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What is the nature of the relationship between inflation and economic growth? Empirical evidence for the 13 least developed African countries

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Abstract. *This study examines the relationship between inflation and economic growth in 13 least developed African countries from 1981 to 2019. Using Two-Step Least Squares (2SLS) and the Generalized Method of Moments (GMM), it identifies a nonlinear relationship between inflation and growth. The findings reveal an inflation threshold of 21.52%: below this level, inflation promotes economic growth, while above it, inflation negatively affects growth. Thus, high inflation hampers economic performance. The results also show that growth in these countries is mainly driven by gross fixed capital formation, population growth, and trade openness. In contrast, public spending and institutional development have a significant negative impact on economic growth. These findings highlight the importance for policymakers to consider the inflation threshold when designing monetary policies to ensure sustainable growth and effective inflation control.*

Keywords: inflation, economic growth, dynamic panel threshold, GMM, 2SLS.

JEL Classification: C23, O40, E31.

1. Introduction

Today, the relationship between inflation and economic growth, an important factor in promoting economic growth and sustainable development, has become one of the most widely discussed and researched topics (Nkemgha et al., 2022), (Ozyilmaz, 2022), (Rahimov, 2024) and (Erick, 2025). Price stability is a key phase in the stabilization of the macroeconomic framework and the improvement of economic growth levels (Girijasankar and Anis, 2001), the control of price increases and the achievement of economic growth are the main criteria for economic performance to which they attach importance for the least developed countries. In addition, the nature of the relationship between general consumer price increase and gross domestic product has been discussed in long-standing theoretical and empirical literature reviews (Phillipes, 1958), (Cili and Alkhaliq, 2022) and (Iriagbonse-Alikor and Priscilla, 2022).

On the one hand, the linear relationship between inflation and economic growth was justified by the research studies of (Dumitrescu and Hurlin, 2012), (An & al., 2016), (Stojanovikj and Petrevski, 2021) and (Cili and Alkhaliq, 2022). This relationship is explained by several transmission channels. In this regard, we can mention the reduction in unemployment and the increase in investment (Ho and Iyke, 2020). Indeed, according to the curve of (Phillips, 1958), the increase in inflation generates the fall in the unemployment rate through the creation of new jobs. However, lower unemployment can improve the level of income and consequently increase demand. In addition, rising inflation can increase the costs of currency trials (Dumitrescu and Hurlin, 2012). This situation redirects the place of capital towards real investment and therefore economic growth.

On the other hand, the negative effect of inflation on economic growth has been shown by the studies of (Sirimaneetham and Temple, 2009), (Robert, 2013), (Faraji and Kenani, 2013), (Ruzima and Veerachamy, 2016), (Veni and Choudhury, 2007), (Shelton & al., 2021) and (Tariq, 2022). The non-linear relationship is explained mainly by the uncertainty of investment and production (Robert, 2013). That is, continued price increases make economic decision-making by public authorities ineffective (Shelton Mandeya & al., 2021). This means that the high uncertainty of inflation can turn speculative economies which should yield more than real investment or output. However, declining real investment can hamper growth processes.

Still, it does not only reduce real investment by negatively affecting the profits of producers but, it can also threaten the purchasing power of consumers by influencing their real incomes. This means that the general increase in consumer prices is eroding the purchasing power of consumers. In this case, the demand can decrease and consequently the production. In addition, inflation can undermine growth and economic development strategies by increasing the degree of uncertainty (Franses, 2018) and it can increase the income gap between individuals, groups, and regions (Çakir, 2023). So these situations can disrupt income distribution. That is, the deterioration of income distribution at the expense of fixed income groups (Şiriner and Doğru, 2005).

Moreover, price instability makes the anticipation of macroeconomic quantities irrational. That is to say, it can increase the gap between the forecast and the real in terms of

production costs and it makes economic calculation difficult. So the combination of these factors can create difficulties within companies that can reduce production. Also, inflation hampers growth through the decline in exports (Tariq, 2022). That is, the general increase in prices can increase production costs. This makes it difficult for exporting companies to compete.

In the light of the previous two sides, the contradiction between the defendants and the ignorant on the linear relationship between inflation and economic growth may explain by the different level of the inflation rate (Omay and Öznur Kan, 2010), (Su Dinh, 2015), (Ehigiamusoe & al., 2019), (Zhiyong & al., 2021),(Muhammad and Saleem, 2022), (Iriagbonse-Alikor and Priscilla, 2022) and (Buthelezi, 2023). Overall, the positive effect of inflation appears to be the case where the rate of inflation is moderate and opposite.

Indeed, according to previous research studies, we note that most of the studies have dealt with the relationship between inflation and economic growth only by testing and the sense of causality and the nature of the effect. But, they are not concerned with determining the level of inflation that guarantees economic growth.

This research study aims to analyze the nature of the relationship between inflation and economic growth and establishes the threshold for inflation, that guarantees economic growth for the 13 least developed African countries from 1981 to 2019 through a dynamic analysis of data panel based on the Least Square method in Two-step (2SLS), the generalized moment method (GMM) and the regression threshold (TR).

