

Oil Dependency and Exchange Rate Asymmetries in Algeria: The Role of Monetary Policy and International Reserves

Benhalima abdelkader aziz ¹

¹ Mustafa Stambouli University, Mascara(Algeria)
, abdelkader.benhalima@univ-mascara.dz

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Abstract:

This research examines the uneven effects of fluctuations in oil prices on Algeria's nominal exchange rate from 1980 to 2024. Utilizing a Nonlinear Autoregressive Distributed Lag (NARDL) model, the study intricately incorporates the roles of monetary policy and international reserves. The findings substantiate the presence of a consistent long-term cointegration relationship, while also uncovering a structural asymmetry: cumulative adverse shocks in oil prices lead to a noteworthy and sustained depreciation of the dinar, in contrast to positive shocks, which result in a disproportionately modest appreciation. Additionally, the analysis reveals that monetary expansion significantly contributes to currency depreciation, with international reserves serving as a vital stabilizing mechanism against external fluctuations. These results underscore the importance of implementing countercyclical monetary policies and maintaining prudent reserve levels to alleviate macroeconomic susceptibility in economies reliant on hydrocarbons.

Keywords: Exchange Rate Asymmetry ,Oil Price Shocks ,NARDL Approach ,Monetary Policy ,International Reserves

JEL Classification Codes: C22, E52, F31, F32, Q43.

1. Introduction

1.1. Oil Dependency and Macroeconomic Vulnerability in Algeria

Economies that rely significantly on hydrocarbons inherently exhibit structural vulnerabilities to fluctuations in global oil prices. In such contexts, oil revenues serve as the primary source of foreign exchange, fund a considerable proportion of public expenditures, and influence

Corresponding author: Benhalima abdelkader aziz, : abdelkader.benhalima@univ-mascara.dz

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the trajectory of domestic liquidity. Consequently, the macroeconomic landscape becomes acutely sensitive to external shocks (Dąbrowski et al., 2022; Malik & Umar, 2019). This reliance facilitates a swift transmission of oil price shocks to external balances, exchange rates, and overall macrofinancial stability.

Algeria epitomizes this phenomenon, where hydrocarbons have historically constituted the majority of exports, thereby rendering oil price variability crucial for shifts in the exchange rate, the level of international reserves, and the state of public finances. Periods marked by declining oil prices consistently coincide with downward pressure on the dinar, a depletion of foreign reserves, and a constriction of the space available for macroeconomic policy (Chekouri et al., 2021). This pronounced dependence on oil renders the Algerian economy perpetually susceptible to external vulnerabilities, with the exchange rate emerging as a vital indicator of macroeconomic adjustments.

1.2. Potential Asymmetries between Oil Shocks and Exchange Rates

In addition to the established connection between oil prices and exchange rates, contemporary scholarship underscores the fundamentally asymmetric nature of this relationship. Increases and decreases in oil prices do not exert equal effects on the national currency, either in terms of intensity or timing. Empirical investigations employing nonlinear methodologies reveal that adverse oil shocks tend to have more significant and enduring impacts compared to beneficial shocks, particularly in economies reliant on hydrocarbon exports (Baek, 2021; Saidu et al., 2021).

These asymmetries can largely be attributed to institutional rigidities, procyclical behaviors in economic policy, and varied approaches to exchange rate management based on the nature of the shock. Monetary authorities frequently exhibit a tendency to restrain currency appreciation during periods of rising oil prices while allowing for, or even encouraging, substantial depreciation in response to negative shocks to safeguard international reserves (Lv et al., 2018). This asymmetric approach to management further exacerbates the non-linear

relationship between oil prices and exchange rates, challenging the applicability of conventional linear models.

1.3. Role of Monetary Policy and International Reserves

In economies rich in natural resources, the dynamics of exchange rates cannot be evaluated in isolation from the influences of monetary policy and the management of international reserves. Recent studies indicate that fluctuations in exchange rates are often more closely associated with monetary mechanisms—such as the monetization of deficits, the growth of domestic credit, and liquidity management—than with the revenues generated from oil (Constantine & Khemraj, 2025). Thus, monetary policy assumes a pivotal role in mediating the effects of oil shocks on exchange rates.

Moreover, international reserves function as a crucial tool for cushioning external shocks. They serve to dampen exchange rate volatility and mitigate the macroeconomic repercussions of depreciation, particularly within emerging and African economies (Coulibaly et al., 2024). Nevertheless, numerous studies highlight that the application of reserves is not always symmetrical; authorities typically engage more vigorously to curtail appreciation than to restrain depreciation, which can intensify the asymmetries noted in the association between oil shocks and exchange rates (George & Ramachandran, 2025).

1.4. Gaps in the Literature and Motivation for the Study

Despite the extensive body of research exploring the relationship between oil prices and exchange rates, several critical gaps persist. Primarily, a substantial portion of the empirical literature continues to rely on linear models, which fail to adequately capture the short- and long-term asymmetries illuminated by nonlinear analyses. Furthermore, existing studies frequently examine the impacts of oil shocks, monetary policy, and international reserves in isolation, neglecting the development of an integrated framework for analyzing their dynamic interrelations.

Additionally, the case of Algeria remains relatively underexplored from a detailed nonlinear perspective, despite its institutional attributes—marked oil dependency, a managed exchange rate regime, and the significant role of reserves—making it an apt candidate for investigating asymmetries. This absence of comprehensive analysis

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hinders a deeper understanding of the mechanisms governing exchange rate adjustments and underscores the necessity of the present study.

1.5. Research Objectives and Contribution

The primary aim of this article is to investigate the asymmetric effects of oil shocks on the exchange rate in Algeria, with a specific focus on the roles played by monetary policy and international reserves. In particular, the study seeks to ascertain whether positive and negative oil shocks yield different outcomes in both the short and long term, and to evaluate the extent to which economic policy instruments mediate these effects.

