

# Inflation Threshold in the Context of Structural Breaks: Evidence from Egypt Using the Logistic Smooth Transition Regression Approach

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**Abstract** The disparities in structure and nature of developing economies, in terms of their level of development, yield mixed results on the linear/nonlinear relationship between inflation and real GDP (i.e., the inflation threshold), which should be revisited. No study examined the effects of inflation on real GDP in Egypt, particularly after the 2011 revolution and the November 2016 exchange rate floating. This study empirically investigates the inflation threshold in Egypt over the period 1976-2019. In other words, it seeks to determine the optimal level of an inflation rate such that beyond it, inflation becomes a destructive element to economic growth. To this end, the logistic smooth transition regression (LSTR) has been performed. Considering structural breaks, this study checked the stationarity of the variables with the Kapetanios unit root test. Results of the LSTR technique highlight a statistically significant positive relationship between inflation and GDP growth in the lower regime at 9.32%. Beyond this threshold, inflation harms GDP growth, indicating an asymmetric relationship between the two variables. Such a specified estimated inflation threshold could assist monetary authorities in setting their inflation target to be below that threshold. This study recommends that policymakers restrict inflation and keep it below the estimated threshold, considering that inflation in the Egyptian economy is derived from the aggregate supply, demand factors and the production apparatus's inelasticity.

**Keywords:** Inflation threshold, LSTR, Kapetanios unit root test, Structural breaks, Egypt

*JEL Classifications:* C36, E31, E43, E52, E58, E61

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## I. Introduction

Fischer (1993) argued that inflation indicates that the government is managing the economy efficiently and effectively. In this context, inflation is one of the most critical indicators that economists track all the time due to its remarkable effects on economic activity and its major impacts on the expectations of economic agents about the future. For decades, economists have argued about the theoretical underpinnings of inflation-growth dynamics. Moreover, economists have debated the relationship between inflation and economic growth rates for many decades.

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Some of them confirm the presence of a negative relationship between both variables, which is manifested in the form that high inflation rates have detrimental effects on economic growth. Others dispute that inflation has a stimulus effect on economic growth. A third group believes that there is no relationship between both variables, ascertaining the long-run money neutrality assumption of Sidrauski (1967). That is, in the long run, the output level is orthogonal to monetary policy. Companies and investors may shift resources from high-inflation to low-inflation countries to hedge against potential losses from growing inflation. Gauging the inflation threshold level, if any, gives the Egyptian monetary authorities a guideline to maintain the inflation rate below its threshold to stimulate growth.

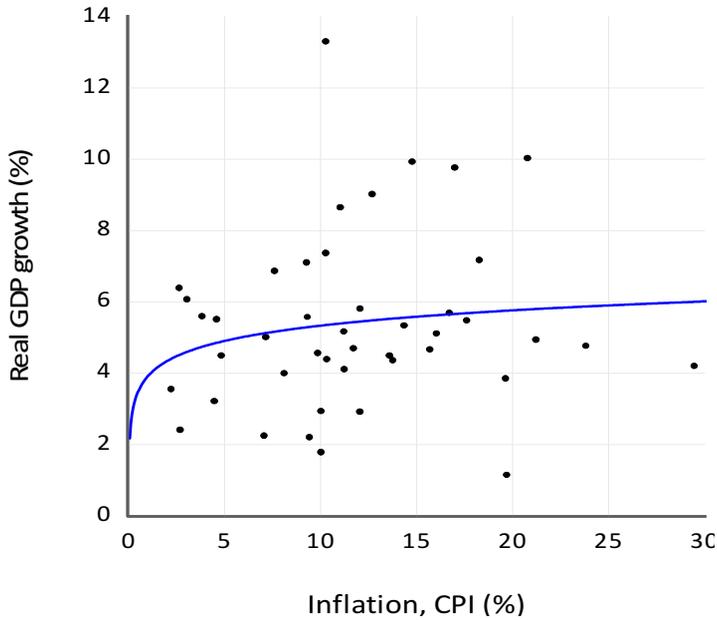
Therefore, it is worth noting that defining a certain level of inflation to target first needs to investigate whether there is a linear or nonlinear relationship between inflation and economic growth in Egypt during the study period (1976-2019). Put differently, it is needed to ascertain if there is a threshold beyond which the relationship between inflation and economic growth turns to be negative; that is, beyond this threshold, inflation's effect on economic growth transforms from a stimulator of economic growth (positive relationship) to a hindrance (inverse relationship). Khan and Senhadji (2001) concluded that if the inflation rate is below its optimum level (threshold), it will have no significant and strong effects on economic growth, and by the same logic, if inflation exceeds its threshold, it will be detrimental to economic growth. If policymakers believe that inflation is harming growth, they should work to reduce it. However, what is the most appropriate level or maximum (threshold) at which the relationship between inflation and economic growth shifts from positive and stimulating to negative and harmful? Thus, the goal of determining the inflation threshold is to determine the level below which inflation should be targeted (i.e., inflation targeting level). For example, if the inflation threshold level is 8%, the inflation target should be less than 8%, for example, between 6-7%.

Motivated by higher inflation rates and monetary instability, as well as their negative effects on the Egyptian economy during the study period, this research focuses on estimating and determining the optimal inflation level to stabilize long-run growth as the ultimate goal of monetary policy.

The importance of this study stems from its attempt to determine the level of Egypt's inflation threshold during a period of political and economic instability (the period after the January 2011 revolution). To the best of my knowledge, the only study that explored this issue in Egypt was that of Abou-Ali and Kheir-El-Din (2009). Their study period was limited to 1982-2006. Apparently, they did not investigate the effect of the 2008 global financial crisis and the effect of the 2011 revolution and their structural breaks on the Egyptian economy. In addition, their findings reveal no inflation threshold in Egypt during their study period, implying that the relationship between inflation rates and economic growth was linear. Figure 1 shows the relationship between the consumer price index (CPI) inflation and Egypt's real

GDP growth rates over (1976-2019). The figure depicts a nonlinear relationship between both variables that starts to be positive and then tends to flatten.

**Figure 1.** Scatterplot of inflation and GDP growth in Egypt 1976-2019)



The present study aims to confirm a nonlinear relationship between the two variables and determine its magnitude, if any. The literature investigating the inflation threshold in different economies with different periods is discussed in Table 1.

**Table 1.** Summary of the Relationship between Inflation and GDP Growth

Author(s) & year	Estimation method	Sample	Findings
Saungweme and Odhiambo (2021)	ARDL model, and Granger causality test.	Kenya (1970-2019)	Long-run economic growth is statistically significantly harmed by inflation. In addition, there is a short-run unidirectional causality from economic growth to inflation.
Abou-Ali and Kheir-El-Din (2009)	Hansen (1999) technique and Khan and Senhadji (2001) (KS) method.	Egypt (1989-2005)	This study does not specify a certain level for the inflation threshold in Egypt. That is, inflation, at any rate, negatively affects economic growth.
Yilmazkuday (2013)	Panel 2SLS technique.	84 countries (1965-2004)	The inflation threshold is 8%.
Ozdemir (2010)	VARFIMA-BEKK MGARCH model.	U.K. (1957-2006)	Inflation uncertainty has a strong positive effect on GDP growth.
Zheng et al. (2019)	Howitt (1999) and Segerstrom (2000) models.	U.S.A (1990-2016)	The inflation threshold is 2.4%.

