inflation	β_0	0.49*** (4.83)	-0.20** (-2.05)	-0.28*** (-3.15)	-0.86*** (-5.27)
	β_1	-0.62*** (-5.16)	0.16 (1.47)	0.19** (2.07)	0.81*** (4.95)
Parameter of the transition function	γ	122	805.8	682	11.92
	c	6.19	20.2	11.01	15.78

Source : Authors' calculations based on WDI(2021) and WGI(2021) data
Note : Significance levels (***) means a p-value < 0.01, (**) a p-value < 0.05, and (*) a p-value < 0.1

For ECOWAS, as presented in Table 11, the estimated threshold is 11.58% with a high gamma parameter that shows that the transition is abrupt. This threshold is between 8.01 and 15.46%, the range proposed by Barcola and Kabola (2018), for West Africa. Here, the β_0 parameter is positive and significant and a negative and significant β_1. This reveals that at low levels, the increase in the inflation rate has a positive effect on growth up to the 11.58% threshold. However, after the 11.58% threshold, a 1% increase in the inflation rate reduces growth by 0.17%. The negative effect of inflation on economic growth in West African countries is amplified with financial development (above the threshold of 24.86) and increased public spending (above 10.57% of GDP). However, trade openness reduces the negative effect of inflation on economic growth (above the 20.01 threshold). Regarding the counterintuitive effect of financial development, there are several channels through which high levels of financial development can harm economic growth. Excessive financial development creates sophisticated products, sometimes disconnected from the real economy, which increases the frequency and size of credit and asset price collapses. Such a situation is conducive to financial crises that can lead to severe recessions that can put a lasting brake on economic growth.

Table 11. Results of PSTR model parameter estimates for West Africa (ECOWAS)

WEST AFRICA (ECOWAS)					
Variable of interest	**Param.**	**INFL**	**FIND**	**DEPPB**	**OUV**
Inflation	β_0	1.10*** (3.58)	-0.35*** (-3.65)	-0.25*** (-3.44)	0.16** (2.12)
	β_1	-1.27*** (-4.05)	0.31*** (3.21)	0.24*** (2.88)	-0.27*** (-3.06)
Parameter of the transition function	γ	758	339	206	788.12
	C	11.58	24.86	10.57	20.01

Source : Authors' calculations based on WDI(2021) and WGI(2021) data
Note : Significance levels (***) means a p-value < 0.01, (**) a p-value < 0.05, and (*) a p-value < 0.1

For the WAEMU zone, as shown in Table 12, the estimated threshold is 3.92% with β_0 positive and β_1 negative. The negative β_1 means that an increase in the inflation rate above 3.92% has a negative effect on economic growth in WAEMU countries. Indeed, above the 3.92% threshold, a 1% increase in the inflation rate reduces growth by 0.39%. This threshold is in line with the 3.9% estimated by Sall (2020), but lower than the 8.05% found by Combey and Nubukpo (2010) and the 11.3% estimated by Prao (2019). In the WAEMU zone, the negative effect of inflation on economic growth in West African countries is amplified by financial development (above the 22.48 threshold) and increased public spending (above 10.63 of GDP). However, trade openness reduces the negative effect of inflation on economic growth (above the 25.25 threshold). The ability of these countries to purchase intermediate consumption at low prices from abroad enables them to provide goods and services within the reach of the population. Indeed, in the WAEMU zone, inflation is largely linked to the rising cost of imported inputs.

