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The Asymmetric Effect of Oil Price Volatility on Inflation Rates in Algeria during the Period (1991-2021): An Empirical Study Using Nonlinear Autoregressive Distributed Lag Models

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Abstract: This paper attempts to measure the response of inflation rates to changes in oil prices in the Algerian economy for the period (1991-2021) using Nonlinear Autoregressive Distributed Lag (NARDL) model. Based on the results of the Wald test, the hypothesis of the asymmetric relationship in the effect of oil prices on inflation rates in Algeria in the short and long term was verified. The estimation results in the short term showed that inflation rates only respond to positive values of oil prices, where an increase in oil prices leads to a decrease in inflation rates in the short term. On the other hand, an increase in oil prices also leads to a decrease in inflation rates in the long term with an estimated elasticity of -0.11%. Negative values of oil prices had no effect on inflation rates in Algeria in the long term.

Keywords: Inflation rate, Oil prices, NARDL model.

Introduction

The recent decades from the previous century until the beginning of the 21st century witnessed significant fluctuations in oil prices in global markets. This has attracted the attention of many researchers around the world due to the wide-ranging impact that these fluctuations have on many macroeconomic indicators in general, as well as on local inflation rates in both producing and consuming countries. According to (Lòpez-Villavicencio & Pourroy, 2019), the impact of oil price shocks on local inflation is transmitted through direct and indirect channels. The direct channel is linked to changes in production costs resulting from an increase or decrease in energy resources, while the indirect channel is associated with exchange rate fluctuations resulting from oil price fluctuations.

Going back to the 1970s, which witnessed high inflation rates in most countries around the world, a rapid and significant increase in oil prices followed. Conversely, the decline in oil prices during the 1980s and 1990s was associated with a decrease in inflation rates during the same period. In contrast to the increase in crude oil prices during the first decade of the 21st century, inflation rates were less responsive and slower to increase in many countries compared to the oil price hikes and inflation that occurred during the 1970s. However, despite all this, a review of the applied literature shows that there are limited studies that indicate that changes in crude oil prices affect inflation (Lu, Liu, & Tseng, 2010).

Regarding the Algerian economy, like other developing oil-based economies that heavily rely on their oil and gas exports to generate revenue, the drop in oil prices led to a sharp decrease in government revenue, resulting in a budget deficit and various economic challenges. With regards to inflation, the oil crisis had a mixed impact on Algeria. The decline in oil prices can be accompanied by a decrease in the cost of imported goods, which can enable a reduction in inflation rates. On the other hand, the decrease in government revenue can cause many structural imbalances that impose greater inflationary pressures on the local economy. The decline in general revenue and budget deficits necessarily lead to an austerity policy regarding public spending. The decrease in general revenue leads to a reduction in support for basic goods such as food and fuel, which led to price increases and contributed to inflation. In addition, the decrease in government revenue resulting from the drop in oil prices also led to a decrease in investment in infrastructure, social programs, and others, which could have contributed to economic growth and job creation. Therefore, the resulting economic slowdown contributes to an increase in unemployment, which may lead to increased pressure on inflation. Moreover, the decrease in government revenue and budget deficit also causes a decrease in the value of the Algerian dinar, which raises the cost of imports and thus imposes further inflationary pressures.

Regarding the inverse situation and the rise in oil prices, the impact of the increasing oil prices on inflation in Algeria can be analyzed through different channels. One of the channels through which rising oil prices affect inflation in Algeria is the cost of imported goods. Algeria heavily relies on imports to meet its domestic demand for many goods, including widely consumed ones. The increase in oil prices raises the import bill, and this affects inflation. Another channel through which rising oil prices can impact inflation in Algeria is government spending. Higher oil prices can lead to increased government spending. Additionally, high oil prices can affect the exchange rate of the Algerian dinar, as demand for the dinar decreases, leading to higher prices for imported goods due to the devaluation of the currency.

The goal of this paper is to highlight the impact of oil prices on inflation in Algeria by capturing both the short-term and long-term asymmetry between these variables and attempting to clarify the relationship between them.

Based on the above, the following question can be raised:

To what extent do both negative and positive shocks in global oil prices affect inflation rates in Algeria in the short and long terms?

1. Experimental Studies

Over the past decades, a large number of scientific papers and publications have been published on the transmission of oil prices to inflation. Most studies that examined the impact of oil prices on inflation rates generally relied on linear time series models. One of the earliest experimental studies that examined the relationship between inflation and oil price volatility (Hamilton, 1983) investigated the impact of oil prices on the overall economy of the United States, including price levels, and found that oil price shocks were one of the causes of the US economic recession after World War II. In the same context, (Hooker, 1999) found that the significant effects of oil prices on the overall economy are indirect effects that are transmitted through inflation and interest rates. (Cologni & Manera, 2008) built a structural model based on the self-regression technique VAR to examine the impact of inflation on oil prices for the Group of Seven (G7) countries, and found a significant inflationary impact of oil prices in the group countries, except for Japan and the United Kingdom. A study by (Jacquinot, Kuismanen, Mestre, & Spitzer, 2009) showed that oil price volatility is essential to understanding short-term inflation based on the dynamic stochastic general equilibrium (DSGE) model in the Euro area. Recently, a study on the case of the Gulf Cooperation Council countries (Nasir, Al-Emadi, Shahbaz, & Hammoudeh, 2019) found the existence of positive and statistically significant indirect effects from oil prices to inflation.

The impact of oil prices on inflation rates is not necessarily symmetrical, meaning that the effect of rising oil prices on inflation may differ from the effect of falling oil prices on inflation. Through a thorough review of the empirical literature, it is clear that the impact of oil prices on inflation rates is asymmetrical across oil-exporting and oil-importing countries. Oil-exporting countries may experience higher economic growth and higher inflation rates when oil prices rise, while oil-importing countries tend to achieve higher inflation rates when oil prices rise and lower inflation rates when oil prices fall (Adrangi, Chatrath, Dhanda, & Raffiee, 2001) (Baumeister & Kilian, 2016) (Cashin, Mohaddes, Raissi, & Raissi, 2014). with one exception where the study conducted by (Apergis & Payne, 2014) found that oil price changes have a symmetrical effect on inflation rates in oil-exporting countries, contradicting the findings of other studies that found evidence of asymmetric effects.