Table 1. Continued

Author(s) & year	Estimation method	Sample	Findings
Rapach (2003)	Structural VAR model.	14 industrialized countries (1949-1996)	Inflation positively affects the real GDP (economic growth). This study rejects the long-run monetary super-neutrality.
Sattarov (2011)	Error correction model, Johansen cointegration test, and KS method.	Finland (1980-2010)	A positive long-run relationship (cointegration) exists between economic growth and inflation rate. Additionally, this relationship is nonlinear (with an inflation threshold equal to 4%).
Fischer (1993)	Generalized least squares, seemingly unrelated regression, and Spline regression.	93 countries. (1961-1988)	An inverse (and nonlinear) relationship between the real GDP and inflation exists. He specified two thresholds for inflation rates (15% and 40%). He found that the strength of that relationship weakens if inflation rates exceed a threshold of 40%.
Benhabib and Spiegel (2009)	Hansen (2000) method	16 countries (1859-2004)	Inflation positively affects real GDP at moderate inflation levels. Such a relationship is nonlinear. For the entire sample, the inflation threshold is 3.25%.
Sarel (1996)	Nonlinear model and OLS technique.	87 countries (1970-1990)	An asymmetric/nonlinear relationship between inflation and economic growth exists, and the inflation threshold is 8%.
Rousseau and Wachtel (2002)	Rolling panel regressions.	84 countries (1960-1995)	A negative relationship exists between inflation and growth after a certain threshold, which ranges between 6% and 8%.
Faria and Carneiro (2001)	Structural VAR model.	Brazil (1980-1995)	Inflation does not influence real GDP in the long run. This ascertains Sidrauski's (1967) assumption of super-neutrality of money, which indicates no relationship between both variables in the long run. On the contrary, a significant inverse causal relationship is derived from inflation to economic growth. This study does not specify a threshold for inflation.
Frimpong and Oteng-Abayie (2010)	KS method and the 2SLS technique.	Ghana (1960-2008)	A significant inverse relationship between inflation and economic growth exists. The inflation threshold is 11%. The Ghanaian central bank's goal of an inflation rate between 6% and 9% is considered a move in the right direction to achieve monetary stability.
Bruno and Easterly (1998)	Pooled cross-country.	31 countries (1961-1994)	The inflation threshold is 40% during hyperinflation crises (as a separator between high and low inflation rates), and an inverse relationship between inflation and growth exists. However, there is no long-run causal relationship between both variables.
Khan and Senhadji (2001)	Nonlinear OLS and Conditional least-squares method.	140 countries (1960-1998)	The inflation threshold in the developed countries ranges between (1%-3%), and in the developing countries ranges between (11%-12%).
Dammak and Helali (2017)	Hansen (1996) threshold regression model	Tunisia (1993-2012)	They detected a nonlinear relationship between inflation and growth. In addition, the inflation threshold is 3.48%.
Erbaykal and Okuyan (2008)	ARDL model and Toda and Yamamoto (1995) causality test.	Turkey (1987-2006)	There is no long-run relationship between inflation and growth, but a short-run significant causal inverse relationship exists between inflation and economic growth.
Nell (2000)	VAR technique.	South Africa (1960-1999)	There is a significant inverse relationship between inflation and economic growth, but no causal relationship emerges from inflation to economic growth. This study recommends that inflation rates remain within the single-digit zone; exceeding it to become within the double-digit zone impedes economic growth.
Ghosh and Phillips (1998)	Nonlinear 2SLS technique.	145 countries (1960-1996)	There is an asymmetric association between inflation and growth. The inflation threshold is 2.5%.
Phiri (2020)	Smooth transition regression (STR) model.	Swaziland (1975-2016)	Inflation impacts economic growth significantly inversely. The inflation threshold equals 7.64%, supporting the nonlinear relationship.

**Table 1.** *Continued*

Author(s) & year	Estimation method	Sample	Findings
Drukker et al. (2005)	Fixed-effects model.	138 countries (1950-2000)	Only one inflation threshold of 19.16% exists. However, for the advanced industrial countries, there are two thresholds for inflation: 2.57% and 12.61%, respectively.
Kremer et al. (2013)	Dynamic panel threshold model, and the KS method.	124 countries (1950-2004)	Inflation impacts economic growth significantly inversely, as inflation rates exceeded an inflation threshold of 2.5% in industrialized countries and 17.2% in nonindustrial countries. This supports the nonlinear relationship.
Ibarra and Trupkin (2016)	Panel STR (PSTR) model.	138 countries (1950-2009)	The inflation threshold for nonindustrialized economies is 19.1%, whereas for industrialized economies is 4.5%.

## A. Background on the Egyptian economy and its monetary policy

Egypt is a developing country with relatively less developed fiscal and financial institutions and a weak monetary transmission mechanism due to oligopolistic banks and less credible monetary institutions. Furthermore, these countries have historically relied on seigniorage as a source of government financing (fiscal deficit monetization) (Ikram, 2007, ch. 7). Goods markets are frequently more vulnerable to international shocks, and real exchange rate fluctuations in these economies are three times that of developed economies (Bhandari and Frankel, 2017; Frankel, 2010; Hausmann et al., 2006).

Between 1975 and 1981, the average budget deficit in Egypt was approximately 23%, financed through the banking system. Consequently, liquidity expanded, and prices rose steadily. Public enterprises generally suffered from over-employment, unprofessional management, poor technology, and were organized as monopolies without an incentive to improve efficiency. They face little repercussions if they default on their payments, putting a strain on the financial system by financing their deficits from the public budget or borrowing at low interest rates from public sector banks (Ikram, 2007, pp. 45-48; Kamar and Bakardzhieva, 2005).

To correct the imbalances in the government budget and the balance of payments and overcome the economic crisis during the 1980s, the Egyptian government implemented the so-called "economic reform and structural adjustment program (ERSAP)" in 1991. In this regard, Egypt implemented a contractionary monetary policy by increasing the nominal interest rates to achieve positive real interest rates (Ikram, 2007, pp. 62-64). Consequently, inflation rates have fallen from double digits to single digits, except for the aftermath of the Egyptian currency floating in January 2003, the 2008 global financial crisis, and the November 2016 exchange rate floating. Between 1990 and 1997, the budget deficit as a percentage of GDP fell dramatically from approximately 18.2% to less than 1%. Egypt has encountered challenges in its pursuit of long-run economic growth but has achieved considerable gains. That is, the economic growth rate has been above 3% since 1983, except in the aftermath of both the 2008 global financial crisis and the 2011 revolution.

Between July 2004 and March 2005, Egypt's money and financial markets have witnessed successful developments. In this vein, the government privatized large state-owned banks that accounted for 80% of the deposits of commercial banks. In addition, it settled nonperforming loans, reorganized the huge public banks, and developed private sector credit policies [see Elshamy (2012), Hosny (2014), and Youssef (2007)]. Since the end of the stabilization program in 1996, the central bank of Egypt (CBE) has been preoccupied with achieving multiple goals simultaneously, some of which were incompatible. These objectives included achieving significant economic growth while maintaining price stability and a stable exchange rate. In view of increasing capital mobility inflows, the multiplicity of purposes made the execution of an autonomous monetary policy practically impossible, and the measurement of the monetary policy position during that time (1996-2005) was clouded (Al-Mashat and Billmeier, 2008; Elshamy, 2012).

The production process was harmed as a result of the economic crises and their consequences, putting pressure on the exchange rate. In response, the CBE used its foreign-exchange reserves to defend the local currency by intervening in the foreign-exchange market. Consequently, foreign-exchange reserves have experienced a significant decrease twice. The first time was between 1999 and 2000 when these reserves decreased by 38.11%, resulting in the halt of the collapse of the exchange rate by only 2.4%. The second enormous reduction was after the 2011 revolution when the reserves were reduced by 65.4% (Maher and Zhao 2022).

Under the collapse of the Egyptian foreign exchange, which comes mainly from rentier activities,<sup>1)</sup> the CBE was forced to float its currency in November 2016. As a result, the value of the Egyptian pound depreciated by almost 50% against the U.S. dollar. This decision coincided with the increase in overnight deposit and lending interest rates by 3% (Maher and Zhao, 2022) in the context of the "leaning against the wind" policy. The economic growth rate has been significantly affected in response to the 2011 revolution and its consequences, decelerating further to an average rate of 3.6%.

Law No. 88 of 2003,<sup>2)</sup> which regulates the work of the CBE, clearly states that its goal is to achieve monetary stability or price stability as its primary objective. During the ERSAP implementation, the CBE relied on monetary policy instruments such as open market operations, discount rates, interest rates on Treasury bills and government securities, and reserve requirements to conduct its monetary policy. The Egyptian monetary authorities changed the monetary policy instrument from banks' excess reserves to the overnight nominal interest rate on interbank transactions in 2005. Furthermore, the discount rate has been chosen as an intermediate target (Al-Mashat, 2008; Elshamy, 2012; Hosny, 2014; Shokr et al., 2019).

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1) According to Maher and Zhao (2022), these include Suez Canal revenues, tourism revenues, workers' remittances, particularly those from Gulf countries, and net direct investment inflows.

2) For further details about Law No. 88 of 2003, visit <https://www.cbe.org.eg/-/media/project/cbe/page-content/rich-text/aml-and-cft/laws/executive-regulations-of-the-cbe-banking-sector-and-money-law-english.pdf>.

The remainder of this paper is organized as follows: Section 2 presents the theoretical framework of the inflation threshold. Section 3 presents the literature review. Section 4 exhibits data specifications and sources, as well as the description of variables. Sections 5 and 6 explain in detail the standard econometric model (LSTR) used to estimate the inflation threshold and the results analysis. Section 7 discusses the results. Finally, Section 8 concludes the paper.

## II. Theoretical Framework

There is controversy among economists about the effect of inflation on economic growth. Milton Friedman (1968) emphasized the main long-run neutrality of the role of money in the economy. He also emphasized that inflation is caused by an increase in the money supply or higher rates of money velocity at a faster rate than output growth. Furthermore, he contended that inflation can negatively affect investment, capital accumulation, the competitiveness of domestic goods, and, ultimately, exports. In turn, this negatively impacts economic growth. He also disputed that, in the long run, prices are affected mainly by changes in money supply without a real impact on economic growth. However, when the growth rates of money supply are higher than the rates of output growth, inflation will increase.

