Inflation, Inflation Uncertainty and Economic Growth in Tunisia: Nonlinear Modelling Framework

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Abstract

Inflation uncertainty is a critical factor influencing not only the market mechanisms but also the economic activity efficiency. In this paper, we investigated the relationship between inflation and growth to capture the impact of inflation uncertainty in Tunisia. The study relied on a dataset covering the period 1984.01-2018.08 and was characterized by a nonlinear specification. We used Hansen's (2001) Threshold Regression (TR) analysis to determine one threshold effect of inflation on growth while explaining the role of inflation uncertainty in the whole process. This study concluded that an optimal inflation rate does exist. Under this rate, a little rise in inflation may enhance economic growth, allowing an adverse impact of inflation uncertainty. Above the critical threshold of 3%, it was revealed that inflation and inflation uncertainty play opposite roles: while the former harms growth, the latter benefits it. Thus, we cannot sustain the Friedman-Ball hypothesis for the two regimes. To the best of the authors' knowledge, this is the first study that aimed to investigate the simultaneous effects of inflation and inflation uncertainty on growth in Tunisia using a non-linear methodology. This study aims to fulfil the knowledge gap of such studies for developing countries.

Introduction

Undoubtedly, both inflation level and inflation uncertainty have an obvious influence on economic growth. Inflation uncertainty specifically refers to the unpredictable inflation volatility. It is captured through the degree of disagreement among inflation forecasts (Binder et al, 2025). Since the pioneering work of Tobin (1965), inflation uncertainty has gained a lot of popularity among researchers because of its role in the inflation-growth nexus (Mandeya & Ho, 2022). High inflation can adversely affect economic growth through inflation uncertainty (Okun, 1971). According to Friedman (1977), more inflation variability reduces the price-setting ability in organising economic

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activities, hampers the information function of price movements, and impedes long-run contracting, which in turn affects economic growth.

Such an importance led Gylfason & Herbertsson (2001), among many others, to confirm that the empirical investigations which ignore inflation uncertainty do not find a robust negative relationship between inflation and growth. Further, the consideration of the inflation uncertainty effect is important to implement relevant policies. Consequently, authorities should not only seek to reduce the level of inflation but also to stabilize it at the same time (Judson & Orphanides, 1999). Recently, using a panel of 33 countries, Binder et al. (2025) show that inflation uncertainty has adverse effects, notably by dampening real economic activity, exacerbating inflation, and reducing real sales and employment. Thus, monitoring inflation uncertainty is essential in monetary policy (Baharumshah *et al*., 2016; Iyke *et al*., 2019).

Nishioka (2022) noted that the two variables that contributed to the huge inflation rate fluctuations are the retreat of globalisation and the lack of clarity in monetary policies. Therefore, inflation uncertainty has become the major cause of aggregate economic uncertainty since the Russian invasion of Ukraine (Londono *et al.,* 2023). Jongrim and Inhwan (2023) claim that over the last five decades, the increased inflation uncertainty was followed by significant decreases in output, particularly consumption of durable goods, and in investment. Furthermore, according to Jongrim & Inhwan (2023), because of "the evolving nature of underlying shocks (and their transmission channels)", the link between inflation and inflation uncertainty has evolved throughout time.

Regarding developing countries, Baharumshah *et al*. (2016) have already highlighted that the issue related to the role of both inflation and inflation uncertainty in influencing economic growth remains enigmatic, mainly for countries recording high inflation rates. Borio et al. (2023) noted that the behaviour of inflation varies depending on the nature of the regime period - a low- or high-inflation regime[1].

Besides, inflation uncertainty in emerging economies may have different dynamics given the diverse range of shocks and the imperfect institutions' credibility (Gülsen & Kara, 2019).

Only a few studies have investigated the tripartite relationship between inflation, inflation uncertainty and growth for middle-income countries (for example, Nas & Perry (2000) for Turkey, Grier & Grier (2006) for Mexico, Iyke *et al*., (2019) for Ghana, Hayati & Nitami (2021) for Indonesia). So, the originality of this study lies in clarifying and delineating this particular relationship in Tunisia.

The primary goal of this study was to use the regime-wise tests of the inflation-growth nexus during the period 1984.01-2018.08 to capture the influence of inflation and inflation uncertainty on growth in Tunisia using the threshold regression econometric technique suggested by Hansen (2001). The addressed question was whether considering the inflation uncertainty variable weakens, strengthens or changes the inflation-economic growth link.

Tunisia has experienced high levels of inflation, as well as significant inflation uncertainty. So, this issue is especially crucial for this country given the volatility of the inflation rate over the past decades and notably the recent surge in inflation after the revolution of January 2011. The post-revolution period has been characterised by an unstable economic environment and high inflation rates (Helali *et al.,* 2021; Becha *et al.,* 2023). According to Becha et al. (2023, p. 4), "Tunisia has not achieved the expected level of economic development due to the problem of inflation". Furthermore, the findings of this study are crucial to the Tunisian authorities who opted for targeting regimes.

