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Inflation-Growth Nexus in the CFA Franc Zone and BRICS: Evidence from Panel Threshold Regression Estimation

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Abstract
This paper examines the impact of inflation on economic growth in a panel of 13 African countries in the franc zone (CFA) and BRICS. Contrary to previous studies that focus on a linear relationship, the present study uses the Panel Smooth Transition Regression model to examine this relationship. The results of this method strongly support the idea that the relationship between inflation and growth is non-linear with a threshold of 3.17% in the Central African Economic and Monetary Union (CAEMU), 11.30% for the West African Economic and Monetary Union (WAEMU) and 7.04% for the BRICS. In particular, the study indicates that the 2% target set by the BCEAO for WAEMU countries can be revised upwards without adversely affecting growth. For the BRICS, they should avoid inflation rates above 7%.
Keywords: inflation; growth; monetary policy; threshold effects; dynamic panel; WAEMU; CAEMU; BRICS.
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1. Introduction

In almost all countries, one of the objectives of macroeconomic policies is to achieve a high growth rate with a low inflation rate. However, inflation and economic growth are intertwined in complex ways, leading to many controversies, the most famous of which is the relevance of the Phillips curve. However, a very controversial issue is about the relationship between economic growth and inflation. Previous theories and studies on the relationship between inflation and economic growth have shown that there may be no relationship (Sidrauski, 1967), or a negative relationship (Fisher, 1993) or even a positive relationship (Mallik and Chowdhury, 2001) between these two variables. There was a consensus on the fact that macroeconomic stability, specifically low inflation, is positively associated with growth rates. Indeed, macroeconomists, central bankers and policy-makers have often pointed to the costs associated with high and variable inflation. In fact, inflation imposes negative externalities on the economy when it affects the efficiency of the economy. An increase in inflation means a decrease in the purchasing power of the currency, which reduces consumption and, consequently, GDP decreases. In addition, high inflation can make investments less profitable, as it creates uncertainty about the future and can also negatively affect the balance of payments by raising export prices. It therefore seems that GDP is negatively linked to inflation. For example, Barro (1995) indicates that high inflation reduces the level of investment and that a reduction in investment is detrimental to economic growth. Gultekin (1983) also explains the negative relationship between inflation and economic growth through rates of return. The growth rate depends on the rates of return, but a decrease in the latter due to inflation has a negative impact on it. In reverse, the Phillips curve shows that high inflation is compatible with low unemployment rates, which implies that there is a positive impact on economic growth. According to the Keynesian theory, inflation can be beneficial to growth through the profit rate, which increases private investment. These different theoretical perspectives underpin the debates on the existence of a non-linear relationship between inflation and economic growth and the question of determining the optimal inflation threshold. The various empirical studies indicate that inflation has negative effects on growth above a certain threshold. However, this non-linearity is discussed (Burdekin et al. 2004). One possible explanation for this lack of consensus is that the inflation-growth relationship depends on differences in the specific characteristics of each country and therefore on the degree of sensitivity as well as the nature of this relationship. In addition, it indicates that the inflation-growth relationship is conditioned by a country-specific and time-specific structural break (Khan and Senhadji, 2001). Moreover, as these authors point out, since inflation can be considered a characteristic of underdeveloped economies, this structural disruption is strong for these economies compared to developed economies. Specifically, the effects of inflation on growth are subject to certain macroeconomic developments that systematically differ from one country to another, such as financial deepening, trade openness, public spending and capital accumulation. Within the Central African Economic and Monetary Community (CEMAC), the monetary policy is managed by an issuing institution, namely the Bank of Central African States (BEAC), and the Community standard for raising the general price level is 3%. Economic growth in this area rose from 1.2% in 2001 to 7.7% in 2004 and 4.6% in 2008 then 5.8% in 2012. This rate fell from 1.8% in 2015 to -0.4% in 2016. The inflation rate rose from 4.4% in 2001 to 0.5% in 2004, 5.9 in 2008 and 3.7% in 2012. It was around 2.5% in 2015 and 1.1% in 2016. In the WAEMU zone, the monetary policy of the Central Bank of West African States (BCEAO) consists in regulating the evolution of the money supply according to objectives such as price stability or the recovery of economic activity. For example, the 1%

reduction of the inflation rate in the Union as a whole requires a cumulative decrease of 0.6% in the area's growth rate (Dramani and Thiam, 2012). Over the last ten years (2002-2011), the average growth rate in the Union was 2.9% with a standard deviation of 1.4 percentage points. The WAEMU real GDP growth rate increased from 0.5% in 1992 to 6.5% in 1996 and then 1% in 2002 to 4.2% in 2008 (BCEAO, 2013). For the BRICS, over the period 2000-2011, South Africa recorded an average growth rate of 3.6%, 4.8% for Russia, 7.8% for India, 10.6% for China and 3.8% for Brazil. Despite a drop in commodity prices and a very weak global economic recovery, China's and India's growth rates in 2015 were 6.9% and 7.6% respectively, according to the International Monetary Fund (IMF). Over the period 2016-2017, India posted a comfortable growth rate of 7.6%. As for Russia, the growth rate fell from -2.8% in 2015 and then 0.2% in 2016 to 1.5% in 2017. Between 2015 and 2017, the inflation rate rose from 12% to 2.5% in 2017. These contrasting trends in inflation and economic growth corroborate several studies on the relationship between inflation and growth indicating a non-linear relationship with different thresholds. One of the reasons for the disparity in the results is that inflation is considered exogenous before testing its effect on growth. From these studies, questions emerge. First, are the adverse effects of inflation on economic growth insensitive to the level of economic development? Second, at what level does inflation inhibit long-term growth? And third, to what extent does the link between inflation and growth depend on the specific characteristics of countries? Thus, the general objective of this study is to highlight the specificities of the franc zone, compared to other countries, in terms of inflation threshold. Specifically, the optimal inflation rates for the CEMAC zone, the WAEMU zone and the BRICS will have to be determined. The choice of BRICS is explained by the fact that all African countries in the franc zone have adopted plans to become emerging economies. In relation to our objective, we assume that franc zone countries pursue restrictive monetary policies.