On the contrary, Structuralists argued that inflation has stimulus impacts on economic growth (Felix, 1961; Taylor, 1983). This viewpoint is based on the idea that inflation stimulates economic growth by stimulating savings via several transmission channels, as represented in the following: First, governments in developing countries that face severe shortages in the volume of public revenues may borrow from the central bank to finance public expenditures. This procedure could result in inflationary effects, but this process transfers financial resources to the government, which can direct them to increase capital formation to enhance economic growth. This is called the "Kalecki effect." This is assuming that the procedure does not result in a crowding-out effect between the government and the private sector. Second, because nominal wages lag behind price increases (i.e., sticky wages), inflation may drive growth by shifting incomes in favor of capitalists and entrepreneurs with a higher marginal propensity to save, increasing savings and thus growth. This is called the "Kaldor effect."

Keynesians relied on the short-run Phillips curve to stress the direct positive relationship between growth and inflation because an inverse relationship exists between inflation and unemployment, and between economic growth and unemployment. Then, the relationship between economic growth and inflation becomes positive (Fischer 1983). From a Keynesian perspective, inflation may stimulate growth by raising the rate of profit, thus boosting private investment. Furthermore, higher inflation rates are likely to reduce the real value of returns on financial investments by lowering the real interest rate and thus shifting the investment portfolio

from the financial sector to its real counterpart.<sup>3)</sup> This, in turn, increases capital intensity (accumulation) and enhances real economic growth. This is known as the "Mundell-Tobin effect" (Fischer 1993; Sidrauski 1967; Tobin 1965). However, when applying the Mundell-Tobin effect to developing countries with distorted and inefficient financial markets, the investment portfolio adjustment, as observed in Egypt, would be from cash balances to either the real estate sector (especially land ownership), consumer durables, or assets determined in foreign currencies at home or abroad via capital flight.

Regarding the endogenous growth theory, inflation affects the growth rate through its impact on the rate of return on capital since economic growth depends on the rate of return on capital. Higher inflation rates reduce investment and capital accumulation, thus reducing economic growth (López-Villavicencio and Mignon, 2011). The relationship between inflation and growth is discussed in these models through the marginal product of capital, which can be physical capital, human capital, or both. The rate of inflation affects the rate of growth by influencing the rate of return on capital. When considering physical capital, inflation is deemed as a tax on human capital. It lowers its rate of return, which decreases the return on aggregate capital accumulation, thus lowering economic growth (Gillman et al., 2004; López-Villavicencio and Mignon, 2011).

Summarizing the previous discussion, economic theories that study the relationship of inflation to economic growth revolve around several axes. First, Sidrauski (1967) referred to the super-neutrality of money, implying that the money supply growth rate has no real effects on the state of the national economy and its variables like real output, unemployment, and consumption. Rather, the effects of the money supply are directed only to nominal variables, such as prices, money wages, and nominal exchange rates. In this context, the effect of inflation on capital investment and thus economic growth depends on how money supply is viewed and dealt with within economic models. This effect becomes independent, as in Sidrauski's view of money as a component of the utility function. He stated that people tend to keep idle cash balances to obtain the self-benefit that makes them feel secure (as a hedge). However, some economists, like Bruno and Easterly (1998) and Fischer (1983), pointed out that at present, economists agree that inflation negatively affects economic growth in the medium and long run.

Second, when money is considered a substitute for capital investment, the effect of inflation on economic growth becomes positive, as proposed by Mundell (1963) and Tobin (1965). Third, as suggested by Stockman (1981), this effect becomes negative, with money seen as a complement and one of the important initial requirements for investing in and financing capital. Therefore, high inflation rates reduce the real value, or purchasing power, of those cash balances, thereby

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3) However, achieving this requires a robust banking system, regulatory expertise, and knowledge of productive investment strategies that stimulate economic activity. In developing countries, these factors are rare. In addition, these financial resources may be used for less productive endeavors, such as real estate ownership and dollarization.

reducing the ability to finance investment operations and thus the long-run economic growth (Ajide and Lawanson, 2012; Drukker et al., 2005; Ibarra and Trupkin, 2016). Fourth, other theories contend that the relationship between the two variables is nonlinear; it is not always positive or inverse. Although these theories corroborate the inverse relationship, they indicate that it does not apply until inflation exceeds a particular threshold.

In general, the strength of the relationship between inflation and economic growth depends on whether inflation is mainly driven by demand-side shocks (demand-pull inflation) or supply-side shocks (cost-push inflation), as discussed earlier. In an economy dominated by demand-side shocks, the relationship between the two variables will likely be positive due to moving along the aggregate supply curve.<sup>4</sup> Conversely, if supply-side shocks dominate the economy, the relationship between both variables is likely to be negative due to moving along the aggregate demand curve (Fischer 1993). Inflation in Egypt cannot be considered an entirely monetary phenomenon (propagated from changes in the quantity of money, whether through the expansion of monetary issuance or the credit expansion), as the Monetarists promote. Rather, inflationary pressures stem mainly from supply-side shocks, aggregate demand-side shocks, and regulatory and structural constraints. Therefore, there are restrictions on the ability of the CBE to fully control inflation.

### III. Literature Review

Many studies have been investigated to examine the relationship between inflation and economic growth. For instance, Fischer (1993) is a pioneering study in this field. He discovered an inverse relationship between both variables and that inflation does not promote long-run economic growth to be sustainable. Vaona (2012) ascertains this inverse relationship. Likewise, Fischer and Modigliani (1978) found a nonlinear inverse relationship between the two variables, and that inflation significantly dampens investment. They ascertained that inflation confines economic growth primarily by reducing the efficiency of investment. Analogously, applying the generalized least squares model, De Gregorio (1992) concluded that an inverse relationship exists between both variables by studying 12 Latin American economies using annual data over the period 1950-1985. Moreover, by studying 100 countries over 1960-1990, Barro (2013) detected an inverse causal relationship between inflation and both investment and economic growth. An increase in inflation by 10% per year results in a decrease in GDP growth at the investment-GDP ratio by 0.2%-0.3% and 0.4%-0.6%, respectively. This inverse relationship becomes significant only when considering countries that experience high inflation rates.

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4) Assuming that the economy is operating under the full employment of its resources. In such a scenario, the rises in the general price level are directly, albeit partly in some cases, reflected in output, and hence aggregate supply increases.

Similarly, Abo-Zaid and Tuzemen (2012) observed that developing and developed countries that target inflation achieve higher GDP growth rates. They concluded that lowering inflation improves economic growth. Additionally, Singh and Kalirajan (2003) investigated this relationship for the Indian economy and revealed that lowering inflation is crucial to boosting growth.

Meanwhile, Thirlwall and Barton (1971) were one of the first studies to find a positive relationship between growth and inflation among a sample of industrialized countries during 1958-1967. In addition, they discovered an inverse relationship between both variables in a sample of developing countries when the inflation rate exceeds 10%. Likewise, Beck et al. (2000) found the same result among a sample of 22 industrialized and 112 developing countries over 1960-1994. In contrast, Johnson (1967) indicated no conclusive evidence of a positive or negative relationship between both variables. However, in the long run, inflation generally has a positive effect on growth at low inflation levels and a negative impact at high levels (Drukker et al. 2005).

Noteworthy, economists do not agree on the optimal inflation rate (i.e., threshold inflation). Its level varies depending on the econometric selection criteria [e.g., the Akaike information criterion (AIC), the Schwarz Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC)], the sample size, and the number of regressors in the regression model (Lütkepohl and Krätzig, 2004, p. 124). It must also be considered that each country has its own economic, geographical, and political conditions, and the nature and structure of its economy. This contributes to determining the level of the inflation threshold to a large extent.

According to Fischer (1993) and Khan and Senhadji (2001), the inflation threshold varies across countries; that is, it is much higher in developing countries than in advanced industrial countries. This is due to several noteworthy factors: (1) The developing countries frequently rely on "indexation systems" to mitigate the negative effects of inflation. Governments use these systems to correlate wage and asset price levels with inflation rates: as prices of goods and services rise, so wages and asset values will also rise (relative prices do not change significantly, and the purchasing power of the domestic currency is preserved). These systems protect economic growth from the negative effects of high inflation rates. (2) The so-called "Balassa-Samuelson effect" indicates that developing countries with high levels of productivity experience significant wage growth not only in the tradable goods sector, but also in nontradable services. Individuals consume more goods and services as wages (and thus incomes) rise, resulting in a concomitant increase in inflation that is higher in faster-growing economies (developing countries) than in slow-growing economies (developed countries).