Referring back to oil-exporting economies, some reference studies focused primarily on oil-exporting countries, such as a study that examined the relationship between oil prices and inflation dynamics in Iran from 1971 to 2014. The researchers found that rising oil prices have a more important and persistent effect on inflation compared to falling oil prices, indicating the presence of an asymmetric effect for the Iranian economy.

(Park & Ratti, 2008) examined the relationship between oil prices and inflation rates in a sample of 13 oil-importing countries and 14 oil-exporting countries. The researchers found that oil price increases have a greater impact on inflation rates in oil-exporting countries compared to oil-importing countries. Similarly, (Pesaran & Mohaddes, 2016) analyzed and measured the relationship between oil prices and inflation rates in a sample of 13 oil-exporting countries during the period (1970-2014). The study found that oil price increases have a greater impact on inflation rates than oil price decreases in these countries. These results were also found in most of the studies that addressed the research topic, such as (Basher, Haug, & Sadorsky, 2018) (Mien, 2022) (Mohaddes & Raissi, 2016) (Nusair & Al-Khasawneh, 2023). In general, these studies and others provide strong evidence that oil price increases have a greater impact on inflation rates than oil price decreases in oil-exporting countries. The results indicate that the impact of oil price changes on inflation is influenced by various factors, including exchange rate volatility (Aizenman & Glick, 2009) (Al-Abri, 2023), trade openness (Khamfula, 2020), financial development (Ersan öz , 2019), economic diversification (Choi, Loungani, Mishra, & Poplawski, 2018) (Ross, 2017), and many other factors that differ depending on the individual characteristics of each country.

One of the valuable studies that examined the relationship between oil prices and inflation in Algeria, with a special focus on the potential asymmetric effect of oil price fluctuations on inflation, are the following:

The study by (Lacheheb & Sirag, 2019) the researchers used the non-linear autoregressive distributed lag (NARDL) model to analyze data from 1980 to 2017. The study found several results, including the presence of a non-linear relationship between oil prices and inflation in Algeria, where the positive impact of oil price shocks on inflation is greater than the negative impact. Additionally, the researchers found that the differential impact of oil price changes on inflation, meaning that the inflation rate responds differently to increases and decreases in oil prices. In another paper by (Sennoussi & al., 2022), the aim was to analyze the fluctuations of oil and natural gas prices and their impact on inflation in Algeria during the period 1971-2020, using the NARDL model. The results showed that positive and negative changes in natural gas prices increase the inflation rate asymmetrically in the short and long term, while oil price fluctuations have an asymmetric impact on inflation in the long term only, and rising oil prices contribute to reducing inflation rates. The results also showed that the inflation rate in Algeria is more responsive to positive changes in oil and natural gas prices than to negative changes.

In another study by (Dahmani & Mouissi 2022), the researchers tested the symmetric effect of oil prices on inflation rates in the Algerian economy during the period of 1990-2019. They relied on the self-regression models of slow nonlinear time gaps and found that there is an asymmetric effect of oil price fluctuations on inflation rates in Algeria in the short term. An increase in oil prices can curb inflation rates in the short term, while a decrease in oil prices leads to an increase in inflation rates in the same time frame, but to a lesser extent than the increase in oil prices. On the other hand, the researchers found that oil price fluctuations have no ultimate effect on inflation rates in the long term. The researchers also pointed out that imported inflation rates represent one of the indirect channels of transmitting shocks in oil prices to local inflation rates. In the same context and using the same methodology, (Jaafar Hani & Daqish, 2019) found that the increase in oil prices can contribute to the decline in inflation rates in the short term, while the increase in oil prices does not affect inflation rates in the short term. On the other hand, both the increase and decrease in oil prices can lead to an increase in inflation rates in Algeria in the long term, with the note that the increase in oil prices had the greatest impact on inflation rates in the long term. which confirms the hypothesis of asymmetry in the effect of oil prices on inflation rates in general.

Generally, studies have indicated the existence of an unequal relationship between oil prices and inflation in many oil-producing countries in particular. Increases in oil prices tend to have a greater impact on inflation than decreases in oil prices. However, the strength of the relationship may vary depending on the specific characteristics of each country, such as the degree of dependence on oil, the structure of the economy, and policy responses to oil price shocks.

What can be inferred based on the above is the conflicting results reached by researchers regarding the problem posed through this study, which calls for further research on the subject to ensure a more accurate and comprehensive understanding of the nonlinear relationship between oil prices and inflation rates in Algeria. Additionally, a review of the applied literature on the Algerian economy shows that most studies have overlooked many factors in the standard models used, particularly regarding the indirect channels through which fluctuations in oil prices can affect inflation rates, such as economic growth rates and monetary policy variables. This paper focuses on including exchange rates, broad money supply, and economic growth rates as secondary explanatory variables, as well as taking into account structural changes in the time series included in the model when testing for stability.

2. Methodology and Tools Used in the Study

2.1 Study Variables and Data Source

To answer the main problem addressed in this paper, which mainly revolves around determining the response of inflation rates to positive and negative fluctuations in oil prices in international markets for the Algerian economy during the period (2021-1991), the study relies on one of the nonlinear dynamic models, namely the Nonlinear Autoregressive Distributed Lag (NARDL) model. This model allows measuring and tracking the impact of both positive and negative shocks in oil prices on short-term and long-term inflation rates. It is worth noting that the aforementioned standard model is nothing but an extension of the Autoregressive Distributed Lag (ARDL) model proposed by researchers (Pesaran & Shin, 1995). Both models rely on the same estimation techniques and critical values for testing boundaries. In addition, both models rely on the same diagnostic tests. The fundamental difference between the two models (NARDL-ARDL) lies in the fact that the linear model studies the impact relationship between variables in one direction (positive or negative) and assumes the symmetry of the effect in the opposite direction. This is the biggest drawback of linear models, which often neglect the asymmetry or asymmetry of the relationship between economic variables. Therefore, NARDL models include tests to determine the symmetry of the relationship between explanatory variables and the dependent variable, as well as measure and track positive and negative shocks in explanatory variables and their transfer to the dependent variable on the other hand.

Regarding the variables used in this study, they were selected based on two main criteria. The first criterion is what is stated in the applied literature on the topic under discussion, in addition to the specificity of the Algerian economy in determining the study period (towards a market economy in 1989). The following table presents a description of the variables used in the study and their data sources.