Table 12. Results of PSTR model parameter estimates for the WAEMU zone

WAEMU ZONE					
Variable of interest	**Param.**	**INFL**	**FIND**	**DEPPB**	**OUV**
Inflation	β_0	0.07 (0.91)	-0.50** (-2.22)	-0.24 (-1.48)	0.18*** (2.73)
	β_1	-0.46*** (-2.83)	0.68*** (2.70)	0.45** (2.03)	-0.28* (-1.83)
Parameter of the transition function	γ	4.853	467.13	0.46	305.8
	C	3.92	22.48	10.63	25.25

Source : Authors' calculations based on WDI(2021) and WGI(2021) data
Note : Significance levels (***) means a p-value < 0.01, (**) a p-value < 0.05, and (*) a p-value < 0.1

At this stage of the study, we note a heterogeneity of thresholds, which could be due to the different levels of development of countries. Therefore, to take this specificity into account, we examined the influence of certain macroeconomic variables on the optimal inflation rate. In addition, we distinguished between low-income and middle-income countries. The results of the estimated optimal inflation threshold for low-income and middle-income countries are shown in Table 13. The results indicate an optimal threshold of 5.38 percent for low-income countries, indicating that below this threshold, an increase in the inflation rate has a positive effect on economic growth and a negative effect above the threshold.

Table 13. Results of the PSTR model estimates for low- and middle-income countries

The parameters of the transition function		Low Income Countries	Middle Income Countries
Smoothing parameter	γ	700	240
Slope parameter	C	5.38	11.64
INFLATION	β_0	0.24*** (4.13)	-0.16*** (-3.16)
	β_1	-0.26*** (-4.38)	0.08 (1.37)

Source : Authors' calculations based on WDI(2021) and WGI(2021) data
Note : Significance levels (***) means a p-value < 0.01, (**) a p-value < 0.05, and (*) a p-value < 0.1

For middle-income countries, the inflation threshold determined and presented in Table 13 is 11.64%. For these countries, below the 11.64% threshold, the inflation rate has a negative and significant effect on economic growth and a non-significant positive effect of inflation on growth above this threshold. This result reveals that the threshold of 11.64% is not optimal for low-income countries, because for these countries, beyond 5.38%, inflation has a negative effect on their growth. On the other hand, for middle-income countries, the threshold of 11.64% is optimal in the sense that the effect of inflation is positive from this threshold. This result sheds important light on the fact that in SSA, when the average income of the population increases, low inflation rates are no longer optimal for economic growth in these countries. However, for low-income countries, above 5.38%, inflation has a negative effect on economic growth. It follows that the economic development of a country influences its optimal inflation rate. The high threshold of 11.64% for all SSA countries and for middle-income countries is probably due to a Balassa-Samuelson effect. Indeed, according to this effect, during economic catch-up, emerging countries experience an increase in the general price level, due to a rise in productivity in the tradable sector, linked to an appreciation of the real exchange rate, and an increase in demand induced by the rise in intertemporal income. Eggoh and Khan (2014) previously reported that the optimal inflation threshold for countries was strongly influenced by changes in macroeconomic variables. Our results indicating a higher inflation threshold, for middle-income countries, than for low-income countries, confirm their findings. Table 7 above summarizes the inflation thresholds obtained under the influence of three macroeconomic variables, namely financial development, trade openness and government spending.

Regarding the level of financial development, it is found that the negative effect of inflation on economic growth is small when the financial development regime is below 23.61 percent while this negative effect is more pronounced for a financial development regime above 23.61 percent. The implication is that in SSA, countries with a more developed financial system should avoid inflation rates higher than the optimal rate. In SSA, the level of financial development influences the level of the optimal inflation rate.

The estimated threshold for public expenditure is 11.14%, and it is found that for a public expenditure regime below this threshold, inflation has a negative effect on economic growth. This effect becomes positive in a public spending regime above 11.14%. Inflation driven by an increase in public investment spending is beneficial to economic growth. It follows that the optimal level of inflation depends on the level of public spending.

With regard to trade openness, the negative effect of inflation on economic growth is weak in a trade openness regime below 44.5%. However, above this threshold, the negative effect of inflation on economic growth is more pronounced. The implication is that SSA countries with high trade openness need to be careful about imported inflation that may affect economic growth. Ultimately, our results establish that the level of economic development, government spending, and trade openness influence the effect of inflation on economic growth in SSA countries. These variables should therefore be considered by monetary authorities and policy makers in the implementation of economic policies in SSA.