This article offers three significant contributions. First, it enhances the existing literature on the relationship between oil prices and exchange rates by introducing a nonlinear analysis within the context of an economy heavily reliant on hydrocarbons. Second, it simultaneously incorporates considerations of monetary policy and international reserves into the exploration of asymmetries, thereby addressing a notable empirical gap. Third, it provides pertinent implications for economic policy, particularly regarding exchange rate management and macroeconomic stabilization in Algeria.

1.6. Structure of the Article

The remainder of this article is structured as follows: Section 2 presents a review of the literature. Section 3 outlines the data and econometric methodology, employing the NARDL model. Section 4 discusses the empirical findings. Section 5 explores the implications for economic policy. Finally, Section 6 concludes the study.

2. Literature Review

2.1. Oil Dependency and Exchange Rate Dynamics

A considerable body of research indicates that the dynamics of exchange rates in oil-exporting nations are intimately tied to variations in global hydrocarbon prices. This connection is primarily facilitated through the mechanisms of terms of trade, export revenues, and currency flow channels. Empirical investigations focusing on countries that export natural resources reveal that disturbances in oil markets lead to notable adjustments in the real exchange rate. The extent of these

adjustments is influenced by the reliance on oil revenues and the specific exchange rate regime in place (Malik & Umar, 2019; Dąbrowski et al., 2022).

Within the African context, Kassouri and Altıntaş (2020) demonstrate that fluctuations in terms of trade related to commodities account for a substantial proportion of real exchange rate variability in exporting nations, underscoring the external vulnerabilities these economies face. Similar findings emerge from studies in the MENA region, where a strong interrelationship among oil prices, the current account balance, and exchange rates intensifies the impact of external shocks (Wang & Luo, 2020).

Focusing specifically on Algeria, prior research underscores that reliance on hydrocarbons enhances the exchange rate's function as a macroeconomic adjustment tool. Chekouri et al. (2021) identify a strong correlation between oil prices and exchange rates, while Boucekkine et al. (2021) assert that both monetary factors and the exchange rate are pivotal for ensuring long-term macroeconomic stability.

2.2. Asymmetric Oil Price Effects on Exchange Rates

While a connection between oil prices and exchange rates is well-established, a growing number of empirical investigations challenge the presumption of symmetry within this relationship. Research utilizing nonlinear methodologies reveals that fluctuations in oil prices—both increases and decreases—exert differing effects on exchange rates, differing in both intensity and duration (Baek, 2021; Saidu et al., 2021). Asymmetric analytical frameworks indicate that negative oil shocks tend to provoke stronger and more prolonged depreciation pressures compared to the appreciation effects stemming from positive shocks, especially in economies reliant on hydrocarbon exports (Nandi et al., 2024). Similar conclusions arise from threshold models and nonlinear cointegration techniques, which affirm the existence of structural breaks and regime-dependent behaviors (Butt et al., 2024; Deheri & Ramachandran, 2023).

In the Algerian context, while the empirical understanding of asymmetries remains limited, existing evidence supports its consistency. Lacheheb and Sirag (2019) illustrate that oil shocks influence inflation asymmetrically, suggesting that analogous

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mechanisms may also characterize the transmission to exchange rates. This body of literature provides a compelling rationale for employing nonlinear models, such as the NARDL framework, to effectively capture the distinct effects of both positive and negative oil shocks.

2.3. Monetary Policy in Oil-Dependent Economies

Monetary policy in economies heavily reliant on oil is characterized by unique constraints that stem from export revenue volatility, fiscal dominance, and the management of exchange rates. Dynamic Stochastic General Equilibrium (DSGE) models applied to resource-exporting nations indicate that optimal responses of monetary policy to oil shocks are contingent upon the exchange rate regime, the structural characteristics of the economy, and the nature of nominal rigidities (Ghiaie et al., 2022; Alba et al., 2020).

Moreover, recent research emphasizes the influence of international monetary conditions in exacerbating macroeconomic fluctuations in oil-exporting countries. Kim (2022) demonstrates that shocks in US monetary policy have a more significant impact on commodity-exporting nations than on those that import commodities, primarily through their effects on commodity prices and financial inflows.

In Algeria, Boucekkine et al. (2021) highlight that the demand for money exhibits a close relationship with both exchange rates and inflation, thereby restricting the efficacy of conventional monetary policy tools. These findings suggest that monetary policies serve as both a conduit for transmission and a moderating force regarding the effects of oil shocks on exchange rates.

2.4. International Reserves and Exchange Rate Stabilization

International reserves are fundamental in stabilizing the exchange rates of economies prone to external shocks. Existing empirical literature indicates that reserves diminish exchange rate volatility and alleviate the macroeconomic repercussions of depreciation, particularly in emerging and developing markets (Aizenman et al., 2024; Sula & Oguzoglu, 2021).

Numerous studies reveal that the accumulation of reserves is closely associated with the endowment of natural resources and fluctuations in

terms of trade. Fatum et al. (2021) argue that countries rich in resources, especially oil, tend to stockpile reserves as a precautionary measure. Coulibaly et al. (2024) contend that reserves play a pivotal role in mitigating the adverse impacts of depreciation on public debt and overall financial stability.

Nonetheless, the effectiveness of reserves is not uniform across contexts. Investigations into foreign exchange market interventions suggest that their efficacy is contingent upon the macroeconomic environment, the degree of financial openness, and the credibility of monetary authorities (Arango-Lozano et al., 2024; Chertman et al., 2020). These findings imply that the stabilizing function of reserves may itself exhibit asymmetry and depend on prevailing regimes.

2.5. Synthesis and Research Gap

The existing literature distinctly emphasizes (i) the crucial role of oil shocks in influencing exchange rate dynamics within exporting economies, (ii) the presence of significant asymmetries in the transmission of these shocks, and (iii) the vital importance of monetary policy and international reserves as mechanisms for absorbing shocks. However, these aspects are seldom investigated in conjunction within a comprehensive empirical framework.