Table (1): Study Variables and Data Source

Variable	Type	Description	Source
Inflation rate (INF)	Dependent variable	Inflation, as measured by the Consumer Price Index, reflects the annual percentage change in the cost to the average consumer for a basket of goods and services that can remain constant or change over specific periods of time, such as every year, for example. Generally, the Spears formula is used.	World Bank

Petroleum prices (PP)	Key independent variable	The price of Brent crude oil per barrel in US dollars.	OPEC
Economic growth (GDPG)	Independent variable	This is a description of GDP (Gross Domestic Product) at constant prices. It refers to the annual growth rate of the GDP calculated on the basis of a fixed price for the local currency. The calculations are based on a fixed price of the US dollar in 2010. GDP is the sum of the total value added by all resident producers in an economy plus any taxes on products and minus any subsidies not included in the value of the products. It is calculated without deducting the value of depreciation of manufactured assets or making any deductions for the depletion and degradation of natural resources.	World Bank
Money supply (M2_GDP)	Independent variable	The broad money supply (IMF, Line: 35L.ZK) is the sum of currency outside banks, demand deposits other than those of the central government; time and savings deposits, and foreign currency deposits held by residents other than the central government; bank and traveler's checks; and securities such as negotiable certificates of deposit and commercial paper.	World Bank
Nominal exchange rate (ER)	Independent variable	The official exchange rate refers to the exchange rate determined by national authorities or the exchange rate set by the exchange market allowed by law. It is calculated as an annual average based on monthly averages (local currency units per U.S. dollar).	World Bank

Source: Compiled by researchers based on (World Bank, 2021).

It should be noted that the variable of broad money supply (M2_GDP) has been divided by the Gross Domestic Product (GDP) to obtain the actual values specific to the latter and to eliminate the effect of inflation. Also, the reliance on international organizations in collecting data is due to the existence of some inconsistencies in the data issued by local specialized institutions in Algeria.

2.2 Description of the study model

The study relied on the Nonlinear Autoregressive Distributed Lag (NARDL) model developed by (Shin, Yu, & Greenwood-Nimmo, 2014) for four reasons. Firstly, unlike competing Error Correction Models (ECMs) that require the time series under study to be of order I(1), the NARDL model allows the use of time series with different degrees of integration, i.e., a mix of first differences I(1) and levels I(0). Secondly, the model allows for modeling the integrative relationship that may exist between oil prices and inflation rates. Thirdly, nonlinear integrative relationships can be modeled within this framework. Fourthly, the NARDL model is a single-equation model that allows for the separation of short- and long-term effects of explanatory variables on the dependent variable, unlike the Vector Error Correction Model (VECM) which consists of a system of equations.

The general mathematical formula for the study model can be written as follows:

$$\boldsymbol{INF} = f(PP, \quad GDPG, \quad M2_{GDP}, \quad ER)$$

$$\mathrm{d}(INF_t) = \alpha + \rho INF_{t-1} + \left(\beta_1^{+} PP^{+}{}_{t-1} + \beta_2^{+} PP^{-}{}_{t-1}\right) + \rho GDPG_{t-1} + \rho M2_{GDP_{t-1}} + \rho ER_{t-1} + \sum_{j=0}^{q-1}(\gamma_n * \Delta GDPG_{t-J}) + \sum_{j=0}^{r-1}(\pi^{+}{}_n * \Delta FDI^{+}{}_{t-J}) + \sum_{j=0}^{r-1}(\pi^{-}{}_n * \Delta FDI^{-}{}_{t-J}) + \mu_t$$

Where:

α Represents the intercept or the estimation constant, ρ is the error correction coefficient, and each of $\left(\boldsymbol{\beta_1^{+} PP^{+}{}_{t-1} + \beta_2^{+} PP^{-}{}_{t-1}}\right)$ represents positive and negative short-term shocks of the main independent variable. While each of $\sum_{j=0}^{r-1}(\boldsymbol{\pi^{+}{}_n} * \Delta \boldsymbol{PP^{+}{}_{t-J}}) + \sum_{j=0}^{r-1}(\boldsymbol{\pi^{-}{}_n} * \Delta \boldsymbol{PP^{-}{}_{t-J}})$ represents the positive and negative shocks in the short term of the key independent variable, and (j; 1……n) represents the model delay degree and (t: 1…T) represents time, and μ_t represents the random error term that is considered as noise too.

2.3 Descriptive statistics of study variables

Before proceeding with estimating the study model and applying its diagnostic tests, it is necessary to first establish a preliminary understanding of the characteristics of the variables included in the model through computing a set of central tendency statistics, as shown in the following table:

Table (02): Descriptive Statistics of Study Variables

Statistics	INF	PP	ER	GDPG	M2_GDP
Mean	8.29834	48.1336	72.8947	2.52	61.103
Median	4.52421	41.13	73.1071	3.1	62.77165
Maximum value	31.6696	109.45	126.776	7.2	96.49804
Minimum value	0.33916	12.28	18.4728	-5.1	33.00584
Standard deviation	9.20945	31.2591	27.3674	2.49197	16.42726
Skewness	1.60536	0.65908	-0.05538	-0.98876	0.043548
Kurtosis	4.04286	2.17944	2.89241	4.57452	2.173129
Jarque-Bera test	14.7203	3.01359	0.0298	7.98713	0.864128
Probability	0.00063	0.22161	0.98521	0.01843	0.649168
Total	257.248	1444.01	2186.841	75.6	1833.09
Number of observations	31	31	31	31	31

Source: Prepared by researchers based on Eviews 12 outputs.

Through the above table, it appears that the arithmetic mean of the oil price variable (PP) reached $48.13, which is a low value that reflects the sharp shocks experienced by the oil markets during the study period, especially with regard to the crisis at the end of 2014. As for the inflation rates (INF), the arithmetic mean for the latter during all study periods was 8.29%, which is a very high rate that reflects the inability of the monetary authorities in Algeria to target inflation rates during the majority of these study periods. On the other hand, the arithmetic means of the economic growth rates (GDPG), exchange rates (ER), and broad money supply (M2_GDP) were 2.52%, $72.89, and 61.10%, respectively.