In this regard, Das and Loxley (2015) found that the inflation threshold is 23.5% for Latin American and Caribbean countries, 11% for Asian countries, and 23.6% for Sub-Saharan African countries. Concerning which causes the other, using the Granger causality test, Paul et al. (1997) explored a unidirectional causal relationship between inflation and real GDP growth in 70

countries using annual data over the period 1960-1989. Furthermore, they noted that the relationship between inflation and growth is not unified across countries. Moreover, 40% of the countries under study do not reveal the existence of any causal relationship, and about 30% of them show a unidirectional causal relationship. Furthermore, approximately 20% of them show a bidirectional causality. Besides, most countries that show a unidirectional or bidirectional causal relationship belong to the industrialized countries group, and that high inflation rates will redistribute the opportunities for real economic growth from developing countries (with high inflation rates) toward their industrial counterparts (with low inflation rates).

Table 1 summarizes a strand of literature that reveals the relationship between inflation and economic growth, as well as the estimated level of inflation threshold across countries and periods.

As clarified in Table 1, the relationship between inflation and real GDP has been examined in several prior studies, especially for developed and industrialized economies. However, research into such a relationship is still limited in developing countries in general. The overwhelming majority of empirical evidence obtained from developed and developing countries reports somewhat mixed and inconsistent results: some found a positive relationship between both variables, whereas others found a negative relationship, and some succeeded in observing an inflation threshold, whereas others did not. This is due to the differences in the structure and nature of these economies in terms of their stage of development. This led the researcher to look for the permissible limit of inflation in a way that does not negatively affect the economic growth in Egypt.

For Egypt, in particular, the research on such a relationship is not clear, inadequate, robust, and did not find a certain threshold for the inflation rate. Furthermore, no study discussed the effects of inflation on real GDP in Egypt, especially after the 2011 revolution. Additionally, no study used the LSTR to estimate Egypt's threshold level of inflation. Therefore, this current study is the first to examine how inflation can affect the real GDP of Egypt, paying an attention to estimating the threshold level of the inflation rate. This threshold is critical for policymakers to build good models for good performance. Most of the prior studies worldwide are based on relatively short periods, which is considered a limitation in providing a plain view of the influence of inflation on the real GDP over time. Given the limitations in prior research (shown in Table 1), the current study tends to overcome these shortcomings by examining the impact of the inflation rate on real GDP in Egypt over the extended study period (1976-2019).

#### **IV. Data Description and Variables**

Before 1975, Egypt witnessed two unique elements that considerably affected the analysis.

The first element was the Arab-Israeli war in October 1973, and the second was the socialist economic policies carried out in Egypt under the political regime of President Nasser. Starting from October 1974, Egypt adopted the Open-Door (Infitah) policy, which retreated from the socialist orientation of Egypt, opening it to both the private and external sectors to play the dominant role. Furthermore, because 2020 is the year the Coronavirus (COVID-19) disease began, economic data, and the conducted economic policies clearly differ from the period before COVID-19. As a result, the study analysis covers the period 1976-2019 because the years between 1976 and 2019 are obviously different from those before and after. In other words, this period was explicitly chosen due to data constraints and the consistency and similarity of economic policies implemented over its course.

Other macroeconomic variables, known as control variables, influence or control the relationship between inflation and economic growth. The researcher's selection of these variables is influenced by different growth models of Solow (1956), Swan (1956), Fischer (1993), and Mankiw et al. (1992), among others, as well as what is indicated and used by growth literature (some of them are reviewed earlier).<sup>5)</sup> Incorporating these variables within the model increases the strength of the relationship between the two main study variables (i.e., inflation and economic growth), provided that they correlate with the dependent variable (Fischer 1993).

Accordingly, I use a set of those variables that consists of: Inflation rate,  $\pi$ , which is measured by the percentage change in the CPI; The growth rate of GDP at constant prices for the year 2010 (real output),  $GDP\_GR$ ; The international terms of trade at constant prices for the year 2000,  $TOT$ , calculated as [exports price index/imports price index]; Trade openness,  $OPEN$ , calculated as [(exports + imports)/GDP]; Investment spending proxied by gross fixed capital formation ratio to GDP,  $GFCF\_GDP$ ; The official nominal exchange rate in logarithmic form,  $\log EX$ ; money supply as a percentage of GDP,  $M2\_GDP$ , to capture the financial sector's depth. Controlling for the effect of the structural breaks in November 2016 (the date of floating the exchange rate in Egypt), I add a dummy variable,  $Dum-17$ , which takes 0 before 2017 and 1 thereafter.<sup>6)</sup> My data set is sourced from the World Bank's world development indicators (WDI) and CBE databases. The general specification of the inflation threshold model can be represented as

$$\Delta GDP\_GR_t = \beta_0 + \beta_1 \pi_t + \beta_2 \Delta \log EX_t + \beta_3 \Delta GFCF\_GDP_t + \beta_4 \Delta M2\_GDP_t + \beta_5 \Delta TOT_t + \beta_6 \Delta OPEN_t + \beta_7 Dum-17 + \varepsilon_t \quad (1)$$

5) For more studies, see Eggoh and Khan (2014), Phiri (2018), Seleteng et al. (2013), López-Villavicencio and Mignon (2011), Ibarra and Trupkin (2016), Vinayagathan (2013), Kremer et al. (2013), and Dammak and Helali (2017).

6) Year dummies for the 2008 global financial crisis and the 2011 revolution are deemed insignificant. Therefore, they have been excluded from the analysis.

where  $\Delta$  denotes the first-difference operator. The parameter  $\beta_1$  signifies the linear effect of inflation on economic growth. This effect will be segmented into two regimes under the smooth transition regression (STR) model. Parameters  $\beta_2 : \beta_6$  capture the effect of explanatory control variables in the growth-inflation nexus. The parameter  $\beta_7$  denotes a dummy variable for the year 2017,  $\alpha_0$  is the intercept and  $\varepsilon_t$  is the random error term, which is assumed to be  $N(0, \sigma_\varepsilon^2)$ . This study uses the STR approach to empirically estimate the inflation threshold (i.e., the potential asymmetric relationship between inflation and economic growth) in Egypt during the period under investigation. This model has never been used before in previous studies applied to Egypt to investigate such a relationship.

## V. Technical Procedures

### A. Multicollinearity and descriptive statistics

The presence of multicollinearity among the regressors has been tested using the pairwise correlation matrix and the variance inflation factor (VIF). Wooldridge (2020, p. 92) and Kennedy (2008, p. 199) noted that a correlation coefficient greater than 0.8 and/or a VIF greater than 10 indicate severe multicollinearity. Some studies, like that of Marcoulides and Raykov (2018), propose that a VIF greater than 5 mirrors serious multicollinearity. Therefore, Table 2 does not reveal a strong correlation among the independent variables.

**Table 2.** Matrix of Correlations and Variance Inflation Factor for Variables

Series	$\Delta GDP\_GR$	$\pi$	$\Delta \log EX$	$\Delta GFCF\_GDP$	$\Delta M2\_GDP$	$\Delta TOT$	$\Delta OPEN$	VIF
$\Delta GDP\_GR$	1.000000							
Inflation ( $\pi$ )	0.051394	1.000000						1.41
$\Delta \log EX$	-0.27651	0.311025	1.000000					1.57
$\Delta GFCF\_GDP$	-0.31761	-0.03293	-0.11157	1.000000				1.36
$\Delta M2\_GDP$	-0.06826	-0.10955	0.126054	0.169828	1.000000			1.15
$\Delta TOT$	0.191229	0.024460	0.148668	-0.14422	0.201355	1.000000		1.21
$\Delta OPEN$	-0.06217	0.174554	0.470266	0.297303	0.085381	0.257922	1.000000	1.70

The descriptive statistics of the variables, shown in Table 3, highlight that the standard deviation for the inflation series is relatively high. On the contrary, the volatility of GDP growth is relatively low. Furthermore, the maximum and minimum values indicate a relatively large dispersion of the values of the two main variables. It is also worth noting that the mean is greater than the median for all study variables, except  $\Delta GDP\_GR$ , indicating that the data distribution has a positive skew. The variable distribution is asymmetrical in this case. The

Jarque-Bera (JB) test statistic decreases as skewness and kurtosis decrease, indicating that the series is approaching the normal distribution. The identical normal distribution implies that a series has a skewness equals zero and kurtosis equals 3. Consequently, the JB test statistic equals zero. The null hypothesis of JB is that the series has a normal distribution (Wooldridge, 2020, ch. 5). Except for  $\Delta M2\_GDP$ ,  $\Delta \log EX$ , and  $\Delta TOT$ , all of the series in Table 3 are normally distributed. Notably, what is important is not the normality of each variable individually, but the normality of the residuals resulting from the regression estimation process.