The interest we place in selecting the 13 least developed African countries is justified by the fact that the 13 least developed African countries are characterized by a high rate of inflation compared to other regions of the world and they suffer from lack of growth and economic development.

The outline of this paper is organized as follows: The second section describes a brief overview of the theoretical and empirical literature on the link between inflation and economic growth. The third section presents the theoretical framework and econometric model. The fourth section displays the results and discussion. The fifth section presents the political conclusion and implications.

2. Literature review

Most theoretical and empirical studies that have shown the linear relationship between inflation and economic growth, have justified this relationship by the low level of inflation (Martin, 2022). This indicates that the small price increase does reduce growth but, it can lubricate their processes. In this perspective, (Cili and Alkhaliq, 2022) determined the link between inflation and economic growth in Indonesia using static panel data from 2010 to 2014. They showed the linear relationship between inflation, investment, the demographic rate and gross domestic product. In addition, they found that the effect of private investment on growth is greater than inflation. In this case, the significant positive effect of inflation is explained by the control of consumer product prices represented by the Indonesian bank which does not reduce demand and does not deteriorate purchasing power.

Again, advanced studies agree that there is a causal relationship between the overall price increase, the gross domestic product deflator and the gross domestic product. In this regard, (Ozyilmaz, 2022) sought to determine the threshold of inflation in which it positively affects economic growth and tested the sense of causality for the countries of the European Union from 1996 to 2019. The results of the (Dumitrescu and Hurlin, 2012) test justify a two-way causal relationship between the general increase in consumer prices and gross domestic product. In addition, they noted the presence of two-way causality between the GDP deflator and economic growth. In the light of these results, we see that it is important for countries with a low level of economic growth to raise prices a little to stimulate the economy.

In addition, using co-integration and error correction (ECM) models, (Girijasankar and Anis, 2001) examined the long-term relationship between inflation and economic growth for the four South Asian countries (Bangladesh, India, Pakistan and Sri Lanka). They showed a positive and significant relationship between the general increase in consumer prices and gross domestic production and that there is a significant feedback between inflation and economic growth. This means that moderate inflation in this region is a favorable factor for economic growth. From this angle, (Girijasankar and Anis, 2001) recommended that the four South Asian countries consider the negative effects of low inflation.

On the other hand, previous reviews of theoretical and empirical literature have explained the negative effect of inflation on economic growth through higher commodity prices. This can reduce demand and therefore growth. In this regard, (Faraji and Kenani, 2013) tested the link between inflation and Tanzanian economic growth by processing historical data from 1990 to 2011. The results of the Johansen co-integration test and the regression of simple linear equations (ILS) showed the negative effect of inflation on economic growth and the absence of a long-term co-integration relationship. Indeed, the negative effect of inflation is explained by rising commodity prices and their effect on falling demand. This is the general increase in energy and agricultural prices in Tanzania. In this case, the lack of availability of products on the market can lead to higher prices for these products.

Moreover, based on the findings of previous studies, economic growth is influenced not only by inflation but also by inflation uncertainty. In this regard, Shelton Mandeya et al. (2021) examined the effects of inflation and inflation uncertainty on gross domestic product in South Africa using the Autoregressive Distributed Lag (ARDL) technique. Their analysis was conducted on quarterly data covering the period from Q1 1961 to Q4 2019. They assessed the effectiveness of inflation targeting by comparing the nature of the effect of inflation and inflation uncertainty on economic growth before and after inflation targeting. This allowed the effect of inflation targeting to be assessed while studying any changes in variable behavior. They showed that inflation has a significant negative effect on short- and long-term growth, however, inflationary uncertainty is a short-term phenomenon in South Africa with no long-term impact on gross domestic product. In addition, they found that to encourage economic growth in South Africa, the authorities must continue to implement policies and strategies that ensure price containment.

Still, the high rate of inflation does not only discourage growth but, it can hinder trade operations with the outside world. In this regard, (Tariq, 2022) focuses on the long-term effect of inflation on foreign trade and economic growth in Pakistan from 1985 to 2019

through the Autoregressive Distributed Lag (ARDL) method and the Wald test (2000). He said that inflation has a negative and significant effect on long-term growth and external trade. In addition, he noted that low inflation is advantageous for growth processes and trade incentives, while high inflation is disadvantageous to the Pakistani economy. In this case, the negative effect of inflation on trade is explained by the increase in raw material prices, which increases production costs and makes Pakistan firms uncompetitive on the external market.

Several other studies have justified the non-linear relationship between inflation and economic growth over a long period of time. From this angle, (Robert, 2013) evaluated the effect of inflation on the economic performance of a sample of 100 countries from 1960 to 1990. He indicated the presence of a significant causal relationship between inflation and economic growth and investment. The regression results showed that an increase in average inflation of 10% per year reduces the growth rate of real gross domestic product per capita from 0.2% to 0.3% and decreases the investment ratio by 0.4% to 0.6% per year. In addition, it showed that the change in monetary policy, which increases the long-term average inflation rate by 10% per year, is estimated to reduce economic growth after 30 years by 4 to 7%, more than enough to justify a strong interest rate for price stability.

