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Examining inflation and economic growth in Tunisia: An ARDL approach

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Abstract

The aim of this paper is to examine the impact of inflation on the growth of the Tunisian economy over three decades (1991–2023). The study implemented the ARDL approach to capture both the short- and long-term interactions. Ultimately, a negative inflation-economic growth relationship emerged and was estimated at -0.85. These estimates illustrate that the presence of inflation substantially lowers the purchasing power of the public, which subsequently distorts investment tendencies and leads to macroeconomic instabilities. In the case of short-run outcomes, the results show that inflation from prior years has a lagged effect on economic growth. Better put, moderate amplifications in price levels may serve to positively bolster economic endeavors until such a time that the adverse ramifications begin to overshadow, at which point the economy will start to shrink. The employer side of the economy also led to increases in short-run growth due to labor force participation, but the level of investment in GFCF suggests an underlying inefficiency in long-run investment growth. They were also able to observe certain integrations in the variables, which suggested that long-run relationships exist. However, the pace at which these nominal variables are able to adjust within the period significantly varies at 88.64%. The results of this examination indicate the need for an inflation level of moderate intensity together with structural changes to achieve an investment multiplier and gain in labor productivity. This analysis may assist policymakers in formulating policies for Tunisia designed for inflation control and sustainable economic growth, which are key components of Tunisia's development goals.

Keywords: ARDL model, Economic growth, Inflation, Macroeconomic stability, Tunisia.

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1. Introduction

There have been continuous debates regarding inflation (INF) and economic growth (EG) at the macroeconomic level for years, owing to their prospects for economic stability and policy issues. Economies define inflation differently, although it primarily refers to a prolonged increase in the general level of prices of goods and services [1]. Economies react to inflation differently depending on its level, persistence, and its interrelationships with other macroeconomic variables. Moderate inflation can enhance economic activities by encouraging spending and investment, while high or hyperinflation can decimate purchasing power, reduce investment incentives, and increase the level of economic uncertainty [2].

On the other hand, economic growth is key to every policymaker, as it is seen as the capacity of any economy to improve living standards over a period of time [3]. The relationship between economic growth and inflation has received considerable attention and analysis, with varying results depending on methods, country details, and other available data [4, 5].

The World Bank notes that Tunisia, much like any other emerging economy in North Africa, has faced its own inflationary hurdles, especially post the 2011 revolution, alongside significant political turmoil and instability, resulting in a dire economic state. During this time, the inflationary factors that came into play included monetary policy, fiscal deficits, movements in the exchange rate, as well as external shocks. While this was occurring, economic growth also exhibited worrying patterns of expansion and contraction, thereby causing severe concern regarding the long-term impacts inflation will have on Tunisia's overall economic well-being.

A hefty amount of research has been conducted on the relationship between economic growth and inflation, but no empirical research has been specifically conducted on Tunisia using advanced techniques like the Autoregressive Distributed Lag model. Tunisia, unlike most developing nations, has a unique economic structure. This makes it crucial to perform a country-specific, detailed analysis. Using traditional economic terms, it would suggest that growth will be inhibited with high levels of inflation; however, contrary to this, empirical studies have shown that increased inflation can have a positive impact depending on the economic circumstances [6, 7].

This research attempts to answer the following research question:

1.1. What is the Impact of Inflation on the Economic Growth of Tunisia, Both in the Short Run and in the Long Run?

Using the Autoregressive Distributed Lag method, we try to test if there is a significant relationship between inflation and Tunisia's GDP growth and if this relationship differs in a long-run versus a short-run setting.

This study attempts to explore the connection between INF and EG in Tunisia while taking short-run and long-run impacts of inflation into consideration. After the 2011 revolution, Tunisia's economy has been very unstable, and as such, it is very important to determine the role of inflation on the economic growth of the nation to ensure that policymakers can effectively promote development and effective inflow. The aim is to determine whether inflation helps stimulate economic activity in the short run or constrains growth in the long run. This study will consider the effects of inflation on economic growth in Tunisia between the years 1991 and 2023, using the sequence of the ARDL approach. Moreover, this study will assess the question of whether there is a rate of inflation that becomes harmful to growth that can be qualified as a threshold value. The research will also aim to determine the Thai interplay of inflation with other macroeconomic indicators such as labor force participation and gross capital formation (GCF). In any case, the recommendations provided will aid in enabling Tunisia to achieve a proper balance between economic growth and inflation and will ensure macroeconomic balance in the long term in Tunisia.

This study seeks to fill the gap in the existing literature concerning inflation-growth dynamics in developing nations by addressing these objectives.

The link between INF and EG has been a highly contested issue in economic literature, with several studies yielding different results based on the economic composition, inflation levels, and policy measures, among other factors, of a particular country. Following the 2011 political transition in Tunisia, which resulted in increased public debt, reduced investment, and heightened macroeconomic instability, inflationary trends have experienced marked volatility [8]. Keeping in mind this volatile scenario, the question that warrants examination is whether inflation acts as a growth-stimulating factor in the short run or if it constitutes a structural impediment to long-term economic growth.

Theoretically, inflation can have either a positive or negative impact on economic growth. On one hand, moderate inflation may stimulate economic activity by reducing real wage rigidity and encouraging consumption and investment [9, 10]. On the other hand, excessive inflation creates economic uncertainty, distorts price signals, and discourages investment, leading to lower productivity and slower growth [2, 4]. Given these contrasting views, this study hypothesizes that the impact of inflation on Tunisia's economic growth depends on the time horizon and inflationary levels.

Thus, the study formulates the following hypotheses:

- H_0 (Null Hypothesis): Inflation has no statistically significant effect on economic growth in Tunisia, implying that inflationary changes do not directly influence GDP growth.
- H_1 (Alternative Hypothesis): Inflation has a statistically significant effect on economic growth in Tunisia, meaning that changes in inflation rates influence economic performance in either a positive or negative direction.

By testing these hypotheses through an ARDL model, this study aims to provide empirical evidence on whether Tunisia's inflation-growth relationship aligns with conventional economic theories or exhibits country-specific deviations that require tailored policy responses. The findings will help policymakers design more effective monetary policies to balance inflation control with sustainable economic growth.