**Table 3.** *Descriptive Statistics*

Series	$\Delta GDP\_GR$	$\pi$	$\Delta \log EX$	$\Delta GFCF\_GDP$	$\Delta M2\_GDP$	$\Delta TOT$	$\Delta OPEN$
Mean	-0.179582	11.89590	0.087393	-0.099900	0.734342	0.325828	-0.04233
Median	0.243989	11.17164	0.002138	-0.232703	0.459217	-1.144802	-1.43411
Maximum	5.463639	29.50661	0.705333	7.476092	20.15025	77.49640	17.2576
Minimum	-4.812764	2.269757	-0.069741	-4.764391	-10.52071	-46.02393	-15.1271
Std. dev.	2.280163	6.096446	0.184970	2.646956	5.879169	16.67217	6.92887
Skewness	-0.109895	0.556107	2.209150	0.503936	1.153645	1.800981	0.62300
Kurtosis	3.252490	3.202445	6.778359	3.508466	5.245225	13.06886	3.40095
JB	0.200772	2.343011	60.55362	2.283197	18.56995	204.8880	3.06968
JB <i>prob.</i>	0.904488	0.309900	0.000000	0.319308	0.000093	0.000000	0.21549

## B. Unit root testing

In the STR specification, all variables should be stationary, i.e.,  $I(0)$ . Stationarity assumption indicates that a variable, say  $x$ , should not exhibit any form of nonstationarity (e.g., autoregressive unit roots, unconditional heteroskedasticity, or deterministic trends). If nonstationarity exists, we must use transformations, including the growth rates of  $x$ , logarithm, or the first difference (Creamer and Botha, 2017; Mátyás et al., 1999; Ogaki, 1993). According to Frankel (2019) and Wintoki et al. (2012), taking the first difference, for example, prevents  $x$  from being influenced by its long-run trend.

To this end, I use unit root tests. These tests ensure that all variables are stationary, preventing spurious correlations and misleading regressions, as discussed in Granger and Newbold (1974) and Phillips (1988). Econometricians usually use conventional unit root tests (without considering structural breaks), such as the augmented Dickey-Fuller (ADF) test of Dickey and Fuller (1981), the Phillips-Perron (PP) unit root test of Phillips and Perron (1988), and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test of Kwiatkowski et al. (1992).<sup>7)</sup> All conventional unit root tests have poor power if structural breaks exist in the data-generating

7) In order to conserve space, the author has omitted the results of the conventional unit root tests, but such results are available upon request.

process (DGP), and they could lead to making false and biased inferences regarding time-series stationarity. Furthermore, structural breaks could result in spurious cointegration and misleading estimations. Furthermore, small sample size distortions considerably affect these tests (Choi, 2015, pp. 28-29; Culver and Papell, 1997; Gregory et al., 1996; Montañés et al., 2005; Ng and Perron, 2001; Perron and Ng, 1996; Schwert, 1989; Shrestha and Bhatta, 2018). Due to the shortcomings, Taylor et al. (2001) argued that the power of these tests can be gravely low against nonlinear unit root tests.

### 1. Kapetanios unit root test with structural breaks

For reliability and robustness of stationarity testing, considering structural breaks, the researcher uses the Kapetanios (2005) unit root test with  $m$  structural breaks chosen endogenously. This test examines the intercept and/or trend stationarity when there are up to five data-dependent structural breaks. Defining the condition differently, by minimizing the sum of squared residuals, this test endogenously determines the structural break dates and estimates the position of the structural break. According to the Kapetanios (2005) notation, this test has the following formula:

$$y_t = \alpha_0 + \alpha_1 t + \rho y_{t-1} + \sum_{i=1}^k \lambda_i \Delta y_{t-i} + \sum_{i=1}^m \phi_i DU_{i,t} + \sum_{i=1}^m \gamma_i DT_{i,t} + \epsilon_t \quad (2)$$

where  $\alpha_0$  and  $\alpha_1$  indicate the intercept and trend, respectively; the parameter of the autoregressive term of order one, AR(1) is denoted by  $\rho$ ;  $DU_{i,t}$  refers to the break dummy variable of the intercept, while  $DT_{i,t}$  is the break dummy variable of the time trend. This test checks unit roots under the null hypothesis of a unit root or nonstationarity with  $m$  structural breaks; that is,  $H_0 : \rho = 1$ .  $DU_{i,t}$  and  $DT_{i,t}$  can be expressed as  $DU_{i,t} = 1$  if  $(t > T_{b,i})$ , 0 otherwise, and  $DT_{i,t} = (t - T_{b,i})$  if  $(t > T_{b,i})$ , 0 otherwise, where  $T_{b,i}$  denotes the structural break date specified by the test. Kapetanios (2005) stated that when the number of breaks grows, the test's power decreases. Therefore, due to the small sample size, I allow only two structural breaks.

Table 4 shows the results of the Kapetanios test, revealing that inflation is stationary at level,  $I(0)$ , at the 5% significance level, and other variables are integrated of order one,  $I(1)$ , around two structural breaks. Because of the nonstationarity of some variables in level, following Juhro et al. (2021) and Mohanty and Klau (2005), I have differenced nonstationary variables to be stationary before estimating the STR model, taking the first-difference operator ( $\Delta$ ). According to Beckworth and Hendrickson (2019), the difference rules allow the central bank to avoid problems with constructing unobservable or latent series.

Table 4 also shows the break dates for the study's variables. For example, it indicates that

GDP\_GR experienced a break date in 1991, which was caused by the implementation of ERSAP in 1991 and its consequences. This is discussed in more detail in the section on the Egyptian economy's background. The second Gulf War between Iraq and Kuwait in 1991 also triggered such a break date, resulting in a drop in Egyptian overseas workers' remittances from Iraq, a restructuring of a significant portion of Egypt's external debt, and a drop in tourism revenues. In addition, Table 4 shows that inflation experienced a break date in 1989. Egypt saw a major surge in inflation in 1989 because of several economic changes designed to address the country's balance of payments crisis. The government devalued the currency and eliminated subsidies on basic products, causing prices to skyrocket. Inflation peaked at around 20% in 1989 and remained high throughout the early 1990s.

**Table 4.** Kapetanios Unit Root Test with Structural Breaks

Series	Test statistics		Constant (C) or Trend (T) §	I(d)	Result	Break dates	
	Level	1 <sup>st</sup> difference				1 <sup>st</sup> break	2 <sup>nd</sup> break
<i>GDP_GR</i>	-4.8390	-5.5686**	C, C	<i>I</i> (1)	Non	1991	1999
$\pi$	-6.2678**	-6.4128**	C, C	<i>I</i> (0)	Stat.	1989	2001
<i>log EX</i>	-4.3991	-7.4302**	C, C	<i>I</i> (1)	Non	2003	2011
<i>GFCF_GDP</i>	-4.6035	-10.555**	C, T	<i>I</i> (1)	Non	1989	2010
<i>M2_GDP</i>	-3.3930	-5.3817**	C, C	<i>I</i> (1)	Non	1983	2005
<i>TOT</i>	-3.8596	-5.6245**	C, C	<i>I</i> (1)	Non	1988	1998
<i>OPEN</i>	-4.5296	-5.1922**	C, C	<i>I</i> (1)	Non	1987	2002

Note. - \*\* denotes the 5% level of significance.

- Critical values at the 5% significance level are provided in Kapetanios (2005, Table 1). The critical values for the constant term and time trend equal -5.096 and -6.113, respectively.
- Due to the small sample size, I have selected only two structural breaks for all variables.
- The trimming parameter is set to 0.15.
- For performing the Kapetanios (2005) unit root test, we use the modified Akaike information criterion (MAIC) to assign the number of lags needed for every variable. The MAIC criterion has significantly improved size over typical information criteria, such as the AIC and SBIC (Cavaliere et al., 2015; Ng and Perron, 2001). The maximum number of lags is determined based on Schwert's (1989) criterion given by  $l = \{4(T/100)^{1/4}\}$ . Claus (2000) proposed that maximum lag length is set equal to three times the seasonal frequency of the data sample size. Accordingly, both propose a maximum lag length of 3 lags.
- I use the same number of lags for every variable shown in conventional ADF, PP, KPSS unit root tests.
- The results are as follows concerning the significance of constant and time trend. The constant is significant for all variables except log EX and OPEN. The trend is significant only for GFCF\_GDP.
- § The letter ordered first, in the notation (C, C), refers to the significance of constant and trend terms for both levels and first differences, respectively.
- Non: Nonstationary series at 5% significance level and need to be differenced. Stat.: Stationary series at 5%.
- *I*(d) denotes the integration order. *I*(0) indicates that the series is stationary at level. *I*(1) denotes the stationary series after taking the first difference.

Another break date for inflation was in 2001. In 2001, Egypt experienced a similar spike in inflation due to a combination of factors, including rising oil prices, a decrease in tourism revenues after the 9/11 attacks, and a drought that led to a decrease in agricultural production. Inflation peaked at more than 11% after 2001 and remained high for several years, leading

the government to implement a series of measures to try to control prices and stabilize the economy. Regarding the exchange rate, the CBE abandoned it as a nominal anchor in 2003. The other break date for the exchange rate was in 2011, as a response to the 2011 revolution in Egypt. This is discussed in more detail in the section on the Egyptian economy's background [see Maher and Zhao (2022) and Maher (2022), for more details].