Also, the study by (Nur Alam, 2023) showed the negative influence of macroeconomic instability of the economic growth of the ASACR (South Asian Association for Regional Cooperation) countries from 1991 to 2020. In this study, macroeconomic instability is measured by the rate of inflation. This type of relationship is explained by the continuous increase in consumer prices. In addition, the results of the regression of the dynamic fixed-effect panel data show the significant positive allocation of foreign direct investment, the domestic credit granted to the private sector, the exchange rate and the quality of the institutions. According to these results, he recommended that policy-makers in ASACR countries stabilize the macroeconomic state to await economic growth.

Again, in an empirical study, (Bui Hoang, 2019) studied the asymmetric effect of inflation and money supply on economic growth using a non-linear autoregressive distributed lag approach introduced by (Shin & al., 2013) for Vietnam from 1990 to 2017. It has shown that the effects of inflation on economic growth are negative and asymmetrical in the long run. In addition, he noted that the impact of money supply on growth is positive in the short and long term. As a result, the impact of rising inflation is greater than the long-term decline.

On the other hand, the negative or positive allocation of inflation to economic growth may be conditioned by the level of inflation. That is to say, the fall in the rate of inflation below a given threshold may reduce or increase economic growth and vice versa. In this regard, using a PSTR model, (Omay and Öznur Kan, 2010) examined the empirical relationship between inflation and economic growth for 6 industrial countries from 1972 to 2005. They provide evidence that there is an inflation threshold of 2.52%. In addition, they noted that the relationship between inflation and growth becomes negative when the inflation rate exceeds this threshold. They tested the robustness of this relationship through unbound regression (SUR). They found that the inflation threshold level changes slightly from 2.52% to 2.42%.

A similar study by (Su Dinh, 2015) tested the hypothesis that the relationship between inflation and economic growth is non-linear for the 5 ASEAN countries from 198 to 2011.The results of the regression of the PSTR model and the generalized moments technique (GMM) show the significant negative relationship between the general increase in consumer prices and the gross domestic product in the long term. In addition, he noted that the inflation rate must not exceed the 7.84% threshold to have the significant positive effect of inflation on the economic growth of the 5 ASEAN countries. In the light of the results obtained, he suggested that the central banks of the 5 ASEAN countries could increase the rate of economic growth by controlling the rate of inflation when it is above or near the estimated threshold. In this case, the threshold level of inflation can therefore be considered as an indicator of inflation targeting to drive monetary policy.

Moreover, previous theories have justified that the moderate inflation effect on economic growth is greater than the high. In this regard, (Iriagbonse-Alikor and Priscilla, 2022) examined the link between inflation and economic growth through the treatment of balanced panel data from Southern African countries from 1980 to 2021. They showed an inflation threshold equal to 24.7 which guarantees the positive and significant allocation of inflation on economic growth. Again, they have justified that economic growth is affected differently at low and high inflation levels. That is, economic growth is inflationary below the inflation threshold. However, the effect of inflation becomes negative only if inflation falls below the threshold. In this regard, they recommended that countries in Southern Africa reduce the rate of inflation to this level to avoid the adverse effects of general price increases on economic growth processes.

Another study was conducted by (Muhammad and Saleem, 2022). They re-evaluated the threshold effect of inflation on economic growth for 27 countries (16 developing and 11 developed economies) from 1975 to 2018. The results of the Achievable Generalized Least Squares and Fixed Effects (FGLS) methods indicate a significant negative connection between inflation and gross domestic product above the inflation threshold. They showed that inflation inhibits growth when inflation exceeds the 5.36% to 12.23% range. In addition, they found that it is important for managing authorities to consider a maximum rate between 5.4 % and 12.3 %, as an inflation interval to overcome the negative effects of high inflation.

3. Theoretical framework and econometric model

This study examines the relationship between inflation and economic growth and determines the inflation threshold that guarantees growth for the 13 least developed African countries according to UNDP (2020) from 1981 to 2019 by the Least Square Two-Step Method (2SLS) and the generalized moment method (GMM) applied to the dynamic panel data and the threshold regression technique. These countries are Niger, the Central African Republic, Chad, South Sudan, Burundi, Sierra Leone, Mali, Liberia, Mozambique, Guinea-Bissau, Eritrea, Nigeria and Togo.

