

ANALYSIS OF THE DETERMINANTS OF INFLATION IN ALGERIA: ARDL COINTEGRATION APPROACH

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RESUME :

Cet article s'ajoute aux diverses études qui ont tenté d'aborder le phénomène de l'inflation, en se focalisant sur le cas de l'Algérie durant la période allant de 1970 à 2022. Pour réaliser cette étude, un modèle de cointégration ARDL (Autoregressive Distributed Lag) a été utilisé. La hausse générale des prix mesurée par l'indice des prix à la consommation (CPI) est approchée par les principales variables macroéconomiques telles que le produit intérieur brut (PIB), la masse monétaire (M3), le prix du pétrole (PO), le taux de change officiel (EXR) et le taux de chômage (ENR). Le résultat obtenu par la présente étude montre que la masse monétaire et les prix du pétrole ont exercé un impact significatif sur l'inflation en Algérie. Une relation significative à court terme a été trouvée entre l'indice des prix à la consommation et la masse monétaire, le taux de change officiel, le prix du pétrole et le taux de chômage. De même, à long terme, l'inflation en Algérie peut être approchée par la masse monétaire, le taux de change officiel et les prix du pétrole. En effet, une augmentation de ces variables par rapport à la production réelle pourrait conduire à une situation inflationniste. Cependant, la croissance économique algérienne a eu un effet inverse sur l'inflation. Ces résultats s'alignent avec la plupart des résultats trouvés.

Mots clés : Inflation, Modélisation ARDL, Cointégration, Masse monétaire, Taux de change.

ABSTRACT:

This paper is one of several studies that have attempted to address the inflation phenomenon, with a focused investigation on Algeria's economic landscape spanning from 1970 to 2022. In order to make this study, an Autoregressive Distributed Lag (ARDL) cointegration model is used. Rise prices

measured by the Consumer Price Index (CPI) is approached by main of macroeconomic variables such as Gross Domestic Product (GDP) ; Money supply (M3); Price of oil (PO); Official Exchange Rate (EXR) and Unemployment rate (ENR). The result given is that money supply and oil prices exerted an impact on inflation in Algeria. A significant short-run relationship has been finding between consumer price index and money supply, official exchange rate, oil price, and unemployment rate. Also, for the long term, inflation in Algeria can be approached by money supply, official exchange rate, and oil prices. Indeed, an increase in these variables relative to real output could lead to an inflationary situation. However, the Algerian economic growth had an inverse effect on inflation. These results align with the most of results found.

Key words: Inflation, ARDL modeling, Cointegration, Money supply, Exchange rate.

I INTRODUCTION

Across the globe, central banks prioritize price stability to underpin economic growth and employment. Inflation, a pivotal macroeconomic metric, offers crucial insights into a nation's economic vitality, commanding both domestic and international attention. The onset of the COVID-19 pandemic in 2020 ushered in an unprecedented global health crisis, sparking a notable surge in inflationary pressures across diverse economic landscapes. Disruptions in supply chains triggered market turbulence, affecting goods, services, and labor markets, thereby exacerbating an already heightened inflationary trajectory, a trend that has persisted amidst the pandemic's aftermath.

The determinants of inflation vary considerably across different countries. While inflation escalated at both national and international levels during the pandemic, its impact was particularly pronounced in developing nations, with some experiencing inflation rates soaring into double digits. The pursuit of inflation control, an integral tenet of Kaldor's "magic square" alongside growth, full employment, and external balance, remains a universal objective among states prioritizing price stability in their economic policy frameworks. Scholars have endeavored to unravel the multifaceted factors driving inflation, attributing long-run inflation to factors such as excessive money creation, while short-run fluctuations are often linked to shifts in global supply and demand, raw material price volatility, technological advancements, exchange rate fluctuations, and climate-related shocks. Moreover, developing nations grapple with unique social, socio-political, and institutional factors that shape their inflation dynamics.

Despite the extensive scholarly attention on inflation, research efforts have predominantly focused on non-developed countries, leaving a noticeable gap in studies pertaining to developing and oil-exporting nations like Algeria, where inflation dynamics pose distinct challenges. Consequently, this study seeks to illuminate the enduring determinants of inflation in Algeria spanning from 1970 to 2022. It is structured into distinct sections:

We start by reviewing the empirical literature. We then examine the model specifications, estimating techniques, and data sources. Third, we analyze the results of various tests,

including cointegration tests, the Augmented Dickey Fuller unit root test, and the ARDL limits testing approach by Peseran et al. We examine the dynamics in both the short and long terms, assessing the long-term model's stability. Lastly, we provide a summary of our findings in our concluding remarks.

II LITERATURE REVIEW

The phenomenon of inflation, a subject of interdisciplinary interest, has sparked diverse interpretations across scholarly domains.[14] posits that inflation arises as a monetary response to socio-economic strains, resulting in a general surge in prices and currency devaluation. Conversely, [13] views inflation as stemming from the proliferation of payment methods, capable of igniting widespread price hikes and currency devaluation. [15] characterize inflation as a sustained rise in price levels, anticipated to endure over time. Meanwhile, [26] argues that inflation can also originate from structural shifts, such as alterations in labor market dynamics or advancements in production technologies. Furthermore, [10] posits that inflation can emerge from expectations of future price increases, influencing present consumption and investment choices.

Monetarist View on Inflation

The Monetarist school, led by scholars like Milton Friedman, asserts that inflation primarily results from excessive growth in the money supply relative to real output. According to this perspective, controlling the rate of money supply expansion is crucial for managing inflationary pressures and maintaining price stability.

The following exchange equation summarizes the Quantity Theory of Money:

Emphasizes the direct relationship between the amount of money in circulation (V), price level (P), money supply (M), and the total number of transactions (Y). Empirical studies, such as Friedman's seminal work [16], offer empirical evidence supporting the positive correlation between money supply growth and inflation rates, thereby confirming the core principles of Monetarist theory.

Keynesian Perspective on Inflation

In contrast to Monetarist principles, Keynesian economics advocates for active government intervention, particularly through monetary policy, to address economic fluctuations and stimulate aggregate demand. From a Keynesian perspective, inflation can result from excess demand, necessitating expansionary monetary policies to boost output and employment. However, Keynesians recognize the Phillips curve's depiction of the trade-off between unemployment and inflation. The early 1980s stagflationary period exposed the shortcomings of demand-side interventions in resolving supply-side constraints, casting doubt on the effectiveness of conventional Keynesian programs.