### C. Durbin-Wu-Hausman test

Before proceeding with the STR approach, we must check it first to avoid the harmful effect of potential endogeneity between the model variables. To this end, I used the so-called "Durbin-Wu-Hausman" or "Hausman specification" test. Hendry (2018) and Wolters (2012) elucidated that this test is used to check the validity of overidentified instruments or to detect endogeneity of the regressors [see Durbin (1954), Hausman (1978), Wu (1973)]. This test is under the null hypothesis that the explanatory variables are exogenous (not correlated with the error term). The properties of the Wu-Hausman test enable us to decide on using OLS versus instrumental variables (IV) results, depending on the result of an exogeneity test. To that end, this test presents two asymptotically equivalent statistics: One uses an instrumental variable estimator ( $\hat{B}^{2SLS}$ ) of the regression standard error, while the other uses the OLS estimator ( $\hat{B}^{OLS}$ ). If we fail to reject  $H_0$  of no endogeneity, both OLS and IV estimators are consistent. Meanwhile, if we reject  $H_0$ , only the instrumental variable estimator is fully efficient and consistent. Put differently,  $H_0$  signifies that the variables are exogenous [see Nakamura and Nakamura (1998), Kennedy (2008, ch. 9), Hall (2005, p. 197), Greene (2018, pp. 414-416)]. The Hausman test statistics,  $H$ , can be expressed, under its null hypothesis, as

$$H = \left\{ \left( \hat{\beta}^{OLS} - \hat{\beta}^{2SLS} \right)' \left[ \widehat{Avar} \left( \hat{\beta}^{2SLS} - \hat{\beta}^{OLS} \right) \right]^{-1} \left( \hat{\beta}^{OLS} - \hat{\beta}^{2SLS} \right) \right\}, \quad (3)$$

where  $\widehat{Avar}(\cdot)$  signifies the asymptotic variance-covariance (Avar) matrix.

Suppose the null hypothesis of the Hausman test of exogeneity of all variables is rejected. In that case, we need to find and include a set of instrumental variables that satisfies the orthogonality condition (Hong, 2020, ch. 7). The  $H$  statistic converges in distribution to a  $\chi^2$  distribution with  $K - 1$  degrees of freedom, where  $K$  equals the number of explanatory variables tested for endogeneity.

Based on the results of the Hausman test, I found that  $\chi^2(6) = 5.36$ ;  $p\text{-value} > \chi^2 = 0.4988$ , indicating that the variables used in this study are exogenous. As a result, there is no need to model the inflation threshold using the generalized method of moments or the two-stage least squares (2SLS). I used a 2SLS model to perform the Hausman test, as Vaona (2012) did. In this context, three lags for the differenced GDP GR, two lags for inflation ( $\pi$ ), one

lag for the differenced  $\log EX$ , and two lags for the differenced values of  $GFCF\_GDP$ ,  $M2\_GDP$ ,  $TOT$ ,  $OPEN$ , and nominal lending short-term interest rate have been used as instruments. The MAIC of Ng and Perron (2001) specifies the number of lags for the differenced series. I use the money supply (proxied by  $M2\_GDP$ ), in the set of instruments, to capture the strong direct relationship between inflation and money supply, especially in high-inflation countries like Egypt, as proposed by Milton Friedman that "Inflation is always and everywhere a monetary phenomenon." [see Grauwe and Polan (2005)].<sup>8)</sup> Additionally, I use the nominal interest rate as an instrument for the inflation rate.

#### D. BDS test for linearity of the inflation series

Another critical step before estimating the STR approach is to check the symmetric/asymmetric process of the variable, which is dealt with as the threshold variable. Therefore, I used the BDS test developed by Broock et al. (1996). Its null hypothesis ( $H_0$ ) of linear independence implies that the DGP for the threshold variable is independently and identically distributed in contrast to the alternative hypothesis ( $H_1$ ) that the series is nonlinear. Rejecting  $H_0$  denotes the existence of a nonlinear or asymmetric dependence on inflation of an unknown type [see Zhang (2017)]. The results of the BDS test, shown in Table 5, reject  $H_0$  in favor of  $H_1$  as both the asymptotic and bootstrapped  $p$ -values are less than the 5% significance level. This indicates that the variable of interest chosen to be a threshold variable (i.e., inflation rate) has a nonlinear process.

**Table 5.** *BDS Test Results*

Dimension	$z$ -Statistic	Asymptotic $p$ -Value	Bootstrapped $p$ -Value
2	3.923	0.000***	0.021**
3	4.273	0.000***	0.013**
4	5.222	0.000***	0.005***

*Note:* - Superscripts \*\*\* and \*\* denote the 0.01 and 0.05 levels of significance, respectively.

- Epsilon ( $\epsilon$ ) value = 0.7.

- Due to the small sample size, I restrict the number of dimensions to 4.

8) According to Milton Friedman's (1968) theory, every significant economic recession was caused by monetary deflation, and every hyperinflation resulted from a monetary expansion. In response to inflation, he suggested employing the money supply as an effective tool for adjusting against economic cycles. Friedman (1968) emphasized the adoption of the "K" percentage rule as a fixed rule, implying that economic growth rate must be tied to a constant annual growth rate of money supply. The perspective of Monetarists may be useful and accurately reflect the state of developed and industrialized economies. Rather, Egyptian policymakers should pay more attention to supply shocks as complementary policies.

## VI. STR Approach

When the statistical properties of the estimated parameters vary over time or across various subsamples of data, this situation is called parameter instability. It can happen for several reasons, including changes to the underlying economic structure, changes to the regimes governing policy, modifications to the quality of the data or measurement errors, or modifications to the conduct of economic agents. It could significantly impact the credibility and validity of empirical findings and the precision of forecasts and recommendations for policymakers. Several approaches, including time-varying parameter models and regime-switching models, can be utilized to address this problem. According to Chan et al. (2017), models with time-varying parameters perform best and can provide more accurate probability projections for important macroeconomic variables.<sup>9)</sup> As a result, my study employs a nonlinear specification of the inflation-growth relationship.

Nonlinear models include Markov switching regression (MSR), LSTR, and threshold regression (TR). Although the design of these models allows for the empirical observation of discrete, nonlinear effects, there are some significant conceptual differences between them. MSR incorporates less prior information than TR and LSTR. In an MSR model, a smoothed regime probability can be considered a transition function flexibly calculated from the data. In other words, MSR models rely on the latent nature of the underlying state process that results in the nonlinear dynamics (regime switching). On the other hand, specifying the transition function in a TR or LSTR model necessitates the selection of a transition variable. In other words, unlike other nonlinear models, such as MSR models, threshold models typically allow the nonlinear effect to be driven by observable variables while assuming the number of thresholds and threshold values are unknown (Chan et al. 2017; Deschamps 2008; Fahmy 2014).

TR models have a discontinuous or abrupt regime switch. Instead, assuming that the regime change occurs gradually and smoothly is reasonable. TR models can be generalized to STR models by replacing the threshold discontinuity with a smooth (rather than abrupt) transition function (Fahmy, 2014; Zivot and Wang, 2005, p. 676). Many people believe that the threshold model's abrupt regime changes are unrealistic or impractical, because most economic variables change regimes gradually, with transitions from one regime to another taking time (Potter 1999). Consequently, my study relies on LSTR models to investigate the dynamic or asymmetric impact of inflation on Egyptian economic growth over the study period.

The STR model is a more realistic approach, enabling us to *endogenously* estimate an optimal inflation rate specified by a smooth transition between different inflation regimes (Phiri, 2020; Zhang, 2017). Lundbergh et al. (2003), Fok et al. (2005), Gonzalez et al. (2005), Teräsvirta

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9) For further information on parameter instability in econometrics, see (Andrews 1993; Bai and Perron 1998; Brown, Durbin, and Evans 1975; Phillips and Hansen 1990; Zivot and Andrews 1992).