This study created the entire database in the form of the 5-year average periods of the variables used to validate and ensure the consistency of the GMM estimator as follows: 1981-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004, 2005-2009, 2010-2014, 2015-

2019. In addition, averaging the data is likely to mitigate the business cycle effect. The model below, which explains the relationship between inflation and economic growth, is inspired by the work of (Khan and Senhadji, 2001) and (Kremer & al., 2013).

$$\dot{Y}_{it} = \alpha_0 + \alpha_1 Initial_{it} + \alpha_2 \pi_{it} + \beta x_{it} + \varepsilon_{it} \quad (1)$$

With:
$\dot{Y}_{it}$: the growth rate of gross domestic product per capita in t in the economy i,
$Initial_{it}$: the growth rate of gross domestic product per head in t_{-1} ,
π_{it}: $the\ rate\ of\ inflation$,
x_{it}: Other variables that could affect economic growth,
ε_{it}: error term,
i = 1,,,13 and t= 1,,,39

In Riding 1, the variable $Initial_{it}$ is added as an explanatory variable. This means that the level of production and the structure of an economy are not entirely independent of previous periods, and thus the output of the previous period is also reflected in subsequent periods. Table 1 presents the definition, measurement, expected sign and source of the variables:

Table 1. *Definition and measurement of variables*

Variables	Ratings	Measure	expected sign	Sources
Economic growth rate	GDP	Five-year average of the annual growth rate of real GDP per capita (2010 Constant $).	-	World Bank Database (2022)
Public expenses	PE	Five-year average of the government final consumption expenditure as a share of GDP.	Positive / Negative	World Bank Database (2022)
Inflation rate	INF	Five-year average of the annual percent changes in the Consumer Price Index (CP	Negative	World Bank Database (2022)
Gross fixed capital formation	GFCF	Five-year average of the gross capital formation as a share of GDP.	Positive	World Bank Database (2022)
Population growth rate	POP	Five-year average of the annual growth rate of population.	Positive / Negative	World Bank Database (2022)
Institutional development	ID	Five-year average of the "Economic freedom" index.	Positive / Negative	Fraser Institute (2021)
Trade openness rate	TO	Five-year average of the annual growth rate of export.	positive	World Bank Database (2022)

Source: Author's

Table 2 presents the results of the descriptive variable statistics.

Table 2. *Descriptive statistics*

Variables	Mean	St.De.	Min.	Max.	Skewness	Kurtosis	JB	P.JB
GDP	0.51	0.14	-10.72	4.06	0.51	4.94	22.74	0.001
PE	6.47	3.91	2.89	22.61	0.02	5.02	13.64	0.042
INF	18.63	5.17	2.01	45.73	-2.83	1.09	3.54	0.100
GFCF	23.31	8.57	5.89	49.04	0.08	7.22	27.09	0.000
POP	7.39	3.64	2.05	10.11	1.98	5.58	19.31	0.011
ID	3.67	1.53	0.17	7.29	-4.17	3.61	10.14	0.079
TO	9.14	3.08	0.55	36.18	3.38	6.27	31.02	0.035

J.B: Test of Jarque-Bera, PJ.B: probability of Jarque- Berra, The null hypothesis of the Jarque-Bera test assumes the distribution of data according to a normal law. The Jarque-Bera test problem is written as H0: p-value < 5% vs H1: p-value > 5%.
Source: STATA 15

Overall, the economic growth rate has an overall average of 0.51 with a low standard deviation of 0.14. In fact, all values are between -10.72 and 4.06. On the other hand, the rate of economic growth takes a form of asymmetric distribution spread to the right as the Skewness exceeds 0. It is leptokurtic where the Kurtosis equals 4.94. In addition, this variable rejects the null assumption of normality because the p-value of 0.001 is much lower than 5%.

Moreover, from 1981 to 2019, inflation in the 13 least developed African countries recorded an overall average value of 18.63 with a very large standard deviation of 5.17. In addition, all minimum and maximum values are between 2.01 and 45.73. Based on these figures, it can be said that from 1981 to 2019, the 13 least developed African countries were characterized by a high annual average inflation rate compared to other regions of Africa and the world. In contrast, the distribution of the variable "inflation rate" is asymmetrical and weakly spread to the left where the Skewness is equal to -2.83<0 and again, it is the leptokurtic where the Kurtosis is positive 1.09 > 0. Overall, the variable "inflation" rejects the null hypothesis of normality because the p-value equal to 0.000 much less than 5%. Table 3 shows the correlation matrix between the variables:

Table 3. *Correlation matrix*

	GDP	PE	INF	GFCF	POP	ID	TO
GDP	1						
PE	-0.39 (0.034)	1					
INF	-0.27 (0.178)	-0.02 (0.045)	1				
GFCF	0.65 (0.007)	0.89 (0.37)	-0.37 (0.071)	1			
POP	0.03 (0.371)	0.57 (0.003)	0.25 (0.051)	0.72 (0.000)	1		
ID	-0.47 (0.009)	0.01 (0.027)	0.67 (0.011)	0.15 (0.296)	0.59 (0.083)	1	
TO	0.46 (0.470)	-0.38 (0.000)	-0.44 (0.174)	0.71 (0.003)	0.09 (0.092)	0.53 (0.077)	1

Source: STATA 15

Table 3 shows that economic growth in the 13 least developed African countries is positively correlated with gross fixed capital formation, trade openness and the population rate. Gross fixed capital formation is the variable most correlated with economic growth. However, it is negatively correlated with institutional development, inflation and public spending. In addition, the inflation rate is the variable most negatively correlated with the rate of economic growth.