New Classical Economics and Rational Expectations

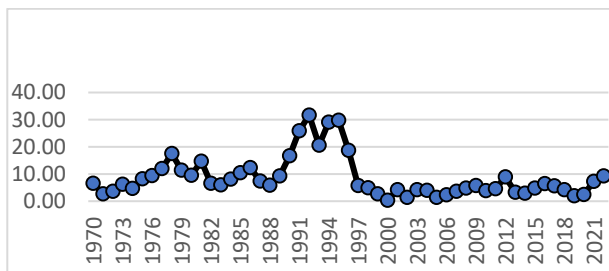
The New Classical school challenges conventional wisdom regarding the effectiveness of monetary policy in influencing real economic outcomes. According to New Classical economists, rational expectations and market efficiency render monetary interventions ineffective in altering long-run economic trajectories. Inflation, in this framework, is attributed to discrepancies between money supply growth and wealth accumulation, with expectations formation playing a pivotal role in shaping inflationary dynamics. Friedman's adaptive expectations hypothesis and the consideration of fiscal policy underscore the importance of forward-looking behavior in understanding inflationary processes.

Algeria's Inflationary Journey

Algeria's inflationary journey traces back to the early 1980s, coinciding with the shift from a planned to a market economy. This transition, initiated in 1991, marked a significant turning point, ushering in a period of heightened inflationary pressures. Inflation, commonly gauged through the Consumer Price Index (CPI), reflects the rate of price growth over the years.

$$MV = PY$$

Fig.1 Customer price index evolution in Algeria



The evolution of the Consumer Price Index (CPI) in Algeria from 1970 to 2022 unveils a turbulent inflationary landscape. Initially stable from 1970 to 1988, inflation surged dramatically from 1988 to 1996, peaking at record highs. Chronic shortages and price liberalization in 1989, triggering a sharp devaluation of the Algerian dinar, contributed to this surge. Subsequent measures, including structural adjustments and foreign trade liberalization, helped stabilize inflation rates post-1996. Efforts to control liquidity and manage inflationary pressures kept rates relatively low and manageable until 2006.

However, since 2006, Algeria has faced challenges, with inflationary pressures ticking upwards, hitting a peak of 8.9% in 2012. Rising import prices, income increases, and supply constraints fueled this uptick. Liquidity injections by the Bank of Algeria initially mitigated inflation but were insufficient to prevent a resurgence from 2016 onwards, exacerbated by declining hydrocarbon revenues and increased import costs.

The onset of the COVID-19 pandemic further exacerbated inflationary pressures globally and locally. Soaring commodity prices and geopolitical tensions, notably the Russo-Ukrainian crisis, compounded Algeria's inflationary woes. Massive liquidity injections, notably through a special refinancing program in June 2021, further fueled inflation, culminating in a second peak in 2022, with an inflation rate of 9.27%.

In essence, Algeria's inflationary trajectory reflects a complex interplay of domestic and global factors, highlighting the challenges of maintaining price stability amidst evolving economic landscapes and external shocks.

Empirical Investigations

Numerous empirical investigations have aimed to elucidate the monetary phenomenon of price rises by analyzing how macroeconomic or monetary factors influence the consumer price index. The key outcomes of these studies are synthesized as follow:

- [24] Focuses on different economic indicators to explain short-term inflation. The study identifies the exchange rate, expected inflation rate, and imported inflation rate as key factors. It highlights the importance of both domestic economic expectations and external price pressures in influencing short-term inflation trends.
- [2] explores the long-run determinants of inflation, emphasizing the exchange rate, GDP, and hydrocarbon exports. The study concludes that the exchange rate and hydrocarbon export revenues positively affect long-run inflation, while GDP has a negative impact. This suggests that while external revenues from exports can drive inflation, economic growth can mitigate it.
- [4] analyze the long-run and short-run factors influencing inflation. They find that long-run inflation is positively influenced by factors such as the budget deficit, exchange rate, imports, money supply, and agricultural production. In contrast, short-run inflation is primarily affected by the lending rate. This highlights the diverse range of factors that can impact inflation over different time horizons.
- [17] Distinguishes between low-inflation and high-inflation countries in analyzing inflation determinants. In low-inflation countries, long-term inflation is influenced by GDP growth and imports. In high-inflation countries, it is driven by money supply, public expenditures, and GDP growth. Short-term inflation in low-inflation countries is affected by money supply, imports, and GDP growth, indicating different inflationary dynamics based on the country's inflationary context.
- [7] focus on the impact of money supply and liquidity ratio on inflation. Their findings indicate that these two factors have the greatest impact on inflation, underscoring the critical role of monetary factors in the inflationary process.
- [3] examine inflation across multiple countries, finding diverse determinants. In Algeria and Nigeria, inflation is explained by exchange rate fluctuations. In Iran, it is determined by the interest rate. In Saudi Arabia, inflation is driven by rising oil prices and public expenditures, while in Venezuela, all studied variables contribute to inflation. This study

highlights the varied and complex nature of inflation determinants across different national contexts.