Understanding and interpreting the relationship between INF and EG is crucial for designing effective macroeconomic policies, especially in developing economies, including Tunisia.

Given the country's economic challenges, including inflation volatility, sluggish growth, and structural constraints, this study provides valuable insights into how inflation affects Tunisia's economic performance in both the short and long run. By employing the ARDL model, the study offers a robust empirical framework to assess whether inflation serves as a catalyst for economic growth or a deterrent to long-term stability. This research is particularly significant as it extends the existing literature by focusing on Tunisia's unique macroeconomic environment, which has been shaped by post-revolutionary reforms, monetary policy adjustments, and external shocks. Additionally, the study's findings will inform policymakers on the optimal inflation levels that sustain economic growth without triggering instability. By identifying the threshold at which inflation transitions from being growth-enhancing to growth-restricting, the study will help guide monetary authorities in implementing effective inflation-targeting strategies. Moreover, the research will benefit financial institutions, investors, and international organizations seeking to understand Tunisia's economic dynamics, ultimately contributing to a more informed approach to macroeconomic planning and development strategies in the country.

The research paper is divided into five main sections with the aim of comprehensively analyzing the relationship between inflation (INF) and economic growth (EG) in Tunisia. Section 1 (Introduction) presents the background of the study, the research problem, objectives, hypotheses, significance, and overall structure of the paper. Section 2 (Literature Review) critically examines theoretical perspectives and empirical findings on the inflation-growth relationship, with a particular focus on developing economies and Tunisia. This section also highlights gaps in the existing literature that justify the need for this study. Section 3 (Methodology) outlines the research design, data sources, and econometric approach, specifically detailing the Autoregressive Distributed Lag (ARDL) model used to analyze both short-run and long-run effects of inflation on economic growth. It also describes the diagnostic tests conducted to ensure the robustness of the model. Section 4 (Results and Discussion) presents the empirical findings, interpreting the estimated coefficients and their implications for Tunisia's macroeconomic stability and policy formulation. The discussion integrates the results with existing literature, highlighting areas of agreement or divergence. Finally, Section 5 (Conclusion and Policy) summarizes the key findings, discusses their implications for economic policy, and provides recommendations for controlling inflation while fostering sustainable economic growth in Tunisia.

2. Literature Review

The research paper is divided into five main sections with the aim of comprehensively analyzing the relationship between INF and EG in Tunisia. Advanced economic models suggest that inflation impedes economic growth by increasing uncertainty, distorting prices, and relegating investment. On the other hand, some suggest that moderate inflation is good for economic growth because it increases demand and resource allocation efficiency. In this subsection, key theoretical perspectives will be studied, such as classical and neoclassical, Keynesian, structuralist perspectives, as well as nonlinear or threshold models.

Traditional economists usually have a much more negative view of inflation. Smith [11] and Ricardo [12] regarded stable prices as a prerequisite for a well-functioning market and thus were vehemently against inflation. They believed inflation overvalues economic prices, which inefficiently allocates market resources and distorts economic functions [1]. A high level of inflation in their context erodes the value of money, increases the cost of conducting economic transactions, and adds uncertainty for businesses and consumers, ultimately hindering economic growth.

Milton Friedman's Quantity Theory of Money strengthened the idea that inflation is largely viewed as a monetary phenomenon that is caused by the growth of the money supply. In this theory, when the money supply growth exceeds the productive potential of the economy, it leads to inflation, deterioration of money value, and lower savings and investment in the economy. This view is consistent with the Solow–Swan growth model, which argues, as does Solow [3], that inflation has dire economic consequences by inhibiting growth from an increase in capital investment and productivity.

Supporting neoclassical empirical research includes [4], who argued that inflation had adverse consequences for economic growth due to increased uncertainty and depressed investment. Likewise, Fischer [2] provided evidence that inflation undermines the level of capital productivity and therefore the level of economic output.

Unlike the Classical and Neoclassical schools of thought, Keynesian theorists suggest moderate levels of inflation have a positive bearing on economic development, particularly in the short run. In his 1936 book, Keynes [9] argued that inflation tends to raise consumption expenditure and lower the real value of debt, which helps enhance aggregate demand. By stimulating firms' production resulting from heightened demand, inflation can increase employment and result in economic growth.

Through this lens, necessitated investment spending not matching potential income generation [10] is termed the Tobin Effect, referring to a phenomenon in which, during conditions of moderate inflation, individual cash hoarding is discouraged, and people are motivated to invest in productive assets instead. The rationale behind this is that during moderate inflation periods, economic growth and capital formation are simultaneously incentivized, and liquid cash is discouraged. This school of thought pushes forward the argument that if properly managed, inflation can facilitate growth.

From a different perspective, structuralist economists like [13] assert that expansionary inflation in developing economies tends to stem from supply constraints rather than a case of excess demand. Factors like a lack of sufficient infrastructure, inefficiencies in the labor market, and even institutional weakness are said to further aggravate inflationary pressure. Therefore, moderation of inflation in such economies cannot be achieved by mere monetary policy but needs forward-looking structural reforms.

The structuralist argument is particularly strong when applied against the case of Tunisia and other developing economies, where inflation tends to cluster with deficits in the fiscal budget, depreciation of national currency, and increased

political instability. Under these conditions, stringent monetarist policies, such as aggressive increases of interest rates, would result in reduced investment and demand, thereby lowering economic growth.

Recent research indicates that the connection between INF and EG could be nonlinear, which means that the impact of inflation on growth could be both beneficial and harmful. The threshold model suggests that while economic growth can be achieved with moderate inflation, it becomes highly detrimental at supernormal levels.

Several nations were studied by Bruno and Easterly [5], and it was revealed that economic growth is higher when inflation is kept below a certain threshold, while excessive inflation reduces output and economic growth. In the same way, Sarel [7] proposed 8-10% as the threshold inflation rate for most developing countries since higher rates drive economic growth down.