To check the robustness of our estimation, we used the dynamic panel generalized method of moments (GMM) (Blundell et al. 2000). The results of the non-linear GMM estimates, presented in Table 14, indicate that all signs of the GMM coefficients are consistent with those of the PSTR estimate. Furthermore, the results show that there is no autocorrelation in the GMM estimation in the nonlinear system, attesting that our results are not biased.

Table 14. Results of GMM estimations in non-linear system

VARIABLES	GDPR
L.GDPR	0.184*** (0.022)
INFL	-0.031*** (0.007)
$INFL^2$	0.001*** (0.000)
DEPPUB	-0.085** (0.031)
OUV	0.029*** (0.007)
INVEST	0.009 (0.011)

FIND	0.016 (0.016)
COR	0.604 (1.032)
DEMC	1.488** (0.583)
Observations	570
Number of ID_Countries	30
AR(1)	0.00316
AR(2)	0.792
Hansen	1
Sargen	0.729
Number of Instruments	221

Source : Authors' calculations based on WDI(2021) and WGI(2021) data
Note : Significance levels (***) means a p-value < 0.01, (**) a p-value < 0.05, and (*) a p-value < 0.1

Conclusions

The purpose of this paper is to determine the optimal threshold of inflation on economic growth in 30 SSA countries over the period 2000-2019. To determine this optimal threshold, in line with recent empirical studies on the non-linearity between inflation and growth, we applied the PSTR model of Gonzalez et al (2005). The results obtained from the estimations confirm the non-linearity between inflation and economic growth in SSA. The optimal threshold for inflation estimated for this effect is 11.64% with a negative effect of inflation below the threshold and a positive effect above the threshold. Our results indicate that this non-linearity is conditioned by the level of economic development of SSA countries. Indeed, in this study, the level of country-specific macroeconomic variables affects the degree of sensitivity of the relationship between inflation and economic growth. The results indicate that the degree of trade openness, the level of financial development, and government spending are macroeconomic variables that modify the non-linearity of the inflation-growth relationship over time and across countries. As a result, specific characteristics related to the macroeconomic environment of certain countries determine both their optimal level of inflation and the welfare cost of inflation. The study shows, for example, that trade openness makes inflation more costly for some countries with higher trade openness (East Africa and CEMAC). For other countries, an increase in public spending makes inflation less costly for economic growth (Southern Africa, CEMAC). To take into account the level of development of countries in the relationship between inflation and economic growth in SSA, we divided our panel into two sub-panels, composed of low-income countries and middle-income countries. The results obtained after estimation revealed an optimal low inflation threshold of 5.38% for low-income countries and an optimal high inflation threshold of 11.64% for middle-income countries. Such a result finds its explanation, following Khan (2014), in the development dynamics of countries with higher productivity growth, and a higher average price level called the "Balassa-Samuelson effect", introduced by Balassa (1964) and Samuelson (1964). The latter could explain the estimated high inflation threshold in SSA, especially in middle-income countries. At the level of the various SSA subregions, the results of the estimates revealed that the inflation thresholds differ from one zone to another : 10.06% for Southern Africa, 4.39% for Central Africa (CEMAC), 6.19% for East Africa, 11.58% for West Africa (ECOWAS) and 3.93% for WAEMU.

The main lesson of this study is that as SSA moves from low-income to middle-income countries, low inflation rates become non-optimal, and high inflation rates become optimal for their economic growth. Thus, our results suggest that the determination of the optimal inflation threshold is done at each stage of economic development of countries. Furthermore, it reveals that the optimal inflation threshold depends on the evolution of a country's macroeconomic variables. It follows that the determination of inflation targets by monetary authorities requires the use of more sophisticated econometric techniques that can include a large number of control variables.

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