- [1] investigates the impact of money supply, interest rates, credits to the economy, oil prices, and output gap on inflation. The study finds that money supply, credits to the economy, and oil prices have a significant positive impact on inflation, while the output gap and interest rates negatively impact price increases. This suggests a multifaceted approach to understanding inflation, involving both positive and negative influences from various economic factors.
- [20] analyzes the long-run determinants of inflation in Algeria, focusing on import prices, public expenditures, GDP level, and oil prices. The findings indicate that import prices, public expenditures, and GDP level determine long-run inflation, while the price of oil has a negative relationship with inflation. In the short run, the studied variables did not show significant signs, suggesting different dynamics at play over different time frames.
- [5] Examines the long-term and short-term effects on inflation in Algeria. The research shows that GDP, money supply, and oil prices significantly boost long-term inflation. Conversely, the import price index and exchange rates markedly decrease short-term prices, reflecting different impacts depending on the time frame.
- [6] focus on the long-run determinants of inflation in Algeria. They find that money supply, import value index, and real effective exchange rate (REER) impact price levels, while oil prices negatively affect price levels. This highlights the importance of monetary factors and external economic conditions in shaping long-run inflation.
- [18] Investigates the long-term factors affecting inflation in Algeria, identifying key elements such as money supply, import unit value index, and nominal effective exchange rate. The study highlights the crucial role these variables play in explaining long-term inflationary patterns.
- [8] Analyzes the connection between money supply and inflation in Algeria. The results suggest that an increase in the money supply results in higher inflation, supporting the monetarist view of inflation. Additionally, the research highlights the significant impact of external factors, particularly fluctuations in oil prices, on inflation in Algeria. This suggests that both monetary factors and external economic conditions are crucial in understanding and managing inflation in the country.
- [10] analyses the effects of inflation expectations on consumption and investment using econometric models. The results show that anticipated future price increases significantly influence current economic behaviours. Households tend to increase current consumption to avoid higher future costs, while businesses often accelerate investments to benefit from lower current costs. Additionally, the study finds that inflation expectations can lead to precautionary behaviours, with some economic agents reducing consumption and investment due to increased uncertainty.
- [26] employs advanced econometric models, including linear regression and time series models, to analyze the impact of inflation on labor market dynamics and production

technologies. The results indicate that high inflation is associated with higher unemployment rates and lower real wages. Additionally, the analysis shows that inflation influences companies' technological choices. During periods of high inflation, businesses are more likely to invest in automated production technologies to reduce labor costs. These inflationary pressures accelerate structural changes in the economy, such as the adoption of more advanced production technologies.

- [14] asserts that inflation is a monetary reaction to economic pressures on society, leading to a general increase in prices and depreciation of currency. On the other hand.
- [13] believes that the development of payment options, which has the potential to cause widespread price increases and currency devaluation, is the cause of inflation.
- [15] Define inflation as a persistent increase in prices that are expected to persist over an extended period of time. In the interim.

These empirical studies contribute significantly to our understanding of the complex and multifaceted nature of inflation. They underscore the importance of both external factors, such as trading partners' inflation and exchange rates, and internal factors, including money supply, public expenditures, and GDP growth. By highlighting the varied influences on inflation across different countries and contexts, these studies provide valuable insights for policymakers aiming to manage and mitigate inflationary pressures effectively.

III DATA SOURCES AND MODEL SPECIFICATION

Data:

This study embarks on a comprehensive analysis of inflation dynamics in Algeria, focusing on the period from 1970 to 2022 and relying on the Consumer Price Index (CPI) as the principal gauge. This temporal scope encompasses transformative economic shifts within Algeria, transitioning from a centrally planned economy to a market-oriented framework, against the backdrop of various contextual factors, including the reverberations of the COVID-19 pandemic.

For our analytical endeavor, we meticulously gathered data from esteemed sources such as the World Bank (WB) and the National Office of Statistics (ONS), ensuring the reliability and coherence of our dataset. The selection of explanatory variables was meticulously guided by their pertinence and significance in capturing the multifaceted nature of inflation dynamics in Algeria. A comprehensive outline of these variables is provided in the subsequent table.

Table 1: Presentation of the variables (series)

Variables	Identifications
CPI_t	Consumer Price Index in %
$M3_t$	Money supply as % of GDP
PO_t	Price of oil expressed in USD
GDP_t	Gross Domestic Product expressed in USD (current)
EXR_t	Official exchange rate USD/DZD
ENR_t	Unemployment rate in %

Fig.2 graphic series



The model:

Developing the empirical model requires integrating knowledge from economic theory, previously published works, and empirical data unique to the Algerian economy. The explanatory factors selected with care aim to capture the complex characteristics of the Algerian economic environment and their possible impact on the dynamics of inflation.

The "AutoRegressive Distributed Lag" (ARDL) models, which are also referred to as distributed lag autoregressive models, are analytical tools that incorporate the temporal dimension when explaining a variable, often a time series. This approach enhances forecasting accuracy and policy effectiveness by considering factors such as adjustment lags and anticipations. Compared to simple models that do not account for this temporal

dynamics, ARDL models provide a more comprehensive view of the variation in the dependent variable, as they capture effects that unfold over time rather than being limited to instantaneous effects. Within the family of dynamic models, three distinct categories can be identified.

If we consider the dependent variable Y_t and the independent variable X_t we can observe:

$$Y_t = a_0 + a_1 Y_{t-1} + a_2 Y_{t-2} + \dots + a_p Y_{t-p} + \varepsilon_t \quad (3a) \quad Y_t \rightarrow AR(p)$$

Where $a_i \in \mathbb{R} \ i = 0, \dots, p, p \in \mathbb{N}^*, \varepsilon_t \rightarrow WN(0, \sigma_\varepsilon^2)$ and $a_p \neq 0$.

The concept of "autoregressive" refers to the regression of a variable based on its previous values. Distributed lag (DL) models are dynamic frameworks in which the explanatory variables comprise both the variable of interest and its lagged or shifted counterparts. Typically, these models are structured as follows:

$$Y_t = b + b_0 X_t + b_1 X_{t-1} + b_2 X_{t-2} + \dots + b_q X_{t-q} + u_t \quad (3b)$$

Where $b_j \in \mathbb{R} \ j = 0, \dots, q, q \in \mathbb{N}^*, u_t \rightarrow WN(0, \sigma_\varepsilon^2)$ and $b_q \neq 0$.

The term "distributed lags" signifies that the short-term effects of X_t on Y_t differ from long-term effects. In other words, Y_t 's reactions to changes in X_t vary over time.