These findings were supplemented with Khan and Ssnhadji's [6] work, which was based on the analysis of panel data from 140 countries, where it was uncovered that developing countries have an inflation threshold of 7-11% while developed countries' threshold is pegged between 1-3%. Their studies confirmed that inflation is advantageous for both developing and developed nations when it is below these levels, but becomes harmful when these thresholds are surpassed.

Such nonlinear models offer an intricate understanding, which is very important for Tunisia, considering that inflation has varied drastically due to political and economic factors. If inflation in Tunisia is kept within an optimal range, it does not seem to pose a major threat to growth. Nevertheless, the sustained high inflation observed after the 2011 revolution may cause economic instability and result in low investment.

Several empirical researches have been conducted to analyze the impacts of inflation on economic growth on a regional and global scale. Barro [4] of over a hundred countries revealed that adding a 10% increase in inflation corresponds to a 0.2%-0.3% decrease in GDP growth rate. Fischer [2] also showed proof for the argument that increased inflation decreases investment and productivity, which contradicted the classical argument that inflation supports economic growth in the long run.

Some studies have also looked deeper into the effects of inflation on a country, considering the structure of its economy. Ghosh and Phillips [14] studied such economic phenomena and concluded that while low inflation does not appear to impact economic growth, higher inflation seems to drastically decrease productivity, especially in developing countries with relatively poor financial institutions.

Many studies have focused on developing countries, where inflationary pressures tend to be higher due to economic instability and policy inefficiencies.

- Ahmed and Mortaza [15] examined the case of Bangladesh and found a 6% inflation threshold, beyond which inflation significantly reduces GDP growth.
- Mubarik and Riazuddin [16] estimated a 9% threshold for Pakistan, suggesting that inflation above this level has an adverse impact on economic performance.
- Hodge [17] analyzed South Africa's economy and showed that inflation below 6% is growth-supportive, while higher inflation diminishes economic expansion.

These findings suggest that developing economies may tolerate slightly higher inflation thresholds than advanced economies before experiencing negative growth effects.

Tunisia has been the subject of several empirical studies assessing the inflation-growth nexus.

- Ben Naceur et al. [18] found a negative long-term relationship between inflation and growth, particularly after the 2011 revolution, which introduced economic instability.
- Karray and Dridi [19] used Nonlinear ARDL (NARDL) models and found that inflation has asymmetric effects on economic growth, meaning that inflationary shocks have stronger negative consequences during economic downturns.
- Boughrara et al. [20] studied the impact of inflation targeting on Tunisia's macroeconomic stability and concluded that price stability policies improve economic growth prospects by reducing uncertainty.

3. Methodology

3.1. Time-Series vs. Panel Data Approaches

Econometric studies on INF and EG employ either time-series or panel data techniques.

- Time-series models (such as ARDL and Vector Error Correction Models, VECM) analyze individual countries over time.
- Panel data models (such as fixed/random effects) examine multiple countries simultaneously, capturing cross-country variations.

While panel data models provide generalizable results, time-series models are useful for country-specific policy analysis, making them ideal for Tunisia's case.

3.2. ARDL Model

The ARDL Model established by Pesaran et al. [21] is today often called as an Inflation-Growth model, and its widespread application is thanks to its unrestricted mixed integration orders (I(0) and I(1)). The ARDL approach estimation is most useful in short-run and long-run analyses because it can estimate the impact of short-run phenomena simultaneously with long-run phenomena. In this study, the ARDL approach will be used to analyze the economic growth in Tunisia due to inflation over various time horizons, hence trying to offer accurate empirical observations.

4. Results and Discussion

4.1. Results

This section will be dedicated to measuring the impact of inflation on economic growth in Tunisia for the period 1991-2023, using the cointegration approach through the bounds test methodology. Before that, we will present some theoretical aspects of ARDL models.

4.1.1. ARDL Models

First, we will outline some theoretical aspects of ARDL models and the cointegration test, followed by the symmetry test.

4.2. ARDL Models

NARDL models are considered an extension of ARDL models, so we will first present some theoretical aspects of ARDL models. The ARDL method was developed for the purpose of testing cointegration and also measuring the relationship between variables in both the short and long run by Pesaran et al. [21] and Pesaran et al. [22].

The general form of the ARDL (p, q1) model (for one independent variable, x) is:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots + \alpha_p y_{t-p} + \beta_0 x_t + \cdots + \beta_{q1} x_{t-q1} + \varepsilon_t$$

$$y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i y_{t-i} + \sum_{j=0}^{q1} \beta_i x_{t-j} + \varepsilon_t$$

ARDL models are essentially autoregressive models because part of the independent variables is the dependent variable itself lagged by different periods (y_(t-1), y_(t-2), ..., y_(t-p)), and they are distributed lag models because the dependent variable is explained by independent variables lagged over multiple periods (x_t, x_(t-1), x_(t-2), ..., x_(t-q)).

The previous formula is adjusted to derive what is known as the Unrestricted Error Correction Model (ECM), as follows:

$$\Delta y_t = \beta_0 + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \sum_{j=0}^{q1} \gamma_j \Delta x_{t-j} + \theta_1 y_{t-1} + \theta_2 x_{1t-1} + +\varepsilon_t$$

This model is used to conduct the cointegration test (Bounds Test). Here, θ_1 and θ_2 represent the long-term parameters, while β_i and γ_j represent the short-term parameters.

Advantages of ARDL Models: ARDL models offer a range of advantages that set them apart from well-known standard models, including:

- They can be used regardless of the integration degree of the variables (whether they are I(0) or I(1)).
- They can be applied even in time series data with small sample sizes.
- The short-term and long-term relationships can be estimated simultaneously (within the same model).
- They account for the lag periods of the dependent variable and independent variables in explaining the dependent variable, meaning that the dependent variable is explained by its past values and by the current and past values of the independent variables.

4.3. Cointegration Test in NARDL Models

Once the ARDL model has been estimated, the cointegration relation between the variables is analyzed with the Fisher F-test:

- Null hypothesis: $\rho = 0$ (no cointegration).
- Alternative hypothesis: $\rho \neq 0$ (cointegration exists).

To make a decision on cointegration, the tabulated values from Pesaran et al. (2001) are used. If the computed Fisher value is greater than the upper bound, we reject H_0 (i.e., there is cointegration between the variables). If the computed Fisher value is smaller than the lower bound, we accept H_0 (i.e., there is no cointegration between the variables).