Notably, few studies have simultaneously explored the asymmetric impacts of oil shocks on exchange rates while explicitly accounting for the roles of monetary policy and international reserves, with even fewer focusing on Algeria. This gap is particularly striking given the Algerian economy's substantial dependence on oil, the implementation of a regulated exchange rate regime, and the proactive utilization of foreign exchange reserves. This study aims to address this gap by employing a NARDL framework to elucidate the short- and long-term asymmetries in the oil-exchange rate relationship, while also considering the moderating influence of economic policy instruments.

3. Methodology

3.1. Empirical model

Presentation of the NARDL model

To capture the potential asymmetric effects of oil prices on the Algerian exchange rate, this study uses the Nonlinear Autoregressive Distributed

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Lag (NARDL) model proposed by Shin et al. (2014). This methodological framework extends the linear ARDL model of Pesaran et al. (2001) by decomposing an exogenous variable into its positive and negative partial sums, thus allowing for the estimation of short- and long-term asymmetric effects.

General form of the model

The general specification of the NARDL model used in this study is as follows:

$$\begin{aligned} \Delta L_EXR_t = & \alpha_0 + \rho L_EXR_{t-1} + \theta_1^+ L_OIL_{t-1}^+ + \theta_1^- L_OIL_{t-1}^- + \\ & \theta_2 L_M2_{t-1} + \theta_3 L_RES_{t-1} + \sum_{i=1}^p \gamma_i \Delta L_EXR_{t-i} + \\ & \sum_{i=0}^q (\pi_i^+ \Delta L_OIL_{t-i}^+ + \pi_i^- \Delta L_OIL_{t-i}^-) + \sum_{i=0}^r \delta_i \Delta L_M2_{t-i} + \\ & \sum_{i=0}^s \zeta_i \Delta L_RES_{t-i} + \psi_1 D2020 + \psi_2 D2022 + u_t \end{aligned}$$

Where:

- L_EXR_t : natural logarithm of the nominal exchange rate (DZD/USD)
- L_OIL_t : logarithm of the price of oil (Brent)
- L_M2_t : logarithm of broad money supply
- L_RES_t : logarithm of international reserves
- Δ : first difference operator
- $D2020D2022$: dummy variables for shocks (COVID-19, war in Ukraine)
- u_t : error term

Decomposition of shocks into positive and negative components (Partial Sum Processes)

Asymmetric decomposition is at the heart of the NARDL methodology. The positive and negative partial sums of oil price changes are constructed as follows:

$$L_OIL_t^+ = \sum_{j=1}^t \Delta L_OIL_j^+ = \sum_{j=1}^t \max(\Delta L_OIL_j, 0)$$

$$L_OIL_t^- = \sum_{j=1}^t \Delta L_OIL_j^- = \sum_{j=1}^t \min(\Delta L_OIL_j, 0)$$

These transformations make it possible to separate cumulative increases (L_OIL^+) from cumulative decreases (L_OIL^-) in oil prices.

Thus:

- The coefficients θ_1^+ and θ_1^- measure the **long-term** effects of price increases and decreases, respectively.
- The coefficients π_i^+ and π_i^- capture **short-term** dynamics.

Inclusion of the error correction term (ECM)

The model can be rewritten as an error correction mechanism (ECM):

$$\Delta L_EXR_t = \phi \cdot ECT_{t-1} + \text{dynamiques de court terme} + u_t$$

Where the error correction term (ECT_{t-1}) is defined as follows:

$$ECT_{t-1} = L_EXR_{t-1} - (\beta_0 + \beta_1^+ L_OIL_{t-1}^+ + \beta_1^- L_OIL_{t-1}^- + \beta_2 L_M2_{t-1} + \beta_3 L_RES_{t-1})$$

This term reflects the long-term deviation from the cointegration equilibrium. Its coefficient ϕ represents the speed of adjustment: a negative and significant coefficient validates convergence towards equilibrium.

The coefficient ρ , associated with the lagged variable L_EXR_{t-1} in the main equation, represents the speed of adjustment towards long-term equilibrium. For the cointegration relationship to be validated, this parameter must be negative and statistically significant. A value between -1 and 0 indicates a partial, rapid but stable adjustment. Furthermore, the long-term coefficients are derived by normalization according to the formula:

$$\beta_i = -\frac{\theta_i}{\rho}$$

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where θ_i denotes the unnormalized coefficients from the model.

The justification for employing the NARDL model lies in its ability to capture the asymmetric impacts of macroeconomic shocks, thereby addressing the shortcomings of conventional linear methodologies such as ARDL, VAR, and VECM, which enforce a symmetric response to variations in explanatory variables. This adaptability is particularly pertinent in the context of Algeria, where the dynamics of the exchange rate are significantly shaped by a substantial reliance on hydrocarbons, the discretionary actions of the Central Bank, and enduring structural inflexibilities. The NARDL model not only accommodates mixed-order integrated variables [I(0) or I(1)], but it also distinctly differentiates between short-term (π_i^+ , π_i^-) and long-term (θ_i^+ , θ_i^-), thereby offering a more nuanced understanding of the transmission mechanisms at play. Ultimately, its efficacy is well-documented in the literature concerning oil-dependent economies, with its application contingent upon prior confirmation of the absence of I(2) variables, which will be determined through standard stationarity tests such as ADF and KPSS.

3.2. Variables and sources

Data sources

The dataset utilized in this study is derived from reputable institutional sources known for their credibility.

Exchange Rates (EXR):

The nominal exchange rate data for the DZD/USD pair is obtained from the Bank for International Settlements (BIS). This institution is tasked with the collection and standardization of exchange rate statistics from all member central banks, ensuring consistency and international comparability of the data. The datasets offer annual averages from 1980 through 2024.