AutoRegressive Distributed Lag (ARDL) models integrate characteristics of both preceding models. They incorporate lagged values of the dependent variable and historical values of the independent variable within the explanatory variables. Typically, they follow this general structure:

$$Y_t = c + \sum_{i=1}^p a_i Y_{t-i} + \sum_{j=0}^q b_j X_{t-j} + v_t \quad (3c)$$

$v_t \rightarrow WN(0, \sigma_\varepsilon^2)$ and $Y_t \rightarrow ARDL(p, q)$

Where $X_t, Y_t \rightarrow I(0)$ or $X_t, Y_t \rightarrow I(1)$

or $X_t \rightarrow I(1), Y_t \rightarrow I(0)$ or $X_t \rightarrow I(0), Y_t \rightarrow I(1)$

These models facilitate the incorporation of both the delayed impacts of the dependent variable and the short and long-term influences of the independent variable. Consistent with any dynamic model framework, information criteria such as the Akaike Information Criterion (AIC), the Schwarz Information Criterion (SIC) — also referred to as the Bayesian Information Criterion (BIC) — and the Hannan-Quinn Information Criterion (HQIC) are employed to determine the optimal number of lags (p^* or q^*). The model that provides the minimum value for one of these criteria is considered to have the optimal lag structure. The specific calculations for these criteria are as follows:

$$AIC(k) = 2k - 2\ln(L)$$

$$SIC(k) = k \ln(T) - 2 \ln(L)$$

$$HQIC(k) = 2k \ln(\ln(T)) - 2 \ln(L)$$

The cointegration test using distributed lags, as proposed by Pesaran et al. (2001) [23], utilizes an ARDL cointegration framework within an Error Correction Model (ECM). This approach examines the dynamics between two series Y_t and X_t .

From (3c) :

$$\Delta Y_t = \alpha_1 Y_{t-1} + \alpha_2 X_{t-1} + \sum_{i=1}^p a_i \Delta Y_{t-i} + \sum_{j=0}^{q-1} b_j \Delta X_{t-j} + e_t \quad (3d)$$

The specification (3d) demonstrates the ARDL model as an Error Correction Model (ECM), indicating cointegration relationships between the series. This can be alternatively expressed as follows:

$$\Delta Y_t = \gamma u_{t-1} + \sum_{i=1}^p a_i \Delta Y_{t-i} + \sum_{j=0}^{q-1} b_j \Delta X_{t-j} + e_t \quad (3e)$$

Where " γ " represents the error correction term, adjustment coefficient, or speed of adjustment. Following estimation based on relation (3e), we can conclude the existence of a cointegration relationship between the variables if and only if $0 < |\hat{\gamma}| < 1$, and if the null hypothesis " $\gamma = 0$ " is rejected (where $\hat{\gamma}$ is negative and statistically significant) [23].

Pesaran et al.'s cointegration test [23] proceeds in two stages, first determining the optimal lag using information criteria such as AIC and SIC. Then, the Fisher test is employed to evaluate the following hypotheses:

Null Hypothesis $H_0 : \alpha_1 = \alpha_2 = 0$, suggesting no cointegration relationship.

Alternative Hypothesis $H_1 : \alpha_1 \neq \alpha_2 \neq 0$, suggesting the existence of a cointegration relationship.

(specification 3d).

Hence, the potential conclusions are as follows:

- If the calculated Fisher value exceeds the upper bound, it indicates the presence of cointegration.
- If the calculated Fisher value falls below the lower bound, it indicates the absence of cointegration.
- If the calculated Fisher value lies between the lower and upper bounds, no definitive conclusion can be made regarding cointegration.

We will focus solely on analyzing the Autoregressive Distributed Lag (ARDL) model to explore both the short-term and long-term dynamics, as well as the equilibrium relationship between inflation and the selected explanatory variables. This model offers a comprehensive framework for examining the dynamics of long-term equilibrium and short-term variations in the relationship between inflation and the explanatory factors.

In line with these considerations, the formulated model is expressed as follows:

$$LCPI_t = c + \sum_{i=0}^p a_i LCPI_{t-i} + \sum_{j=0}^q b_j LM3_{t-j} + \sum_{k=0}^r d_k LGDP_{t-k} + \sum_{l=0}^s f_l LPO_{t-l} + \sum_{m=0}^u g_m LEXR_{t-m} + \sum_{n=0}^v h_n LENR_{t-n} + \varepsilon_t$$

With

$$c, a_i, b_j, d_k, f_l, g_m, h_n \in \mathbb{R}, \quad i, j, k, l, m, n \in \mathbb{N}, \quad \text{and} \quad \varepsilon_t \text{ a white noise.}$$

Descriptive Statistics:

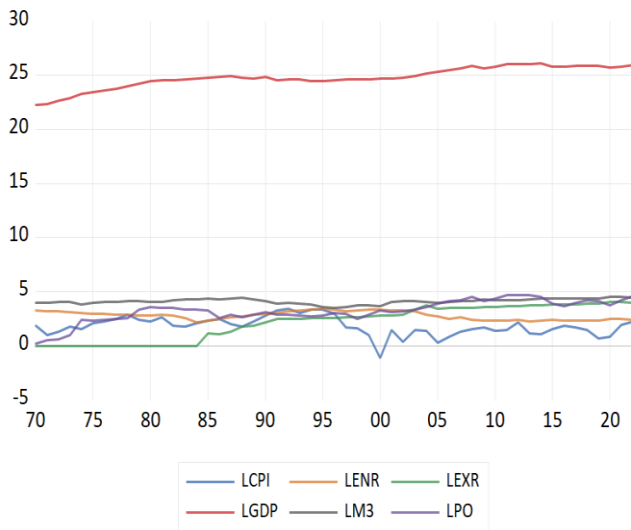
Prior to initiating the modeling process, a descriptive analysis of the variables was performed to achieve a thorough understanding of their volatility. The results of this analysis are presented in the following table:

Fig.3: Descriptive Statistics of Used series

	LCPI	LENR	LEXR	LGDP	LM3	LPO
Mean	1.825681	2.803514	2.182035	24.80278	4.121218	3.229463
Median	1.786272	2.834389	2.556944	24.74207	4.138748	3.317816
Maximum	3.455359	3.460723	4.046923	26.08835	4.564470	4.695488
Minimum	-1.081274	2.164472	-1.00E-09	22.30503	3.496684	0.190620
Std. Dev.	0.853381	0.388248	1.556329	0.966532	0.245115	1.028515
Skewness	-0.478801	0.035443	-0.413770	-0.775513	-0.601943	-1.002604
Kurtosis	4.307825	1.582489	1.567055	3.283212	2.932180	4.286714
Jarque-Bera	5.802192	4.448381	6.046753	5.489679	3.210788	12.53559
Probability	0.054963	0.108155	0.048637	0.064259	0.200810	0.001896
Sum	96.76110	148.5863	115.6479	1314.547	218.4246	171.1615
Sum Sq. Dev.	37.86950	7.838317	125.9523	48.57753	3.124232	55.00781
Observations	53	53	53	53	53	53

The tabulated data shows that the official exchange rate and oil prices had bigger standard deviations than other variables, indicating higher volatility over the research period. Moreover, the Jarque-Bera test (Probability > 5%) indicates that all variables have a normal distribution, with the exception of the official exchange rate and oil prices.

