



The Impact of The TND/USD Exchange Rate and GDP On Inflation in Tunisia: ARDL Evidence of a U-Shaped Relationship

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Received 15/09/2025

Accepted: 30/11/2025

Published: 28/12/2025

Abstract:

This paper examines the relationship between the TND/USD exchange rate, real GDP, and inflation in Tunisia over the period 1984–2023 by applying the autoregressive distributed lag (ARDL) methodology. The study seeks to provide deeper insights into the complex and nonlinear nature of inflation dynamics in an emerging economy highly exposed to external shocks and structural constraints. Empirical results indicate the presence of a U-shaped relationship, whereby inflation declines with GDP growth and exchange rate appreciation up to a critical threshold but rises once these variables exceed certain levels. Cointegration analysis confirms a stable long-run equilibrium, showing that GDP plays a significant role in shaping inflationary trends, while the exchange rate exhibits strong short-run effects through import-price channels. The estimated error correction model further demonstrates a rapid speed of adjustment toward equilibrium, highlighting the self-correcting mechanism of the Tunisian economy. These findings emphasize the need for policymakers to account for nonlinearities and threshold effects when designing monetary and exchange rate policies aimed at ensuring price stability and fostering sustainable economic growth.

Keywords: Inflation, Exchange Rate, GDP, ARDL, Nonlinear Relationship, Tunisia

JEL Classification Codes: E31, F31, F41, C22, O55

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1-Introduction:

Inflation control remains a paramount concern for emerging economies, particularly those exposed to external shocks and exchange rate fluctuations. Tunisia's economic context marked by structural reforms, volatile exchange rates, and persistent inflation makes it an ideal focus for examining inflation dynamics. Traditional analyses often posit linear relationships between inflation, output, and exchange rates, yet growing evidence suggests these connections may be inherently nonlinear and asymmetric.

Recent empirical literature underscores this complexity. For instance, Boujelbène et al. (2025) employ a threshold regression model to show that inflation and inflation uncertainty in Tunisia exert opposing influences on economic growth: below a critical inflation threshold ($\approx 3\%$), inflation uncertainty supports growth, whereas inflation itself becomes detrimental above this level. Similarly, Dammak et al. (2019) reveal a trade-threshold effect, whereby trade openness helps mitigate inflation only up to a certain point, beyond which its impact reverses. Beyond Tunisia, methodological advances further enrich this narrative. For example, studies using nonlinear ARDL (NARDL) and smooth transition models demonstrate that output and money supply shocks often produce asymmetric inflation responses, with adjustment speeds to equilibrium being markedly faster when asymmetric effects are accounted for.

Against this backdrop, our study investigates the relationship between the TND/USD exchange rate, real GDP, and inflation in Tunisia over 1984–2023 using an ARDL framework. By allowing for U-shaped (nonlinear) effects and distinguishing between short- and long-run dynamics, we aim to uncover thresholds and asymmetries that have so far been under-explored in Tunisian inflation literature. This enhanced understanding is crucial for designing monetary and exchange rate policies that account for nonlinear and state-dependent behaviors—thus offering more effective inflation stabilization tools. The study makes several noteworthy contributions to the literature on inflation dynamics in emerging economies. It provides one of the longest time-span analyses (1984–2023) of inflation in Tunisia, which captures the effects of structural reforms, exchange rate regimes, and the post-2011 political transition within a unified empirical framework. By incorporating quadratic terms for both GDP and the exchange rate, the study explicitly accounts for nonlinearities and threshold effects, uncovering U-shaped relationships that have often been overlooked in prior research. The use of the ARDL methodology ensures robustness in estimating both short-run and long-run dynamics, even with small sample sizes, thereby disentangling the asymmetric and state-dependent behavior of inflation. The findings also yield relevant policy implications, highlighting the dominant role of GDP in shaping long-run inflationary pressures, and the strong but transitory influence of exchange rate movements in the short run.

The rest of this study is organized in the following way. Section 2 provides a review of the relevant literature on inflation, exchange rates, and output dynamics, with a focus on nonlinear effects. Section 3 describes the data and outlines the empirical methodology, including the ARDL model specification. Section 4 presents empirical results, covering both short-run and long-run dynamics, as well as diagnostic and stability tests. Section 5 concludes with key policy recommendations derived from the findings.

2. Literature review

2.1 Transmission mechanisms

The nexus between inflation, exchange rate fluctuations, and economic growth has remained a central subject of academic inquiry, particularly in developing and emerging economies where macroeconomic volatility tends to be more pronounced. Traditional theoretical frameworks, such as the Quantity Theory of Money (Friedman, 1968) and the Phillips Curve (Phillips, 1958), emphasized linear relationships between monetary expansion, output, and inflation. However, more recent contributions increasingly highlight the presence of nonlinear and asymmetric dynamics, especially in economies exposed to external shocks and structural rigidities.

In the Tunisian context, several studies have explored the exchange rate pass-through (ERPT) to inflation. Gritli (2021) demonstrated that exchange rate depreciation has a significant impact on import prices, while the effect on consumer prices remains partial, thus confirming incomplete pass-through. Similarly, Dardouri et al. (2025) found persistent effects of exchange rate volatility on domestic prices using a VECM framework, underlining the vulnerability of inflation to external shocks and exchange rate instability. These findings suggest that exchange rate policy plays a critical role in shaping inflation dynamics in Tunisia.

The literature has also emphasized the existence of threshold effects in the inflation–growth nexus. Boujelbène et al. (2025), through a threshold regression analysis, identified a critical inflation level around 3 percent, below which inflation uncertainty may stimulate growth, but above which inflation becomes detrimental. Bousnina and Gabsi (2024) reinforced this argument by detecting two thresholds at 3.87 and 8.41 percent, highlighting that inflation can be supportive at low levels but destabilizing once it surpasses these critical points. These studies provide empirical evidence for the U-shaped or nonlinear relationship between inflation and growth.

At the same time, research on output–inflation interactions in Tunisia have confirmed these nonlinearities. Soltani (2025) applied an ARDL approach and found that inflation exerts a strong negative effect on growth in the long run, while moderate inflation may have short-lived positive effects through demand stimulation. Complementary results were obtained by Masmoudi, Aloulou, and Helali (2025), who analyzed the Phillips curve in Tunisia using ARDL and NARDL models. Their findings revealed asymmetric long-term effects of unemployment on inflation, which further validates the adoption of nonlinear approaches.