The variable for Brent crude oil price (PP) recorded its highest value during the study period, which was estimated at $109.5 in 2012, while its lowest value was $12.25 in 1998.

As for the standard deviation values of the study variables, relatively low values were recorded for both the inflation rate (INF) and the economic growth rate (GDPG). On the other hand, the rest of the variables recorded high values for the standard deviation, due to the difference in the units of the study variables, in addition to the presence of a certain dispersion in the observations of the latter compared to the economic growth and inflation rates. It also appears that the majority of the variables used in this study follow the normal distribution according to the J-Bera statistic, which is a good preliminary indicator that suggests the possibility of obtaining good estimation results statistically and conceptually in the model of the study.

3. Results and Discussion

3.1 Diagnostic Tests for the Model

One of the most important assumptions of applying autoregressive models for slow-moving time series and nonlinear models is that the time series of the variables included in the model are stable at level and/or first difference. In addition, the long-term equilibrium relationship between the explanatory or independent variables and the dependent variable must be verified. This is in addition to the classical assumptions required in the residual estimation of the model and the structural stability of the model. Therefore, this stage is the basis of the standard modeling process according to the NARDL approach.

3.1.1 Stability study results

Time series are considered stable if they do not contain a unit root. One of the most commonly used tests to detect the presence of a unit root in applied literature are the Philips and Perron (Pp) and Augmented Dickey Fuller (ADF) tests. These tests are used in three models (with a constant, with a constant and a trend, and without a constant and a trend), and they are based on the following assumptions:

- **H0:** The series is not stable (there is a unit root)
- **H1:** The series is stable (there is no unit root)

Looking at Appendix 2 for stability tests, it appears that the ADF and Pp tests yield similar results for the three models at both the level and first difference. Based on the Pp test, the time series for variables PP, ER, and M2/GDP are not integrated or stable at the level and in the three models of this test (with a break, with a break and a trend, and without a break and a trend) given that the probability values for the t-statistic are much greater than the critical value (0.05) for the aforementioned variables and in the three models of the PP test.

Regarding the variable (GDPG), the results of the (P-P) test showed that this variable is integrated of degree (0), where the statistical values of the test in the three models were, respectively, $(t_{stat} = -4.06; -4.03; -2.08)$. These values are greater than the corresponding tabular values at a significance level of (5%), given that the probability values associated with all these statistics are much less than the critical value (0.05).

As for the inflation rate variable (INF), the two tests showed instability of the latter in the second and third models of the tests, where the probability values of the (Student) statistic for this variable are much greater than the critical value (0.05). On the other hand, the two tests (ADF; P-P) showed that this variable is integrated or stable in the first model at the level of (no intercept and a general trend), given that the probability value associated with the (Student) statistic was (0.03), which is less than the critical value (0.05). This variable can be considered non-integrated at the level, as it is unstable in two out of three models in terms of the tests used in the stability study. Additionally, the graphical representation of the inflation rate variable clearly shows its containing a break, thus the judgment regarding the instability of the inflation rate at the level is correct.

After conducting the initial differences, the stability of all study variables that were previously unstable at the level becomes clear. The probability values associated with the Student statistic for all variables in the three models used to test stability were completely less than the critical value (0.05), except for one exception. This exception pertains to the first difference variable in exchange rates (DER), where the results of the P-P test indicated instability in this variable at the first difference and in the third model of the test (with a breakpoint and a general trend). The probability value associated with the Student statistic for this test was (0.051), which is greater than the critical value (0.05). Therefore, the hypothesis of non-stationarity for the P-P test of the first difference variable in exchange rates at the first difference is accepted. It should be noted here that first-generation stability tests are usually biased towards non-stationarity, as they do not take into account breakpoints in time series, which will be verified in the next step for the first difference variable in exchange rates, and the results of the stability tests will be considered with the breakpoints in the time series of this variable, as shown in the following table.

Table (03): Stability tests results at the first difference of the exchange rates variable in the presence of a breakpoint

Null hypothesis: D (ER) has a unit root			
Trend specification: trend and intercept			
Break date: 2014			
Augmented dickey-fuller test statistic		T-statistic	Prob.*
		-5.31435	< 0.01
Test critical values:	1% level	-5.15112	
	5% level	-4.64352	
	10% level	-4.37629	

Source: Prepared by the researchers based on Eviews 12 outputs.

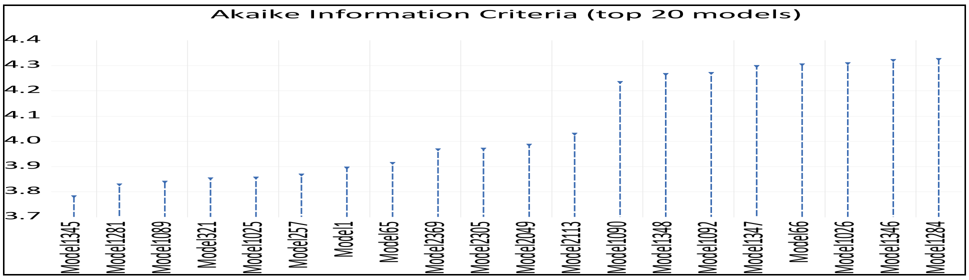
Based on the results of the (ADF) test in the presence of a break point in 2014, the stability of the first differences variable in exchange rates is clearly evident, where the statistical value (T_{STAT}= -5.31) is significantly greater than the corresponding tabular value at a significance level of 5%, which was (4.64). Therefore, it can be said that the time series of first differences in exchange rates is stable.

Furthermore, based on the results of the stability tests, which showed that the study model variables were integrated at the level and first difference, it is possible, according to (), to have a long-term equilibrium relationship between oil prices and the explanatory variables on the one hand, and inflation rates on the other hand. Hence, the first assumption of applying (ARDL) models in general, and (NARDL) models in particular, is achieved. The other diagnostic tests, such as verifying the conditions of the error correction coefficient and conducting bond tests, will be performed on the data.