This study is not lacking in interest and challenge. Indeed, in the case of African countries in the franc zone, the question of the links between inflation and growth is of particular interest in several respects. Indeed, the high poverty rate prevailing in the area requires the achievement of the high growth rates necessary to reduce poverty. These challenges are particularly acute for African central banks, which are responsible for price stability and the preservation of the internal and external value of currencies. In the case of rich countries, a structurally low level of inflation not only distorts economic activity, but can also increase the risk of deflation. The study contributes to advancing the literature on the relationship between the rate of inflation and the rate of economic growth.

From a methodological point of view, this study adopts the procedure for identifying the endogenous threshold in the Hansen (2000) way. The study uses annual data covering the period from 1990 to 2016. The choice of this period is due to the unavailability of data for some of the countries studied. This article is organized as follows. Section 2 is devoted to literature review. Section 3 will present the specification of the econometric model and data sources. Section 5 will deal with the empirical results and section 6 with the conclusion.

2. Review of Literature

The relationship between inflation and growth has been the subject of much theoretical and empirical input. In theoretical terms, Mundell (1965) and Tobin (1965) predict a positive relationship between inflation and capital accumulation, which ultimately implies a positive impact on growth. What the economic 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, resulting in a substitution between resources in favour of real assets. In this way, capital accumulation will stimulate the rate of economic growth. Considered a necessary "lubricant" for a well-functioning economy, inflation can be positively correlated with growth. From this perspective, in the case of price and wage rigidity, a certain level of inflation can allow relative prices to adjust in response to structural changes in output during periods of economic transition (Lucas, 1973; Akerlof, Dickens and Perry, 1996; Kiley, 2000). Already, in a very influential book on the monetary history of the United States from 1867 to 1960, Friedman and Schwartz (1963) show that money plays an essential role in economic fluctuations. The Phillips curve also highlights an inverse relationship between inflation and unemployment. Keynesian and New-Keynesian theories highlight an explicit relationship between inflation rate and growth in the AS-AD model. According to the latter, there is a short-term trade-off between output and inflation rate, but it is not permanent.

In neoclassical models, the inflation rate has a negative impact on the investment rate and capital accumulation. Thus, Fisher (1993) shows that the relationship between inflation and economic growth is negative where Sidrauski (1967) believed that there was no relationship between the two variables. Challenging the relationship between inflation and unemployment, Phelps (1967) and Friedman (1968), then Sargent and Wallace (1975), showed, through the introduction into Keynesian models of so-called adaptive and then rational expectations, the non-existence of the Phillips curve. The literature on the negative effects of inflation on long-term economic growth is based on the idea that high inflation increases economic inefficiencies and reduces growth through lower investment and productivity growth rates (Fischer, 1993). Empirically, there are many studies and they are very controversial. Regional empirical studies have confirmed a negative relationship between inflation and economic growth: De Gregorio (1992) for Latin America; Fischer, Sahay and Vegh (1996) for transition economies; Gillman, Harris and Matyas (2004) for OECD and APEC countries. The main conclusion of these studies is that inflation hinders the efficient allocation of resources by distorting the signaling of price changes and causing various inefficiencies in reducing output. On the contrary, studies focusing on the sample of developing countries have shown a positive relationship between inflation and economic growth. For developing economies, inflation would contribute positively to economic growth by stimulating both savings and investment (Baer, 1967; Georgescu-Roegen, 1970; Taylor, 1983). Faced with financing budget deficits, developing country governments often resort either to borrowing from central banks or to tax resources linked to inflation. These resources can enable governments to increase capital formation by financing real investment. As long as this financing mechanism does not crowd out private sector investment, inflationary financing contributes to economic growth. Ghosh and Phillips (1998), using a sample of 145 countries over the period 1960 to 1996, found that at a low level of inflation rates (less than 3%), inflation and economic growth are positively correlated. However, they are negatively correlated with high inflation rates. More specifically, they found two non-linearities in the relationship between inflation and growth. The relationship between the two seems to be negative for very low inflation rates (about two to three percent). They also found a negative correlation for higher values, but the relationship was convex, meaning that a decline in growth associated with a 10-20% increase in inflation was more significant than that associated with a 40-50% increase in inflation. In the case of four South Asian countries, Malik and Chodhurry (2001) examine the short- and long-term dynamics between inflation and economic growth. They find that inflation is not harmful to growth in the short term but can hinder it in the long term. Moreover, Bruno and Easterly (1996) found that the relationship between the two variables only exists if inflation rates are high. To determine high inflation rates, they set a threshold of 40%. Above this threshold, inflation has a negative temporal impact on growth, while below this threshold, they have not found a robust relationship. Sarel (1996) shows a non-linearity relationship between inflation and growth, with an inflation threshold around 8% that would shift the sign of the inflation-growth relationship from a positive value to a negative value. Drukker et al (2005) conducted a study on a large sample of 138 countries covering the period 1950-2000. Based on the threshold level detection technique recommended by Hansen (1999) on dynamic panel models, they find that above the 19.6% inflation threshold level, any increase in inflation reduces economic growth. However, for developed countries, they find two thresholds (2.57% and 12.61%). Similarly, Khan and Senhadji (2001) find that the acceptable level of inflation is in the range of 1% to 3% for developed countries and 11 to 12% for developing countries. Based on a sample of 44 countries over the period 1961-2007, López-Villavicencio and Mignon (2011) find that inflation has a positive impact on growth with a threshold of 5% for the entire sample, 1.23% for developed countries, 14.54% for emerging countries, 10.27% for middle-income countries and 19.64% for low-income countries, respectively. For 32 Asian countries, Vinayagathasan (2013) indicates an inflation threshold of 5.43% above which inflation is detrimental to economic growth but has no effect below this level. Most recently, for 47 African countries, Ndoricimpa (2017) examines non-linearities in the link between inflation and growth. A dynamic panel threshold regression is applied to account for the potential endogeneity bias in the model. The results of this study confirm the existence of non-linearities in the link between inflation and growth. An inflation threshold of 6.7% is estimated for the entire sample, 9% for the sub-sample of low-income countries and 6.5% for middle-income countries. The results suggest that low inflation stimulates growth for the middle-income sub-sample, but does not affect economic growth for the entire sample or for the low-income sub-sample. However, inflation above the threshold is detrimental to economic growth in all cases considered. For the WAEMU zone, Combey and Nubukpo (2010) highlighted the existence of a non-linear relationship between the inflation rate and the economic growth rate and determined the inflation threshold (8.1%) from which an arbitrage between inflation and growth is effective. For CEMAC, over the period 1987-2008, Bikai and Kamgna (2011) identified an optimal inflation threshold of 6% in CEMAC.