(1994), and Granger and Teräsvirta (1993) proposed and modified this technique. The STR models' base formula, with a single transition function and two extreme regimes, is given as

$$y_t = \beta_0\pi_t + \beta_1\pi_t\psi(q_t;\gamma,c) + \delta_0z_t + \varepsilon_t, \quad t = 1, \dots, T \tag{4}$$

where  $y_t$  is a scalar and signifies the dependent variable (i.e., GDP\_GR);  $\pi_t$  is the independent variable of the regime or threshold (i.e., inflation);  $z$  denotes a control variables'  $k$ -dimensional vector usually used in the inflation-growth nexus' literature (shown earlier). The parameter vectors  $\beta_0$  and  $\beta_1$  represent the linear and nonlinear components, respectively; and  $\varepsilon_t$  denotes the error term. When  $\beta_0 = \beta_1$ , the previous relationship is linear. Nonlinearity is incorporated into the model, which signifies the smooth transition function between different inflation regimes (the linear and nonlinear regimes). This function is continuous and bounded between 0 and 1. In addition, it relies on: (1) the threshold or continuous transition variable ( $q$ ), and (2) a vector of location parameters, transition values or the threshold parameter ( $c$ ), where  $c = (c_1, \dots, c_m)'$ . The threshold parameter ( $c$ ) is located in the center of the shift from low to high inflation. The transition function decides whether the economy is located in the "high regime," the "low regime", or somewhere in between. The parameter  $\gamma$  refers to the slope of the transition function or the rate of shifting from one regime to another. Eggoh and Khan (2014) illustrate that in the STR models, the estimated variables can have varying coefficients depending on the value of another observable variable. Furthermore, individuals can change over time in response to changes in the "threshold variable(s)" in the model. Following Gonzalez et al. (2005), Granger and Teräsvirta (1993), and Lundbergh et al. (2003), this study's inflation LSTR function takes the form of

$$\psi(q_t;\gamma,c) = \left[ 1 + \exp\left(-\gamma \prod_{j=1}^m (q_t - c_j)\right) \right]^{-1}, \tag{5}$$

where  $\gamma > 0$ , and  $c_1 \leq c_2 \leq \dots c_m$ . In my study, based on the specification of the "remaining nonlinearity test,"<sup>10</sup> I restricted the smooth threshold ( $m = 1$ ), i.e., the STR is expressed as logistic, LSTR(1). If  $m = 2$ , the STR model is called "exponential," ESTR(2). When the slope  $\gamma$  is large, the transition has an irregular surface (i.e., becomes rougher), and the transition function  $\psi(q_t;\gamma,c)$  leans toward the indicator function. In contrast, when the slope is close to zero, it becomes constant and the LSTR model becomes unidentified (i.e., linear or has only one regime). In this case, the parameter  $\beta_0$  relates to the direct impact of the inflation rate on economic growth, indicating a linear relationship between inflation and growth rate. Finally,

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10) Its result is shown in the discussion section.

low and high values of  $q$  represent the two extreme regimes.

To calculate the effect of inflation on economic growth in the lower regime (before the threshold), we need to consider the estimated coefficient  $\beta_0$ , whereas capturing this effect in the upper regime (beyond the threshold) can be done by adding the coefficients obtained on the lower regime ( $\beta_0$ ) and the upper regime ( $\beta_1$ ) of the STR model (i.e.,  $\beta_0 + \beta_1$ ).

## VII. Discussion

Table 6 reports the estimates of the results of the STR model for the inflation threshold in Egypt over 1976-2019. My STR estimates show a statistically significant positive relationship between inflation and economic growth at the 1% significance level (equals 0.4769;  $p$ -value < 0.01) in the lower regime (before approaching the estimated inflation threshold of  $\hat{c} = 9.32\%$ , as shown in Figure 2). To put it another way, as long as the inflation rate is less than 9.32%, inflation plays a substantial role in promoting Egypt's GDP growth rate during the study period. Inflation harms GDP growth above this threshold, indicating that the relationship between the two variables is nonlinear (asymmetric). The coefficient of inflation can capture the effect of inflation on GDP\_GR in the lower regime ( $\pi$ ) in the linear part (equals 0.4769). This positive relationship could be justified by the "Tobin effect"; that is, increased inflation (below the threshold) reduces the real interest rate, which, in turn, increases capital accumulation at the expense of holding money, as proposed by Creamer and Botha (2017).

Inflation is negatively and significantly associated with GDP\_GR after crossing the threshold (equals -0.3468;  $p$ -value < 0.01). This positive relationship is attributed to the fact that inflation reduces the future value of money, increasing the incentive to consume while discouraging savings. Inflation volatility reduces an investor's or firm's ability to plan for the long run and may cause hesitancy in long-run investment or capital formation, as proposed in Creamer and Botha (2017). Capturing this effect in the upper regime can be done by adding the coefficients obtained in both the lower regime ( $\beta_0$ ) and the upper regime ( $\beta_1$ ) of the STR model [i.e.,  $0.4769 + (-0.3468) = 0.142$ ]. Overall, *ceteris paribus*, if  $\pi$  increases by one percent, GDP\_GR is expected to increase by approximately 0.14%.

My estimates show that, for Egypt, an increase in the inflation rate, above 9.32%, by 1% lowers economic growth by approximately 0.35% due to the deleterious effects of inflation on the productivity of production factors and investment rates, as argued in Fischer (1993). This nonlinear relationship, which I obtained from the LSTR model, is harmonious with the predominant strand of literature, summarized in Table 1.

Furthermore, the estimated threshold level for Egypt for the whole sample period, 9.32%, is less than the Khan and Senhadji's (2001) estimated threshold of 11%, Kremer et al. (2013)

of 17.2%, and Ibarra and Trupkin (2016) of 19.1% for developing and nonindustrialized countries. In this regard, if the CBE has a plan to benefit from the inflation targeting regime, it should keep its inflation target below 9.32%, and the target rate, in this case, should be, for example, between 7%-9%. According to the IMF (2020), for the first time in its history, the CBE declared in May 2017 an inflation target of 13% (+/-3%). In December 2018, it adjusted this target to 9% (+/-3%).

**Table 6.** *LSTR Estimates of the Inflation Threshold Model for Egypt (1976-2019)*

Dependent variable: GDP growth rate ( $\Delta GDP\_GR$ )				
Regressors	Coefficient	Std. error	t-Statistic	p-Value
<i>Threshold variable (Linear part)</i>				
Low inflation ( $\pi_L$ )	0.4769	0.0990	4.8154	0.0000***
<i>Threshold variable (Nonlinear part)</i>				
High inflation ( $\pi_H$ )	-0.3468	0.0792	-4.3805	0.0001***
<i>Transition parameters</i>				
Threshold ( $\hat{c}$ )	9.32	0.0102	909.71	0.0000***
Slope ( $\hat{r}$ )	55.75			
<i>Nonvarying regressors</i>				
$\Delta \log EX$	-0.5760	0.0974	-5.9138	0.0000***
$\Delta GFCF\_GDP$	-0.4324	0.1851	-2.3364	0.0259**
$\Delta M2\_GDP$	0.0720	0.0482	1.4932	0.1452
$\Delta TOT$	0.0104	0.0095	1.0971	0.2808
$\Delta OPEN$	0.0821	0.0766	1.0718	0.2918
<i>Dum-17</i>	1.6048	0.6510	2.4652	0.0192**
$\beta_0$	-1.8710	0.4711	-3.9712	0.0004***
<i>Diagnostic tests</i>				
<i>Adj.</i> R-squared			0.4080	
Sum of squared residuals (SSR)			131.195	
Wald test			23.4840 [0.0000]	
Autocorrelation (LM test)			18.1314 [0.0528]	
Heteroscedasticity (BPG test)			4.5190 [0.7184]	
Normality (JB test)			0.9039 [0.6364]	
Remaining nonlinearity test			0.8522 [0.3631]	
Parameter constancy test			0.3763 [0.9228]	

*Note.* - *Variables* notation: Inflation rate ( $\pi t$ ); Differenced logarithm nominal exchange rate ( $\Delta \log EX$ ); Differenced GFCF ratio to GDP ( $\Delta GFCF\_GDP$ ); Differenced money supply ratio to GDP ( $\Delta M2\_GDP$ ); Differenced TOT ( $\Delta TOT$ ); Differenced trade openness ( $\Delta OPEN$ ); *Dum-17* is a dummy variable that captures the effect of the exchange rate floating in Egypt in November 2016; and  $\beta_0$  denotes the intercept.

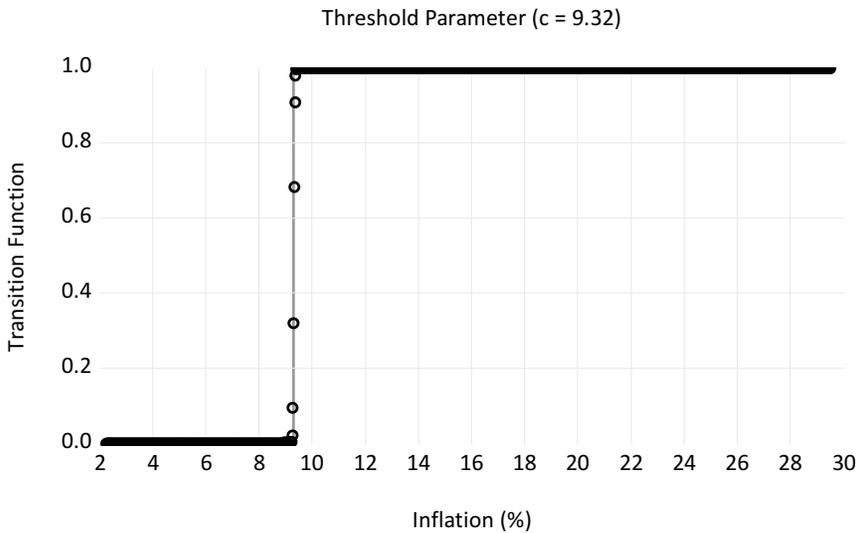
- \*\*\*, \*\*, and \* denote the 0.01, 0.05, and 0.1 significance levels, respectively.