Noteworthy, this is the first study that investigates the simultaneous effects of inflation and inflation uncertainty on growth in the case of a developing country, Tunisia, using a non-linear methodology. Besides, it might be viewed as an additional novel contribution to the papers of Boujelbene & Helali

[1] "While in a high-inflation regime the inflation rate is not self-stabilising, the regime itself is self-entrenching, just as is its low-inflation counterpart" (Borio et al., 2023)

(2017)[2], Helali et al. (2021)[3] and Becha et al. (2023)[4] that examined two types of relationships characterising the Tunisian economy: the inflation-growth nexus, on the one hand, and the inflation-financial development, on the other. Finally, we revisit the causality between the variables, which are inflation, inflation uncertainty and growth, investigated by Hachicha & Lean (2013) using the GARCH-in-mean model with a lagged variance equation for quarterly observations from 1988 Q3 to 2011 Q4 in Tunisia. Their findings show the importance of maintaining a low-inflation level since slow economic growth is essentially due to a high inflation uncertainty.

The remainder of the paper is organised as follows. A brief review of the literature was given in the second section. The materials and methods were revealed in Section 3. Section 4 introduced the empirical findings in full. The discussion was developed in Section 5, and the key findings and policy recommendations were provided in Section 6.

Literature Review

The theoretical literature shows a lack of the tripartite link between inflation, inflation uncertainty and economic growth. The theoretical examination by writers like Okun (1971); Friedman (1977); Cukierman & Meltzer (1986) and Ungar & Zilberfarb (1993) generated unclear, if not perplexing, results.

Inflation and Economic Growth Relationship

The findings of the various studies dealing with the causal link between inflation and economic growth, and ignoring inflation uncertainty, have been different across countries and time. Indeed, authors like Gylfason & Herbertsson (2001), Oikawa & Ueda (2018), Rocha et al. (2020), and Hayati & Nitami (2021) highlight a positive relationship. Other studies, like the one performed in South Africa (Hodge, 2006), assert that inflation negatively impacts long-run economic growth but has a positive influence on growth over the short term. Inversely, using the ARDL bounds testing, Ho (2018) focuses on the economic growth sources in Thailand during the period 1975 to 2014 and concludes that inflation harms this growth over the short term but has a long-term beneficial influence.

Meanwhile, several researchers, who considered the evidence of a threshold effect, outline a mix of beneficial and harmful impacts in this relation. In line with this conclusion, Sarel (1996), Ndoricimpa (2017), Boujelbene & Helali (2017) and, recently, Phiri (2020) underline an asymmetric relation in the inflation-growth nexus. These studies assert that inflation plays a rather positive role in growth until reaching a certain threshold, after which its impact becomes negative.

Inflation Uncertainty and Economic Growth Relationship

A second set of studies investigated the inflation uncertainty influence on economic growth without considering inflation. Some researchers emphasised that this relationship is negative (Evans & Wachtel, 1993; Judson & Orphanides, 1999), among others, whereas others revealed a positive type of relationship or even a weak, if not negligible, one (e.g., Bredin & Fountas, 2009). According to Tobin (1965), inflation uncertainty prompts households to gather more real tangible wealth, boosting capital productivity and fostering growth. Recently, Metiu & Prieto (2023) concluded that in the US, an unanticipated increase in the uncertainty about core inflation produces inflationary consequences similar to a positive aggregate demand shock: after the shock, there is a considerable increase in industrial production, consumption, and consumer prices. The authors suggest that households' inflation expectations may act as a transmission channel, but this channel "does not come into play after a shock to the uncertainty of headline inflation".

Inflation, Inflation Uncertainty and Economic Growth Relationship

Additionally, researchers like Judson and Orphanides (1999); Nas & Perry (2000), Baharumshah *et al.* (2016), and Iyke *et al.* (2019) estimated the influence of the two inflation types (e.g., both inflation and inflation

[2] Boujelbene and Helali (2017) addressed the issue of the threshold inflation effects on the relationship between inflation rate and economic growth in Tunisia for the 1982-01–2012-11 period using the Threshold Regression econometric technique suggested by Hansen (2001). The authors show a statistically significant negative relationship between the inflation rate and economic growth if the inflation rate is below the threshold value.

[3] Helali et al. (2021) utilised a threshold regression model to examine the nonlinear link between economic growth and financial development in Tunisia from 1982 to 2018, with inflation as the threshold variable. The study found that a low inflation rate (less than 4.89%) promotes economic growth.

[4] Becha et al. (2023) use non-linear logistic smooth transition regression to study the relationship between financial development and economic growth in Tunisia, using inflation as a threshold, from 1965 to 2019. They conclude that inflation below 3.63% has a positive impact on economic growth. When inflation surpasses this threshold, it has a strong negative impact.

uncertainty) on economic growth and reached controversial and inconclusive results. Inflation uncertainty may therefore untangle the impact of inflation on economic growth. Accordingly, we reviewed the empirical literature in light of this set of studies. According to the Friedman-Ball hypothesis, both inflation and inflation uncertainty have the potential to harm economic growth. This hypothesis states that there is a positive correlation between the rate of inflation and the degree of inflation uncertainty (Friedman, 1977; Ball, 1992). It suggests that as inflation rises, uncertainty about future inflation also increases, due mainly to asymmetric information in the economy. Thus, the Friedman-Ball hypothesis emphasises the often-overlooked indirect costs of inflation, particularly those arising from heightened inflation uncertainty. A negative influence of the two types of inflation on growth is thus proven (e.g., Judson & Orphanides, 1999; Bhar & Mallik, 2013). A high inflation rate generates high inflation uncertainty because the public will begin to doubt the credibility of the monetary authorities (Ball, 1992). De Gregorio (1993) investigated a sample of twelve Latin American countries over the period 1950 to 1985 using panel data with random effects and White's robust correction for the standard errors. The author concluded that inflation hampers economic growth as it sends the capital cost high, limits its accumulation and decreases its productivity. Besides, since individuals do not know whether policymakers are able to control the inflation rate, they postpone their saving and investment-related decisions, fearing potential negative impacts on the resource allocation efficiency (Friedman, 1977).