3. Econometric Methodology

This section presents the Hansen threshold effect method and the inference indicated for the PTR model. This is a necessary step before the model can be estimated.

3.1. Presentation of the Hansen Threshold effect Method

To examine the inflation-economic growth relationship, we use a threshold panel model. Threshold effect models are an instrument for analysing non-linear economic phenomena, allowing economic series to have different dynamics depending on the regimes in which they operate. 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 modelling: the modelling proposed by Hansen (1999) and

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that of Gonzalez et al (2005).

In Hansen's (1999) study, non-linearity is reflected in the fact that the dependent variable is generated by two distinct processes. We are in one process or another depending on the value taken by a transition variable. Hansen's (1999) modelling assumes that the transition between the two regimes is abrupt. Indeed, we are in the dynamics of one process or the other. In this study, we adopt the Hansen (1999) threshold effect model used by Im, Pesaran and Shin (2003) to characterize the non-linearity of a relationship between two or more variables in a regression model. The general specification of the threshold model is as follows:

$$y_{it} = u_i + \sum_{k=0}^{K-1} \beta_{k+1} x_{it} \, \mathbb{I}\,(\gamma_k < q_{it} \leq \gamma_{k+1}) + \beta_{K+1} x_{it} \, \mathbb{I}\,(\gamma_K < q_{it} \leq \gamma_{K+1}) + \varepsilon_{it} \quad (1)$$

Where the index i refers to the individual dimension with ($1 \leq i \leq N$) and t the time dimension with ($1 \leq t \leq T$). u_i represents the specific fixed effect for each country and the error term that is independent and identically distributed ((idd)) of zero mean and finite variance ($idd(0, \sigma_\varepsilon^2$).

In this model, the transition mechanism is modelled using an indicator function $\mathbb{I}\,(.)$ that takes the value 1 if the constraint between brackets is respected, and zero otherwise. It is defined by the threshold variable q_{it} and threshold parameter γ. y_{it} is the dependent variable and x_{it} is the vector of explanatory variables. It is also noted that $\gamma_0 = -\infty$ and $\gamma_{K+1} = +\infty$. Equation (1) allows us to obtain K threshold values and $(K+1)$ speeds. At the level of each regime, the marginal effect of $x_{it}(\beta_k)$ on y_{it} can then vary. In addition, following the analysis of Gong and Zou (2001) and Bick and Nautz (2008), we consider a constant discriminator that is not specifically individual but statistically captures the common effect for the entire time dimension. Ignoring (δ_k)in the model could lead to biased estimates of threshold values and, consequently, the impact of the corresponding marginal effects. With regard to this requirement, equation (1) becomes:

$$y_{it} = u_i + \sum_{k=0}^{K-1} (\beta_{k+1} + \delta_{k+1}) x_{it} \, \mathbb{I}\,(\gamma_k < q_{it} \leq \gamma_{k+1}) + \beta_{K+1} x_{it} \, \mathbb{I}\,(\gamma_K < q_{it} \leq \gamma_{K+1}) + \varepsilon_{it} \quad (2)$$

Where the difference between the interceptions of regimes is represented by δ_k. Equation (2) assumes that δ_k remains the same for all sections (time dimension) but is not specifically individual. It should also be noted that with this estimation method, two problems could arise: the estimation of individual effects common to the different regimes on the one hand and the estimation of slope coefficients and threshold parameters on the other. Consequently, it is impossible to estimate directly by OLS because the explanatory variables depend on the threshold parameters. To solve this problem, Bai (1997) and Fouquau et al (2008) advise to transform the model (2) as follows:

$$\tilde{y}_{it} = \tilde{u}_i + \sum_{k=0}^{K-1} (\beta_{k+1} + \delta_{k+1}) \tilde{x}_{it} \, \mathbb{I}\,(\gamma_k < q_{it} \leq \gamma_{k+1}) + \beta_{K+1} \tilde{x}_{it} \, \mathbb{I}\,(\gamma_K < q_{it} \leq \gamma_{K+1}) + \varepsilon_{it} \quad (3)$$