- I use the heteroskedasticity and autocorrelation-consistent (HAC) estimator to correct for autocorrelation and heteroskedasticity. p-Values are shown in [square brackets].

- Values of the selection criteria are as follows: AIC = 4.465, SBIC = 4.916, and HQIC = 4.631.

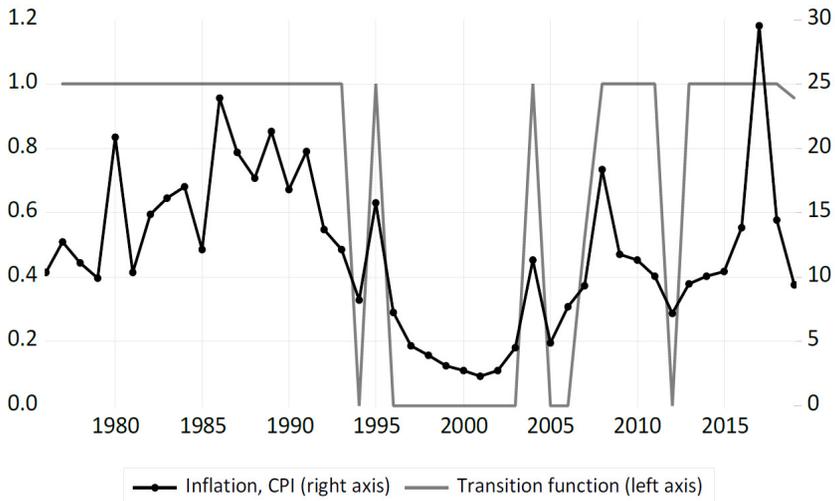
Table 6 and Figure 2 show that the estimated slope ( $\hat{\gamma} = 55.75$ ) is relatively high in the transition function, implying a somewhat quick but smooth change of regime. As a result, inflation has two extreme regimes with a smooth transition that describes the inflation-growth association. The dynamic behavior of the transition function and the transition variable ( $\pi$ ) can be detected by looking at Figure 3.

Figure 2. A plot of the threshold smoothing weight



Note. The transition variable is Inflation ( $\pi$ ).

Figure 3. A plot of the transition function



Regarding the control variables, my results show a negative relationship between the nominal exchange rate and economic growth in Egypt at the level of significance of 1% (equals -0.576;  $p$ -value < 0.01). That is, a decrease in the Egyptian pound's exchange rate results in an increase in inflation rate, and, in turn, lowers the economic growth rate by approximately 0.58%. This result is consistent with that obtained earlier from the estimated inflation targeting model. Furthermore, it is consistent with the results of some literature, for example, Ghosh and Phillips (1998) and Fischer (1993), who found a significant inverse relationship between the exchange rate and economic growth.

Furthermore, a significant negative relationship exists between the investment-GDP ratio (GFCF\_GDP) and economic growth at the 5% significance level (equals -0.43;  $p$ -value < 0.05). An increase in this ratio of 1% decreases economic growth by about 0.43%. This result is consistent with the findings of Bruno and Easterly (1998), who found that GFCF\_GDP is inversely related to economic growth during inflation crises. It is also consistent with the findings of Eggoh and Khan (2014), who discovered a significant and inverse relationship between the two variables. However, this result contradicts the theory. This contradiction can be justified by the fact that Egypt lacks the necessary preconditions that must be met to attract domestic and foreign direct investment, which Egypt depends heavily on.

Another result obtained from Table 6 reveals that the ratio of money supply to GDP positively impacts economic growth, but this relationship is insignificant. This result is in line with Bruno and Easterly (1998), Beck et al. (2000), and Eggoh and Khan (2014), who found that money supply is linked positively but insignificantly with economic growth. Moreover, it is consistent with the findings of Nell (2000). Furthermore, my STR estimates show a positive impact of both terms of trade and trade openness on economic growth, but these impacts are insignificant. This result is also consistent with that of Bruno and Easterly (1998), Sattarov (2011), Ghosh and Phillips (1998), and Kremer et al. (2013).

## A. Diagnostic tests

Regarding diagnostic tests (post-estimation tests), of my STR estimates for the inflation threshold model, Table 6 also highlights that, based on the adjusted  $R^2$  value, the STR can explain approximately 41% of the total variations in economic growth in Egypt during the study period. In this context, Wooldridge (2020, p. 35) confirms that a regression model with a low  $R^2$  does not automatically imply it is worthless. Furthermore, Stock and Watson (2020, p. 406) argue that the  $R^2$  is a mediocre measure of fit for the linear probability model. Consequently, considering  $R^2$  as the primary criterion of effectiveness in an econometric analysis can cause serious problems.

In addition, I use the Wald test to determine the significance of my explanatory variables and

to emphasize whether the estimated equation meets the constraints imposed by economic and statistical theory. The joint Wald  $F$ -statistic is 23.48, with a  $p$ -value of 0.01. Therefore, I reject its null hypothesis that the explanatory variable coefficients are jointly restricted to zero. The regression residuals are normally distributed since I failed to reject the null hypothesis of the JB test. Its test statistic = 0.90;  $p$ -value > 0.1. In addition, the STR model is free of autocorrelation and heteroscedasticity; that is, their  $p$ -values are greater than the 5% significance level. Furthermore, I checked that the STR model fits my data well with only one threshold, i.e., LSTR(1) rather than two thresholds, i.e., ESTR(2). To this end, I used the so-called "remaining nonlinearity test." This test tests for the number of regimes. Its result indicates that there are no other nonlinear relationships in my estimated model, and I have only one threshold. Its null hypothesis indicates that the LSTR has one threshold against an alternative one that the LSTR model has more than one threshold.<sup>11)</sup> I failed to reject its null hypothesis as its test statistics = 0.85;  $p$ -value > 0.1.

Finally, a nonconstant parameters test indicates model misspecification or simply a change in the connection between economic variables over time. A smooth and monotonic change in parameters through time is tested against the null hypothesis of parameter constancy.<sup>12)</sup> I tested for parameter constancy, and the results reveal that the null hypothesis cannot be rejected as its test statistics = 0.376;  $p$ -value > 0.1.

## VIII. Conclusions

This study concentrated on empirical evidence of the relationship between the inflation rate and the real GDP (inflation threshold). The LSTR was carried out to that end. Furthermore, many conventional unit root tests, as well as the Kapetanios unit root test with structural breaks, were used to check the stationarity of the variables. The LSTR estimates revealed a statistically significant positive relationship between inflation and economic growth in the lower regime (before approaching the inflation threshold at 9.32%). Beyond this threshold, inflation has deleterious effects on GDP growth, indicating the asymmetric relationship between the two variables. In Egypt, an increase in the inflation rate above 9.32% by 1% reduces economic growth by approximately 0.35%. The present study's findings are in harmony with the predominant strand of literature.

My findings also show that the nominal exchange rate negatively affects economic growth. This result is consistent with some research, for example, Ghosh and Phillips (1998) and Fischer (1993). Interestingly, a significant negative relationship exists between the investment-GDP ratio

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11) See Seleteng et al. (2013).

12) See Galadima and Aminu (2018).

and economic growth. This result is in line with Bruno and Easterly (1998) and Eggoh and Khan (2014). The ratio of the money supply to GDP positively impacts economic growth, but this relationship is insignificant, which is consistent with Bruno and Easterly (1998) and Eggoh and Khan (2014), *inter alia*. Additionally, TOT and OPEN positively impact real GDP, but these relationships are insignificant. This result is also consistent with Bruno and Easterly (1998) and Kremer et al. (2013), *inter alia*. Lastly, my LSTR estimates passed all diagnostic tests.

I believe that by delving into this relationship, my research and findings will be able to assist policymakers in making economic growth plans. Inflation below the threshold level can offer a favorable environment for enhancing long-run macroeconomic policies. Hence, this study suggests that policymakers focus more on limiting inflation and keeping it below the estimated threshold, given that inflation in Egypt is determined by aggregate supply, demand factors, and the inelasticity of the production apparatus. Put differently, policymakers must focus on integrating and consistency between monetary, fiscal, and development policies.

Lastly, the current study has some limitations. It focuses only on the period 1976–2019, but recently the Egyptian economy has been exhibiting economic crises regarding higher inflation rates, the shortage of foreign currency, exchange rate speculative attacks, and the existence of the exchange rate black market. Besides, this study investigates only one country, Egypt. So, future research may concentrate on the evolution of the Egyptian economic and monetary stance. In addition, investigating the impact of inflation on economic growth in some developing economies, e.g., the Middle East and North Africa region, may be given more attention.

## Compliance with Ethical Standards

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