The inflation rate dataset shows that there is a higher inflation rate. In this regard, Ghosh and Phillips (1998) recommend adding the logarithm to the inflation rate to avoid the adverse effects of high inflation on regression outcomes. As the inflation rate data had negative values, the semi-logarithmic transformation was applied to the inflation rate variable by (Khan and Senhadji, 2001), (Drukker & al., 2005) and (Kremer & al., 2013). This transformation is done as:

$$\bar{\pi}_{it} = \begin{cases} \pi_{it} - 1 \; si \; \pi_{it} \leq 0 \\ Ln(\pi_{it}) \; si \; \pi_{it} > 0 \end{cases}$$

The use of lagged values of variable $\dot{Y}_{it}$ it as an explanatory variable in a fixed-effect and random-effect statistical panel data model emerges a relationship between lagged values $\dot{Y}_{it-1}, \dot{Y}_{it-2}, ,,$ and error term ε_{it}. This relationship requires an estimation of the fixed-effect model and has random effect and therefore inconsistent Green (2000) estimates. Because, in some cases, the use of dynamic panel data eliminates such a relationship between the offset values of the variable depend and the error terms, and improves the reliability of the estimator and the coherence of the estimators.

This paper used the (Kremer & al., 2013) Dynamic Panel Threshold Model and extended the (Hansen, 1999) static model for endogenous regressions. In this case, we chose the initial level of gross domestic product as endogenous regression $(Initial\ _{it} = dGDP_{it-1})$. In addition, the threshold of the dynamic panel data model was constructed on the threshold of the (Caner and Hansen, 2004) transversal model in which GMM-type estimators are used to solve the endogeneity problem. Riding 2 describes this model.

$$Y_{it} = \mu_i + \beta_1' Z_{it}\, I(q_{it} \leq y) + \beta_2' Z_{it}\, I(q_{it} > y) + \varepsilon_{it} \qquad (2)$$

With:
i : Units within the perimeter of the section (i= 1 …n),
t : The time dimension in the series of each unit (t= 1…T),
Y_{it} : The dependent variable,
μ_i : The individual fixed specific effect,
$\varepsilon_{it} = (0, \sigma^2)$: Independent and identical distribution of the error term,
$I(.)$: Speed indicator function,
q_{it} : The threshold of the variable,
y : The level of the threshold,

And Z_{it} The m-dimensional vector of repressor explanations which may include offset values of the dependent variable and other endogenous variables. The vector of explanatory variables is divided into a subset of exogenous variables Z_{1it} uncorrelated.

With:
ε_{it} is a subset of endogenous variables Z_{2it} et Z_{2it} is correlated with ε_{it}.

In addition, in equation (2), an appropriate set of $K \geq m$instrumental variablesx_{it} including Z_{1it} Kremer & al. (2013).

The estimation of equitation 2 requires elimination of the individual effects $\mu_i$through a fixed-effect transformation and the use of the orthogonal allocation method of Arellano and Bover (1995). This method is expressed in équiation 3:

$$\varepsilon_{it}^* = \sqrt{\frac{T-1}{T-t+1}} * \left[\varepsilon_{it} - \frac{1}{T-t}\left(\varepsilon_{i\,(t+1)} + \cdots + \varepsilon_{iT}\right)\right] \qquad (3)$$

With:
$\varepsilon_{it}\ error\ term,$
$\varepsilon_{it}^*\ is\ a\ series\ is\ not\ correlated,$
$Var\ \varepsilon_{it} = \sigma^2 I_T\ and\ Var\ \varepsilon_{it}^* = \sigma^2 I_{T-1}$

When this procedure is applied in equation 2, the following equation is obtained.

$$y_{it}^{*} = \beta_1^{*} Z_{it}^{*} I(q_{it} \leq y) + \beta_2^{*} Z_{2it}^{*} I(q_{it} > y) + \varepsilon_{it}^{*} \quad (4)$$

With:

$t = 1,,,,T-1$ and * denotes post transformation data.