Where $\tilde{y}_{it} = y_{it} + \bar{y}_{it}$ with $\bar{y}_{it} = \frac{1}{T}\sum_{t=1}^{T} y_{it}$; $\tilde{u}_{it} = u_{it} + \bar{u}_{it}$ with $\bar{u}_{it} = \frac{1}{T}\sum_{t=1}^{T} u_{it}$; $\tilde{x}_{it}(\gamma) = x_{it}(\gamma) + \bar{x}_{it}(\gamma)$ with $\bar{x}_{it}(\gamma) = \frac{1}{T}\sum_{t=1}^{T} x_{it}(\gamma)$

Once the fixed effects have been eliminated, the approach consists in applying the Sequential Least Squares (SLS). Indeed, for fixed thresholds, it is possible to estimate the slope coefficients β. Thus, it is first estimated at $\hat{\beta}(\gamma)$ as follows:

$$\hat{\beta}(\gamma) = \left[\sum_{i=1}^{N}\sum_{t=1}^{T} \tilde{x}'_{it}(\gamma) \times \tilde{x}_{it}(\gamma)\right]^{-1} \left[\sum_{i=1}^{N}\sum_{t=1}^{T} \tilde{x}'_{it}(\gamma) \times \tilde{y}_{it}(\gamma)\right] \quad (4)$$

Then, the residual sum of squares (RSS):

$$RSS\,(\gamma) = \sum_{i=1}^{N}\sum_{t=1}^{T} (u_{it}^2) = \sum_{i=1}^{N}\sum_{t=1}^{T} (\tilde{y}_{it} - \hat{\beta}'(\gamma) x_{it}(\gamma))^2 \quad (5)$$

This approach should be repeated for all possible threshold values within an interval of Ω, which is defined to ensure a minimum number of observations in each regime. Chan (1993) and Hansen (1999) recommend that threshold parameters be used as optimal estimators $\hat{\gamma} = (\hat{\gamma}_1, \dots \dots, \hat{\gamma}_{k+1})$ which minimizes the residual sum of squares:

$$\hat{\gamma} = \arg minRSS\,(\gamma) \quad (6)$$

With $\gamma \in \Omega$

Slope coefficients $\hat{\beta}'(\gamma)$ are then obtained again using the Ordinary Least Squares (OLS) calculated at $\hat{\gamma}$. From this, it is possible to deduce the empirical residual variance:

$$\partial^2 = \sum_{i=1}^{N}\sum_{t=1}^{T}\frac{1}{n(T-1)}\hat{u}_{it}^{*}\hat{u}_{it}^{*} = \frac{1}{n(T-1)}S(\hat{\gamma}) \quad (7)$$

After this treatment, we now introduce an intersection regime in a threshold model to eliminate the individual specific effect with standard fixed effects by transforming the slope coefficients β_k and β_{k+1} in β_1 and β_2 (in the case of two regimes). Thus, this particular form of a Hansen threshold effect model with two (02) regimes is written:

$$y_{it} = u_i + \beta_1 x_{it}\|(q_{it} \leq \gamma) + \delta_1\|(q_{it} \leq \gamma) + \beta_2 x_{it}\|(q_{it} \geq \gamma) + \epsilon_{it} \quad (8)$$

In this equation, $(q_{it} \leq \gamma)$ represents the intersection regime. This formulation of equation (8) assumes that the difference between the regime intersections, represented by δ_1, is not specifically individual but rather the same for all sections. Therefore, the slope estimates for each regime are identical to those of a regression using only observations from the regime that reflect the orthogonality of the explanatory variables $\|(x_{it} \leq x_m)$ and $x_i\|(x_{it} > x_m)$. They can be obtained by the OLS method. But if they are biased, then they have other consequences in the panel data threshold model. The model to be estimated becomes:

$$y_{it} = u_i + \beta_1 x_{it}\|(q_{it} \leq \gamma) + \delta_1\|(q_{it} \leq \gamma) + \beta_2 x_{it}\|(q_{it} \geq \gamma) + \epsilon_{it} \quad (9)$$

In this equation (9), the null hypothesis for testing the significance of the threshold must be extended by $\delta_1 = 0$ on the one hand, and the derivation of the asymptotic distribution of the threshold estimate is now based on the following additional technical assumption: $\delta_1 \to 0$ when $N \to \infty$ on the other hand.

This means that the difference in intercepts between the two regimes is "minimizable" in relation to the sample size, which is completely similar to the assumption regarding slope coefficients. This is why in the appendix to his article Hansen (1999) theoretically demonstrates that the expressions: $\theta' = [(\beta_2 - \beta_1)' - \delta_1]$ and $z_{it} = (x'_{it}1)C$ could be considered as additional regressors of the intersection regime (Im, Pesaran and Shin, 2003).

3.2 Inference in the PTR Model

•The linearity test

It is a crucial test to prove whether the threshold effect is statistically significant and vice versa to show that the relationship between the explanatory variables and the explained variable can be represented using a regime change model. To do this, a null hypothesis test of linearity is constructed against the alternative of a sudden transition model with a single threshold. More precisely, this test consists in testing the equality of the coefficients of the different regimes. In equation (9), the absence of threshold effect is represented by the following hypothesis:

$H_0: \beta_2 = \beta_1$ against $H_1: \beta_2 \neq \beta_1$

The test is then constructed by considering the threshold as being set at its estimated value. It is thus possible to use standard test statistics such as Fisher's:

$$F_1 = \frac{S_0 - S_1(\hat{\gamma}_1)}{\partial^2} \quad \text{where} \quad \partial^2 = \frac{1}{n(T-1)}S(\hat{\gamma}_1) \quad (10)$$

Where S_0 is the residual sum of squares of the linear model and $S(\hat{\gamma}_1)$ the residual sum of squares of the model at a threshold. However, since the estimator of the threshold parameter is obtained by maximizing the likelihood function of the observations, the distribution of the test statistics is not known. The resolution is based on Hansen's (1996) methodology.