Table 1.
Variables of study.

GDP Growth Rate (GGDP)	Annual percentage growth rate of GDP at market prices	World Bank	Percentage (%)
Inflation Rate (CPI) (INF)	Annual inflation rate, measured by the Consumer Price Index	World Bank	Percentage (%)
Labor Force (L)	Total number of people employed or actively seeking employment	World Bank	Persons
Gross Fixed Capital Formation (GFCF)	Total value of new and replacement investments in fixed assets	World Bank	USD (constant 2015 prices)

4.4. Stationarity of Time Series

Regression models on non-stationary series can yield misleading results, a phenomenon known as spurious regression. Therefore, we will attempt to examine the possibility of cointegration between the series under study. However, before conducting this test, it is necessary to examine the stationarity of the series to determine their integration order.

To study the stationarity of the time series, we will apply the Dickey-Fuller simple and augmented (ADF) test on the series before differencing and after differencing. The results of these tests are summarized in the following table:

Table 2.
Stationarity of Variables.

Variables	At Level			After First Differencing			Integration Order
	Model 1	**Model 2**	Model 3	Model 1	Model 2	Model 3	
GGDP	0.0048	0.0006	0.0000	/	/	/	I(0)
INF	0.9907	0.9907	0.2420	0.0475	0.2083	0.0012	I(1)
L	1.000	0.1687	0.9964	0.2403	0.0009	0.0101	I(1)
GFCF	0.7996	0.4593	0.9244	0.000	0.000	0.000	I(1)

The numbers in the table represent the probability (p-value) of the test.

The above table summarizes the results of the stationarity test. To conduct the unit root test, we first selected the appropriate model from three options: a model with a trend and constant, a model with only a constant, and a model with neither a trend nor a constant. Instead of presenting the tabular and calculated values, we directly show the probability, as it leads to the same conclusion. If the probability is greater than 0.05, the null hypothesis is accepted; otherwise, it is rejected.

4.5. Test Results

The results of this test show that all series are integrated of order one (I(1)), except for the economic growth variable (GGDP), which is stationary at level (I(0)). This confirms that the necessary condition for cointegration according to the ARDL methodology is met, as all series are integrated of order less than 2.

4.6. Determining the Optimal Lag Length for the ARDL Model and Testing for Cointegration

After confirming there are no series integrated of order 2, we can now estimate the ARDL model and perform the bounds test.

We will rely on information criteria (Akaike Information Criterion - AIC) to determine the best ARDL model (optimal lag lengths).

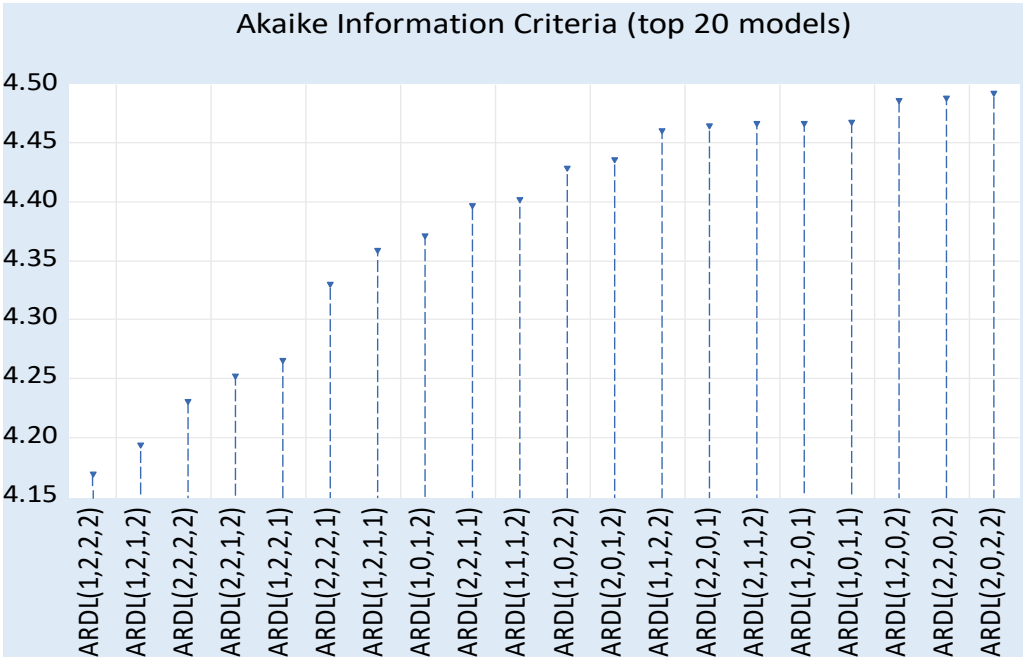

Figure 1.
Determining the Optimal Lag Length for the NARDL Model.

From the above figure, we notice that the criterion used indicates that the ARDL (1,2,2,2) model is the most suitable for the data, as it takes the lowest value for the Akaike Information Criterion (AIC).

After determining the optimal model, we will now perform the bounds test. The results of the test are shown in the following table:

Table 3.
Cointegration Test (Bounds Test).

Bounds Test						
Null hypothesis: No levels of relationship.						
Number of cointegrating variables: 3						
Trend type: Rest. constant (Case 2)						
Sample size: 31						
Test Statistic					Value	
F-statistic					8.117372	
Bounds Critical Values						
	10%		5%		1%	
Sample ...	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
30	2.676	3.586	3.272	4.306	4.614	5.966
35	2.618	3.532	3.164	4.194	4.428	5.816
Asymptotic	2.370	3.200	2.790	3.670	3.650	4.660

Note: * I(0) and I(1) are respectively the stationary and non-stationary.

We accept the alternative hypothesis of the existence of a cointegrating relationship and reject the null hypothesis, in which we state there is no cointegrating relationship because the calculated Fisher value F = 8.117 is greater than the upper bound (I(1)) at all significance levels with the value at 5% being 3.67. This verifies the existence of a long-term equilibrium relationship among economic growth, inflation, labor, and capital in Tunisia.