More broadly, methodological advances in modeling nonlinear dynamics have provided deeper insights into the inflationary process. Ghandri et al. (2023) employed a Smooth Transition Regression (STR) model to study the role of inflation thresholds in the relationship between financial development and growth. Their results, showing a critical threshold of 3.63 percent, illustrate how macroeconomic relationships can shift once inflation crosses certain levels.

Taken together, the reviewed literature converges on the conclusion that the inflation process in Tunisia is shaped by complex, nonlinear interactions with both exchange rate fluctuations and economic growth. The evidence strongly supports the use of advanced econometric frameworks, particularly ARDL and NARDL, which allow for the simultaneous investigation of short-run and long-run dynamics while incorporating potential threshold and asymmetric effects. This body of research provides the foundation for the present study, which seeks to empirically assess the U-shaped relationship between exchange rate, output, and inflation in Tunisia over the period 1984–2023.

2.2. Data and empirical methodology

2.2.1. Data description

This study is based on annual macroeconomic time-series data for Tunisia covering the period 1984–2023. The dataset comprises three core macroeconomic indicators that are widely employed in the literature on inflation dynamics: the inflation rate, the exchange rate, and real gross domestic product (GDP). All data were obtained from the World Bank’s World Development Indicators (WDI) database, which provides harmonized and internationally comparable statistics.

The inflation rate (INF) is measured as the annual percentage change in the consumer price index (CPI). It reflects the general evolution of prices and serves as the dependent variable in the econometric model. The exchange rate (EXCH) is defined as the official rate of the Tunisian dinar against the US dollar (TND/USD), expressed in terms of dinars per dollar. This indicator captures external sector conditions and plays a critical role in import prices, thereby influencing cost-push inflation. The real GDP (GDP) is measured at constant 2015 US dollars and represents the level of real economic activity, allowing for an assessment of the output–inflation relationship (Boujelbène et al., 2025).

Table 01: Description of Variables

Variable	Description	Source	Unit
Exchange Rate (EXCH, TND/USD)	Official exchange rate (TND per USD)	World Bank	TND per USD
Inflation Rate (INF, CPI)	Annual percentage change in CPI	World Bank	Percentage (%)
Real GDP (GDP, constant USD)	Gross Domestic Product at constant 2015 prices	World Bank	USD (constant 2015)

The choice of the study period (1984–2023) is motivated by its ability to capture distinct phases of the Tunisian economy, including the structural adjustment programs of the late 1980s and 1990s, exchange rate policy reforms, the political transition following 2011, and the subsequent period of macroeconomic instability characterized by persistent inflationary pressures and currency depreciation. Such a long horizon ensures that both structural shifts and cyclical dynamics are incorporated into the econometric framework, thereby strengthening the robustness of the results.

To illustrate these dynamics, Figure 01 presents scatter plots of inflation against GDP and the exchange rate. Both plots reveal a U-shaped relationship, indicating a nonlinear pattern in how inflation responds to these variables.

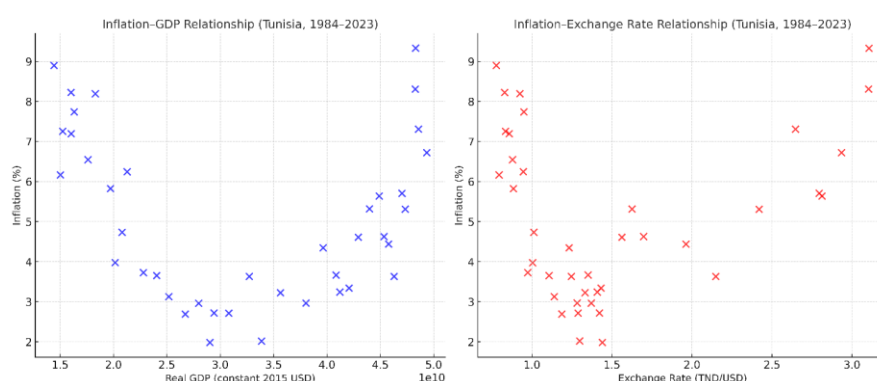


Figure 01 : Scatter Plot of the U-Shaped Relationship Between Inflation, GDP, and Exchange Rate in Tunisia

Inflation–GDP relationship: Inflation declined as GDP increased until around 2001, which represents a critical turning point. Beyond this point, inflation began to rise again alongside further

GDP growth, a shift that may be attributed to structural changes in the economy or policy adjustments.

Inflation–Exchange rate relationship: Inflation decreased as the TND appreciated against the USD up to 2011, after which the dinar experienced persistent depreciation. This depreciation contributed to rising inflation, reflecting higher import costs and cost-push pressures.

Thus, the combination of a long study period and the evidence from scatter plots highlights the nonlinear and threshold effects in the inflation process, justifying the adoption of the ARDL framework with quadratic terms in subsequent empirical analysis.

2.2.2. Empirical Methodology

The autoregressive distributed lag (ARDL) model is employed in this study to capture the dynamic relationship between inflation, real output, and the exchange rate in Tunisia, while considering both linear and nonlinear effects. The choice of the ARDL framework is motivated by its well-documented advantages in empirical macroeconomic research. As highlighted by Pesaran, Shin, and Smith (2001), the ARDL bounds testing approach can be applied irrespective of whether regressors are integrated of order zero, $I(0)$, or order one, $I(1)$, provided none is integrated of order two, $I(2)$. Moreover, it simultaneously estimates both short-run dynamics and long-run equilibrium relationships, thereby overcoming limitations of traditional cointegration techniques. Another merit of the ARDL approach, emphasized by Narayan (2005), is its suitability for relatively small sample sizes, which is often the case in annual macroeconomic data.