Money Supply (M2) and International Reserves (RES):

Data on the M2 money supply and foreign exchange reserves is gathered from the official statistics published by the Bank of Algeria, which are elaborated upon in the bank's annual reports and statistical bulletins. These figures are expressed in billions of Algerian dinars (DZD) for M2 and billions of US dollars (USD)

for reserves. The Bank of Algeria complies with the definitions and measurement standards set forth by the International Monetary Fund (IMF) for these aggregates.

Oil Price (OIL):

Information regarding Brent crude oil prices is sourced from Investing.com, a comprehensive financial platform that aggregates oil market quotations. Brent is the primary benchmark for Algerian crude oil exports. Prices are noted in US dollars per barrel (USD/barrel) and reflect annual averages derived from daily quotes spanning 1980 to 2024.

Study Period and Data Processing:

The datasets encompass the period from 1980 to 2024, resulting in a total of 45 annual observations. A meticulous review was conducted to ensure consistency and continuity of the data. Any identified gaps were filled using linear interpolation where appropriate, although a complete series exists throughout the entire period. Before estimation, all quantitative variables (EXR, M2, RES, OIL) were transformed into their natural logarithmic forms.

Rationale for Utilizing a Restricted Constant (Case 2 as per Pesaran et al., 2001):

Pesaran et al. (2001) delineate five specific scenarios for deterministic specification in the bounds test related to cointegration, based on the presence or absence of a constant and a trend in both the cointegration relationship and the dynamic model. The choice of the most appropriate specification depends on the economic characteristics of the relevant variables as well as a visual analysis of the data series.

In this study, we have chosen Case 2, which incorporates a restricted constant applicable only to the long-term relationship while excluding a deterministic trend. This decision is justified by several considerations:

1. **Absence of a Deterministic Trend:** The nominal exchange rate of Algeria does not display a significant linear trend over the entire period. Instead, the variations are largely cyclical, closely linked to the fluctuations in oil prices.

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2. Presence of a Non-Zero Average Level: The logarithmic transformations of the variables exhibit non-zero average levels, which necessitate the inclusion of a constant in the long-term relationship.
3. Conciseness of Model Specification: The addition of a deterministic trend lacks economic rationale and would reduce the degrees of freedom without providing substantial improvements to the model's fit.
4. Consistency with Existing Literature: A significant portion of studies examining exchange rates in developing countries adopts this specification (Bahmani-Oskoei & Fariditavana, 2016)..

Cointegration test (Bounds Test)

Once the optimal lag structure has been determined, we proceed to the cointegration test using the Bounds Test. This test examines the null hypothesis of no long-term relationship:

$$H_0: \rho = \theta_1^+ = \theta_1^- = \theta_2 = \theta_3 = 0$$

Against the alternative that at least one of these coefficients is non-zero. The test statistic is an F statistic calculated on the joint significance of the lagged variables. Pesaran et al. (2001) provide two sets of critical values: a lower bound $I(0)$ assuming that all variables are $I(0)$, and an upper bound $I(1)$ assuming that they are all $I(1)$.

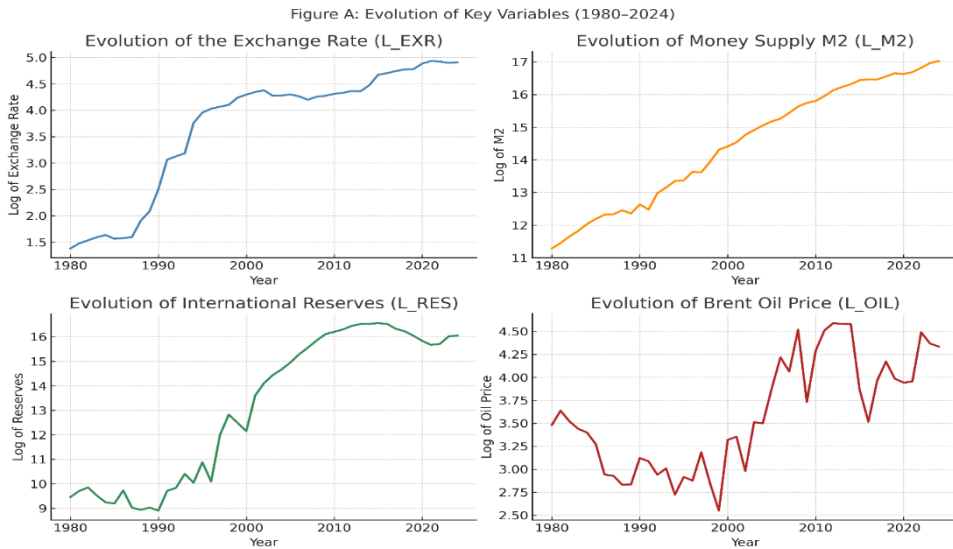
The decision rule is as follows:

- If $F\text{-stat} > \text{upper bound } I(1)$: rejection of H_0 , cointegration confirmed
- If $F\text{-stat} < \text{lower bound } I(0)$: do not reject H_0 , no cointegration
- If $\text{lower bound } I(0) < F\text{-stat} < \text{upper bound } I(1)$: inconclusive result

4. Results

4.1 Historical Evolution of Variables

The following figures illustrate the evolution of the variables over the period 1980-2024.