3.1.2 Cointegration Test using Bounds Methodology

In this stage, the long-term equilibrium relationship between the explanatory variables and inflation rates will be tested, relying on the bounds test and verifying the required conditions in the error correction coefficient for the long-term equilibrium relationship between the variables in the study model. Before estimating the cointegration equation, it is necessary to first determine the optimal lag length for the explanatory variables in the short term. This is done by estimating a wide range of models with different lags for the explanatory variables with a maximum lag of three time periods, given that the data used in the study is annual data. The best model is chosen by selecting the model that is consistent with the lowest value of the AIC criterion and the results of the comparison process shown in the figure below.

Figure (01): Optimal Lag Test Results



Source: Prepared by researchers using Eviews 12 software.

Based on the above figure, the model that corresponds to the minimum value of the AIK information criterion (AIC) is: ARDL(2, 2, 2, 3, 3, 3), where the dependent variable is lagged by two time periods, while the independent variables are lagged (2, 2, 3, 3, 3) respectively as shown in the table below. The following table shows the results of estimating the cointegration equation for the study model:

Table (04): Long-term relationship and cointegration test

Dependent Variable: D(INF)				
Selected Model: ARDL(2, 2, 2, 3, 3, 3)				
Sample: 1991 2021				
Variable	Coeff	Std. Error	t-Statistic	Prob.
C	11.26583	13.39935	0.840774	0.4388
INF(-1)*	-1.20366	0.198642	-6.05945	0.0018
M2_GDP(-1)	0.726065	0.169305	4.288506	0.0078
PP_POS(-1)	-0.13505	0.047558	-2.83971	0.0363
PP_NEG(-1)	-0.14008	0.177374	-0.78973	0.4655
ER(-1)	-0.55982	0.250191	-2.23756	0.0754
GDPG(-1)	-0.94449	0.926953	-1.01892	0.355
D(INF(-1))	0.195365	0.159321	1.226234	0.2747

D(M2_GDP)	-0.03642	0.212198	-0.17165	0.8704
D(M2_GDP(-1))	-0.45837	0.175397	-2.61334	0.0475
D(PP_POS)	-0.14664	0.086161	-1.70194	0.1495
D(PP_POS(-1))	0.144256	0.068034	2.120337	0.0875
D(PP_NEG)	-0.00919	0.105125	-0.08738	0.9338
D(PP_NEG(-1))	0.151797	0.146405	1.036831	0.3473
D(PP_NEG(-2))	0.271536	0.094217	2.882038	0.0345
D(ER)	-0.05749	0.237543	-0.242	0.8184
D(ER(-1))	0.500942	0.241936	2.070554	0.0932
D(ER(-2))	0.683647	0.251532	2.717928	0.0419
D(GDPG)	-0.33564	0.383709	-0.87472	0.4217
D(GDPG(-1))	-0.18739	0.510308	-0.36722	0.7285
D(GDPG(-2))	-0.67498	0.327053	-2.06383	0.094
Long-term coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
M2_GDP	0.603213	0.14974	4.028397	0.01
PP_POS	-0.1122	0.040274	-2.7859	0.0386
PP_NEG	-0.11638	0.14575	-0.79846	0.4608
ER	-0.46509	0.195258	-2.38195	0.063
GDPG	-0.78468	0.747869	-1.04922	0.3421
Long-term equation				
EC = INF - (0.6032*M2_GDP -0.1122*PP_POS -0.1164*PP_NEG -0.4651 *ER -0.7847*GDPG)				

Source: Prepared by the researchers based on EVIEWS 12 outputs

- **Error correction coefficient**

The value of the error correction coefficient for the study model was (1.203-), and it satisfies the required sufficient and necessary conditions for this coefficient, as its sign is negative, and this coefficient is statistically significant at a significance level of (5%), where its statistical value (T_STAT) was (6.05-), which is much larger than the corresponding tabular value at a significance level of (5%).

This can be inferred from the probability value of this statistic, which did not exceed (0.05). The error correction coefficient represents the force of attraction towards equilibrium from the short term to the long term, and the time unit required for the error correction coefficient to correct short-term imbalances and thus reach equilibrium in the long term is ($\frac{1}{1.20}$ = 0.83), approximately ten months.

- **Bond test**

Table (05): Bounds Test

F-Bounds Test				
Null Hypothesis: No levels relationship				
Test Statistic	Value	Sig	I(0)	I(1)
			Finite Sample: n=30	
F-statistic	9.078888	10%	2.578	3.858
k	5	5%	3.125	4.608

Actual Sample Size	26	1%	4.537	6.37
t-Bounds Test				
Null Hypothesis: No levels relationship				
Test Statistic	Value	Sig	I(0)	I(1)
t-statistic	-6.05945	10%	-2.57	-3.86
		5%	-2.86	-4.19
		2.50%	-3.13	-4.46
		1%	-3.43	-4.79

Source: Prepared by researchers based on EVIEWS 12 outputs.

For the boundary test, the test statistic exceeds the upper limit of the critical value at a 5% significance level and with 5 degrees of freedom, which is 4.60. This means that we can accept the alternative hypothesis for the boundary test, which suggests the existence of a long-run equilibrium relationship between oil prices and the explanatory variables included in the study model in the direction of inflation rates in Algeria. The same results were obtained based on the t-statistic, where the calculated value for this test is greater than the absolute value of the corresponding critical value at a 5% significance level. Therefore, we can conclude that there is a long-run equilibrium relationship between the explanatory variables and inflation rates in Algeria.

Based on diagnostic tests (stability tests, cointegration tests), autoregressive models for slow-moving time series, whether linear or nonlinear, can be applied to the study model with a high degree of reliability, assuming that all estimation assumptions are met according to this methodology.

3.2 Measurement problems tests

Before starting the process of economic and statistical analysis of the estimated model, it is necessary to first verify the availability of classical assumptions in the residuals of the model, including problems of (autocorrelation between errors, heteroscedasticity, non-normal distribution of residuals). In addition, it is necessary to verify the structural stability of the model through the study of the suitability of the functional form of the model, as well as cumulative sum tests, as shown in the following figures and tables:

Table (06): Summary of Classical Measurement Problems Tests

Test Type	Test	Statistical value	Probability value
Autocorrelation between residuals	Breusch-Godfrey Serial Correlation LM Test:	0.5447	0.6283
Non-constant variance	Heteroskedasticity Test : ARCH	3.4087	0.0649
Normality of residuals	jarque-berra	1.8703	0.3925
Appropriateness of functional form	Ramsey RESET Test	1.0366	0.3662

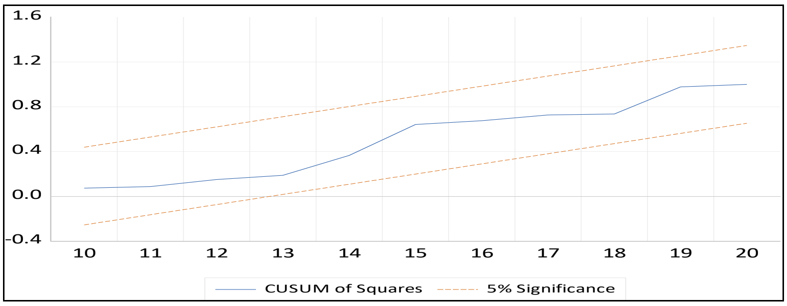
Source: Prepared by researchers based on EVIEWS 12 outputs.