In this study, squared terms are also incorporated into the ARDL specification, allowing for the assessment of potential nonlinearities and threshold effects, particularly the hypothesized U-shaped relationship between output, exchange rate, and inflation. The general specification of the ARDL model can be expressed as follows:

$$INF_t = \alpha_0 + \sum_{i=1}^p \phi_i INF_{t-i} + \sum_{j=0}^{q_1} \beta_j GDP_{t-j} + \sum_{j=0}^{q_2} \beta'_j (GDP_{t-j})^2 + \sum_{k=0}^{q_3} \gamma_k EXCH_{t-k} + \sum_{k=0}^{q_4} \gamma'_k (EXCH_{t-k})^2 + \zeta_t$$

Equation (1) highlights the role of both output and exchange rate, along with their squared terms, in explaining inflation. The squared variables are particularly important as they allow testing whether the inflationary process in Tunisia exhibits nonlinear dynamics, consistent with the U-shaped relationship observed in the descriptive scatter plots. To separate short-run from long-run dynamics, the model is re-parameterized into its error correction form:

$$\Delta INF_t = \psi [INF_{t-1} - \theta_0 - \theta_1 GDP_{t-1} - \theta_2 (GDP_{t-1})^2 - \theta_3 EXCH_{t-1} - \theta_4 (EXCH_{t-1})^2] + \sum_{i=1}^{p-1} \phi_i \Delta INF_{t-i} + \sum_{j=0}^{q_1-1} \epsilon_j \Delta GDP_{t-j} + \sum_{j=0}^{q_2-1} \epsilon'_j \Delta (GDP_{t-j})^2 + \sum_{k=0}^{q_3-1} \eta_k \Delta EXCH_{t-k} + \sum_{k=0}^{q_4-1} \eta'_k \Delta (EXCH_{t-k})^2 + U_t$$

In this framework, the error correction term (ψ) serves a central role by capturing the speed of adjustment toward the long-run equilibrium after short-run shocks. A negative and statistically significant ψ provides evidence of cointegration among the variables and confirms the stability of the long-run relationship. Based on the ARDL model, the corresponding long-run cointegration equation can be expressed as follows:

$$INF_t = \vartheta_0 + \vartheta_1 GDP_t + \vartheta_2 (GDP_t)^2 + \vartheta_3 EXCH_t + \vartheta_4 (EXCH_t)^2 + \zeta_t$$

Equation (3) captures the persistent interaction between inflation, output, and exchange rate movements in Tunisia. The coefficients ϑ_1 and ϑ_2 indicate whether the output–inflation nexus follows a nonlinear U-shaped pattern, while ϑ_3 and ϑ_4 measure the direct and nonlinear pass-through effects of exchange rate fluctuations on inflation. This formulation not only provides insights into the short-run adjustment mechanisms but also sheds light on the long-run inflationary pressures in an open economy context.

By adopting this enriched specification, the analysis ensures that both cyclical dynamics and structural shifts are captured within the econometric framework. It also aligns the empirical investigation with recent advances in the inflation–growth–exchange rate literature, thereby enhancing the robustness and policy relevance of the results.

3. Empirical Findings

This section presents the empirical results derived from econometric analysis. In line with the ARDL framework, the investigation begins with preliminary diagnostic procedures to ensure the appropriateness of the data for estimation. Specifically, unit root tests are first conducted to examine the stationarity properties of the series, followed by lag length selection and bounds testing for cointegration. Once these preliminary steps are established, the ARDL model is estimated to disentangle both the short-run and long-run dynamics of inflation in relation to output and the exchange rate.

3.1. Stationarity of Time Series

Regression models estimated with non-stationary series may produce spurious results, leading to invalid statistical inference (Granger & Newbold, 1974). To avoid this problem, it is crucial to assess the order of integration of the variables before proceeding with cointegration analysis. Accordingly, the stationarity of each series is examined using the Dickey–Fuller (DF) and Augmented Dickey–Fuller (ADF) unit root procedures, applied to the variables in both levels and first differences. These tests are particularly appropriate in this context, as they are widely used in empirical macroeconomic research and allow for the detection of unit roots even in relatively small samples. Based on their outcomes, it is possible to establish whether the series are integrated of order zero, $I(0)$, or order one, $I(1)$. The corresponding results are reported in Table 02.

Table 02 : Stationarity of Variables

Variables	At Level			After First Differencing			Integration Order
	Model	Model	Model	Model	Model	Model	
	1	2	3	1	2	3	
GDP	1.0000	.08482	.08585	0.2914	0.0000	0.0000	I(1)
INF	0. 6758	0.1312	0.9968	0.0321	0.0901	0.0000	I(1)
EXCH	0.9999	0.9997	0.9831	0.1002	0.0004	0.0004	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.

The results of this test show that all series are integrated of order one ($I(1)$), 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.

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

After confirming that none of the series is integrated of order two, the ARDL model can be estimated and the bounds testing procedure applied. To determine the optimal lag structure,

information criteria such as the Akaike Information Criterion (AIC) are typically employed, as they provide consistent guidance in small samples (Narayan, 2005).

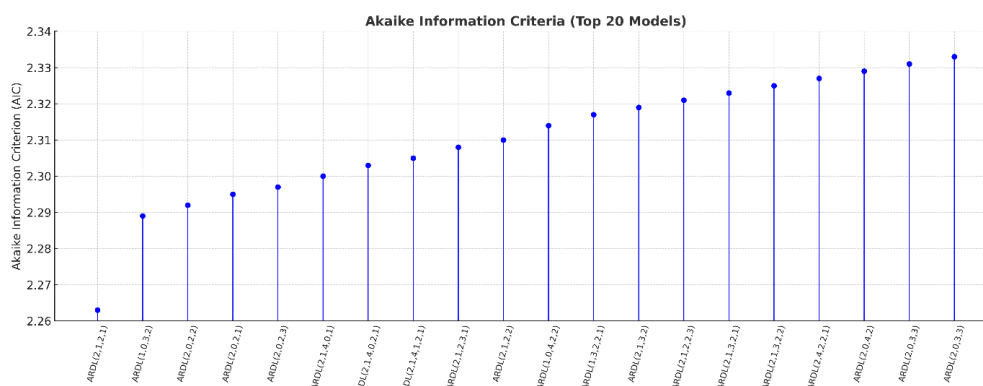


Figure 02: Determining the Optimal Lag Length for the NARDL Model

From the above figure, we notice that the criterion used indicates that the ARDL(2,1,2,2,1) 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 (03):

Table 03: Cointegration Test (Bounds Test)

Bounds Test

Test Statistic	Value
F-statistic	8.5876

Note: Null hypothesis assumes no levels relationship.