•The test for determining the number of regimes

This test applies if there is a proven threshold effect. Its procedure is similar to the one used to test linearity. For example, to test whether the model has two regimes (null hypothesis $H_0: \beta_2 = 0$), or at least three regimes (alternative hypothesis alternative $H_1: \beta_1 \neq 0$), the following Fisher test is applied:

$$F_2 = \frac{S_1(\hat{\gamma}_1^*) - S_2(\hat{\gamma}_1^*, \hat{\gamma}_2^*)}{\partial^2} \quad (11)$$

where S_2 is the residual sum of squares of the three-regimes model. The null hypothesis of a single threshold is rejected in favour of at least two, if the value of F_2 is higher than the critical values simulated by bootstrap. If the null hypothesis of a threshold model is rejected, the process of determining the number of regimes continues. It is then necessary to test the null hypothesis of two thresholds $H_0: \beta_3 = 0$ against a model containing at least three $H_1: \beta_3 \neq 0$. The corresponding Fisher test F_3 is presented in equation (11) as follows:

$$F_3 = \frac{S_2(\hat{\gamma}_1^*, \hat{\gamma}_2^*) - S_2(\hat{\gamma}_1^*, \hat{\gamma}_2^*, \hat{\gamma}_3^*)}{\partial^2} \quad (12)$$

Where S_3 is the residual sum of squares of the four (04) regimes model. If the null hypothesis is rejected, the specification must contain at least four regimes, and the process should continue until the null hypothesis[1] is not rejected.

• **Confidence interval on the threshold**

When the threshold effect is proven and the number of regimes is determined, Chan (1993) and Hansen (1999) show that the thresholds obtained $\hat{\gamma}$ are convergent estimators of true values and that the asymptotic distribution of these is non-standard. To estimate their confidence interval, it is then necessary to form a nonrejection region using the Fisher tests just presented in the non-linearity tests. Thus, in a PTR representation at $K+1$ regimes, the Fisher test is equivalent to testing $H_0: \gamma_j = \gamma_0$ against $H_1: \gamma_j \neq \gamma_0$ from the following test statistics:

$$LR(\gamma) = \frac{S\frac{\gamma_j}{(\gamma_1,\ \gamma_{j-1},\ \gamma_{j+1} \dots, \gamma_m)} - S\frac{\hat{\gamma}_j}{(\gamma_1,\ \gamma_{j-1},\ \gamma_{j+1} \dots, \gamma_m)}}{\partial^2} \quad (13)$$

where γ_0 is the true value of the threshold, γ_j represents the threshold on which the confidence interval is created and $S(\gamma_j)$ is the residual sum of squares obtained in γ_j conditional on the other thresholds. Knowing that the null hypothesis is rejected for strong values of $LR_1(\gamma_0)$, the confidence interval at ($1-\alpha$)% is therefore the "no release" zone or, in other words, the set of values of γ_j for which $LR_1(\gamma) \leq \gamma(\alpha)$, where $\gamma(\alpha)$ represents the critical test values associated with a first species risk of α%. To obtain the latter, Hansen (1999) considers the following critical values:

$$\gamma(\alpha) = -2\log(1-\sqrt{1-\alpha}) \quad (14)$$

The theoretical conclusion of the test shows that the null hypothesis $H_0: \gamma_j = \gamma_0$ is rejected for a risk α if the value of $LR_1(\gamma)$ exceeds $\gamma(\alpha)$.

4. Specification of the Econometric Model and Data Sources

In this section, we first present the model specification and then the data sources.

4.1. Specification of the Econometric Model

As defined above, we apply the modified threshold model based on panel data in several countries to analyze the effect of inflation on economic growth. To do this, we consider the following empirical specification:

$$TXPIBH_{i,t} = \mu_{i,t} + \beta_1 INF_{i,t} \| (INF_{i,t} \leq \gamma) + \delta_1 \| (INF_{i,t} \leq \gamma) + \beta_2 INF_{i,t} \| (INF_{i,t} > \gamma) + \alpha_i X_{i,t} + \varepsilon_{i,t} \quad (15)$$

$i = country\ index\ \ and\ \ t = time\ index$

In equation (15), from left to right, the following are labelled:

• $TXPIBH_{i,t}$: the growth rate of the GDP per capita. This is the variable explained by a set of explanatory variables.

• $INF_{i,t}$: the inflation rate observed in each of the countries in the study sample.

The indicator functions $\|(INF_{i,t} \leq \gamma)$ and $\|(INF_{i,t} > \gamma)$ are likely to take the values 1 if the term between parentheses is true and 0 if the condition between parentheses is not verified. It is assumed that $\beta_1 \leq 0\ \ and\ \ \beta_2 > 0$ because in theory, low inflation can lead the country into a favourable deflationary spiral of economic recession while high inflation can promote growth.

• $X_{i,t}$ is a matrix of control variables that can explain the growth rate of the economy. In this analysis, we use the population growth rate (TXPOP), the economic openness rate (TXOUV), government spending (DEPGOUV), the investment rate (INVEST) and a financial development indicator (FINDEPH).