In fact, (Arellano and Bover, 1995) method corrects the problem of serial correlation of transformed error terms. Again, this method applies the estimation procedure derived by (Caner and Hansen, 2004) for a transversal model to the dynamic panel data models (Kremer & al,. 2013). In addition, for equation 4, the determination of the inflation threshold requires the use of the two-stage least squares method (2SLS). Indeed, the reduced form regression in equation (5) is constructed for endogenous variables (Z_{2it}^{*}) which represent instrumental variables according to (Caner and Hansen, 2004).

$$Z_{2it}^{*} = \lambda_1' x_{it} I(q_{it} \leq y) + \lambda_2' x_{it} I(q_{it} > y) + \upsilon_{it} \quad (5)$$

With:

x_{it} : $Instruments\ that\ understand\ Z_{1it}^{*}$ and

$E(\upsilon_{it}, x_{it}) = 0$

Again, the predicted values $\left(\widehat{Z_{it}^{*}}\right)$ which contains the endogenous variables $\left(\widehat{Z_{2it}^{*}}\right)$ and exogenous variables$\left(\widehat{Z_{1it}^{*}}\right)$ obtained from structural equation 6.

$$y_{it}^{*} = \beta_1^{*} \hat{z}_{it}^{*} I(q_{it} \leq y) + \beta_2^{*} \hat{z}_{2it}^{*} I(q_{it} > y) + \varepsilon_{it}^{*} \quad (6)$$

With:

$\hat{z}_{2it}^{*} = Z_{1it}^{*}, \hat{z}_{2it}^{*}$

Equation 6 is predicted by the two-step least squares method (2SLS) for a fixed γ threshold. This operation is repeated for subsets of the variable threshold q. Of the resulting thresholds, the appropriate threshold with the sum of squares (S(γ)) is chosen as (γ). This constraint is expressed in equation 7.

$$\hat{y} = argmin\ S_n(y) \quad (7)$$

According to studies by (Hansen, 2000), (Caner and Hansen, 2004) and (Kremer & al., 2013), critical confidence interval values at a 95% confidence level are calculated for the inflation threshold. Therefore, the calculation of the critical values requires the consideration of the constraint below.

$$\Gamma = \{y : LR(y) \leq c(a)\} \quad (8)$$

In this case, c (a) determines the percentage at the 95% level of the asymptotic LR (y) probability distribution. According to (Hansen, 1999) the likelihood ratio takes into account the time used in each cross-section. After the appropriate threshold is determined, the slopes of the coefficients in the dynamic panel threshold model are predicted by the generalized method of moments for predetermined instrumental variables and the predicted threshold. Again, equation (9) shows the threshold model of the dynamic panel which

establishes by the generalized method. It is the treatment of the effect of inflation on economic growth.

$$dgdp_{it} = \mu_i + \beta_1 \pi_{it}\ I(\pi_{it} \leq y) + \delta_1(\pi_{it} \leq y) + \beta_2 \pi_{it}\ I(\pi_{it} > y) + \emptyset\, Z_{it} + \varepsilon_{it} \quad (9)$$

With:
π_{it} : $the\ rate\ of\ inflation\ for\ two\ types\ of\ scheme,$
Z_{it} : $vector\ of\ control\ variables,$
$\beta_1\ et\ \beta_2$: $the\ efficiency\ of\ the\ slope\ of\ the\ regime,$
δ_1 : $the\ fixed\ coefficient\ of\ the\ regime,$

Model 9 considers the initial level of Z_{2it} revenue as an endogenous variable. Analysis of dynamic panel data can result in errors and biased type estimates and may result in a low over-identification test (Bowsher, 2002) and (Windmeijer, 2005). This is explained by many of the estimation instruments in the model (Roodman, 2009). For this reason, it is necessary to reduce the instrumental variables and use a dependent variable offset threshold as an instrumental variable in order to avoid an over-adjustment of the instrumental variables that can lead to biased estimates.

4. Discussion of results

Table 4 presents the results of the regression of model 9 which expresses the inflation rate as a threshold of the variable.

Table 4. *Results of Dynamic Panel Threshold Model*

Estimated Threshold Value (π)	Model 1a
$\hat{y}$	21.52
95% confience interval	[12,79% − 29,03%]
Effect of inflation	
$\widehat{\beta_1}$	3.07 (0.092)
$\widehat{\beta_2}$	-0.49 (0.049)
Effect of control variables	
Initial	-2.73 (0.004)
PE	-0.41(0.167)
GFCF	0.27 (0.000)
δ_1	-12.52 (0.195)
Number of observations	
$(\pi \leq \hat{y})$	34
$(\pi > \hat{y})$	28
Number of countries	13

Note: One lag of the dependent variable were used as instruments in the analysis: $\mathrm{dgdp}_{\mathrm{it}-1}$
Standard errors are given in parentheses.
*, **, *** indicate significance at 10%, 5% and 1% levels, respectively.
Source: Author's calculation using STATA 15

The upper part of table 4 shows the estimated level of the inflation threshold and the 95 % confidence interval, and the central part shows the nature of the impact of inflation on economic growth in two cases. In this part:

- $\widehat{\beta_1}$ refers to the marginal impact of inflation on economic growth in a low inflation regime. Indeed, a low inflation regime means a situation where the inflation rate is below the estimated threshold value.
- $\widehat{\beta_2}$ prefers the marginal effect of inflation on economic growth in a high inflation regime. In this case, the high inflation regime indicates the situation in which the inflation rate exceeds the value of the estimated threshold.