4.7. Estimation of the ARDL Model and Analysis of Long-term and Short-term Relationships

4.7.1. Estimation of the Long-term Relationship

The estimation of the long-term relationship is presented in the following table:

Table 4.
Estimation of the Long-term Relationship.

Variable *	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
INF(-1)	-0.850520	0.370638	-2.294743	0.0297
L(-1)	-1.75E-06	2.65E-06	-0.661445	0.5139
GFCF(-1)	-1.53E-10	5.41E-10	-0.283504	0.7790
C	13.34076	6.182827	2.157713	0.0400

Based on Table 4, the long-term relationship model can be written as follows:
GGDP= -0.850520*INF - 0.000002*L - 0.000000 *GFCF + 13.340765
Based on the long-term relationship model presented in the table, we observe the following:

- Inflation (INF) bears a statistically significant negative impact on economic growth (GGDP), at a value of -0.850520. This implies that over time, an increase in the inflation rate will lead to a reduction in the economic growth rate, which is consistent with the prevailing economic theory that high inflation is likely to hurt economic growth.
- Labor (L(-1)) and GFCF(-1) do not show statistically significant effects on economic growth, as their coefficients are very small and not statistically meaningful at common significance levels. This indicates that, while these variables may theoretically influence growth, their long-term relationship with GDP growth is not significant in this model.

  b. Estimation of the Error Correction Model (ECM) (Short-Term Relationship):
  The following table shows the estimation of the short-term relationship:

Table 5.
Estimation of the Short-Term Relationship.

Error Correction
Dependent Variable: D(GGDP)
Method: ARDL
Date: 12/29/24 Time: 12:45
Sample: 1993 2023
Included observations: 31
Dependent lags: 2 (Automatic)
Automatic-lag linear regressors (2 max. lags): INF L GFCF
Deterministic: Restricted constant and no trend (Case 2)
Model selection method: Akaike info criterion (AIC)
Number of models evaluated: 54
Selected model: ARDL (1,2,2,2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ*	-0.886396	0.127012	-6.978842	0.0000
D(INF)	-0.167444	0.256695	-0.65231	0.5204
D(INF(-1))	0.914127	0.246742	3.704793	0.0011
D(L)	2.36e-05	5.55e-06	4.263483	0.0003
D(L(-1))	-3.16e-05	5.53e-06	-5.721035	0.0636
D(GFCF)	6.36e-10	4.36e-10	1.459085	0.1575
D(GFCF(-1))	-1.38e-09	4.7e-10	-2.942677	0.0071

R-squared	0.882195	Mean dependent var	-0.250535
Adjusted R-squared	0.852744	S.D. dependent var	0.404015
S.E. of regression	0.244116	Akaike info criterion	0.424357
Sum squared residuals	57.68651	Schwarz criterion	1.233423
Log likelihood	-3.111004	Hannan-Quinn criterion	0.734129
F-statistic	29.95451	Durbin-Watson stat	2.060734
Prob(F-statistic)	0.000000		

Note: * p-values are incompatible with t-Bounds distribution.

The results of the error correction model (ECM) based on the ARDL method are presented in the table above. Here is an interpretation of the key elements:

4.8. Cointegration and Long-term Relationship

- COINTEQ (Error Correction Term): The coefficient of the error correction term is -0.886396 with a t-statistic of -6.978842 and a p-value of 0.0000, which is significant at any level of significance, say 1%, 5%, or 10%. This suggests that there is a relationship between the variables over the long term, and the error correction term indicates that the system is adjusting itself towards equilibrium at a rate of roughly 88.64% per period. Its negative sign corroborates the hypothesis of long-term equilibrium being achieved after short-term fluctuations.

4.9. Short-term Dynamics

- D(INF) (Inflation): The lagged coefficient inflation now equals negative 0.167444 with a t-value of negative 0.652310 and p-value of 0.5204, which is not significant. It implies that inflation affects economic growth significantly in the short run for this particular model.
- D(INF(-1)) (Lagged Inflation): For the coefficient of the first lag of inflation, the value stands at 0.914127 with a t-stat of 3.704793 and a p-value of 0.0011, which makes it significant at the 1% level. It therefore, can be noticed that the value of inflation in the prior period is positively significant to the economic growth of the current time.
- D(L) (Labor): The present value of the labor coefficient is 2.36E-05 with a corresponding t-statistic of 4.263483 and p-value of 0.0003, which is statistically significant. This implies that in the short run, an increase in labor would be beneficial for economic growth.
- D(L(-1)) (Lagged Labor): The estimated coefficient for lagged labor is -1.16E-05, while the associated t-statistic is -1.945101 and the p-value is 0.0636, which is marginally significant at the 10% level. This means that the impact of labor on economic growth from the previous period is negative and weak.
- D(GFCF) (Gross Fixed Capital Formation): The current period GFCF coefficient is equal to 6.36E-10. Its t-statistic value equals 1.459085, whereas the p-value is 0.1575, meaning it is not statistically significant. This suggests that gross fixed capital formation does not impact economic growth in the short run.

- D(GFCF(-1)) (Lagged GFCF): The coefficient for the first lag of GFCF is -1.38E-09. The t-statistic is equal to -2.942677, and the corresponding p-value is 0.0071, which is statistically significant at the 1% threshold. This tells us that the studied variable, GFCF in the previous period, has a significant negative impact on economic growth.

4.10. Model Fit and Diagnostics

- R-squared: With a value of 0.882195, the R-squared value shows that about 88.22% of the changes in the dependent variable (economic growth, GGDP) is due to the factors that the model's independent variables describe.
- Adjusted R-squared: The value of 0.852744 is adjusted R-squared and it shows that the model still holds accurately in describing the data, even though overfitting is accounted for, confirms that the model fits the data well while penalizing for overfitting.
- F-statistic: The F-statistic is 29.95451, and its power 0.000000 gives a p significance of probability, which is great, showing that the independent variables have a strong correlation with the dependent variable, suggesting that the model as a whole is significant.
- Durbin-Watson Statistic: The value of 2.060734 is the Durbin-Watson statistic, and it denotes that there is no positive or negative autocorrelation in the residuals because this value is almost equal to 2, showing the errors are likely to be autonomous.