4.2. Data Sources

For the purposes of this study, the countries selected are those of the CEMAC zone, the WAEMU zone and the BRICS. For CEMAC, these are Cameroon, Central African Republic, Chad, Congo, Equatorial Guinea, Gabon and Gabon. Concerning WAEMU, the countries are Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal and Togo. Guinea-Bissau was excluded for unavailability of data. Comoros is also out of the sample for the same reason. The BRICS countries are Brazil, Russia, India, China and South Africa. The data are annual and all come from the World Development Indicator (WDI). The study covers the period 1990-2016. The choice of this period

[1] In practice, we usually stop at four. The preferred solution for considering a larger number of them is to use a smooth rather than a brutal transition mechanism (Fouquau et al. 2008).

is due to the unavailability of data from Russia before 1990.

5. Results and Discussion

The empirical analysis follows the following approach. First, we present the results of statistical analyses and econometric inferences. Second, we present the results of the threshold effects of inflation on economic growth.

5.1. Results of Statistical and Econometric Inference

In this section, we present the results of the statistical and econometric tests that we applied before estimating threshold models. These include correlation tests and descriptive statistics on the one hand and tests of linearity, determination of the number of regimes and localization of the confidence interval on the respective thresholds determined on the other hand. The analysis in Table 1 shows that over the period of the study, on average, in the CEMAC region, the average growth rate of GDP per capita was 2.65%. The average inflation rate in the area is around 4.5.

Table 1. Description of CEMAC Variables

Variables	*Mean*	*Std. Dev.*	*Min.*	*Max.*
TXPIBH	2.654	14.711	-36.829	140.501
TXPOP	2.914	0.807	0.205	4.605
TXOUV	0.440	0.343	0.132	2.511
INVEST	0.119	0.320	-0.587	1.812
DEPGOUV	12.276	4.854	2.736	27.740
FINDEPH	11.184	5.456	0	30.54
INF	4.5168	8.342	-11.686	42.439

Source: Author, based on WDI data (2017)

Table 2. Correlation Matrix of the Variables Included in the Model with CEMAC Countries

Variables	*[1]*	*[2]*	*[3]*	*[4]*	*[5]*	*[6]*	*[7]*
[1]TXPIBH	1						
[2]TXPOP	0.272*	1					
[3]TXOUV	0.530*	0.303*	1				
[4]INVEST	0.287*	0.154	0.361*	1			
[5]DEPGOUV	-0.116	-0.037	0.251*	-0.144	1		
[6]FINDEPH	-0.253*	-0.357*	-0.111	-0.167*	0.345*	1	
[7]INF	0.058	-0.069	0.093	0.163*	-0.036	-0.106	1

Source: Author, based on WDI data (2017)

Table 2 indicates a strong correlation between the variables. Of all these variables, the GDP per capita growth rate (TXPIBH) and the openness rate (TXOUV) have the highest correlation coefficient (0.53), but less than 0.8. The inflation rate (INF) pair and the GDP per capita growth rate have a low and positive correlation coefficient of 0.058. For WAEMU countries, the descriptive analysis is recorded in the following tables. The analysis in Table 3 shows that over the period of study, on average, the average growth rate of GDP per capita is 0.91 while the average inflation rate was 2.18.

Table 3. Description of WAEMU Variables

Variables	*Mean*	*Std. Dev.*	*Min.*	*Max.*
TXPIBH	0.921	3.613	-17.009	12.256
TXPOP	2.911	0.439	1.784	3.843
TXOUV	0.308	0.091	0.141	0.6076
INVEST	-18.446	74.296	-379.384	54.521
DEPGOUV	15.131	3.496	6.925	26.064
FINDEPH	19.756	8.219	0	44.22
INF	2.185	12.527	-113.830	39.162

Source: Author, based on WDI data (2017)

Table 4 shows a strong correlation between the variables. Of all these variables, the openness rate (TXOUV) and government spending (DEPGOUV) have the highest correlation coefficient (0.554), but less than 0.8. The inflation rate (INF) pair and the GDP per capita growth rate have a low and positive correlation coefficient of 0.017.

Table 4. Correlation Matrix of the Variables Included in the Model with WAEMU Countries

Variables	*[1]*	*[2]*	*[3]*	*[4]*	*[5]*	*[6]*	*[7]*
[1]TXPIBH	1						
[2]TXPOP	0.009	1					
[3]TXOUV	-0.019	-0.405*	1				
[4]INVEST	0.262*	-0.082	-0.031	1			
[5]DEPGOUV	0.045	0.096	-0.554*	0.048	1		
[6]FINDEPH	-0.081	-0.249*	0.523*	-0.172*	-0.053	1	
[7]INF	0.017	-0.072	0.0884	-0.081	-0.080	-0.057	1

Source: Author, based on WDI data (2017)

For BRICS, the descriptive analysis is recorded in Tables 5 and 6. The analysis in Table 5 shows that over the period of the study, on average, the average growth rate of GDP per capita is 3.20 while the average inflation rate was 124.8.

Table 5. Description of BRICS Variables

Variables	*Mean*	*Std. Dev.*	*Min.*	*Max.*
TXPIBH	3.207	4.915	-14.568	13.633
TXPOP	1.048	0.726	-0.460	2.500
TXOUV	0.201	0.075	0.043	0.364
INVEST	6.530	13.370	-41.5	75.412
DEPGOUV	16.257	3.364	10.014	21.067
FINDEPH	62.543	37.230	0	165.036
INF	124.811	468.199	-1.407	2947.733

Source: Author, based on WDI data (2017)

Table 6 indicates a strong correlation between the variables. Of all these variables, the GDP per capita growth rate (TXPIBH) and investment rates (INVEST) have the highest correlation coefficient (0, 80). The inflation rate (INF) pair and the GDP per capita growth rate have a negative but high correlation coefficient of -0.34.