Table 4 (Model 1a) shows the results of the regression of the Model 9 by Two-Step Least Square Method (2SLS). It shows that the value of the optimal inflation threshold is equal to 21.52 within a corresponding 95% confidence interval $[12.79\% ; 29.03\%]$.

The high level of inflation in the 13 least developed African countries can be explained by the widespread use of the wage and interest rate index system. According to the logic of the (Kremer & al., 2013) study, this strategy can reduce the negative effect of inflation on economic growth.

In addition, Table 4 shows that regime-dependent coefficients are statistically significant $\widehat{\beta_1}$ = 3.07 at a probability of 0.092 and $\widehat{\beta_2}$ = -0.49 at a probability of 0.049. This means that the inflation rate has a significant positive marginal effect on economic growth in a low inflation environment. However, this effect becomes significant in a high inflation regime. That is, if the inflation rate falls below the optimal threshold $\hat{y} = -21.52$, inflation positively affects economic growth. Conversely, the negative effect of inflation on growth appears if the inflation rate exceeds the optimal inflation rate threshold.

On the other hand, if the average inflation rate falls below the threshold, we can say that a 1% increase in inflation leads to an improvement of 3.07% in the level of economic growth. Moreover, when the average inflation rate becomes higher than estimated, the 1% increase in public spending will reduce economic growth by 0.41%. The inverse relationship between public expenditure and economic growth can be explained by the fact that most public expenditure is directed at the administrative office at the expense of productive investment.Thus, the continuity of this strategy can contribute to the inefficiency of long-term economic strategies. In this case, inflation can have an indirect negative effect on economic growth.

The delayed variable has a significant negative effect on economic growth. This effect is explained by the conditional convergence hypothesis of the neoclassical theory of economic growth.This indicates that the convergence hypothesis is strongly supported. That is to say, the most backward countries converge faster on the steady state of the average rate of economic growth compared to developed countries.

In addition, the sign associated with the variable gross fixed capital formation is positive and statistically significant. This means that the economic growth of the 13 least developed African countries is mainly based on private investment.

Table 4 shows that the relationship between inflation and economic growth is not linear and follows a single-threshold, two-system process, and that there is a difference in effect between the two types of inflation regime. This means that, when the inflation rate is high,

it negatively affects economic growth, but if the inflation rate becomes low, it positively affects and significantly handles economic growth.

According to the results in Table 4, there is an inverse "U" relationship between inflation and economic growth in the 13 least developed African countries. This test is explained by the fact that when setting their targets, countries must choose between targets of high growth and low inflation. Thus, the choice between achieving economic growth and controlling inflation depends on different assumptions. This means that economies that want growth are based on the assumption that there is a positive relationship between inflation and growth.The other country believes there is a non-linear relationship between inflation and economic growth. Otherwise, the old exude the logic of the structuralist approach; the second is favorable to monetarism. These are based on the results of the study by (Fischer, 1993) and (Martin, 2022) which justify that the low levels of inflation oil the processes of economic growth. Table 5 shows the results of model 9 re-estimation using the dynamic panel threshold using all possible delayed values of the dependent variable as instrumental variable$(dgdp_{it-1}, dgdp_{it-2},,,,, dgdp_{i0})$ model (1b).

Table 5. *Results of Dynamic Panel Threshold Model*

Estimated Threshold Value (π)	Model 1b
$\hat{y}$	21.52
95% confience interval	$[12{,}79\% - 29{,}03\%]$
Effect of inflation	
$\widehat{\beta_1}$	3.81 (0.019)
$\widehat{\beta_2}$	-0.73 (0.033)
Effect of control variables	
Initial	-1.24 (0.293)
PE	-0.19 (0.152)
GFCF	1.17 (0.084)
δ_1	- 10.46 (0.147)
Number of observations	
$(\pi \leq \hat{y})$	34
$(\pi > \hat{y})$	28
Number of countries	13

Note: All possible lags of the dependent variable wereused as instruments in the analysis : $(\mathrm{dgdp}_{\mathrm{it}-1}, \mathrm{dgdp}_{\mathrm{it}-2},,,,, \mathrm{dgdp}_{\mathrm{it}-\mathrm{T}}$ and $(\mathrm{i_t} - \mathrm{i_T} = 0)$

Source: Author's calculation using STATA 15

Table 5 shows that the choice of instrumental variables does not have a significant effect on previous results. Indeed, the results of the two models (1a) and (1b) appeared rather similar, with the exception of rather minor differences. In addition, the estimated levels of the inflation thresholds and their confidence intervals were found to be the same. Again, the signs of the coefficients and significance record no change. However, the increase in the number of instruments only affects estimates of control variables where standard errors are slightly reduced.

To study the sensitivity of the results to additional explanatory variables, this paper performed some robustness tests. Indeed, this step consists in regressing the model by adding the variable of population, the development of institutions and trade openness.

The model is estimated in two stages. Indeed, the first step adds the variables to the model variable by variable and estimates the model. However, the second step includes all additional variables in the model and repeats the estimate. Table 6 presents the results of the dynamic panel threshold model with additional explanatory variable.