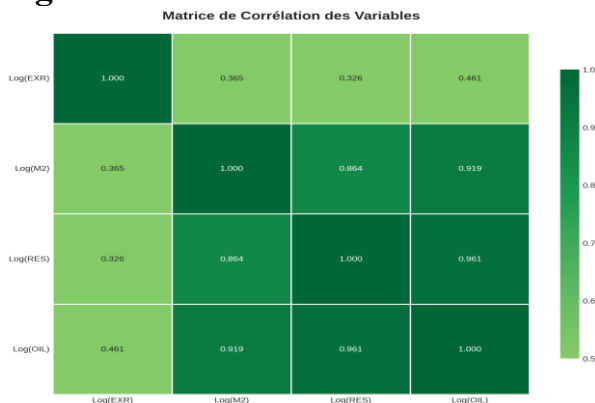
Figure A: Evolution of variables in levels (1980-2024)

Source: Authors' calculations based on data from the BIS (exchange rates), Bank of Algeria (M2 and reserves), and Investing.com (Brent oil prices)

Figure A shows the evolution of the four main variables over the period 1980-2024. There is a general trend towards depreciation of the dinar (upper left panel), with a notable acceleration after 2014. The M2 money supply (upper right panel) shows almost continuous growth, reflecting sustained monetary expansion. Foreign exchange reserves (lower left panel) show marked cycles of accumulation during periods of high oil prices and decline during periods of low prices. The price of oil (bottom right panel) is highly volatile, particularly during the two exogenous shocks modeled by the dummy variables: the **COVID-19** pandemic in **2020** (temporary collapse in prices) and the **war in Ukraine in 2022** (spike in energy prices).

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Figure B: Variable correlation matrix



Source: Authors' calculations

The correlation matrix reveals very strong correlations between the variables: EXR-M2 (0.919), M2-RES (0.961), RES-OIL (0.789). These high correlations suggest the existence of long-term relationships between the variables.

4.1.2. Descriptive Statistics

Table 1 presents the descriptive statistics for the variables.

Table 1: Descriptive statistics

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
<i>L_EXR</i>	40	4.198	0.712	1.563	4.933
<i>L_M2</i>	40	15,187	1,441	12,191	17,027
<i>L_RES</i>	40	14,255	2,434	8,937	16,557
<i>L_OIL</i>	40	3,698	0.581	2,550	4,590

Source: Authors' calculations based on data from the BIS (exchange rates), Bank of Algeria (M2 and reserves), and Investing.com (Brent oil prices)

4.1.3. Stationarity Tests

Before estimating the NARDL model, we performed stationarity tests to determine the order of integration of the variables. We used the

Augmented Dickey-Fuller (ADF) test and the KPSS test as complementary tests.

Table 2: Stationarity tests (ADF)

Variable	ADF (Level)	p-value	ADF (Difference)	p-value	Conclusion
<i>L_EXR</i>	-5.369	0.0000	-	-	I(0)
<i>L_M2</i>	-1.946	0.3107	-8.236	0.0000***	I(1)
<i>L_RES</i>	-3.159	0.0225	-	-	I(0)
<i>L_OIL</i>	-1.543	0.5119	-8.190	0.0000***	I(1)

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Source: Authors' estimates

The results show that the variables have mixed integration orders: **L_EXR** and **L_RES** are stationary in level [I(0)], while **L_M2** and **L_OIL** are integrated of order 1 [I(1)]. This particular configuration substantiates the employment of the NARDL model, which remains relevant irrespective of the integration order of the variables, as long as none of the variables exhibit I(2) characteristics.

4.2. Results of Cointegration

The implementation of the bounds testing methodology for cointegration is an essential procedure for verifying the presence of a long-term equilibrium relationship among the variables. The subsequent table delineates the findings of the Bounds Test.

Test Statistic	Value
F-statistic	4.116474

Bounds Critical Values (Case 2: Restricted constant and no trend)

Significance Level	I(0) Bound	I(1) Bound
10	2.427	3.395
5	2,893	4,000
1	4,093	5,532

Source: EViews output based on Pesaran et al. (2001).

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The calculated F statistic of 4.116 notably exceeds the critical threshold of I(1) at the 5% significance level, which is set at 4.000. This result allows us to reject the null hypothesis postulating the absence of cointegration. Such evidence supports the existence of a stable long-term equilibrium relationship among the Algerian exchange rate, oil prices, the money supply, and international reserves. As a result, this confirmation bolsters the estimation of the complete NARDL model and facilitates the examination of the long-term coefficients .

4.3. Results of the NARDL model

ARDL model selection criteria (AIC, BIC, HQ)

Specification	AIC	BIC	HQ
ARDL(4,3,1,4)	-1.2468	-0.2757	-0.8957

Long-term coefficients

The table below displays the estimated long-term coefficients achieved by normalizing the coefficients of the lagged variables.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
L_M2_{t-1}	2.508531	0.508804	4.930250	0.0000
L_RES_{t-1}	-0.624795	0.302704	-2.064046	0.0465
$L_OIL^+_{t-1}$	-0.262552	0.367534	-0.714363	0.4797
$L_OIL^-_{t-1}$	0.602437	0.446985	1.347779	0.1864
Constant (C)	-22.72552	3.657167	-6.213968	0

Source: EViews output. ARDL(4,1,3,4) model selected by AIC.

Significant effects of M2, RES

the long-term analysis uncovers several critical economic interactions: Money supply (L_M2): The coefficient, which is both positive and statistically significant (2.509, $p < 0.001$), demonstrates that a 1% rise in the money supply corresponds to a long-term depreciation of the dinar by 2.51%. This elasticity exceeding one indicates an amplifying mechanism, aligning with monetary theory, particularly within a framework characterized by substantial dollarization and currency

substitution. The expansion of the money supply, frequently employed to address budget deficits in Algeria, imposes a persistent downward influence on the exchange rate. International reserves (L_RES): The coefficient, which is negative and statistically significant (-0.625, $p < 0.05$), reinforces the protective function of reserves.. A 1% increase in reserves leads to a 0.62%

appreciation of the dinar in the long term. This result highlights the importance of the reserve cushion in maintaining confidence in the currency and defending its value against external

shocks. Asymmetry between OIL+ and OIL-

Although the individual coefficients of L_OIL(+) and L_OIL(-) are not statistically significant at the conventional 5% threshold, their difference is economically and statistically significant, as confirmed by the Wald test presented below. The coefficient of L_OIL(-) (0.602) is positive, indicating that a cumulative decline in oil prices leads to a depreciation of the dinar. Conversely, the coefficient of L_OIL(+) (-0.263) is negative, suggesting that a cumulative increase in oil prices tends to appreciate the dinar, but to a lesser extent . This asymmetry reflects the differentiated response of monetary authorities and the market depending on the direction of the oil shock.