Table 6. Correlation Matrix of the Variables Included in the Model with BRICS

Variables	*[1]*	*[2]*	*[3]*	*[4]*	*[5]*	*[6]*	*[7]*
[1]TXPIBH	1						
[2]TXPOP	-0.0906	1					
[3]TXOUV	0.2245*	-0.3913*	1				
[4]INVEST	0.8014*	0.0794	0.0573	1			
[5]DEPGOUV	-0.5342*	-0.1466	0.0721	-0.3369*	1		
[6]FINDEPH	0.4615*	0.0705	0.2979*	0.3622*	-0.1185	1	
[7]INF	-0.3434*	-0.0236	-0.3531*	-0.2200*	0.1226	-0.248*	1

Source: Author, based on WDI data (2017)

After the descriptive analysis, the results of the statistical inference of the model should be presented, the theoretical aspects of which are clearly presented above. To do this, we use the endogenous threshold determination algorithm provided by Hansen (1999) using the examples of Fiodendji and Evlo (2013) and Fiodendji et al (2014). This is a regression procedure based on the sequential least squares technique on all candidate threshold values until the threshold value is obtained, i.e. the optimal threshold corresponds to the value of γ which minimizes the residual sum of squares. Afterwards, the linearity test of the model, the determination of the number of revolutions and the estimation of the confidence interval of the optimal threshold are performed on the basis of Hansen's recommendations for the use of the likelihood ratio test and the bootstrap procedure (Hansen, 1996; 1999). Thus, the detailed compilation of the results of these tests can be found in the tables below (Tables 7, 8 and 9).

For CEMAC, WAEMU and BRICS countries, as shown in Tables 7, 8 and 9, when applying the Hansen test (1999) with 300 replications of the bootstrap to test non-linearity, we find that the likelihood ratios of the LR Hansen Test and its p-values lead to the rejection of the null hypothesis at the critical 5% threshold. These results reflect the fact that there is a non-linear relationship between inflation and economic growth in the countries studied. Such results imply that the number of regimes in the process must be determined. To this end, the same tables show that the iterative Fisher Test allows us to conclude that the null hypothesis is accepted for a critical threshold of 5% for the period and sub-periods considered. As a result, there are two aid schemes. These results reflect the idea that the non-linearity of the relationship between inflation and economic growth in the countries studied requires the determination of a single threshold value.

Table 7. Results of the Inference on the Threshold Effect Model in Panel Data

Zone	CEMAC Zone
Period	1990-2016
Threshold (γ)	3.170
IC	[3.021-3.193]
Regime[1] Test	
LR-Hansen Test	F stat 102.00 P-value 0.000
VC10%	13.736
VC 5%	15.604
VC 1%	19.997
Linearity Test	
F test	F (5, 140) = 3.44 Prob > F = 0.005
Bootstrap	300

Source: Author based on results from Stata software

Table 8. Results of the Inference on the Threshold Effect Model in Panel Data

Zone	WAEMU Zone
Period	1990-2016
Threshold (γ)	11.305
IC	[7.787- 13.441]
Regime[2]Test	
LR-Hansen Test	F stat 9.82 P-value 0.050
VC10%	6.721
VC 5%	9.682
VC 1%	15.055
Linearity Test	
F test	F (6, 158) = 2.46 Prob > F = 0.026
Bootstrap	300

Source: Author based on results from Stata software

Table 9. Results of the Inference on the Threshold Effect Model in Panel Data

Zone	BRICS Zone
Period	1990-2016
Threshold (γ)	7.044
IC	[5.062 – 7.050]
Regime[3] Test	
LR-Hansen Test	F stat 9.23 P-value 0.026
VC10%	6.1965
VC 5%	7.3051
VC 1%	8.8170
Linearity Test	
F test	F (4, 120) = 7.38 Prob > F = 0.000
Bootstrap	300

Source: Author based on results from Stata software

In this procedure, we find that the threshold value of the inflation rate that minimizes the residual sum of squares from the sequential least squares estimates is 3.17% in the CEMAC zone, 11.30% for the WAEMU zone and 7.04% for the BRICS. The confidence interval, calculated on the basis of the distribution simulated by Hansen's (1999) methodology, indicates that at a first-order risk of 5%, this threshold value of the inflation rate would be between 3.021% and 3.193% for CEMAC and between 7.787% and 13.441% for WAEMU and between 5.062% and 7.050% for BRICS. These results are quite rich and interesting, especially when compared to those of other studies. Consequently, for the WAEMU zone, they are relatively closer to the results of Adama Combey and Kako Nubukpo (2000), which find an optimal threshold of 8.08%. On the other hand, for CEMAC,

[1] The threshold was chosen at the end of the test
[2] The threshold was chosen at the end of the test
[3] The threshold was chosen at the end of the test

our results remain less close to those found in the work of Khan and Senhadji (2001) who found that the acceptable level of inflation is in the order of 1% to 3% for developed countries and 11 to 12% for developing countries. Two arguments can be put forward to justify our results. The first is about the context of the studies and refers to the fact that these studies are not carried out over the same period. The second is about the methodology for determining endogenous thresholds. This is the argument according to which the value of the aid threshold could vary not only according to the number of replications of the applied bootstrap, but also and especially according to whether the simulations are conditioned by other variables or not.

5.2. Results of the Threshold effects of Inflation on Economic Growth

Now, we analyze the results of the threshold effects of the inflation rate on growth through a model (Equation 15) that specifies a vector of two (02) coefficients $\beta 1$ and $\beta 2$ indicating the effects of aid in the regimes before and after the threshold. The results are reported in Tables 10, 11 and 12.