The null hypotheses for the tests shown in the table above state that the estimated model does not suffer from these problems. The results of the first three classical tests related to the estimation residuals show that their statistical values are completely lower than the corresponding tabular values at a significance level of 5%, as all associated p-values are larger than the critical value of 0.05. Therefore, the null hypotheses of no problems with these tests are accepted.

As for the test of functional form adequacy, the statistical value of the Ramsey RESET Test is completely lower than the corresponding tabular value at a significance level of 5%, as the associated p-value (0.3662) is larger than the critical value of 0.05. Therefore, the functional form adopted is completely suitable for the study model.

Regarding the test of structural stability of the model, the cumulative sum of squares were represented through the figure below:

Figure (02): Cumulative Sum Test Results



Source: Prepared by the researchers based on EVIEWS 12 outputs.

From the above figure, it can be seen that the cumulative value squares (in blue) fall within the confidence intervals (in red), indicating that the estimates of the study model are stable throughout the study period. In other words, there is only one equation for the model during the entire period of the study.

On the other hand, looking at Table (07), it can be seen that the model estimated in this study is statistically significant overall, where the Fisher statistic (18.74) is statistically significant at the (0.00) level, meaning that the value associated with it was (t_Stat) is statistically significant. Additionally, the presented model is characterized by a high interpretive power, as indicated by the high coefficient of determination (R2 = 96%). Thus, the explanatory variables included in the study model contribute to explaining (96%) of the variation in inflation rates in Algeria, while the remaining (4%) represents other factors not included in the model but included in the margin of error.

In general, the results of the statistical and standard analysis of the study model show that the adopted model has high quality from both statistical and measurement perspectives. It possesses both the properties of overall significance and interpretive capability, in addition to having estimation residuals that do not suffer from measurement problems. Furthermore, the majority of the estimated parameters in the short- and long-term for the study model are statistically significant, meaning that this model can be relied on with high reliability in the process of analyzing results from an economic perspective.

4. Analysis and discussion of results

4.1 Economic analysis of the study model

It should be noted that the focus of the economic analysis will be on the statistically significant parameters, especially in the short and long term. The following results can be recorded through the following tables:

4.1.1 In the short term

Table (07): Short- term estimation results according to the NARDL model

Dependent Variable: D(INF)				
Selected Model: ARDL(2, 2, 2, 3, 3, 3)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	11.26583	1.341024	8.400916	0.0004
D(INF(-1))	0.195365	0.065281	2.992669	0.0304
D(M2_GDP)	-0.03642	0.073986	-0.49231	0.6434
D(M2_GDP(-1))	-0.45837	0.076173	-6.01753	0.0018
D(PP_POS)	-0.14664	0.047036	-3.11762	0.0263
D(PP_POS(-1))	0.144256	0.037036	3.894987	0.0115
D(PP_NEG)	-0.00919	0.043929	-0.2091	0.8426
D(PP_NEG(-1))	0.151797	0.049792	3.048606	0.0285
D(PP_NEG(-2))	0.271536	0.060497	4.488453	0.0065
D(ER)	-0.05749	0.07979	-0.72047	0.5035
D(ER(-1))	0.500942	0.11932	4.198297	0.0085
D(ER(-2))	0.683647	0.124627	5.485552	0.0027
D(GDPG)	-0.33564	0.163199	-2.05661	0.0948
D(GDPG(-1))	-0.18739	0.174547	-1.0736	0.3321
D(GDPG(-2))	-0.67498	0.153446	-4.39881	0.007
CointEq(-1)*	-1.20366	0.115318	-10.4378	0.0001
R-squared	0.965652	F-statistic		18.7425
Adjusted R-squared	0.91413	Prob(F-statistic)		0.000024
Durbin-Watson stat		2.515331		

Source: Prepared by the researchers using EVIEWS 12 outputs.

Referring back to the previous table, it appears that all the non-cointegrated explanatory variables had no effect on short-term inflation rates, as their coefficients were not statistically significant at the 5% level. On the contrary, most of the lagged variables with a lag of one or two time periods had a statistically significant effect on inflation rates. The estimation results showed that both the growth rate variable with a lag of two time periods and the nominal exchange rate variable with the same lag had the greatest impact on inflation rates in Algeria during the study period at the short term. An increase in exchange rates by 1% led to a 0.68% increase in inflation rates, while an increase in economic growth rates by 1% led to a 0.67% decrease in inflation rates. Therefore, the impact of the broad money supply variable with a lag of one time period was such that an increase in the latter by 1% led to a 0.45% decrease in inflation rates.

As for the positive valued variable of oil prices, it caused a frequent response to changes in inflation rates with its direct effect, and slowing down this variable by one time period had a relatively reduced effect between the two periods. An increase in oil prices led to a direct reaction causing a 0.14% decrease in inflation rates. This can be explained on the basis that oil is an important resource in the Algerian economy and a major source of hard currency; thus, an increase in oil prices may lead to an improvement in the trade balance and the flow of hard currency, which reduces inflationary pressures.