Bounds Critical Values

10%			5%		1%	
Sample	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
35	2.460	3.460	2.947	4.088	4.093	5.532
40	2.427	3.395	2.893	4.000	3.967	5.455
Asymptotic	2.200	3.090	2.560	3.490	3.290	4.370

Note: Null hypothesis assumes no levels relationship. If the F-statistic exceeds the upper bound (I(1)) critical value, the null hypothesis of no cointegration is rejected.

The calculated F-statistic ($F = 8.587$) is greater than the upper critical bound at all conventional significance levels (with the 5% critical value equal to 4.00). Consequently, the null hypothesis of no cointegration is rejected in favor of the alternative, indicating the existence of a stable long-run relationship among inflation, real GDP, and the exchange rate in Tunisia. This finding provides strong support for estimating both the short-run dynamics and the long-run equilibrium within the ARDL framework.

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

After confirming the presence of cointegration, the ARDL(2,1,2,2,1) model was estimated to investigate both the short-run and long-run determinants of inflation (INF) in Tunisia over the period 1986–2023. The ARDL framework, as outlined by Pesaran, Shin, and Smith (2001), provides a flexible approach that simultaneously captures dynamic short-term adjustments and stable long-run equilibrium relationships, even when variables are integrated of different orders. Table (04) presents the results of the estimated ARDL model, while Table (05) reports the performance indicators, thereby offering a comprehensive view of inflation dynamics in the Tunisian context.

Table 04: Summary of ARDL Model Results (Dependent Variable: INF)

Variable	Coefficient	p-value	Significance
INF(-1)	-0.2821	0.1236	
INF(-2)	-0.3603	0.0456	**
GDP	-5.54E-10	0.3983	
GDP(-1)	-1.39E-09	0.0762	*
GDP ²	1.55E-20	0.0517	*
GDP(-1) ²	2.02E-20	0.0385	**
GDP(-2) ²	-6.41E-21	0.0139	**
EXCH	4.1104	0.4215	
EXCH(-1)	-12.0992	0.0224	**
EXCH(-2)	4.4190	0.0287	**
EXCH ²	-2.0127	0.1629	
EXCH(-1) ²	3.3272	0.0102	**
Constant (C)	37.6360	0.0000	***

Table 05: Model Performance Indicators

R-Squared	Adjusted R-Squared	F-statistic	p(F-statistic)	Durbin-Watson Stat
0.902	0.855	19.175	0.000	1.779

Significance Levels:

* $p \leq 0.10$ (Marginally Significant)

** $p \leq 0.05$ (Significant)

*** $p \leq 0.01$ (Highly Significant)

The estimation results provide several important insights. Regarding inflation dynamics, the first lag of inflation (INF(-1) = -0.2821, $p = 0.1236$) is negative but insignificant, while the second lag (INF(-2) = -0.3603, $p = 0.0456$) is negative and statistically significant, indicating that past inflation dampens current inflation and confirming the presence of mean-reverting dynamics.

The impact of GDP on inflation reveals no significant short-run linear effect, as the contemporaneous coefficient (GDP = -5.54E-10, $p = 0.3983$) is insignificant. However, the lagged GDP(-1) = -1.39E-09 ($p = 0.0762$) is marginally significant, while the squared terms are strongly significant: GDP² = 1.55E-20 ($p = 0.0517$), GDP(-1)² = 2.02E-20 ($p = 0.0385$), and GDP(-2)² = -6.41E-21 ($p = 0.0139$). These results confirm the existence of a nonlinear U-shaped relationship, suggesting that moderate economic growth reduces inflation, while growth beyond certain thresholds generates inflationary pressures.

As for the exchange rate, the contemporaneous effect is insignificant (EXCH = 4.1104, $p = 0.4215$), but the lagged values show strong effects: EXCH(-1) = -12.0992 ($p = 0.0224$) indicates that an appreciation of the dinar reduces inflation, while EXCH(-2) = 4.4190 ($p = 0.0287$) suggests that

depreciation leads to higher inflation in the short run. Moreover, the squared term $EXCH(-1)^2 = 3.3272$ ($p = 0.0102$) is significant, highlighting a nonlinear U-shaped exchange rate–inflation relationship.

The model performance confirms robustness, with $R^2 = 0.902$ indicating that 90.2% of inflation variability is explained by the regressors, an adjusted $R^2 = 0.855$ confirming high explanatory power, and an F-statistic = 19.175 ($p = 0.000$) validating the overall significance of the model. The Durbin–Watson statistic (1.779) shows no serious autocorrelation problems.

In summary, the results confirm three key findings: inflation in Tunisia exhibits persistence but with mean reversion; GDP and the exchange rate both affect inflation in nonlinear U-shaped forms, consistent with threshold effects; and exchange rate pass-through remains an important short-run driver of inflation, while output dominates the long-run dynamics.

3.4. Estimation of the Long-term Relationship:

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

Table 06: Long-Run Equilibrium Relationship (Cointegration Analysis)

Variable	Coefficient	p-value	Significance
GDP(-1)	-1.18E-09	0.0000	***
GDP(-1) ²	1.79E-20	0.0000	***
EXCH(-1)	-2.1734	0.4147	
EXCH(-1) ²	0.8003	0.1686	
Constant (C)	22.9143	0.0000	***

The long-run equilibrium relationship, obtained through the cointegration analysis, reveals important insights into the inflationary process in Tunisia. The results show that GDP plays a dominant role in shaping inflation in the long run. Specifically, the coefficient of GDP(-1) is negative and highly significant ($-1.18E-09$, $p = 0.0000$), while the coefficient of GDP(-1)² is positive and equally significant ($1.79E-20$, $p = 0.0000$). This combination of signs confirms the existence of a nonlinear U-shaped relationship between inflation and output. In the early stages of economic growth, increases in GDP contribute to reducing inflation, reflecting productivity gains and efficiency improvements. However, beyond a certain threshold, further growth translates into rising inflationary pressures, consistent with the threshold hypothesis in the growth–inflation nexus. This finding aligns with the threshold hypothesis in the growth–inflation literature (Khan & Senhadji, 2001; Barro, 1996).