4.11. Diagnostic Tests for the Model

We will conduct various diagnostic tests on the ARDL model.

4.11.1. Autocorrelation of Errors Test

The results of the autocorrelation of errors test (LM Test) are shown in the following table:

Table 6.
Autocorrelation of Errors Test.

Breusch-Godfrey Serial Correlation LM Test Results

Null hypothesis: No serial correlation at up to 2 lags

F-statistic	0.121767	Prob. F(2.18)	0.8861
Obs*R-squared	0.413822	Prob. Chi-Square (2)	0.8131

Note: Since Prob = 0.88 > 0.05, we accept the null hypothesis, which states that there is no autocorrelation of the errors.

4.11.2. Test of Normality of Errors

The results of the Jarque-Bera test for the normality of errors are shown in the following Figure 2:

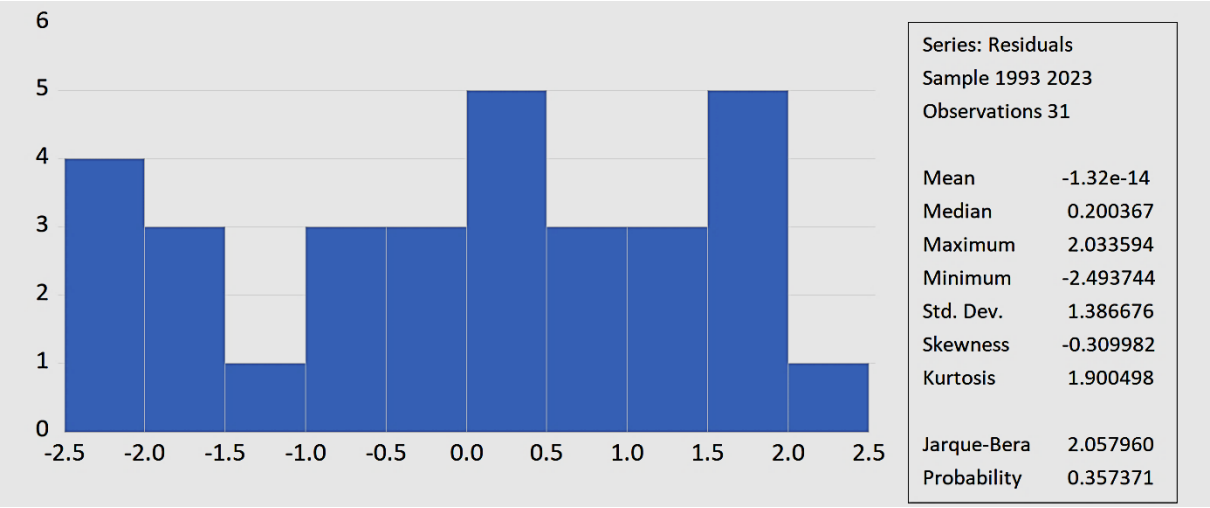

Figure 2.
Test of Normality of Errors.

Since Prob = 0.35 > 0.05, we accept the null hypothesis, which states that the errors follow a normal distribution.

4.11.3. Test for Homoscedasticity of Errors

The results of the Breusch-Pagan-Godfrey (BPG) test for homoscedasticity are shown in the following table:

Table 7.
Test for Homoscedasticity of Errors.

Heteroskedasticity Test: Breusch-Pagan-Godfrey

Null hypothesis: Homoskedasticity

F-statistic	0.316055	Prob. F(10,20)	0.9675
Obs*R-squared	4.230341	Prob. Chi-Square (10)	0.9364
Scaled explained SS	0.792802	Prob. Chi-Square (10)	0.9999

Note: Since Prob = 0.96 > 0.05, we accept the null hypothesis, which states that the variance of the errors is constant (homoscedasticity).

4.11.4. The Graphical Representation of CUSUM and CUSUMSQ is Shown in the Following Figure 3:

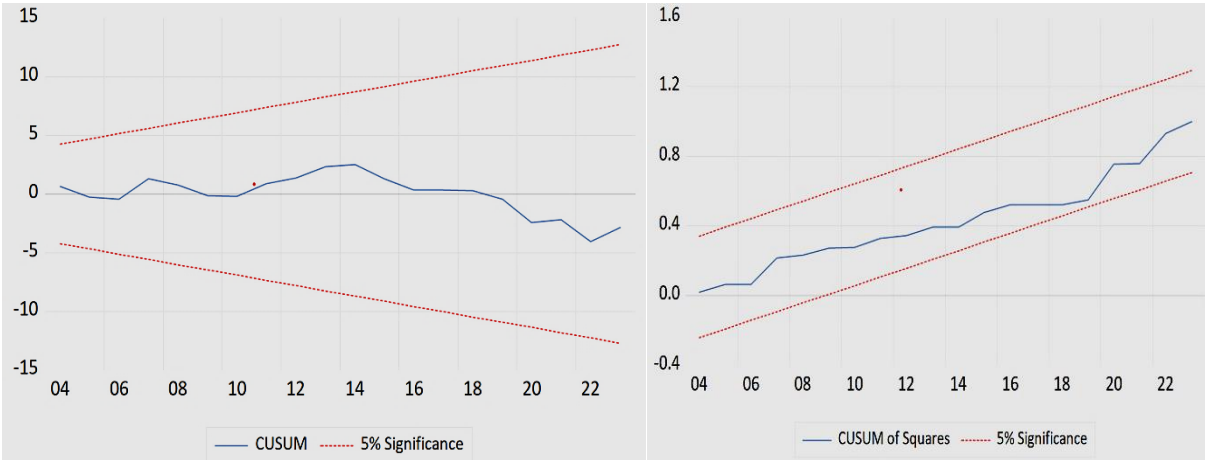

Figure 3.
CUSUM and CUSUMSQ Graphical Representation.

The figure depicting the CUSUM and CUSUMSQ does not indicate any change in the parameters of the model because both curves reside within the critical limits at the 5% level.