While the positive impact of these values is reflected in oil prices, turning it into a positive effect, the increase in inflation rates reached a percentage of (0.14%), due to the increase in public spending that usually accompanies oil price hikes, leading to an increase in demand for local products and services, and thus may increase inflationary pressures in the short term. Rapid increases in oil prices can also lead to a decline in the value of the local currency, increasing the cost of imports and leading to inflation. In terms of the decline in oil prices, it had a positive impact on oil prices, increasingly between the first and second slowdowns, where a 1% increase in oil prices led to an increase in inflation rates of (-0.270.15%) in the respective periods. When oil prices decline, the revenues that the Algerian government receives from oil exports also decline, along with high levels of public spending, leading to an increase in demand for goods and services in the economy. Therefore, a rise in prices and an acceleration of inflation can occur. It is also possible that the decline in oil prices could reduce the money supply in the economy, making things worse if the Algerian economy is already suffering from a shortage of money supply, which could increase inflationary pressures in the short term.

4.1.2 In the long-term

Table (08): Estimation Results in the long-term according to the NARDL Model

Dependent Variable: D(INF)				
Long-term coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
M2_GDP	0.603213	0.14974	4.028397	0.01
PP_POS	-0.1122	0.040274	-2.7859	0.0386
PP_NEG	-0.11638	0.14575	-0.79846	0.4608
ER	-0.46509	0.195258	-2.38195	0.063
GDPG	-0.78468	0.747869	-1.04922	0.3421
Long-term equation				
EC = INF - (0.6032*M2_GDP -0.1122*PP_POS -0.1164*PP_NEG -0.4651 *ER -0.7847*GDPG)				

Source: Prepared by the researchers using the outputs of EVIEWS 12.

Based on the outputs presented in the above table, the following results can be recorded:

The positive sign associated with the parameter of the broad money supply variable (M2/GDP) indicates its positive effect on inflation rates in Algeria in the long term. An increase in the variable (M2/GDP) by 1% leads to a highly elastic increase in inflation rates by 0.60%.

The negative sign of the parameter associated with the positive value of oil prices (PP_POS) variable indicates its inverse effect on inflation rates. A decrease in oil prices by 1% leads to a decrease in inflation rates by 0.11%. This result can be interpreted from the perspective that an increase in oil prices represents more revenue available to the government from oil exports, which can be invested in infrastructure and other economic projects. Therefore, directing these financial benefits to different economic sectors ensures more diversity in the local economy and increases the overall productivity of the economy, ensuring the sustainability of economic growth rates, which can play a leading role in stabilizing and reducing inflation rates to acceptable levels.

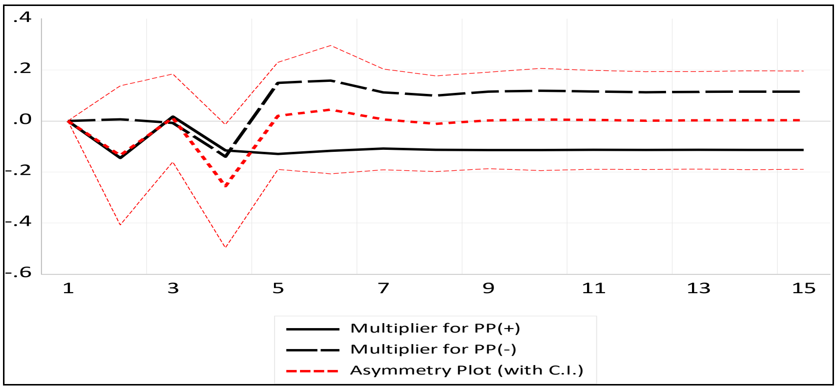
The negative sign of the parameter associated with nominal exchange rates (ER) indicates its inverse effect on inflation rates. An increase in exchange rates by 1% leads to a decrease in inflation rates in the long term by 0.46%.

As for the two variables of negative values in oil prices and economic growth rates, the results showed the insignificance of the parameters associated with these variables in the long term, and therefore they do not affect inflation rates.

4.2 Analysis of the asymmetric impact of positive and negative shocks in oil prices and their transmission to inflation rates

Before analyzing or testing for asymmetry, it was first necessary to test the symmetry of the relationship in the short and long terms between both oil prices and inflation rates. The results of the test (Wald Test) are shown in Appendix 3, which demonstrates the acceptance of alternative hypotheses for the tests (Wald Test) where the statistical values of $f_{stat} = 40.36\,;8.57$ are much greater than the corresponding tabular values at a significance level of (5%) and at the degrees of freedom used in this test. Therefore, the relationship between inflation rates and oil prices is asymmetric in the short and long terms, which is clearly demonstrated through the graphical representation of the dynamic cumulative multiplier effect, especially in the short term.

Figure 3: The Asymmetric Dynamic Cumulative Effect on Oil Prices and Its Transmission to Inflation Rates



Source: Outputs of EVIEWS 12 program.

Referring back to the previous figure, it appears that inflation rates only respond to positive changes in oil prices, without responding to negative changes, in the short term (before year three). In the medium term, the response of inflation rates to negative changes in oil prices turns from negative to positive, where inflation rate sharply increases by 0.14% to record positive values within a year (6). Positive shocks require about 5 years to converge to the long-run coefficient of 0.11, while negative shocks take about 8 years to fully transmit to local prices and converge to the long-run coefficient of 0.12.

Conclusion:

This paper attempts to measure the response of inflation rates to changes in oil prices in the Algerian economy for the period from 1991 to 2021, using the Non-linear Autoregressive Distributed Lag (NARDL) model. Based on the results of the WOLD test, it was verified that the relationship between oil prices and inflation rates in Algeria is asymmetric in the short and long terms. The estimated results in the short term show that inflation rates only respond to wave values in oil prices, where an increase in oil prices leads to a decrease in inflation rates in the short term. On the other hand, an increase in oil prices also leads to a decrease in inflation rates in the long term with an elasticity of 0.11%. Negative values of oil prices had no effect on inflation rates in the long term in Algeria.

Algeria is among the least diversified economies in the world, relying heavily on oil and gas exports as the main source of foreign currency and government revenues, making it vulnerable to shocks resulting from global oil prices. Therefore, sustaining economic growth and reducing unwanted inflation requires implementing sound and balanced fiscal and monetary policies, enhancing economic competitiveness, and improving the business environment. In addition, cash reserves can be enhanced and invested in other projects to diversify the Algerian economy and reduce the impact of oil price fluctuations on inflation. Based on the results of the analysis of the response of inflation rates to shocks in oil prices, whether positive or negative, policy makers can focus on targeting inflation in the short and long terms by taking advantage of financial surpluses resulting from an increase in oil prices, where positive shocks in oil prices had a positive effect on suppressing inflation rates in both the short and long terms.