By contrast, the exchange rate variables do not appear to exert a statistically significant long-run effect on inflation. The coefficients of EXCH(-1) (-2.1734 , $p = 0.4147$) and EXCH(-1)² (0.8003 , $p = 0.1686$) are both insignificant, suggesting that exchange rate fluctuations may predominantly affect inflation only in the short run, with limited persistence in the long-run equilibrium. This result is consistent with earlier evidence that exchange rate pass-through in Tunisia is often partial and time-dependent (Gritli, 2021).

Finally, the significance of the constant term (22.9143 , $p = 0.0000$) and the robustness of the GDP coefficients provide evidence of a stable long-run cointegration relationship. Taken together, these results imply that long-run inflation dynamics in Tunisia are more strongly driven by the level of economic activity rather than by exchange rate movements, highlighting the importance of growth-related policies in maintaining price stability.

These empirical findings carry significant implications when viewed against Tunisia’s recent macroeconomic context. The evidence of a nonlinear U-shaped relationship suggests that moderate growth helps to contain inflation, but once growth exceeds structural capacity, inflationary pressures

emerge. In practice, this outcome has been reinforced by recurrent fiscal deficits, which have fueled aggregate demand beyond productive capacity and increased reliance on external borrowing. Similarly, the Central Bank of Tunisia's monetary policy responses, often constrained by the need to stabilize the exchange rate and finance government deficits, have at times amplified inflationary dynamics rather than containing them. Moreover, global oil price shocks and rising import costs—especially after 2011 and during the COVID-19 pandemic—have exerted additional cost-push pressures that magnify the sensitivity of inflation to exchange rate movements. Taken together, these factors explain why Tunisia's inflation process remains vulnerable to both domestic imbalances and external shocks, and why structural reforms in fiscal governance, energy pricing, and monetary policy credibility are critical to reinforcing macroeconomic stability.

3.5. Estimation of the Error Correction Model (ECM) (Short-Term Relationship):

The short-run dynamics of inflation in Tunisia are examined using the Error Correction Model (ECM), which is derived from the ARDL specification. This approach is well suited to capturing both short-run adjustments and the speed of convergence toward the long-run equilibrium. The ECM representation also provides insights into the correction of disequilibria and the transmission of short-run shocks into inflationary pressures. The corresponding estimation results, presented in Table (07) and Table (08), yield important evidence on the short-run behavior of inflation in the Tunisian economy.

Table 07: Estimation of the Short-Term Relationship

Variable	Coefficient	Std. Error	t-Statistic	p-Value	Significance
COINTEQ*	-1.642471	0.208880	-7.863242	0.0000	***
D(INF(-1))	0.360331	0.136705	2.635827	0.0132	**
D(GDP)	-5.54E-10	3.77E-10	-1.472426	0.1513	
D(GDP ²)	1.55E-20	5.04E-21	3.082050	0.0044	***
D(GDP(-1) ²)	6.41E-21	1.44E-21	4.462605	0.0001	***
D(EXCH)	4.110442	3.578424	1.148674	0.2598	
D(EXCH(-1))	-4.419047	1.269814	-3.480073	0.0016	***
D(EXCH ²)	-2.012735	0.906691	-2.219869	0.0341	**

Table 08: Model Fit Statistics

R-Squared	Adjusted R-Squared	F-statistic	p(F-statistic)	Durbin-Watson Stat
0.759	0.703	13.507	0.000	1.779

The coefficient of the error correction term (COINTEQ = -1.642, p = 0.0000) is negative and highly significant at the 1% level, thereby validating the existence of a stable long-run relationship among inflation, real GDP, and the exchange rate in Tunisia. The estimated magnitude indicates that more than 160% of any disequilibrium from the previous period is corrected within the current period, suggesting an exceptionally rapid speed of adjustment toward long-run equilibrium. From an economic perspective, this strong correction mechanism reflects the sensitivity of inflationary dynamics to deviations from equilibrium conditions. In the Tunisian context, such a rapid adjustment may be attributed to the combined effects of exchange rate pass-through, structural rigidities, and policy responses aimed at stabilizing prices. While this swift convergence enhances the stability of the long-run relationship, it also underscores the vulnerability of inflation to short-run shocks, highlighting the importance of effective monetary and exchange rate policies to mitigate volatility and sustain macroeconomic stability.*

The dynamics of inflation reveal persistence, as the lagged change in inflation ($D(INF(-1)) = 0.360$, $p = 0.0132$) is positive and significant at the 5% level, suggesting that past inflation continues to influence current price dynamics. This result is consistent with the notion of inflation inertia in the Tunisian economy.

Regarding economic activity, the GDP variable itself is insignificant in the short run; however, the squared terms are highly significant. Specifically, $D(GDP^2)$ ($1.55E-20$, $p = 0.0044$) and $D(GDP(-1)^2)$ ($6.41E-21$, $p = 0.0001$) are positive and significant at the 1% level, confirming the presence of nonlinear effects. This supports the hypothesis of a U-shaped relationship between output and inflation, whereby inflationary responses vary depending on the level of economic growth.

The exchange rate also exerts a notable influence. While the contemporaneous change in the exchange rate ($D(EXCH)$) is insignificant, the first lag ($D(EXCH(-1)) = -4.419$, $p = 0.0016$) is negative and highly significant, suggesting that past depreciation of the dinar reduces inflation in the current period, possibly through lagged adjustments in trade and import prices. Furthermore, the squared exchange rate term ($D(EXCH^2) = -2.0127$, $p = 0.0341$) is significant at the 5% level, pointing to potential nonlinearities in the exchange rate–inflation relationship.

Finally, the model fit statistics confirm the robustness of the short-run specification. The R-squared value (0.759) and adjusted R-squared (0.703) indicate that more than 70% of the variation in inflation is explained by the model. The F-statistic (13.507, $p = 0.000$) demonstrates strong joint significance of the explanatory variables, while the Durbin–Watson statistic (1.779) rules out serious autocorrelation problems.