Table 10. Result of the Direct Threshold Effect of Inflation on Economic Growth in CEMAC

Variables	*Coef.*	*Standard Deviation*	*p-value*
TXPOP	2.858*	1.565	0.070
TXOUV	19.345***	2.789	0.000
INVEST	4.023*	2.168	0.066
DEPGOUV	-0.5681**	0.168	0.001
FINDEPH	-0.072	0.142	0.614
INFsup	0.121	0.308	0.694
INF	0.029	0.072	0.688
INFinf	0.019	0.075	0.796
CSTE	-7.579	5.536	0.173

Source: Author based on estimates in STATA
Note: ** * (**)* represent 1%, 5% and 10% significance levels

Table 11. Result of the Direct Threshold Effect of Inflation on Economic Growth in WAEMU

Variables	*Coef.*	*Standard Deviation*	*p-value*
TXPOP	2.014**	0.955	0.037
TXOUV	2.014*	5.153	0.051
INVEST	10.122**	0.004	0.004
DEPGOUV	0.013	0.129	0.418
FINDEPH	-0.035	0.039	0.361
INFsup	0.010	0.052	0.848
INF	0.082**	0.037	0.031
INFinf	0.159**	0.519	0.003
CSTE	-6.352*	3.733	0.091

Source: Author based on estimates in STATA
Note: ** * (**)* represent 1%, 5% and 10% significance levels

Table 12. Result of the Direct Threshold Effect of Inflation on Economic Growth in the BRICS

Variables	*Coef.*	*Standard Deviation*	*p-value*
TXPOP	-1.828**	0.762	0.018
TXOUV	15.649**	4.661	0.001
INVEST	0.197***	0.015	0.000
DEPGOUV	-0.572***	0.155	0.000
FINDEPH	0.006	0.008	0.448
INFsup	0.001*	0.0006	0.065
INF	0.001 *	0.0006	0.057
INFinf	-0.182**	0.083	0.032
CSTE	10.973**	3.173	0.001

Source: Author based on estimates in STATA
Note: ** * (**)* represent 1%, 5% and 10% significance levels

Inflation coefficients have different signs and degrees of significance across the two regimes in the three areas studied. In the CEMAC zone, the population growth rate, the openness rate and the investment rate have a positive impact on the growth rate. However, government spending has a negative impact on growth. The inflation rate appears to be insignificant as an explanatory factor for growth in the area. In the WAEMU area, the population growth rate, the openness rate and the investment rate have a positive impact on the growth rate. The inflation rate has a positive effect on the growth rate. But this effect remains positive up to the indicated threshold. On the other hand, for inflation values above the threshold, the marginal effect of inflation on growth is positive, but not significant. For the BRICS, the population growth rate, the openness rate and the investment rate have a positive impact on the growth rate. However, government spending has a negative impact on growth. The marginal effect of the inflation rate on growth is negative and significant when it has not reached the threshold. It is only for inflation rates above the threshold that the effect becomes positive and significant. Nevertheless, this paradoxical result is based on the economic structures of these economies, which must opt for wage-led growth. If the marginal propensity to consume wages is higher than that of profits, a transfer from profits to wages would stimulate aggregate demand. Moreover, as Lavoie and Stockhammer (2012) point out, wage-led growth can be self-sustaining. On the one hand, Verdoorn's law tells us that an acceleration in output growth is usually accompanied by better productivity growth. This means that higher wages can be partly financed and may not be very inflationary. On the other hand, companies can respond to rising labour costs by investing more in labour-saving technologies, which also tend to contain inflation. The BRICS must rely on domestic demand, driven by high wages, which ultimately leads to a high but acceptable inflation rate of between 7% and 8%. This naive empiricism is supported by Onaran and Galanis (2012), who found that, in several developed countries, the increase in the profit share of GDP has been associated with a decline in aggregate demand. In all three zones, the analysis of the control variables indicates that whatever the level of the inflation rate, the population growth rate, the openness rate and the investment rate have a positive impact on growth.

6. Concluding Remarks

The objective of this study was therefore to analyse the relationship between inflation and growth in 18 countries grouped in three zones (CEMAC, WAEMU and BRICS) over the period 1990 to 2016. This study used Hansen's (1996, 1999, 2000) methodology for determining endogenous thresholds. The results show that the effect of inflation on growth is not linear. The study indicates an optimal inflation threshold of 3.17% for CEMAC, 11.3% for WAEMU and 7.04% for BRICS. For CEMAC, our results differ from those of Bikai and Kamgna (2011) which indicate a threshold of 6%. On the other hand, for the WAEMU countries and the BRICS, our results confirm those of Khan and Sendhadji (2001) who establish that an inflation rate above 11% negatively affects growth, and that lower rates have no significant impact on growth. Above these thresholds, the relationship between inflation and economic activity is non-linear. For the BRICS, below the optimal threshold, any inflationary policy will have restrictive effects on economic activity. Bick (2010) attributes these differences to biases such as the existence of variables omitted in the specification and in the identification or not of variance regimes in inflation. In terms of economic policy involvement, these economies need to relax their monetary policy to gain growth points. In the WAEMU zone, above the inflation target (2%), inflation has a positive impact on economic growth. As a result, multilateral surveillance constraints can be relaxed, and in view of the inflation target set by the BCEAO (2% maximum), it can be observed that there is unused room for manoeuvre that would make monetary policy ineffective, thus implying a flattening of demand. Indeed, additional monetary creation can increase the financing of the economy through the creation of structuring projects known for their ability to generate inflation. For CEMAC, the marginal effects of inflation on growth, before and after the optimal threshold, are undetermined. Such results lead to methodological improvements, in particular through the adoption of a smooth transition threshold panel model called Panel Smooth Treshold Regression (PSTR).

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