Short-term coefficients

The table below shows the main short-term coefficients from the error correction mechanism.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECT_{t-1} (COINTEQ)	-0.548240	0.096972	-5.653602	0.0000
ΔL_EXR_{t-1}	0.594546	0.122449	4.855440	0.0000
ΔL_EXR_{t-2}	-0.049705	0.158870	-0.312868	0.7573
ΔL_EXR_{t-3}	0.323362	0.151866	2.129260	0.0447
ΔL_M2_t	0.489566	0.218391	2.241696	0.0354
ΔL_M2_{t-1}	-0.082872	0.044768	-1.851161	0.0776
ΔL_RES_{t-1}	0.291738	0.079507	3.669321	0.0013
ΔL_RES_{t-2}	0.142293	0.049593	2.869221	0.0089
$\Delta L_OIL_t^+$	0.329692	0.120028	2.746797	0.0118
$\Delta L_OIL_t^-$	0.105751	0.107231	0.986201	0.3348

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<i>D2020</i>	0.116552	0.086893	1.341324	0.1935
<i>D2022</i>	-0.561102	0.135119	-4.152660	0.0004

Note: Δ refers to the first difference operator. ΔL_OIL^+ and ΔL_OIL^- are the asymmetric components (positive and negative) of the change in oil prices. ECT_{t-1} corresponds to the error correction term, reflecting the adjustment towards long-term equilibrium.

Source: EViews output. Only the main coefficients are presented.

Instantaneous reactions to oil shocks

The coefficients of contemporary oil price variations reveal interesting short-term dynamics. The immediate impact of a rise in oil prices ($D(L_OIL(+))$) is both positive and statistically significant (0.330, $p < 0.05$), which paradoxically points to an instant depreciation of the dinar. This unexpected outcome can be attributed to several factors: (1) anticipations of future expansionary monetary policies in response to increased oil revenues, (2) the lagged effect associated with the conversion of oil revenues into foreign currency, or (3) the authorities' actions to sterilize the inflow of foreign currency.

In contrast, the impact of a reduction in prices ($D(L_OIL(-))$) is not statistically significant in the short run, suggesting that the adjustment mechanism for price declines requires a more extended period to manifest.

With regard to the influence of exogenous shocks (dummies), the variable *D2020*, which captures the effects of the COVID-19 pandemic, presents a positive coefficient of 0.117; however, this result does not reach statistical significance ($p = 0.19$).

This indicates that while the pandemic did coincide with a decline in the exchange rate, this impact does not stand out as statistically different from other influences when accounting for the price of oil, which saw a significant drop in 2020.

In contrast, the *D2022* variable for the war in Ukraine shows a negative and highly significant coefficient (-0.561, $p < 0.001$). This result indicates that in 2022, the dinar- appreciated exceptionally, probably

due to the surge in natural gas prices (of which Algeria is a major exporter) and the authorities' strengthened exchange control measures.

ECM term: speed of adjustment towards equilibrium

The error correction term coefficient (COINTEQ(-1)) is negative (-0.548) and highly significant ($p < 0.001$), confirming once again the existence of a cointegration relationship. This coefficient indicates that 54.8% of any deviation from long-term equilibrium is corrected within one year. This speed of adjustment is moderate, reflecting the structural rigidities of the Algerian economy and the administered nature of the exchange rate regime. A complete adjustment towards equilibrium therefore takes approximately 1.8 years ($1/0.548$).

Wald Test: confirmation of long-term asymmetry

The formal Wald test for asymmetry in the effects of oil prices provides statistical confirmation of the central hypothesis of this study.

Coefficient Symmetry Tests

Horizon	Test	Statistic	Value	Probability
Long-run	F-statistic	F(1,17)	6.130283	0.0241
	Chi-square	$\chi^2(1)$	6.130283	0.0133
Short-run	F-statistic	F(1,17)	0.010389	0.9200
	Chi-square	$\chi^2(1)$	0.010389	0.9188

Source: EViews output.

Hypotheses tested:

- **Long run:**
 $H_0: \theta_1^+ = \theta_1^-$ (symétrie de long terme)
- **Short run:**
 $H_0: \sum \pi_i^+ = \sum \pi_i^-$ (symétrie de court terme)

The results clearly show that the long-run symmetry hypothesis is rejected at the 5% level ($F = 6.130$, $p = 0.024$). This confirms that the long-run effects of oil price increases and decreases on the exchange rate are statistically different. However, the short-run symmetry hypothesis cannot be rejected ($F = 0.010$, $p = 0.920$), indicating that

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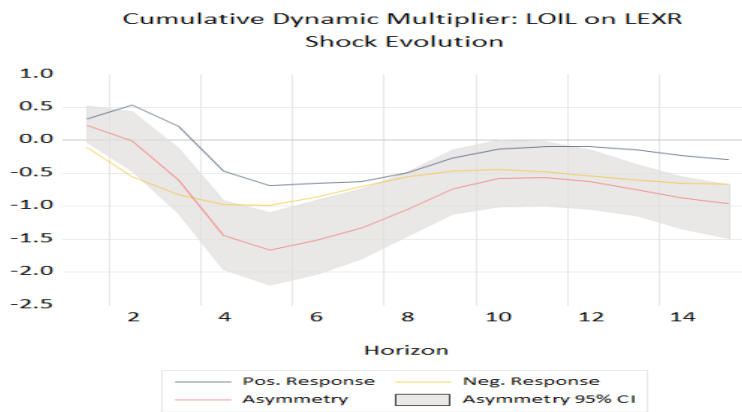
immediate adjustments are similar regardless of the direction of the shock.