Using a panel dataset of 87 countries over 30 years (1960–1992), Judson and Orphanides (1999) conclude that for countries recording high inflation rates, both inflation and inflation uncertainty[5] hamper economic growth. Specifically, if the inflation level exceeds 10% per year, it is negatively and significantly correlated with growth. Therefore, the above-stated authors insist that the stability of inflation is crucial while looking forward to a high economic growth rate. Accordingly, the authorities should not only seek to lower the inflation level but also to stabilise it at the same time.

According to Grier *et al*. (2004), who used the bivariate GARCH model, inflation uncertainty negatively influences both the inflation rate and economic growth in the United States. In the same vein, the empirical investigation of Grier & Grier (2006), which relied on the multivariate EGARCH-M during the period 1972–2001, postulates that inflation uncertainty has a negative and significant effect on growth in Mexico.

Mohd *et al*. (2013) test the relationship between inflation, its uncertainty and economic growth in five ASIAN nations from 1980 to 2011 using the Exponential GARCH model. They conclude that in all of the analysed countries, inflation uncertainty increases more in reaction to positive inflation shocks than to negative ones, as expected by the Friedman–Ball theory. However, the findings refute the idea that inflation is caused by inflation uncertainty. Instead, they suggest that inflation slows the economy, directly or indirectly, through the inflation uncertainty channel.

Hartmann & Roestel's (2013) empirical evidence for 34 developed and emerging economies from 1990 to 2010 using VARX-MGARCH-M models demonstrates that both inflation and inflation uncertainty significantly decrease growth. According to the authors, the negative effects of inflation or inflation uncertainty on growth appear to be negligible if inflation is low. This means that if the country is characterised by a modest inflation rate, it is probably going to incur output losses from the increasing inflation. In sum, they highlight that the detrimental effect of inflation on the economy fluctuated only in relation to magnitude. Furthermore, they notice that the impact of inflation on output is greater than the impact of output on inflation. If output increases by 1%, the resulting inflation effect is only 4 basis points. However, if inflation increases by 1%, output drops by about 1%. In addition, uncertain output affects the expansion of production.

Bhar & Mallik (2013) studied the issue in the United Kingdom and used the EGARCH-M model to assess the detrimental impact of inflation-on-inflation uncertainty, on the one hand, and growth, on the other. They showed that inflation uncertainty has a significant positive influence on the inflation rate but a significant negative impact on the production expansion. Moreover, in line with the hypothesis of Friedman, they found that inflation uncertainty considerably raises the rate of inflation. Further, the Generalised Impulse Response Functions reveal that inflation significantly enhances inflation uncertainty.

Nonetheless, a good deal of research argues that while inflation may adversely affect economic growth, inflation uncertainty can stimulate it. As an illustration and using GMM estimates for 88 countries during 1976-

[5] Inflation uncertainty is inflation volatility defined as intra-year inflation observations.

2001, Lensink & Scholtens (2006) argue that inflation uncertainty has a significantly positive influence on the fluctuation of the economy.

In their study conducted in South Africa, during the period 1961Q1 - 2019Q4, Mandeya and Ho (2021) concluded that while increasing prices negatively affect growth in both the short and long runs, inflation uncertainty only affects the near run.

Considering a sample of 100 countries from 1960 to 1990, Barro (2013) studied the simultaneous impacts of inflation and uncertainty of inflation on economic growth. The author maintains that inflation reduces growth by decreasing the investment propensity. He found that inflation has a negative and considerable influence on growth, even at low rates, because it deeply affects both prices and market performance. In addition, if the average inflation increases by ten percentage points, the investment ratio decreases by 0.4-0.6 percentage points. However, the inflation uncertainty has no significant impact on growth.

Baharumshah *et al*. (2016) examine the impact of inflation and inflation uncertainty on growth in a set of 94 developing countries using the System Generalised Method of Moments (SGMM) over the period 1976–2010. They proved that both inflation and its uncertainty[6] have substantial independent and meaningful influence on growth transmitted via the investment channel (Barro, 2013). The authors show that while inflation hampers growth, inflation uncertainty boosts it in non-inflation crisis countries. Notably, the positive impact of inflation uncertainty on growth is established when the level of inflation ranges between 5.6% and 15.9%[7]. Consequently, considering the inflation uncertainty variable, it weakens the inflation-growth link in the model. Indeed, if inflation uncertainty increases by one percentage point, the annual growth increases by about 0.028%. Yet, if we take into account the adverse impact of inflation, the overall outcome is detrimental.

Živkov et al. (2020) conclude that the Friedman-Ball hypothesis is confirmed for a sample of eight Central and Eastern European Countries investigated from January 1998 to December 2019. Following the evidence provided by the different GARCH models, inflation displays a remarkably less important negative effect on GDP compared to inflation uncertainty. So, inflation seems to have an indirect effect on growth via inflation uncertainty.