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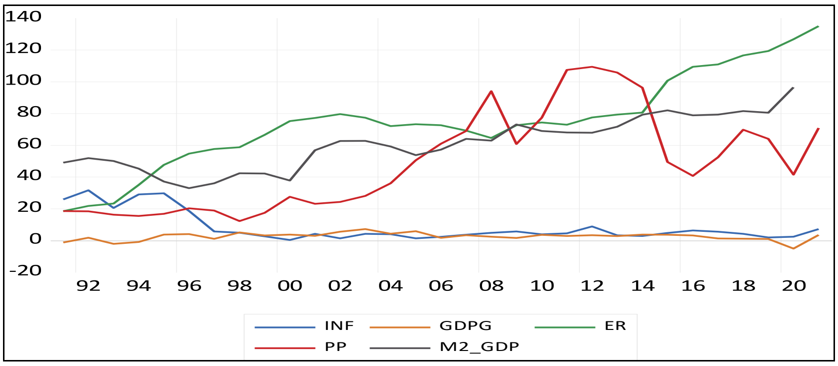
Appendices

Appendix (1): Graphic Representation of Time Series



Appendix (4): Symmetry Tests (Short and Long-term Symmetry)

Wald Test: Short -term			
Test Statistic	Value	df	Probability
t-statistic	6.353035	11	0.0001
F-statistic	40.36105	(1, 11)	0.0001
Chi-square	40.36105	1	0
Null Hypothesis: -C(3)/C(2)=C(4)/C(2)			
Wald Test: long-term			
Test Statistic	Value	df	Probability
F-statistic	8.576078	(3, 11)	0.0032
Chi-square	25.72823	3	0

Appendix (2): Stability Tests

			With Constant			With Constant & Trend			Without Constant & Trend		
			t-Stat	Prob.		t-Stat	Prob.		t-Stat	Prob.	
UNIT ROOT TEST TABLE (PP)	At Level	M2_GDP	0.603	0.987	n0	-2.113	0.517	n0	2.225	0.992	n0
		GDPG	-4.061	0.004	***	-4.030	0.018	**	-2.088	0.037	**
		INF	-2.122	0.238	n0	-1.704	0.724	n0	-2.174	0.031	**
		ER	-0.453	0.887	n0	-1.489	0.811	n0	2.547	0.996	n0
		PP	-1.496	0.522	n0	-1.973	0.592	n0	-0.197	0.607	n0
	At First Difference	d(M2_GDP)	-4.064	0.004	***	-4.341	0.010	***	-4.091	0.000	***
		d(INF)	-5.786	0.000	***	-7.291	0.000	***	-5.702	0.000	***
		d(GDPG)	-9.243	0.000	***	-13.141	0.000	***	-9.439	0.000	***
		d(ER)	-3.631	0.011	**	-3.561	0.051	*	-2.674	0.009	***
		d(PP)	-4.830	0.001	***	-4.684	0.004	***	-4.862	0.000	***
UNIT ROOT TEST TABLE			With Constant			With Constant & Trend			Without Constant & Trend		
			t-Stat	Prob.		t-Stat	Prob.		t-Stat	Prob.	
	At Level	M2_GDP	0.068	0.957	n0	-2.610	0.279	n0	1.391	0.955	n0
		INF	-2.155	0.226	n0	-1.774	0.692	n0	-2.116	0.035	**
		GDPG	-	0.00	**	-4.060	0.017	**	-1.172	0.215	n0

Notes: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant

*MacKinnon (1996) one-sided p-values.

			4.077	4	*								
		ER	-0.258	0.920	n0	-3.706	0.042	**	3.404	1.000	n0		
		PP	-1.519	0.511	n0	-1.973	0.592	n0	-0.305	0.567	n0		
	At First Difference	d(M2_GDP)	-4.314	0.002	***	-4.503	0.007	***	-4.113	0.000	***		
		d(INF)	-5.802	0.000	***	-6.257	0.000	***	-4.125	0.000	***		
		d(GDPG)	-8.657	0.000	***	-8.600	0.000	***	-8.825	0.000	***		
		d(ER)	-3.683	0.010	***	-3.616	0.046	**	-2.751	0.008	***		
		d(PP)	-4.889	0.001	***	-4.779	0.003	***	-4.925	0.000	***		

Appendix (3): Estimation of the Study Model

Dependent Variable: DINF				
Method: Variable Selection				
Included observations: 27 after adjustments				
Number of always included regressors: 7				
Stopping criterion: p-value forwards/backwards = 0.05/0.05				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
C	6.356182	6.035244	1.053177	0.3148
INF(-1)	-1.10039	0.151346	-7.27066	0
M2_GDP(-1)	0.656747	0.110958	5.918896	0.0001
PP_POS(-1)	-0.12282	0.024242	-5.06645	0.0004
PP_NEG(-1)	-0.10486	0.057843	-1.81285	0.0972
ER(-1)	-0.43736	0.106256	-4.1161	0.0017
GDPG(-1)	-1.10009	0.229776	-4.78767	0.0006
D(M2_GDP(-1))	-0.46854	0.102453	-4.57317	0.0008
D(PP_NEG(-1))	0.103997	0.073024	1.42416	0.1821
D(PP_POS)	-0.08032	0.050263	-1.59806	0.1383
D(ER(-2))	0.606764	0.148544	4.084741	0.0018
D(INF(-1))	0.178045	0.106884	1.665784	0.1239
D(PP_NEG(-2))	0.255497	0.079039	3.232538	0.008
D(GDPG(-2))	-0.54339	0.171402	-3.17026	0.0089
D(ER(-1))	0.407525	0.141486	2.880312	0.015
D(PP_POS(-1))	0.123656	0.054617	2.264049	0.0448
R-squared	0.936508	Mean dependent var		-0.80821
Adjusted R-squared	0.849927	S.D. dependent var		4.017312
S.E. of regression	1.556275	Akaike info criterion		4.009711
Sum squared resid	26.6419	Schwarz criterion		4.777614
Log likelihood	-38.1311	Hannan-Quinn criter.		4.238049
F-statistic	10.81663	Durbin-Watson stat		1.939188
Prob(F-statistic)	0.000162			