4.4. Graphical analysis

Dynamic comparison of the effect of OIL+ vs. OIL–

The cumulative dynamic multipliers graph is the key visual tool for illustrating the asymmetry of oil price effects.

Figure D: Cumulative dynamic multiplier Shock



Source: EViews output. 15-year horizon.

This graph depicts the cumulative impact on the exchange rate resulting from a positive shock (represented by the blue line, labeled "Pos. Response") and a negative shock (indicated by the red line, labeled "Neg. Response") of one unit in the oil price. The yellow line serves to illustrate the asymmetry, highlighting the disparity between the two responses, while the shaded area represents the 95% confidence interval pertaining to this asymmetry.

Several important observations emerge:

- 1 **Clear visual asymmetry:** The response to a negative shock (price decrease) is significantly more pronounced in absolute terms than the response to a positive shock.

- 2 **Persistence of asymmetry:** The gap between the two responses widens over time and remains significant even over a 15-year horizon.
- 3 **Statistical significance:** The shaded area of the asymmetry does not contain zero for most of the horizon, confirming the statistical significance of the asymmetry.
- 4 **Economic interpretation:** A 1% drop in oil prices leads to a cumulative depreciation of around 1.8% of the dinar in the long term, while a 1% increase leads to an appreciation of only around 0.3%.

Symmetric cumulative dynamic multipliers (M2 and RES)

The following graphs show the dynamic multipliers for variables without asymmetry (M2 and RES).

Figure E: Cumulative dynamic multiplier

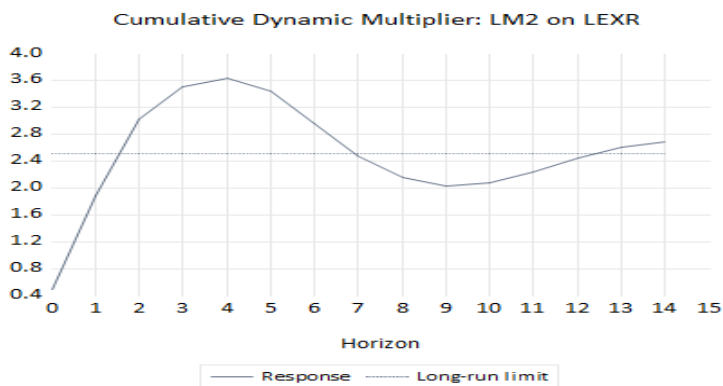
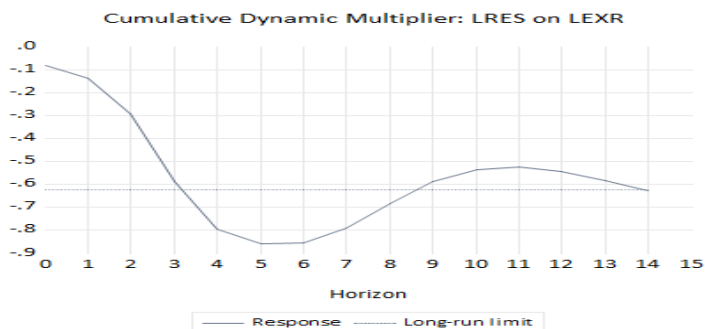


Figure F: Cumulative dynamic multiplier



Source: EViews output. 15-year horizon.

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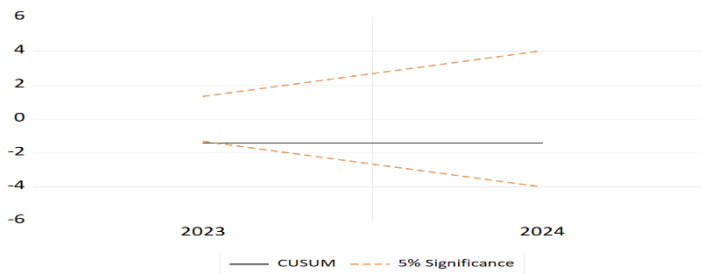
L_M2 multiplier (upper panel): The effect of money supply on the exchange rate is monotonic and increasing, reaching its long-term level of around 2.5 after 8-10 years. The trajectory is positive over the entire horizon, confirming the persistent depreciation effect of monetary expansion. The dotted line represents the long-term limit.

L_RES multiplier (bottom panel): The effect of international reserves is negative (appreciation of the dinar) and stabilizes at around -0.6 in the long term. The trajectory shows a relatively rapid adjustment, with most of the effect achieved in 5-6 years. The dotted line represents the long-term limit.

Model stability tests (CUSUM)

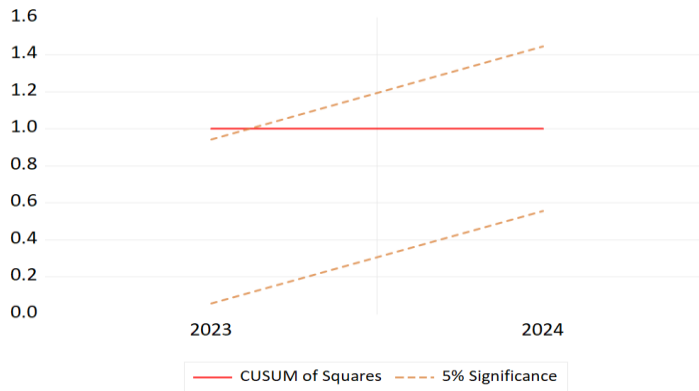
To ascertain the structural stability of the NARDL model that has been estimated, we employ graphical tests known as CUSUM and CUSUM of Squares. These tests are designed to identify any structural breaks or instabilities within the estimated parameters throughout the analysis period.

Figure G : CUSUM test



Source: EViews estimates, period 1985-2024

The CUSUM graph illustrates that the cumulative sum of recursive residuals, represented by the blue line, consistently falls within the 5% confidence intervals delineated by the red lines during the period of 2023-2024. This observation suggests that the estimated coefficients exhibit a degree of stability. Furthermore, the lack of any breaches of the critical bands reinforces the conclusion that there are no significant structural breaks present in the estimated relationship.