Using a Bayesian panel SVAR with monthly data employed as a baseline for 2004-2019, Jongrim & Inhwan (2023) conclude that "a one-standard-deviation rise in inflation uncertainty was related to a reduction in industrial production by up to 10 per cent within two years after the shock in G7 countries". However, the impacts were very short-lived and less significant (up to a 6% drop) in the seven emerging market countries. The authors also claim that "Unlike G7 countries, where the inflation rate drops in response to higher uncertainty, EM7 countries usually experience higher inflation".

In their review of the literature, the study conducted by Mandeya & Ho (2022), dealing with the two inflation types and their impact on economic growth, the authors state that inflation inhibits growth. The literature, however, seems to be reluctant when discussing the effects of inflation uncertainty.

Therefore, given the controversial results of the previous studies, this investigation tried to shed light on this topic by studying the impact of inflation, inflation uncertainty and economic growth in a developing country, Tunisia. Moreover, to the best of our knowledge, the only study investigating the affinity between inflation, inflation uncertainty and growth in the Tunisian case was that of Hachicha & Lean (2013). The authors used the GARCH-M model with a lagged variance equation for quarterly observations from 1988 Q3 to 2011 Q4 in Tunisia. Their study relies on time series of nominal inflation rate as well as nominal and real gross domestic product. They point out that inflation uncertainty positively influences inflation but only over the long run. This research study, however, focused on the tripartite relationship in Tunisia using a threshold method.

Methodology

This study dealt with the asymmetric effects of inflation uncertainty on the inflation-growth nexus. To achieve this, we used Hansen's (2001) Threshold Regression (TR) approach to allow for a single threshold effect of inflation on growth. We defined growth in terms of inflation, its uncertainty and money supply. Our simple model considers the industrial production index as an endogenous variable. As for the explanatory variables,

[6] Inflation uncertainty is calculated as the standard deviation of inflation over a five-year period.

[7] In robustness, Baharumshah *et al*., (2016) found that inflation uncertainty has a negative and significant impact on growth at low inflation rates, while it is positive and significant at high inflation rates.

the model takes the inflation rate, inflation uncertainty and money supply as proxies reflecting the financial sector depth. Our linear regression equation is therefore written as follows:

$$lnIPI_t = \alpha_0 + \alpha_1\pi_t + \alpha_2 lnM_{3t} + \alpha_3 INFUN_t + \varepsilon_t \quad (1)$$

where $lnIPI_t$ stands for the Industrial Production Index. Just like Vazquez (2002) and Boujelbene & Helali (2017)[8], we referred to the IPI as an indicator of economic growth instead of the Gross Domestic Product (GDP) because of the lack of monthly data. π_t denotes CPI inflation. lnM_{3t} expresses the logarithm of money supply as a proxy for financial sector depth; $INFUN_t$ reflects the uncertainty of inflation. *ln* denotes the operator of the natural logarithm, $\alpha = (\alpha_0, \alpha_1, \alpha_2, \alpha_3)$ are the coefficients of the model; ε_t is the white-noise error term; t is the time subscript.

In theoretical terms, rising inflation is predicted to impede growth, as highlighted by Friedman (1977) and Ball (1992), among others (see Mandeya & Ho, 2022). Thus, the coefficient α_1 is expected to be negative. Theoretically, money supply boosts growth, which means that the coefficient α_2 is expected to be positive. In addition, inflation uncertainty may hinder or enhance growth (see Friedman, 1977; Ball, 1992; Blackburn, 1999). Therefore, the coefficient α_3 3 can be either negative or positive.

The standard linear model is shown in Equation (1). Unlike several studies, the investigated threshold variable in this research should be some optimal inflation rate values. This implies an asymmetric relationship between economic growth, inflation rate and inflation uncertainty. However, the probable econometric issues that may interfere with the threshold effects estimation urged the development of some suitable estimation methods. Equation (1) can therefore be rewritten as follows:

$$\begin{aligned} LnIPI_t = {} & (\alpha_{10} + \alpha_{11}\pi_t + \alpha_{12} LnM_{3t} + \\ & \alpha_{13} INFUN_t) d[\pi_t \le \gamma] \\ & + (\alpha_{20} + \alpha_{21}\pi_t + \alpha_{22} LnM_{3t} + \\ & \alpha_{23} INFUN_t) d[\pi_t > \gamma] + u_t^* \end{aligned} \quad (2)$$

We used the minimization of the residual sum of squares to get a threshold value. Taking into account the main target of this study, investigating the inflationary threshold effects on inflation, inflation uncertainty and economic growth nexus, we referred to the *CPI* as an indicator of inflation and π_t *the* threshold variable.

Consequently, we estimated equation (2) with the hypothesis of no threshold effect (H_0: $\alpha_{1i} = \alpha_{2i}$ where $i = 0, \dots, 3$) versus the hypothesis where (H_1: $\alpha_{1i} \neq \alpha_{2i}$ for $i = 0, \dots, 3$).

The traditional approaches cannot be used here since they cannot test the threshold value "γ" as it is unknown. Similar to Hansen (1996), we determined the asymptotic critical value and the p-value using the Lagrange Multiplier (LM) Bootstrap Technique. Taking into account the null hypothesis H_0, the below standard F-statistics was used:

$$F_1 = \frac{S_0 - S_1(\hat{\gamma})}{\hat{\sigma}^2} \quad (3)$$

with S_0 and S_1 are the residual sums of squares under the hypothesis: H_0: $\alpha_{1i} = \alpha_{2i}$ for $i = 0, \dots, 3$.