Fig.4 : Evolution of Studied Variables from 1970 to 2022



The graphical representation above suggests an overall stability of the variables under study throughout the period examined, implying a presumption of stationarity on average. Furthermore, no notable volatility phenomenon is observed across all variables.

IV RESULTS AND DISCUSSIONS

ARDL Modeling: Impact of Variables on the Consumer Price Index (CPI):

- **Stationarity Study of Series:**

We employed the Dickey-Fuller (ADF) test strategy on the series under consideration. The results are outlined below:

ADF Test Results for Logarithmic Series: At the 5% significance level**Table 2: ADF Test Results**

Series	Level			1st Difference			Conclusion
	Optimal ADF model	Unit root first test (prob)	Unit root second test (prob)	Optimal ADF model	Unit root first test (prob)	Unit root second test (prob)	
$lCPI_t$	5	-3.14 (0.02)	2.87 (0.0059)	/	/	/	I(0)
$lM3_t$	4	0.45 (0.80)	/	4	-6.29 (0.00)	/	I(1)
lPO_t	5	-3.12 (0.11)	5.70 (0.005)	4	-6.56 (0.00)	/	I(1)
$lGDP_t$	4	-3.41 (0.01)	3.56 (0.008)	/	/	/	I(0)
$lEXR_t$	4	1.71 (0.97)	/	4	-6.32 (0.00)	/	I(1)
$lENR_t$	4	-0.82 (0.35)	/	4	-4.99 (0.00)	/	I(1)

We note that the logarithmic series of money supply, oil price, official exchange rate, and unemployment rate exhibit integration of order 1, becoming stationary after the first difference. In contrast, the GDP and consumer price index series remain stationary at their original level, without requiring differentiation. As a result, the series display integration at different orders, rendering traditional cointegration tests such as the Engle-Granger and Johansen methods inappropriate in the multivariate context. Therefore, it is imperative to adopt the bounds testing approach to cointegration, as advocated by Pesaran in 2001 [23].

- **The optimal ARDL model:**

We applied the Akaike Information Criterion (AIC) to pinpoint the optimal ARDL model, favoring those with statistically significant outcomes and the fewest parameters. The estimation results of the chosen optimal ARDL model are detailed below:

Analysis of the Determinants of Inflation in Algeria : ARDL Cointegration Approach

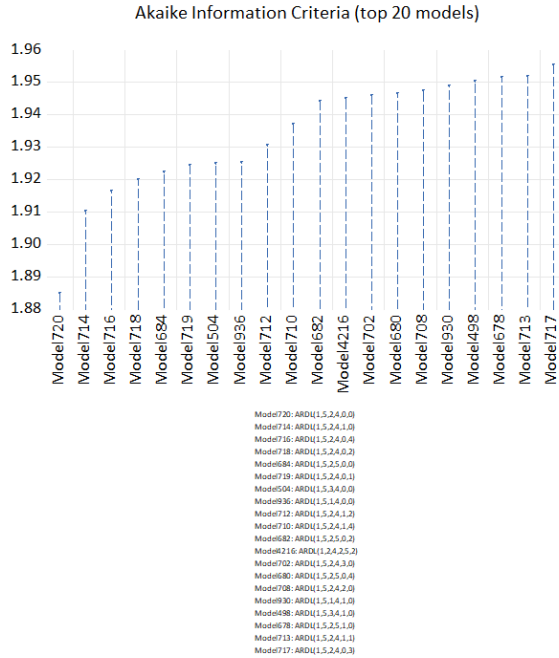
Dependent Variable: LCPI
Method: ARDL
Date: 04/27/24 Time: 20:07
Sample: 1975 2022
Included observations: 48
Dependent lags: 1 (Automatic)
Automatic-lag linear regressors: LM3 LGDP LPO LEXR
LENR
Deterministics: Restricted constant and no trend (Case 2)
Model selection method: Akaike info criterion (AIC)
Number of models evaluated: 7776
Selected model: ARDL(1,5,2,4,0,0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LCPI(-1)	0.237879	0.188839	1.259689	0.2175
LM3	0.442831	1.188205	0.372689	0.7120
LM3(-1)	-1.533681	1.329645	-1.153451	0.2578
LM3(-2)	2.819802	1.321771	2.133351	0.0412
LM3(-3)	-0.282005	1.368512	-0.206067	0.8381
LM3(-4)	0.795401	1.269809	0.626394	0.5358
LM3(-5)	1.590254	0.841392	1.890027	0.0685
LGDP	-0.306293	1.210587	-0.253012	0.8020
LGDP(-1)	-1.524107	1.310125	-1.163329	0.2539
LGDP(-2)	-1.710293	1.066229	-1.604058	0.1192
LPO	-0.083975	0.465219	-0.180507	0.8580
LPO(-1)	0.362429	0.534241	0.678400	0.5027
LPO(-2)	1.343922	0.494919	2.715439	0.0109
LPO(-3)	-0.302843	0.461781	-0.655817	0.5169
LPO(-4)	0.965745	0.387971	2.489223	0.0186
LEXR	0.460886	0.229252	2.010390	0.0535
LENR	0.910160	0.612838	1.485155	0.1479
C	62.84077	25.68300	2.446785	0.0205
R-squared	0.761912	Mean dependent var		1.859255
Adjusted R-squared	0.626996	S.D. dependent var		0.883833
S.E. of regression	0.539793	Akaike info criterion		1.884734
Sum squared resid	8.741290	Schwarz criterion		2.586434
Log likelihood	-27.23361	Hannan-Quinn criter.		2.149907
F-statistic	5.647291	Durbin-Watson stat		1.991622
Prob(F-statistic)	0.000020			

*Note: p-values and any subsequent test results do not account for model selection.

Source: Authors' estimations using Eviews 13

We used the Akaike Information Criterion (AIC) to confirm our decision to select the ARDL model (1,5,2,4,0,0) out of the 19 other models that were examined. This model minimizes the AIC information quantity, which is why we chose it.