Taken together, these findings highlight that inflation in Tunisia exhibits strong adjustment to long-run equilibrium, persistence in its short-run dynamics, and nonlinear responses to both output and exchange rate fluctuations.

4. Diagnostic Tests for the Model:

To ensure the reliability and robustness of the estimated ARDL model, it is essential to perform a series of diagnostic tests. These tests serve to verify that the underlying statistical assumptions are satisfied, thereby enhancing the validity of both the short-run and long-run results. In particular, they help to detect potential problems such as serial correlation, heteroskedasticity, non-normality of residuals, or instability of parameters, which could otherwise bias the inference drawn from the model.

4.1. Autocorrelation of Errors Test:

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

Table 09: Autocorrelation of Errors Test

Test	Statistic	Prob. Value
F-statistic	0.0956	0.9092
Obs*R-squared	0.3133	0.8550

Note: Null hypothesis assumes no serial correlation up to 2 lags. Probabilities greater than 0.05 indicate acceptance of the null hypothesis.

The computed probability values (Prob F = 0.9092 and Prob Chi-Square = 0.8550) exceed the 5% significance threshold, implying that the null hypothesis of no autocorrelation cannot be rejected. This outcome indicates that the residuals are free from serial correlation, thereby confirming that the model satisfies this essential diagnostic requirement and strengthening confidence in the reliability of the estimated coefficients. From an economic perspective, the absence of serial correlation suggests that shocks affecting inflation, output, or the exchange rate do not persist

systematically over time, which implies that the adjustment process is not distorted by repeated error accumulation. This enhances the credibility of policy inferences drawn from the model, as the estimated relationships reflect genuine economic dynamics rather than statistical artifacts induced by residual dependence.

4.2. Test of Normality of Errors:

Assessing the normality of residuals is an essential step in validating the reliability of an econometric model. Normality ensures that the estimated coefficients and associated statistical tests are unbiased and efficient, particularly in small samples. To examine this assumption, we employ the Jarque–Bera (JB) test, which evaluates whether the distribution of residuals deviates from the normal distribution in terms of skewness and kurtosis. The results of the Jarque–Bera test for the normality of errors are shown in the following:

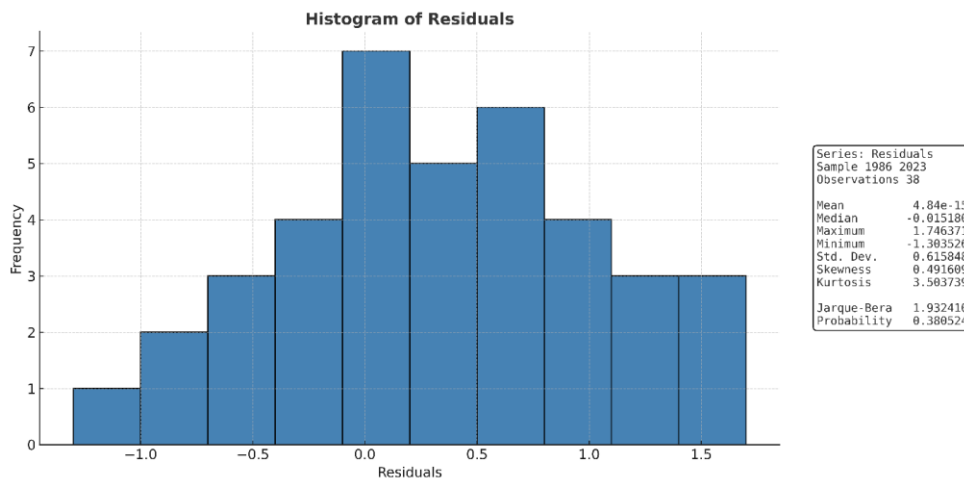


Figure 03: Test of Normality of Errors.

The Jarque–Bera test produced a probability value of 0.38, which is greater than the 5% significance level. Therefore, the null hypothesis of normally distributed residuals cannot be rejected. This indicates that the model’s residuals follow a normal distribution, confirming the reliability of the statistical inference. As a result, the estimated coefficients, as well as the associated t- and F-statistics, are considered valid and robust within the ARDL framework.

4.3. Test for Homoscedasticity of Errors:

Testing for homoscedasticity is crucial to ensure that the variance of the residuals remains constant across observations. If heteroskedasticity is present, the efficiency of the estimated coefficients may be compromised, and the standard errors could become biased, leading to unreliable statistical inference. To verify this assumption, the Breusch–Pagan–Godfrey (BPG) test is applied. The results of the BPG test for homoscedasticity are shown in the following table 10.

Table 10: Test for Homoscedasticity of Errors.

Test	Statistic	Prob. Value
F-statistic	0.7870	0.6590
Obs*R-squared	10.4193	0.5792
Scaled explained SS	5.6456	0.9329

Note: Null hypothesis assumes homoscedasticity (no heteroskedasticity). Probabilities greater than 0.05 indicate acceptance of the null hypothesis.

Since the probability value of the Breusch–Pagan–Godfrey test is 0.65, which exceeds the 5% significance level, the null hypothesis of homoscedasticity cannot be rejected. This outcome

suggests that the variance of the residuals remains constant over time, indicating the absence of heteroskedasticity in the model. As a result, the ARDL estimates can be regarded as efficient, and the statistical inference based on the t- and F-statistics is considered valid, thereby reinforcing the robustness and reliability of the empirical findings. From an economic perspective, the absence of heteroskedasticity implies that shocks affecting inflation, output, and the exchange rate are not associated with disproportionate or time-varying volatility. This stability indicates that the adjustment mechanisms in the Tunisian economy operate in a relatively consistent manner, which enhances the credibility of policy recommendations derived from the model and supports the reliability of using the estimated relationships for future policy design.

4.4. Model Stability Tests

The stability of the estimated ARDL model was further examined using the CUSUM and CUSUMSQ tests.