We tested the null hypothesis to detect whether linearity is strongly rejected. If a threshold effect exists, the next issue is whether this threshold value can be known or not.

Results

Data Description

The Industrial Production Index (IPI) and the Liquid Liabilities (M_3) were collected from the Tunisian Central Bank. As for the Consumer Price Index, it was gathered from the Tunisian National Institute of Statistics database. Our dataset covers the period 1984.01 - 2018.08. The variables are described in Table 1.

The results in Table 2 show descriptive statistics, including the mean, median, maximum, minimum, standard deviation, skewness and kurtosis coefficients, and the Jarque-Bera statistics to test the null hypothesis that all the variables are normally distributed.

[8] Vazquez (2002) examined the nature of the relationship between output and inflation in 15 countries of the European Union and the United States. The author uses the index of industrial production to reflect production.

-The study of Boujelbène and Helali (2017) examined the threshold effects on the relationship between inflation rate and economic growth in Tunisia. The authors use the index of industrial production to reflect economic growth.

Table 1
Definitions of the variables

Variables	Definition	Source
IPI	Industrial Production Index (with 2010 serving as the base year)	Tunisian Central Bank
CPI	Consumer Price Index (with 2010 serving as the base year)	Tunisian National Institute of Statistics
M_3	Liquid liabilities	Tunisian Central Bank
INFUN	Inflation uncertainty (the standard deviation of inflation)	Tunisian National Institute of Statistics

Note: According to Grier & Perry (1998), "Inflation uncertainty, referring to unanticipated volatility in the general prices, is an unknown variable". Furthermore, Kliber et al. (2023) define uncertainty as the standard deviation of the variable in question. Even if it is true that this approach is by no means the only alternative to define uncertainty, it is still the most well-established in economic theory. Therefore, similar to Kliber et al. (2023), the uncertainty of inflation was obtained via the standard deviation of inflation in this study.
Source: Authors

Table 2
Summary statistics

Designation	IPI	CPI	M3	INFUN
Mean	83.018	89.352	30570.75	0.090
Median	89.000	82.150	23268.00	0.068
Maximum	110.000	149.500	76526.00	0.495
Minimum	43.430	53.800	6562.00	0.002
Standard Deviation	16.670	25.338	20684.77	0.078
Skewness	-0.886	0.629	0.608	1.994
Kurtosis	2.546	2.299	2.060	8.472
Jarque-Bera	42.976	26.653	30.320	588.444
Probability	0.000	0.000	0.000	0.000
Observations	308	308	308	308

Source: Authors

We find it relevant here to unveil the characteristics of the IPI, CPI, M3 and INFUN variables. The IPI mean was around 83.018 from the period 1984.01 - 2018.08, with a standard deviation of about 16.670. The variable has a minimum and maximum of 43.430 and 110, respectively. The distribution is asymmetric on the left (skewness lower than 0). In addition, this variable is platykurtic with a kurtosis greater than 0. Furthermore, the results of Jarque-Bera test provide enough evidence to reject the null hypothesis, indicating that the series in question is not normally distributed.

Considering the 308 observations spanning from 53.8 to 149.5, the CPI variable has a mean of 89.352, a median of 82.150, and a standard deviation of 25.338. The skewness of the series is 0.629, indicating a rightward asymmetry, and the kurtosis has a high value of 2.299, supporting the leptokurtic nature of the series. Furthermore, the test developed by Jacque & Bera (1987) yields negative results for the null hypothesis of normal distribution.

The M3 variable has an average of 30570.75, a median of 23268, and a standard deviation of 20684.77. Spanning from 6562 to 76526, the range of the 308 observations shows how widely this variable may vary. This series has a slightly right-skewed distribution, as indicated by its skewness of 0.608, and a leptokurtic distribution, as indicated by its high kurtosis of 2.060. Additionally, the normality null hypothesis according to the Jacque & Bera (1987) test can be rejected.

The mean of Inflation uncertainty (INFUN) was around 0.09 with a minimum and maximum of 0.002 and 0.495, respectively. The variable has a standard deviation of about 0.078. The distribution is asymmetric on the left (skewness greater than 0). Moreover, this variable is weakly platykurtic with a kurtosis value more than 0. Besides, the null hypothesis of normality was rejected by the Jarque-Bera test.

Regarding symmetry, the distributions are asymmetric for the variables CPI, M3 and INFUN on the right. However, the distribution for the variable IPI is asymmetric on the left. Such characteristics in descriptive statistics might indicate that the variables are non-stationary at the level. Consequently, we checked their stationarity using some other well-known methods.

Unit Root Test

Before using the threshold regression approach, it is recommended to test the stationarity of all the variables of the model. We used the Perron (1997) unit root test, which allows for a break under both of the null and alternative hypotheses. These tests are less effective than the usual DF-type test when there is no break.

Table 3 displays the results of Perron's (1997) stationarity tests. It can be observed that all the variables in the three models (A, B and C) are stationary in the first difference for 1% and 5% risks. The results also reveal a significant rupture for the three models, proving the asymmetry of the data in the series considered in this research.