4.11.5. The Graph of the Dynamic Cumulative Impact Multiplier is Shown in the Following Representation

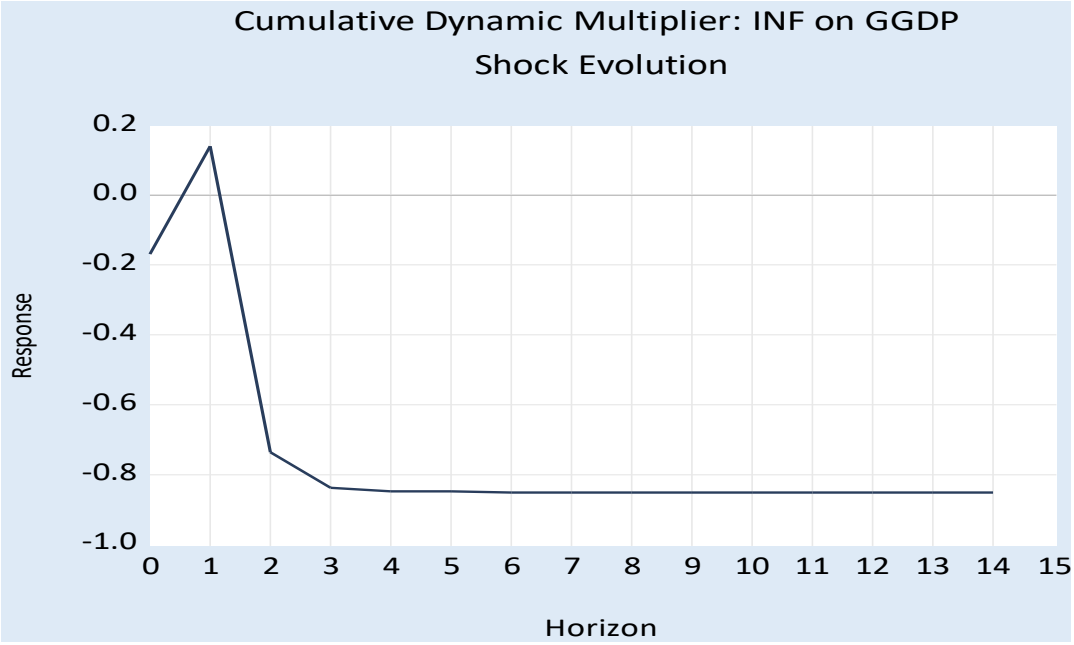

Figure 4.
Graph of the Asymmetric Dynamic Cumulative Impact Multiplier.

Based on the above figure, we observe that the impact of inflation on economic growth is initially positive and weak in the short term, with a value of 0.1. However, it quickly turns negative in the long term and stabilizes at a value of -0.82.

5. Discussion

The discrepancy between INF and EG has been studied and reported in economic literature as having numerous theories and empirical evidence that are contradictory. This study contributes to the discussion by analyzing the inflation-growth

dynamics of Tunisia between the years of 1991 and 2023 using the ARDL model. The empirical evidence provides confirmation of the significant impact that INF and EG have in the long run; however, their effects in the short run are uncertain, showing that inflation can endorse economic growth in the short run, albeit hindering it in the long run.

The long-run results demonstrate that inflation exerts a statistically significant negative impact on economic growth in Tunisia, with an estimated coefficient of -0.850520. This finding is consistent with the classical and neoclassical views, which argue that inflation distorts price signals, reduces investment, and increases economic uncertainty, thereby inhibiting long-term economic performance [2, 4]. The result aligns with studies on developing economies that have identified inflation thresholds beyond which inflation becomes detrimental to growth [5, 6].

In contrast, the short-run results indicate that inflation in the previous period (lagged inflation) has a statistically significant positive impact on economic growth (0.914127). This suggests that moderate inflation may temporarily stimulate aggregate demand, encouraging firms to invest and households to consume, which is consistent with Keynesian economics Keynes [9]. Tobin [10] also suggested that inflation can promote investment by discouraging the hoarding of money. However, as inflation persists and becomes high or unpredictable, its effects turn negative, leading to declining economic performance. The results suggest that Tunisia may benefit from moderate inflation in the short run but needs to avoid persistently high inflation levels.

These results are consistent with previous empirical research on Tunisia. For instance, Ben Naceur et al. [18] found that high inflation had a negative long-term impact on economic growth, especially after the 2011 revolution, which introduced macroeconomic instability. Similarly, Karray and Dridi [19] applied a Nonlinear ARDL model and showed that inflation had asymmetric effects on economic growth, with inflationary shocks causing stronger negative effects during economic downturns. The findings also align with international studies on inflation-growth dynamics, such as those by Ghosh and Phillips [14], who found that inflation above certain thresholds significantly reduces economic growth.

Labor force participation (L) plays a significant role in short-run economic growth, as indicated by its positive and statistically significant coefficient. However, in the long run, labor force participation does not have a significant effect. This suggests that while employment growth supports economic activity in the short term, other structural factors such as productivity and technological advancements may be more crucial for sustaining long-term growth. This finding aligns with economic growth theories that emphasize human capital accumulation and productivity [3, 23].

The role of Gross Fixed Capital Formation (GFCF) is particularly interesting. The long-run results indicate that capital investment does not have a significant impact on Tunisia's economic growth, which is inconsistent with traditional economic growth theories that emphasize investment-driven growth [3, 24]. In the short run, capital formation even exhibits a negative lagged effect (-1.38E-09). One possible explanation is inefficient investment allocation in Tunisia, where public investments may not translate into productive economic activities due to bureaucratic inefficiencies, corruption, and mismanagement [8]. This aligns with Boughrara et al. [20] who argued that Tunisia's economic growth prospects depend more on improving investment efficiency than increasing investment volumes.

The cointegration test results confirm the presence of a long-term equilibrium relationship between economic growth, inflation, labor force participation, and capital investment. The error correction term (-0.886396) is highly significant, indicating that any short-term deviations from the long-run growth path are corrected at a relatively fast rate (88.64% per period). This suggests that Tunisia's macroeconomic system is highly responsive to inflationary shocks, with the economy adjusting relatively quickly to stabilize.