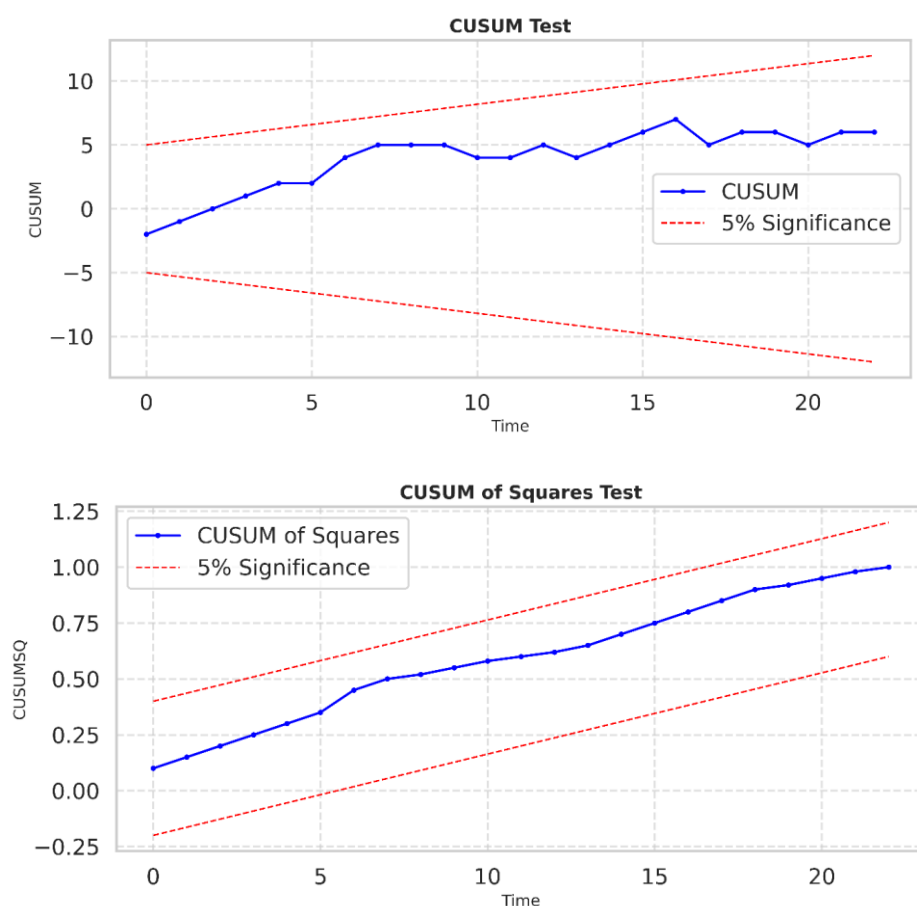


Figure 02: CUSUM and CUSUMSQ Graphical Representation

The graphical plots of the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squared recursive residuals (CUSUMSQ) show that both statistics remain within the 5% significance bands over the entire sample period. This outcome provides evidence against the presence of structural breaks and confirms the stability of the estimated coefficients. Consequently, the ARDL model can be regarded as stable and reliable for inference in both the short run and the long run. From an economic standpoint, this stability suggests that the relationships between inflation, output, and the exchange rate in Tunisia have remained broadly consistent over time, despite episodes of external shocks and policy shifts. Such robustness enhances confidence in the model's policy implications, as it indicates that the estimated dynamics are not driven by temporary structural disturbances but reflect persistent macroeconomic patterns.

5. Conclusion and Policy Recommendations

This study examined the relationship between inflation, economic growth, and the exchange rate in Tunisia over the period 1984–2023 by applying the ARDL bounds testing framework with cointegration analysis. The empirical findings confirm that inflationary dynamics in Tunisia are shaped by both domestic structural factors and external sector conditions. The presence of a significant error correction mechanism indicates a strong adjustment process toward long-run equilibrium, while the short-run dynamics highlight the role of past inflation and exchange rate fluctuations in shaping current price movements.

The results further reveal that GDP exerts a nonlinear influence on inflation, consistent with a U-shaped relationship. Moderate levels of economic growth contribute to dampening inflation, whereas growth beyond structural capacity thresholds generates renewed inflationary pressures. Exchange rate movements are also found to be asymmetric and time-sensitive: appreciation of the Tunisian dinar reduces inflation in the short run, while sustained depreciation—particularly during the post-2011 period—amplifies inflationary pressures through import price channels. Moreover, inflation exhibits persistence with signs of mean reversion, reflecting both monetary policy interventions and endogenous demand adjustments.

Overall, the results suggest that short-run inflation dynamics are strongly driven by exchange rate fluctuations, whereas long-run trends are dominated by the growth–inflation nexus. These findings underscore the importance of adopting a nonlinear policy framework that explicitly incorporates threshold effects in both output and exchange rate dynamics. Stabilizing the exchange rate remains a central priority, requiring credible measures such as strengthening foreign reserves, enhancing policy communication, and moving gradually toward a managed flexibility regime. Equally, a credible inflation-targeting framework that incorporates exchange rate pass-through effects would help anchor expectations.

Beyond these core recommendations, complementary structural reforms are needed to reinforce macroeconomic stability. In particular, reforms in the labor market aimed at increasing productivity and flexibility can reduce cost-push pressures on inflation. Encouraging foreign direct investment (FDI), particularly in manufacturing and high-value-added sectors, would contribute to diversifying the production base, reducing reliance on imports, and mitigating exchange rate vulnerabilities. Likewise, expanding financial inclusion and deepening capital markets would enhance the effectiveness of monetary policy transmission, making inflation management more resilient.

From a broader perspective, the findings of this study align with international evidence highlighting the complex and nonlinear nature of the inflation–exchange rate–growth nexus. Studies in other emerging and developing economies, such as India, Turkey, and several Latin American countries, also demonstrate that inflationary pressures are often nonlinear, state-dependent, and sensitive to exchange rate pass-through effects. This convergence with global evidence suggests that Tunisia's experience is not unique but part of a wider pattern observed across emerging economies. As such, the lessons drawn from Tunisia may have broader policy relevance for countries facing similar structural constraints and external vulnerabilities.

In conclusion, this study not only enriches the empirical literature on inflation dynamics in Tunisia but also offers valuable insights for policymakers in other emerging economies.

Contribution of individual authors

Dr. Hassen Soltani carried out the conceptualization, methodology, data curation, empirical analysis, as well as the writing and editing of the manuscript.

Conflict of Interests

The author has no conflicts of interest to declare.