Table 3
Results of the Perron (1997) test

Model	Designation	IPI	CPI	M_3
In level				
A	Break date	2013:06	2016:013	2009:12
	t-statistic	-2.565	0.457	-1.681
B	Break date	2007:11	2009:12	2004:06
	t-statistic	-5.186	-1.641	-3.578
C	Break date	2011:11	2017:09	2005:11
	t-statistic	-2.865	-3.532	-3.793
Decision		NS	NS	NS
In first difference				
A	Break date	2010:06	2017:02	2007:08
	t-statistic	-8.639***	-5.22**	-5.778**
B	Break date	2010:06	2005:02	2008:03
	t-statistic	-8.563***	-6.156**	-5.716**
C	Break date	2007:10	2004:02	2002:11
	t-statistic	-7.177***	-5.171**	-5.227**
Decision		S	S	S

Notes: NS: non-stationary; S: stationary. The unit root hypothesis is rejected at the 1% level (***) and at the 5% level (**). Model A allows for a modification in the constant. Model B evaluates the series' stationarity around a broken trend. Model C allows for changes in both the constant and the trend. Model A's critical values are (-5.70), (-5.10), and (-4.82); model B's are (-6.21), (-5.55), and (-5.25); and model C's are (-5.28), (-4.65), and (-4.38).
Source: Author's computation

Testing the Existence of Inflationary Threshold

To investigate the impact of inflation uncertainty and money supply on growth in Tunisia, we used Hansen's (2001) approach, taking into consideration different inflation regimes. In this context, inflation served as a threshold variable. This procedure allows us to test the linear model (null hypothesis) versus the two-regime model (alternative hypothesis). The obtained results of the above-mentioned tests are displayed in Table 4. The F1 statistics equals to 17.07 and is statistically significant at a bootstrap p-value of 0.005. This confirms that a threshold of 3.00% does exist, indicating the presence of a structural break in our data.

Table 4
Results of the optimal Threshold Test

Test Hypothesis	F_1 test	Bootstrap P-Value	Optimal Threshold Estimates %	95 % Confidence Interval
H1: one threshold	17.07***	0.005	3.00 %	[1.36%, 3.92%]
H0: no threshold	10.41	0.244	4.98 %	-

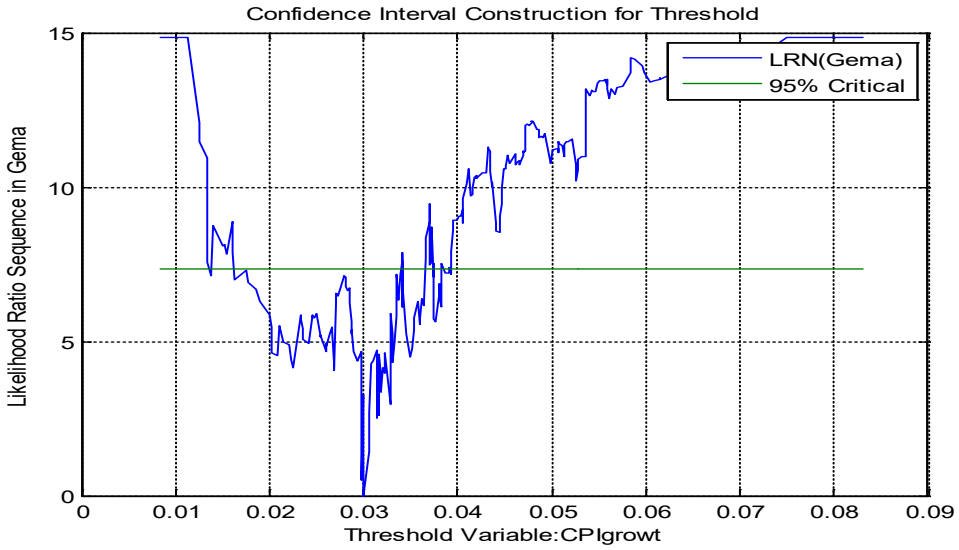
Notes: The null hypothesis of no threshold is tested against the alternative hypothesis of the threshold. The threshold is calculated by minimising the sum of the squared residuals. *** indicates statistical significance at the 5% level.
Source: Author's computation

The likelihood ratio (LR) test was then analysed to investigate the confidence interval around the determined threshold. The 95% asymptotic confidence interval is [1.36%, 3.92%]. Figure 1 shows the standardised LR (γ) statistics as a function of the threshold of the inflation rate.

The least squares estimate of the threshold (γ) is the value that minimises the function LR (γ) at γ = 3.00%. This finding suggests that the threshold estimates are extremely accurate. Thus, there is strong evidence to support one breakpoint in the link between economic growth and inflation uncertainty. This validates the hypothesis that some dynamics among inflation, its uncertainty and output may be prone to structural change, as already suggested by Kontonikas (2004), Bredin et al. (2009), among others.

Figure 1

The normalised likelihood ratio sequence statistics: function of the inflation rate threshold



Source: Author's computation

So far, the link between inflation, inflation uncertainty, and growth has been studied considering different inflation regimes. The findings are displayed in Table 5. For comparison purposes, the first column shows the estimates for a linear regression, equation (1), that ignores the threshold effect, whereas columns 2 and 3 provide the estimates of the two-regime TR model, equation (2).

Table 5

Results of the estimation of the linear and TR model

Variables	Linear Regression	Threshold Regression Model	
		Regime 1 ⩽ 3.00%	Regime 2 > 3.00%
Constant	0.04 (2.01)**	-0.06 (3.25)***	0.041 (2.09)**
π	-0.59 (3.28)***	1.77 (3.05)***	-0.47 (3.41)***
LnM_3	0.02 (4.15)***	0.07 (4.37)***	0.017 (3.36)***
INFUN	-0.003 (3.04)***	-0.004 (5.02)***	0.009 (3.34)***
Observations	415	201	214

Notes: ***, **, and * represent statistical significance at 1%, 5%, and 10% levels, respectively.