Table 6. *Results of Dynamic Panel Threshold Model with Additional Explanatory Variable*

Estimated Threshold Value (π)	Model 2a	Model 2b	Model 2c	Model 2d
$\hat{y}$	21.52	21.52	21.52	21.52
95% confience interval	[14,71% ; 29,59%]	[11,19% ; 26,38%]	[15,22 ; 33,69%]	[9,67% − 35,57%]
Effect of inflation				
$\widehat{\beta_1}$	3.23 (0.064)	3.01 (0.000)	2.47 (0.029)	1.89 (0.002)
$\widehat{\beta_1}$	0.64 (0.039)	0.33 (0.045)	0.36 (0.0852)	0.28 (0.079)
Effect of control variables				
Initial	-1.92 (0.036)	- 0.81 (0.000)	-2.01 (0.715)	-0.96 (0.234)
PE	-0.38 (0.702)	-0.55 (0.094)	-0.27 (0.031)	-0.06 (0.004)
GFCF	0.93 (0.088)	0.54 (0.564)	1.07 (0.105)	1.02 (0.227)
POP	0.24 (0.001)	-	-	1.79 (0.000)
ID	-	-1.74 (0.033)	-	-1.08 (0.025)
TO	-	-	0.24 (0.000)	0.04 (0.000)
δ_1	13.47(0.824)	10.99 (0.000)	14.54 (0.006)	13.07 (0.019)
Number of observations				
$(\pi \leq \hat{y})$	34	34	34	34
$(\pi > \hat{y})$	28	28	28	28
Number of countries	13	13	13	13

Source: Author's calculation using STATA 15

The results obtained are similar to those reported in Table 4, where the inflation threshold is still at 21.52 without any change. In addition, the regime-dependent coefficients are statistically significant at the conventional level and the results of the robustness checks mentioned above show that the results are qualitatively robust.

According to table 6, the signs of the coefficients of all the additional variables are merged with the expected signs. In addition, they are positive and statistically significant with the exception of the institutional development variable. Indeed, the significant positive effect of the population on economic growth is explained by the economic growth of the 13 least developed African countries relies mainly on the labour factor.That is, they are economies characterized by a high degree of work. In addition, the significant negative impact of institutional development on economic growth is due to the poor quality of regulatory institutions in the 13 least developed African countries.

Again, the linear relationship between trade openness and economic growth is explained by the high degree of trade openness. This can facilitate the export of low value-added raw materials. In the light of these results and explanation, this paper recommends that the 13 least developed African countries improve the quality of the institutional framework and open up the current account more commercial transactions to exploit more commercial advantages compared to the rest of the world.

5. Conclusion

This study determined the non-linear relationship between inflation and economic growth in the 13 least developed Africain countries from 1981 to 2019. The results of the regression of the dynamic panel threshold model by (Kremer & al., 2013) using the two-step least squares (2SLS) method and the generalized moments (GMM) method are new evidence for the presence of a non-linear relationship between inflation and long-term economic growth. On the one hand, if inflation is above a critical threshold, the effect of inflation becomes significant negative on economic growth. On the other hand, if the moderate inflation rate falls below the threshold, it positively affects economic growth. This result based on the opinion that the expected critical value was found at 21.52%.

Again, this study shows no causal link between inflation and economic growth. It simply shows the existence of a relationship. It also indicates the importance of the inflation threshold in determining the relationship between inflation and economic growth in the 13 least developed African countries.Indeed, the problem of high inflation is explained by decision-makers have massively and repeatedly used the system of indexing the interest rate and salary. This system reduces the negative effects of inflation, although they are in part, making it essential for improving economic growth. Thus, the importance of the system becomes evident when we consider that inflation can have a negative impact on growth when the threshold is exceeded; including the results of the analysis.

Moreover, in view of the fact that the moderate inflation rate has a positive effect on economic growth, growth will therefore certainly be induced. However, if central banks turn to other policy objectives at the expense of price stability, which is one of their main objectives, inflation can have a detrimental effect on economic growth, rather than strengthening one. At this stage, it becomes clear once again that maximum attention should be given to inflation targeting, which is carried out in many countries. From this point of view, it can be said that the central banks, which are supposed to be free of any political authority and therefore decide on policies to curb inflation, ensure price stability.

This paper does not take into account the explanation of the test and the meaning of the causality between inflation and economic growth in the least developed African countries. Moreover, it does not empirically determine the role of monetary policies in contributing to economic growth and controlling inflation. In the future, this paper can divide the sample into groups and compare the effectiveness of monetary policies in relation to inflation-economic growth. It may also seek to examine the effect of the complementarity between inflation and monetary policies on economic growth in African least developed countries.

In addition, this study finds that it is important for officials in the 13 least developed African countries to develop the institutional framework to affect economic growth. In addition, it is recommended to reprogram the strategies of the distribution of public expenditure by increasing the share destined for the productive sector to obtain the economic efficiency in the long term.

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