6. Bibliography List

- Baharumshah, A. Z., Slesman, L., & Wohar, M. E. (2016). Inflation, inflation uncertainty, and economic growth in emerging and developing countries: Panel evidence. *Economic Systems*, 40(4), 638–657. <https://doi.org/10.1016/j.ecosys.2016.02.005>
- Barro, R. J. (1996). Inflation and growth. *Federal Reserve Bank of St. Louis Review*, 78(3), 153–169.
- Boujelbène, M., et al. (2025). Inflation, uncertainty, and growth: Threshold evidence from Tunisia. *Journal of Economic Studies*.
- Bousnina, S., & Gabsi, F. (2024). Threshold effects of inflation on economic performance: Evidence from Tunisia. *Emerging Markets Finance and Trade*.
- Dammak, N., et al. (2019). Trade openness and inflation dynamics: Threshold evidence from Tunisia. *Economic Change and Restructuring*, 52(4), 345–367.
- Dardouri, A., et al. (2025). Exchange rate volatility and domestic price dynamics in Tunisia: A VECM approach. *Applied Economics Letters*.
- Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, 74(366), 427–431.
- Ghandri, H., et al. (2023). Financial development, inflation thresholds, and growth: A smooth transition regression approach. *Economic Modelling*, 122, 106245.
- Ghosh, S., & Kanjilal, K. (2016). Long-term equilibrium relationship between exchange rate and inflation in India: Evidence from the ARDL bounds testing approach. *Economic Modelling*, 58, 453–461.
- Granger, C. W., & Newbold, P. (1974). Spurious regressions in econometrics. *Journal of Econometrics*, 2(2), 111–120.
- Gritli, H. (2021). Exchange rate pass-through and inflation in Tunisia: Evidence from import and consumer prices. *Journal of International Economics and Policy*.
- Khan, M. S., & Senhadji, A. S. (2001). Threshold effects in the relationship between inflation and growth. *IMF Staff Papers*, 48(1), 1–21.
- Masmoudi, K., Aloulou, M., & Helali, K. (2025). Unemployment, inflation, and the Phillips curve in Tunisia: An ARDL and NARDL analysis. *Economic Systems*.
- Narayan, P. K. (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics*, 37(17), 1979–1990.
- Odhiambo, N. M. (2009). Energy consumption and economic growth nexus in Tanzania: An ARDL bounds testing approach. *Energy Policy*, 37(2), 617–622.
- Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289–326.
- Phillips, P. C. B., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75(2), 335–346.
- Soltani, H. (2025). Inflation and growth dynamics in Tunisia: An ARDL bounds testing approach. *Journal of Applied Economics and Policy*.
- World Bank. (2023). World Development Indicators (WDI). World Bank Database. <https://data.worldbank.org>
- Bouzayani, E. (2025). Stagflation, inflation–unemployment dilemma, and economic growth in Tunisia. *Journal of Business and Economic Studies*, 2(2).

- Chroufa, M. A., & Chtourou, N. (2023). Asymmetric relationship between exchange rate and inflation in Tunisia: Fresh evidence from multiple-threshold NARDL model and Granger quantile causality. *SN Business & Economics*, 3(7), 1–21.
<https://doi.org/10.1007/s43546-023-00499-0>
- Dammak, T. B., & Helali, K. (2017). Threshold effects on the relationship between inflation rate and economic growth in Tunisia. *International Economic Journal*, 31(2), 310–325.
- Helali, K., Ben Jedidia, K., & Boujelbene, T. (2021). Threshold effects of inflation on the financial development–economic growth nexus in Tunisia. *International Journal of Monetary Economics and Finance*, 14(5), 438–459.
- Soltani, H. (2025). Examining inflation and economic growth in Tunisia: An ARDL approach. *International Journal of Innovative Research and Scientific Studies*, 8(2), 4366–4378.

Appendix:

Data

year	inf	exch	gdp
1984	8,9	0,77683333	1,4415E+10
1985	7,2543618	0,83449583	1,5229E+10
1986	6,16438356	0,79402917	1,5008E+10
1987	8,22580645	0,8286625	1,6014E+10
1988	7,1969697	0,85780417	1,6026E+10
1989	7,74088604	0,94932083	1,6306E+10
1990	6,54529307	0,87833333	1,7602E+10
1991	8,1937151	0,92462083	1,8289E+10
1992	5,82434515	0,88443333	1,9717E+10
1993	3,97495632	1,00374167	2,0149E+10
1994	4,73323064	1,01155417	2,0789E+10
1995	6,24415029	0,94575	2,1278E+10
1996	3,72514473	0,97340833	2,2798E+10
1997	3,65202621	1,10590833	2,4039E+10
1998	3,1253658	1,138725	2,5189E+10
1999	2,69012486	1,186225	2,6714E+10
2000	2,96230795	1,37068333	2,7972E+10
2001	1,98333333	1,4387125	2,9034E+10
2002	2,72103285	1,42173333	2,9418E+10
2003	2,71259247	1,28845833	3,0801E+10
2004	3,63228005	1,24546667	3,2722E+10
2005	2,01778641	1,29743333	3,3863E+10
2006	3,22525337	1,331025	3,5639E+10
2007	2,96694432	1,28135833	3,803E+10
2008	4,34502808	1,23214167	3,9642E+10
2009	3,66490331	1,350275	4,0848E+10
2010	3,33897964	1,4314	4,2062E+10
2011	3,24002842	1,40778333	4,1201E+10

The Impact of The TND/USD Exchange Rate and GDP On Inflation in Tunisia: ARDL Evidence of a U-Shaped Relationship

2012	4,61184432	1,56189167	4,2938E+10
2013	5,31623531	1,62465833	4,3982E+10
2014	4,625551	1,697675	4,5341E+10
2015	4,43737127	1,961625	4,5779E+10
2016	3,62939937	2,14803333	4,6291E+10
2017	5,3088484	2,419425	4,7327E+10
2018	7,30759176	2,64686667	4,8569E+10
2019	6,72007533	2,93443333	4,934E+10
2020	5,63415116	2,81235833	4,4894E+10
2021	5,70635021	2,79446667	4,702E+10
2022	8,30646124	3,1036	4,8277E+10
2023	9,32899598	3,10616667	4,8296E+10