Source: Author's computation

Discussion

According to the linear regression, both inflation and its uncertainty slow growth in Tunisia. Apart from this effect, our findings suggest that the money supply (M3), a proxy for financial development, contributes to the economic expansion. This is in line with the findings of Ghali (1999) and Ben Jedidia et al. (2014), who found that financial development is an important component of the long-term growth in Tunisia.

A non-linear model can be divided into two regimes based on whether inflation is above or below the 3.00% threshold. Inflation and inflation uncertainty do not have the same effect in the two regimes. Indeed, inflation boosts economic growth (with a coefficient of 1.77) up to the threshold, while at higher rates the effect becomes negative (with a coefficient of -0.47). Although the inflation uncertainty coefficient shifts from positive to negative, both values are significant. Our empirical results are consistent with those of Baharumshah *et al.*, (2016). Thus, for both regimes, we cannot sustain the Friedman-Ball hypothesis suggesting that both inflation and its uncertainty may hinder growth.

It was found that if the inflation rate is lower than 3%, it positively affects the economic growth in Tunisia. This evidence is opposite to the results achieved by Barro (2013), who considered a large sample of countries and sustained that inflation, however low its rate is, has a

negative influence on growth. Nevertheless, if the level of inflation exceeds 3%, it significantly impedes growth. This can be explained by the fact that if inflation exceeds the optimal threshold, it impedes the information function of price fluctuations, preventing long-term contracting and, as a result, slowing economic growth (Friedman, 1977). Inflation has a distortionary impact on the market allocation efficiency. The effect of inflation on growth in Tunisia appears to differ not just in terms of magnitudes, as in Hartmann and Roestel's (2013) analysis, but the positive influence seems to become negative. As argued by Mohd *et al*. (2013), this can be because inflation slows the expansion of the economy, whether directly or indirectly (*via* the inflation uncertainty channel). In addition, this corroborates the results of the study of Boujelbene & Helali, suggesting that, in Tunisia, inflation fosters growth when it is above a threshold value (3.48%).

In Tunisia, financial development boosts economic progress under both regimes because banks dominate the financial system in a context of a narrow financial market. Credits offered by banks help finance investment and consequently stimulate economic growth (Ben Jedidia *et al*., 2014). In addition, it can be noted that the effect of M3 is higher in the first regime than in the second. This can be attributed to the fact that the increase in inflation disturbs the banking intermediation and its contribution to fund allocation. In other words, if inflation exceeds the threshold, there will be a decline in the deposits and savings collection and credit rationing, which ultimately affects the economy.

The impact of inflation uncertainty is negative in the first regime but becomes positive in the second, which means that inflation uncertainty has to be taken into account in the inflation-growth link in Tunisia. This result is in line with that of Grier & Grier (2006) in their study on Mexico but differs from that of Fountas (2010), who proved that inflation uncertainty is harmful to production growth. Furthermore, unlike Hachicha & Lean (2013), our findings came to support Friedman's claim that inflation uncertainty has negative impacts. Oppositely, Baharumshah *et al*. (2016) showed that the uncertainty of inflation boosts growth in countries that do not experience an inflation crisis, especially when it ranges between 5.6 and 15.9%.

In regime 2, in the context of this research study, the uncertainty inflation positively influences economic growth in Tunisia despite its very low coefficient (0.009), which contradicts the prevailing theory. So, for this regime, the results are non-consistent with those of Grier & Grier (2006), highlighting that inflation and its uncertainty have a negative impact. We can argue the findings of Baharumshah *et al*. (2016) by the fact that inflation has a stronger negative impact than the positive impact of inflation uncertainty in developing countries.
The nonlinearity of the link between inflation uncertainty and growth was found to depend mostly on the inflation regime in Tunisia. It can, therefore, be concluded that the inflation uncertainty matters in the nexus between inflation and growth in both regimes. It is worth noting that inflation and its uncertainty have contradictory effects on the economy.

In the first regime and below the 3% threshold, the rate of inflation is a positive driver of growth; nevertheless, inflation uncertainty is a headwind to this growth. This is in line with Stockman's (1981) idea when he introduced a cash-in-advance model, arguing that money and capital play complementary roles in enhancing the economy, but highlighted that uncertainties about inflation deeply affect the efforts made to acquire capital stock. This inevitably leads to an unforeseen redistribution of wealth, which, in turn, hinders economic growth even at a low inflation rate.

However, in the second regime, it was revealed that inflation and inflation uncertainty play opposite roles: while the former harms growth, the latter benefits it. Thus, when we simultaneously consider the influence of both types of inflation, we can point out that they have opposite effects on economic growth in Tunisia. This can be explained by the idea suggesting that the inflation uncertainty encourages people to accumulate more financial assets while reducing the non-interest-bearing assets, boosting capital formation and consequently economic growth (Tobin, 1965). Another explanatory alternative was provided by Baharumshah et al. (2016), who came to the conclusion that while the impact of inflation on growth is negative, the uncertainty of inflation enhances growth through inciting precautionary savings, which will thereby serve as funds for investment, which confirms our findings. Metiu & Prieto (2023) have provided a third explanation, claiming that an unanticipated rise in unpredictability about the core inflation rate in the US produces inflationary consequences similar to a positive aggregate demand shock. After the shock, there is a considerable increase in industrial production, consumption, and consumer prices. The authors suggest that households' inflation expectations may act as a transmission channel that "does not come into play after a shock to the uncertainty of headline inflation".