Source: Estimations by the authors using Eviews 13

• Examination of the model residuals:

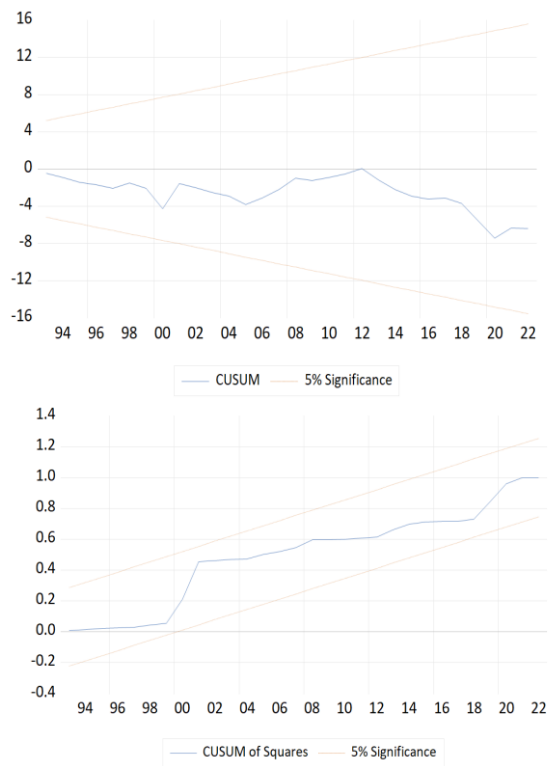
To validate our ARDL model, we conducted tests for normality, heteroscedasticity, autocorrelation and stability of the model residuals. The results are summarized in the table below:

Test Hypothesis	Tests	P-Values
Autocorrelation	Breusch-Godfrey (1 st order)	0.001 (0.96)
	Breusch-Godfrey (2 nd order)	0.22 (0.89)
Heteroskedasticity	Breusch-Pagan-Godfrey	21.03 (0.22)
	Arch-test 5 th order	5.03 (0.41)
Normality	Jarque-Bera	11.13 (0.003)
Stability (specification)	Ramsey (Fisher)	0.5 (0.48)

Source: Authors' estimations using Eviews 13

Except for the normality test, all other tests accept the null hypothesis, confirming the statistical validity of our model. The estimated ARDL model (1,5,2,4,0,0) demonstrates robustness, accounting for 76% of the changes in the Consumer Price Index between 1970 and 2022. According to the normality test, the model's residuals are non-Gaussian white

noise. Additionally, the CUSUM and CUSUM SQ tests, depicted in the following charts, affirm the model's stability:



Source: Performed by the authors using Eviews 13

• **F-Bounds Test for Cointegration:**

We performed a bounds test for cointegration to verify that the series of variables under investigation had a long-term relationship. The following table provides an overview of the findings:

Table 3: Results of the Bounds Cointegration Tests

Series	$LCPI_t, LM3_t, LGDP_t, LEXR_t, LPO_t, LENR_t$	
F-stat	4.385866	
Critical threshold	Lower bound	Upper bound
1%	3.06	4.15
5%	2.39	3.38
10 %	2.08	3

The cointegration bounds test results confirm the presence of a cointegration relationship among the studied series (with the F-stat value exceeding the upper bound). The estimation of the long-term interactions between the series, $LCPI_t$, $LM3_t$, $LGDP_t$, $LEXR_t$, LPO_t et $LENR_t$. Before delving deeper into this analysis, it is important to examine the causality between these variables.

• Causality Test:

In instances where non-stationary variables lack cointegration or are integrated at disparate orders, the traditional Granger causality test proves inadequate. Consequently, the Toda-Yamamoto (1995) causality test [27] is employed, leveraging the Wald statistic "W," which conforms to a chi-square distribution. The null hypothesis posits the absence of causality between the variables (with a probability exceeding 10%).

Table 4: Results of the causality Test

K	dmax	Dependent Variables	Explanatory and/or Causal Variables (p-value)					
			lcpi	lpo	lexr	lm3	lenr	lgdp
4	1	lcpi	-	4.85 (0.08)	0.18 (0.91)	9.62 (0.008)	2.52 (0.28)	3.2 (0.2)
		lpo	2.67 (0.26)	-	6.23 (0.04)	1.68 (0.43)	0.76 (0.68)	1.03 (0.59)
		lexr	1.15 (0.56)	8.66 (0.01)	-	0.35 (0.83)	4.65 (0.09)	11.46 (0.003)
		lm3	17.17 (0.0002)	0.98 (0.61)	1.03 (0.59)	-	4.21 (0.12)	0.29 (0.86)
		lenr	1.22 (0.54)	5.07 (0.07)	1.28 (0.52)	4.43 (0.1)	-	3.6 (0.16)
		lgdp	0.29 (0.86)	2.4 (0.3)	4.16 (0.12)	0.69 (0.7)	1.13 (0.56)	-

k: The optimal lag length of the at levels (AIC),

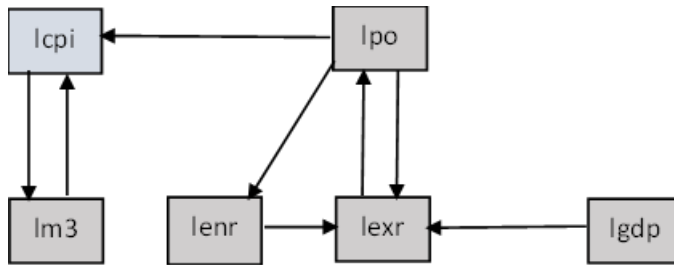
dmax: The maximum order of integration of the variables.

Based on the outcomes presented in this table, the Toda-Yamamoto approach [27] allows us to deduce the following causal relationships at a 10% significance level:

- There exists a bidirectional relationship Between price of oil and official exchange rate, indicating that fluctuations in oil prices influence the official exchange rate, and vice versa.
- A reciprocal causality is observed between costumer price index and money supply suggesting that changes in the money supply affect the consumer price index, and the consumer price index, in turn, influences the money supply.

- The consumer price index is significantly affected by variations in oil prices.
- Both the unemployment rate and GDP exert influence on the official exchange rate.
- Additionally, the unemployment rate is affected by changes in oil prices and the money supply.