These results are crucial for policymakers, as they indicate that short-term fluctuations in INF and EG do not persist indefinitely but rather correct over time. However, they also highlight the need for effective inflation control policies to ensure that inflation does not exceed levels that disrupt long-term stability.

6. Conclusion and Policy

This study provides a comprehensive analysis of the inflation-growth nexus in Tunisia over the period 1991–2023, employing the ARDL model to examine both short-run and long-run dynamics. The findings confirm that inflation negatively affects economic growth in the long run, reinforcing the classical economic view that high inflation erodes purchasing power, distorts investment decisions, and generates macroeconomic instability. However, the short-run analysis suggests that lagged inflation has a positive effect on economic growth, indicating that moderate inflation may initially stimulate economic activity before its adverse effects become dominant. These results align with existing literature on inflation thresholds, where low-to-moderate inflation may support growth while excessive inflation is detrimental.

Another critical finding is the insignificant role of GFC in long-term growth, which challenges the conventional view that capital accumulation is a key driver of economic expansion. This suggests that investment inefficiencies, misallocation of resources, and governance challenges may be preventing Tunisia from fully leveraging its capital investments for sustainable growth. Similarly, while labor force participation positively influences short-term growth, it does not significantly contribute to long-term economic performance. This indicates that simply expanding the labor force is insufficient for sustained development—productivity enhancements, technological advancements, and structural reforms are equally important.

The presence of cointegration among the variables indicates that despite short-term fluctuations, Tunisia's economy adjusts over time to maintain long-run equilibrium. The significant and negative error correction term (-0.886396) suggests that deviations from the long-term growth path are corrected at a rapid pace, reinforcing the need for stability-focused macroeconomic policies. The findings underscore the importance of maintaining inflation at a moderate level, ensuring that price stability does not come at the expense of economic growth.

From a policy perspective, the study highlights the necessity of an inflation-targeting framework that balances inflation control with economic expansion. The Central Bank of Tunisia (CBT) should focus on stabilizing inflation expectations while coordinating with fiscal authorities to maintain budget discipline, enhance revenue collection, and improve public investment efficiency. Addressing structural inefficiencies in capital formation and improving labor market productivity are also crucial for sustaining long-term economic growth. Additionally, exchange rate policies should be carefully managed to minimize inflationary pressures from external shocks while promoting trade competitiveness.

In conclusion, this study contributes to the ongoing debate on the inflation-growth relationship in developing economies, offering empirical evidence specific to Tunisia's macroeconomic environment. The results suggest that inflation control policies should be designed with a clear understanding of their short-run and long-run trade-offs. Future research could explore nonlinear models to identify inflation thresholds and sector-specific impacts to provide a more detailed policy framework. By adopting evidence-based monetary and fiscal policies, Tunisia can achieve sustainable economic growth while ensuring macroeconomic stability in the years ahead.

The results of this paper's research provide important policy implications for Tunisia's economic management, particularly in balancing inflation control and economic growth. Given the negative long-term impact of inflation on GDP growth, the Central Bank of Tunisia (CBT) should adopt a moderate inflation-targeting strategy, ensuring that inflation remains below the estimated harmful threshold while allowing room for economic expansion. Monetary policy should be complemented by fiscal discipline, reducing budget deficits and ensuring that government spending is productive and growth-enhancing. Additionally, the study's results highlight the inefficiency of capital formation in driving long-term growth, indicating a need for investment efficiency reforms rather than merely increasing capital spending. The government should prioritize high-productivity sectors, improve governance, and minimize corruption in public investments. Furthermore, while labor force participation positively influences short-term growth, long-term sustainability requires policies that enhance labor productivity through education, vocational training, and innovation-driven industries. Given Tunisia's exposure to external inflationary shocks, exchange rate policies should also be carefully managed to mitigate imported inflation while maintaining trade competitiveness. A holistic macroeconomic framework that integrates monetary, fiscal, and structural policies will be essential for ensuring sustained economic growth and stability in Tunisia.

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Appendix

Table 8.
Data.

Year	L	Inf	GDP%	GFCF
1991	2589545	8.1937151	3.9045453	3436456482
1992	2661391	5.82434515	7.80572888	4067509338
1993	2751031	3.97495632	2.18982886	4226199504
1994	2836249	4.73323064	3.17841132	4268653396
1995	2918136	6.24415029	2.35166985	3980427869
1996	2999008	3.72514473	7.14608097	4067765093
1997	3079908	3.65202621	5.4409435	4416474474
1998	3131627	3.1253658	4.78376248	4672626881
1999	3183536	2.69012486	6.05463448	5069797406
2000	3235027	2.96230795	4.70997291	5287782475
2001	3285012	1.98333333	3.79627166	5964919951
2002	3332710	2.72103285	1.32255715	5863498941
2003	3377826	2.71259247	4.70239953	5759580080
2004	3418273	3.63228005	6.23579072	5817171618
2005	3451807	2.01778641	3.48654554	5974268070
2006	3520496	3.22525337	5.24409983	6539213683
2007	3592686	2.96694432	6.70952097	6951118212
2008	3670001	4.34502808	4.23778148	7319532781
2009	3747954	3.66490331	3.04345012	7574531668
2010	3826864	3.33897964	2.97113275	1.0633E+10
2011	3896341	3.24002842	-2.0466339	9236121932
2012	3987219	4.61184432	4.21667712	9829501219
2013	3996064	5.31623531	2.42993096	9880988597
2014	4018818	4.625551	3.09032803	9633237452
2015	4041124	4.43737127	0.96770311	9605199771
2016	4086147	3.62939937	1.11742595	9700018110
2017	4105250	5.3088484	2.23783868	9666882669
2018	4133385	7.30759176	2.62493011	9657706701
2019	4169695	6.72007533	1.58784665	9704606095
2020	4017735	5.63415116	-9.01193412	7764908338
2021	4061737	5.70635021	4.73632075	8012149708
2022	4282032	8.30646124	2.67331822	8152847889
2023	4367259	9.32899598	0.03915657	7527862489

Source: https://databank.worldbank.org/source/world-development-indicators