Robustness Check

Assessment tests were performed on the regression residuals during the final stage of our empirical method. The threshold regression model was evaluated for autocorrelation, ARCH effects, and normality effects. The assessment test findings are provided in Table 6.

Table 6
Diagnostic tests

Tests	t-statistic	p-value	Decision
LM test	40.160	0.567	No autocorrelation
ARCH test	1.700	0.190	No ARCH effects
Shapiro-Wilk test	0.734	0.890	Normal distribution

Note: The Lagrange Multiplier test for the Breusch–Godfrey serial correlation is known as the LM test. The autoregressive conditional heteroscedasticity test is known as the ARCH test. The Shapiro-Wilk test utilises to test the presence of normality.
Source: Author's computation

First, the serial correlation among the error term of the estimated regression was confirmed when the LM statistic was employed to test the null hypothesis for no autocorrelation. In addition, no ARCH effects were detected in the regression residuals. While the JB test statistic was estimated to be 9.34 with a p-value of 0.000, rejecting normal distribution of residuals in the estimated regression model.

Conclusion

Inflation uncertainty and inflation are critical factors influencing the market mechanisms, on the one hand, and the efficiency of economic activities, on the other. Therefore, most central banks have been committed to pursuing and maintaining low and stable inflation rates to enhance capital formation, information flow, productivity and economic expansion. The literature focused on studying the effects of inflation or inflation uncertainty on economic growth separately and reached mixed conclusions. This study, therefore, aimed at investigating the influence of the two types of inflation on economic growth in a developing country, Tunisia, given the recent surge in inflation after the revolution of January 2011. The novelty of this research was to examine the moderating influence of inflation uncertainty through the assessment of the effect of inflation on economic growth in Tunisia. It contributed to the existing literature through investigating a tripartite relationship between inflation, inflation uncertainty and economic growth. Methodologically, the study relied on a non-linear approach. It addressed the issue of the effects of inflation uncertainty on the inflation-economic growth link in Tunisia. So, it used the regime-wise tests to reveal the type of link between inflation and growth and capture the impact of inflation uncertainty on this growth.

Considering the linear and nonlinear specifications of a dataset covering the period 1984.01-2018.08, inflation and inflation uncertainty were found to have mixed, if not opposite, effects on economic growth. It can be concluded that there exists an optimal inflation rate. Below this optimal rate, a weak increase in inflation may enhance growth; however, above the 3% threshold, a rise in the inflation rate adversely affects real growth. Moreover, our empirical findings show that, in the second regime, the inflation drawbacks seem to outnumber the advantages of inflation uncertainty. Thus, for both regimes, we cannot sustain the Friedman-Ball theory suggesting that both inflation and its uncertainty may hurt economic growth.

To stimulate the expansion of the Tunisian economy, the authorities should keep on aiming for a lower inflation target of 3%, while ensuring minimum inflation uncertainty. Nevertheless, keeping inflation uncertainty under control in an inflation-targeting system requires a credible and independent monetary policy. Besides, controlling inflation and its variability is not enough to boost economic growth; it is the whole financial system that requires being updated, if not reviewed. Specifically, enhancing the savings–investment process requires both the restructuring of the banking sector and the development of a well-functioning financial market.

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Inflacija, inflacijska negotovost in gospodarska rast v Tuniziji: nelinearni model

Izvleček

Negotovost inflacije je ključen dejavnik, ki vpliva ne le na tržne mehanizme, temveč tudi na učinkovitost gospodarske dejavnosti. V tem prispevku smo raziskali razmerje med inflacijo in gospodarsko rastjo, da bi ugotovili vpliv inflacijske negotovosti v Tuniziji. Študija temelji na podatkovnem nizu za obdobje od januarja 1984 do avgusta 2018 in vključuje nelinearno specifikacijo. Uporabili smo Hansenovo (2001) metodo pragovne regresije (Threshold Regression - TR), da bi določili nelinearni učinek inflacije na gospodarsko rast ter pojasnili vlogo inflacijske negotovosti v celotnem opazovanem obdobju. Ugotovili smo, da obstaja optimalna stopnja inflacije. Pod to mejo lahko rahlo zvišanje inflacije spodbudi gospodarsko rast, vendar hkrati povzroči neugoden vpliv inflacijske negotovosti. Nad kritičnim pragom 3 % pa inflacija in inflacijska negotovost igrata nasprotni vlogi: medtem ko inflacija škodi gospodarski rasti, ima inflacijska negotovost pozitiven vpliv. Zato hipoteze Friedmana-Balla ni mogoče potrditi za obe obravnavani obdobji. Po najboljšem vedenju avtorjev je to prva študija, ki preučuje sočasne učinke inflacije in inflacijske negotovosti na gospodarsko rast v Tuniziji z uporabo nelinearne metodologije. Študija poskuša zapolniti vrzel v poznavanju tovrstnih vplivov v državah v razvoju.

Ključne besede: pragovni regresijski model, inflacija, negotovost glede inflacije, gospodarska rast, Tunizija