The diagram below summarizes the causal relationships identified between the variables:



Source: Made by the authors

- ***The ARDL cointegration model results:***

$$\Delta I CPI_t = \gamma e_{t-1} + \alpha \Delta I M 3_t + \sum_{i=1}^4 \alpha_i \Delta I M 3_{t-i} + \beta \Delta I GDP_t + \beta_1 \Delta I GDP_{t-1} + \theta \Delta I PO_t + \sum_{j=1}^3 \theta_j \Delta I PO_{t-j} + \varepsilon_t$$

Dependent Variable: D(LCPI)
 Method: ARDL
 Date: 04/27/24 Time: 20:07
 Sample: 1975 2022
 Included observations: 48
 Dependent lags: 1 (Automatic)
 Automatic-lag linear regressors (5 max. lags): LM3 LGDP LPO LEXR
 LENR
 Deterministics: Restricted constant and no trend (Case 2)
 Model selection method: Akaike info criterion (AIC)
 Number of models evaluated: 7776
 Selected model: ARDL(1,5,2,4,0,0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
COINTEQ*	-0.762121	0.125562	-6.069702	0.0000
D(LM3)	0.442831	0.801261	0.552668	0.5839
D(LM3(-1))	-4.923452	0.967128	-5.090797	0.0000
D(LM3(-2))	-2.103650	1.073456	-1.959699	0.0578
D(LM3(-3))	-2.385656	0.881418	-2.706611	0.0103
D(LM3(-4))	-1.590254	0.691406	-2.300030	0.0274
D(LGDP)	-0.306293	0.817069	-0.374868	0.7100
D(LGDP(-1))	1.710293	0.879434	1.944767	0.0596
D(LPO)	-0.083975	0.367685	-0.228389	0.8206
D(LPO(-1))	-2.006824	0.486571	-4.124418	0.0002
D(LPO(-2))	-0.662902	0.339471	-1.952747	0.0587
D(LPO(-3))	-0.965745	0.292032	-3.306987	0.0021
R-squared	0.633936	Mean dependent var		0.014142
Adjusted R-squared	0.522083	S.D. dependent var		0.712788
S.E. of regression	0.492761	Akaike info criterion		1.634734
Sum squared resid	8.741290	Schwarz criterion		2.102534
Log likelihood	-27.23361	Hannan-Quinn criter.		1.811516
F-statistic	5.667589	Durbin-Watson stat		1.991622
Prob(F-statistic)	0.000033			

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

Source: Authors' estimations using Eviews 13

At the 5% threshold, according to the Fisher test, the model is statistically significant as a whole. Moreover, the coefficient of the adjustment or error correction term is statistically significant. It is negative (-0.762121) and falls between zero and one in absolute value, ensuring an error correction mechanism and thus the existence of a long-run relationship (cointegration) between variables. This adjustment or correction will occur at a speed of 76% per period (year), meaning that after one year and four months, the entirety of the deviation from the equilibrium relationship (the error) will be corrected.

$$e_{t-1} = LCPI_{t-1} - (a_0 + a_1 LM3_{t-1} + a_2 LGDP_{t-1} + a_3 LEXR_t + a_4 LPO_{t-1} + a_5 LENR_t)$$

Deterministics: Rest. constant (Case 2)

$$CE = LCPI(-1) - (5.028860 * LM3(-1) - 4.645840 * LGDP(-1) + 2.998575 * LPO(-1) + 0.604741 * LEXR + 1.194245 * LENR + 82.455073)$$

Variable *	Coefficient	Std. Error	t-Statistic	Prob.
LM3(-1)	5.028860	1.504882	3.341697	0.0018
LGDP(-1)	-4.645840	1.681134	-2.763515	0.0085
LPO(-1)	2.998575	1.092996	2.743446	0.0089
LEXR	0.604741	0.336134	1.799107	0.0792
LENR	1.194245	0.841208	1.419679	0.1631
C	82.45507	34.60128	2.383006	0.0218

Note: * Coefficients derived from the CEC regression.

Source: Authors' estimations using Eviews 13

The findings indicate that all long-term series coefficients, except for the unemployment rate, are statistically significant. For instance, a 1% rise in the money supply from the previous year correlates with an approximate 5.02% increase in the Consumer Price Index (CPI) in the current year. Similarly, a 1% reduction in the official exchange rate in the prior year is associated with around a 0.6% increase in the CPI. Regarding the oil price from the previous year, a 1% increase correlates with an approximate 2.99% rise in the CPI. Lastly, economic growth, as measured by GDP increase, suggests a deflationary effect, with about a 4.64% decrease in inflation. The long-term coefficient for the unemployment rate is zero, indicating no long-term relationship between the unemployment rate and CPI, although short-term CPI fluctuations are influenced by changes in the unemployment rate.

V CONCLUSION

This study aimed to uncover the primary drivers of inflation in Algeria spanning from 1970 to 2022, with a key objective of establishing a robust empirical framework to understand the long-run inflationary patterns and the key contributing factors highlighted in existing literature. To achieve this, we utilized Autoregressive Distributed Lag (ARDL) modeling to explore the enduring relationships between inflation, measured by the Consumer Price Index (CPI) in Algeria, and various factors including money supply (M3), official exchange rate (EXR), gross domestic product (GDP), the price of oil (PO), and the unemployment rate (ENR).

Given that the series are integrated at different levels (some I(1) and others I(0)), the Toda and Yamamoto causality test [27] was applied, revealing that certain series do not have a direct influence on inflation as indicated by the CPI. These include GDP, the official exchange rate, and the unemployment rate. Furthermore, the study found a bidirectional causality between the money supply and the CPI, whereas the causality between oil prices and the CPI is unidirectional.

Pesaran et al.'s use of the bounds testing approach provided additional evidence for a cointegrating relationship between the variables, facilitating the estimation of both long and short-term elasticities and coefficients.

The econometric investigation employing the Autoregressive Distributed Lag (ARDL) cointegration model provides profound insights into the inflation dynamics in Algeria. The statistically significant coefficients of the long-term series highlight their considerable impact on inflation. Notably, a 1% increase in the money supply from the previous year correlates with a significant 5.02% rise in the Consumer Price Index (CPI) in the current year. This supports monetary theory, indicating that expansionary monetary policy contributes to inflationary pressures.

Furthermore, a 0.6% rise in the Consumer Price Index (CPI) for each 1% depreciation of the official exchange rate in the prior year indicates that currency devaluation leads to increased inflation. This reflects the transmission effect of exchange rate variations on local prices. Moreover, the positive coefficient of about 2.99% for the previous year's oil price underscores the substantial impact of global oil price changes on Algeria's inflation, showcasing the nation's susceptibility to external economic shocks because of its dependence on oil revenues.

Interestingly, the negative coefficient of 4.64% for GDP growth indicates a deflationary effect, implying that economic expansion leads to a reduction in inflation rates. This finding contradicts conventional wisdom but suggests that improvements in economic productivity and output may offset inflationary pressures by increasing supply and reducing price levels.

Although short-run changes in unemployment can affect consumer price levels, there does not appear to be a substantial long-run relationship between the unemployment rate and CPI, indicating that labor market dynamics have little direct influence on inflation in Algeria.

Furthermore, we analyzed and dissected the positive and significant long-run relationships between the factors studied:

- The relationship between money supply and inflation: According to studies [5], [18], an increase in the money supply can lead to slower growth in the real output of goods and services compared to the growth of the money supply, resulting in higher overall price levels.
- Official exchange rate and inflation: Long-run exchange rates should reflect price level differences between countries, in line with research by [2], [3], [18].
- Price of oil and inflation: the fluctuations in oil prices significantly impact the Algerian economy, affecting money supply and subsequently the general price level. This aligns with research by [1], although [20], and [6] found contradictory effects.

- Economic growth and inflation: GDP growth is associated with lower prices and decreased inflation, as found by [2], although contrary findings were reported by [17].

Overall, these findings provide valuable insights for policymakers in Algeria, highlighting the importance of monetary policy effectiveness, exchange rate management, and economic diversification strategies in maintaining price stability and fostering sustainable economic growth.

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VII APPENDIX

A. Autocorrelation tests:

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 1 lag

F-statistic	0.001189	Prob. F(1,29)	0.9727
Obs*R-squared	0.001968	Prob. Chi-Square(1)	0.9646

Breusch-Godfrey Serial Correlation LM Test:
Null hypothesis: No serial correlation at up to 2 lags

F-statistic	0.066156	Prob. F(2,28)	0.9361
Obs*R-squared	0.225754	Prob. Chi-Square(2)	0.8933

B. Heteroskedasticity tests:

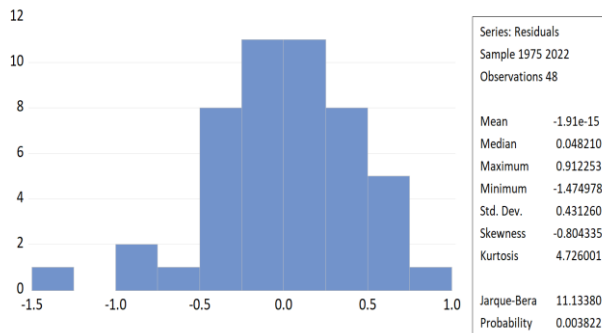
Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	1.376285	Prob. F(17,30)	0.2162
Obs*R-squared	21.03212	Prob. Chi-Square(17)	0.2249
Scaled explained SS	15.30580	Prob. Chi-Square(17)	0.5735

Heteroskedasticity Test: ARCH

F-statistic	0.981082	Prob. F(5,37)	0.4423
Obs*R-squared	5.033543	Prob. Chi-Square(5)	0.4118

C. Normality tests:



D. Ramsey's test:

Analysis of the Determinants of Inflation in Algeria : ARDL Cointegration Approach

Ramsey RESET Test
Equation: EQ01
Omitted Variables: Squares of fitted values
Specification: LCPI LCPI(-1) LM3 LM3(-1) LM3(-2) LM3(-3) LM3(-4)
LM3(-5) LGDP LGDP(-1) LGDP(-2) LPO LPO(-1) LPO(-2) LPO(-3) LPO(-4) LEXR LENR C

	Value	df	Probability
t-statistic	0.707306	29	0.4850
F-statistic	0.500282	(1, 29)	0.4850
Likelihood ratio	0.820992	1	0.3649

E. Causality test results:

Sample: 1970 2022
Included observations: 51

Dependent variable: LCPI

Excluded	Chi-sq	df	Prob.
LENR	2.522360	2	0.2833
LEXR	0.184342	2	0.9119
LGDP	3.202288	2	0.2017
LM3	9.625067	2	0.0081
LPO	4.853509	2	0.0883
All	15.58565	10	0.1121

Dependent variable: LENR

Excluded	Chi-sq	df	Prob.
LCPI	1.223429	2	0.5424
LEXR	1.287899	2	0.5252
LGDP	3.609316	2	0.1645
LM3	4.430963	2	0.1091
LPO	5.079253	2	0.0789
All	14.85568	10	0.1374

Dependent variable: LEXR

Excluded	Chi-sq	df	Prob.
LCPI	1.156348	2	0.5609
LENR	4.653079	2	0.0976
LGDP	11.46395	2	0.0032
LM3	0.353385	2	0.8380
LPO	8.665282	2	0.0131
All	16.48025	10	0.0867

Dependent variable: LGDP

Excluded	Chi-sq	df	Prob.
LCPI	0.298801	2	0.8612
LENR	1.130503	2	0.5682
LEXR	4.164511	2	0.1246
LM3	0.690222	2	0.7081
LPO	2.406696	2	0.3002
All	10.76249	10	0.3763

Dependent variable: LM3

Excluded	Chi-sq	df	Prob.
LCPI	17.17305	2	0.0002
LENR	4.218249	2	0.1213
LEXR	1.035520	2	0.5959
LGDP	0.298983	2	0.8611
LPO	0.981706	2	0.6121
All	35.98226	10	0.0001

Dependent variable: LPO

Excluded	Chi-sq	df	Prob.
LCPI	2.670201	2	0.2631
LENR	0.768122	2	0.6811
LEXR	6.233841	2	0.0443
LGDP	1.032935	2	0.5966
LM3	1.681525	2	0.4314
All	15.93491	10	0.1015