Figure H : CUSUM of Squares Test

Source: EViews estimates, period 1985-2024

The CUSUM of Squares test further corroborates the stability of the model, as evidenced by the statistic (illustrated by the red line) consistently remaining beneath the critical threshold of 5% (represented by the horizontal blue line). This particular test, noted for its heightened sensitivity to fluctuations in variance, affirms the resilience of the NARDL model while indicating that significant structural breaks were not present throughout the analysis spanning from 1985 to 2024. The findings regarding stability enhance the reliability of both the long-term and short-term coefficient estimates, as well as bolster the economic interpretation of the identified asymmetries.

Summary of model validation:

The diagnostic evaluations significantly confirm the validity of the estimated NARDL model. To address the autocorrelation revealed by the Breusch-Godfrey test, additional lags were introduced until the residuals exhibited no signs of autocorrelation. The verification of homoscedasticity and the normal distribution of the residuals further strengthens the dependability of the statistical conclusions drawn. CUSUM tests indicate that the coefficients maintain structural stability throughout the entire study period. In addition, the Bounds Test substantiates the existence of a cointegration relationship, while the

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Wald test reinforces the central hypothesis concerning the long-term asymmetry in the effects of oil prices. These results assure that the estimates retain their unbiased nature despite any potential infringements of the model's assumptions.

5. Discussion

5.1. Interpretation of Results

The findings derived from the NARDL model substantiate the presence of a stable long-term correlation among the nominal exchange rate of the Algerian dinar, oil prices, money supply, and international reserves, as demonstrated by the significant outcomes of the Bounds cointegration test. The negative and statistically significant coefficient associated with the error correction term ($ECM = -0.548$) indicates a relatively swift movement towards long-term equilibrium, suggesting that roughly 55% of any discrepancies are rectified within one time period. This observation underscores a pronounced dynamic in the exchange rate adjustment within Algeria, reflecting a strong reliance on fundamental macroeconomic variables.

From a monetary perspective, the long-term elasticity of the money supply ($M2$) is observed to be positive, substantial, and statistically significant. An increase of 1% in $M2$ is associated with a depreciation of the dinar exceeding 2.5% in the long term, revealing a magnifying influence of money creation on exchange rate movements. This heightened sensitivity implies the presence of non-neutral transmission mechanisms, which align with a context characterized by fiscal deficit monetization, currency substitution, and a lack of confidence in monetary policy.

In contrast, international reserves exhibit a pronounced stabilizing effect. The negative and significant coefficient indicates that an increase in reserves fosters a long-term appreciation of the dinar, reinforcing their role as a macrofinancial buffer. This outcome implies that reserves serve as a signal of external solvency and enhance the authorities' capacity to mitigate exchange rate fluctuations amid external shocks. When examining oil prices, the results reveal a structural asymmetry in the response to positive versus negative shocks.

Notably, cumulative declines in oil prices provoke a significant depreciation of the dinar, whereas price increases yield a more modest and less statistically robust appreciation effect. The Wald test corroborates that these impacts are distinct, validating the hypothesis of long-term asymmetry. This asymmetry reflects a differentiated response from both authorities and markets, contingent upon the type of oil shock encountered.

In the short run, the dynamics observed are more intricate. Counterintuitively, an increase in oil prices correlates with an immediate depreciation of the dinar. This seemingly paradoxical response may be interpreted as a reflection of anticipated expansionary monetary policies, delays in the conversion of oil revenues, or the partial sterilization effects stemming from currency flows. Conversely, negative oil price shocks generate rapid depreciation pressures, affirming the asymmetric vulnerability of the exchange rate.

5.2. Comparison with Previous Studies

These findings align broadly with existing empirical literature concerning oil-exporting nations. The observed depreciation effect of monetary expansion on the exchange rate corroborates the conclusions drawn by Boucekkine et al. (2021) for Algeria, as well as those of Malik and Umar (2019) for economies rich in resources. Similarly, the stabilizing influence of international reserves is consistent with the research conducted by Aizenman et al. (2024) and Coulibaly et al. (2024), which emphasizes their role as a self-insurance mechanism against external shocks.

The asymmetrical nature of the transmission of oil shocks is also supported by studies employing nonlinear frameworks. The results affirm that negative shocks tend to incur greater costs and exhibit greater persistence than positive shocks, as shown in the works of Baek (2021), Saidu et al. (2021), and Chekouri et al. (2021) pertaining to Algeria. However, this study advances the discourse by integrating monetary policy and international reserves within a cohesive NARDL framework, thereby enhancing the understanding of the observed partial dampening mechanisms.

Furthermore, the finding that increases in oil prices do not result in a symmetrical appreciation of the exchange rate aligns with the assertions put forth by Lv et al. (2018), which posit that the monetary authorities

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of exporting nations often seek to limit appreciation to maintain external competitiveness and build reserves. This asymmetric management of the exchange rate emerges as a critical factor elucidating the nonlinear adjustments observed.

5.3. Policy Implications

The insights garnered from this study carry significant implications for economic policy in Algeria. First, the pronounced sensitivity of the exchange rate to the money supply underscores the necessity for enhanced monetary discipline. Any monetary expansion that lacks backing through productivity gains or sustainable foreign exchange inflows risks exacerbating the depreciation of the dinar and perpetuating macroeconomic imbalances.

Second, the stabilizing role of international reserves highlights the importance of implementing a prudent reserve management strategy. Their deployment should aim not solely at smoothing short-term exchange rate fluctuations but also at bolstering the credibility of long-term economic policy. However, an overreliance on reserves as a stabilization mechanism may prove costly in the event of prolonged downturns in oil prices.

Third, the asymmetrical effects of oil shocks suggest that economic policies must be deliberately countercyclical. During periods of oil booms, it is imperative to accumulate reserves, diminish fiscal dependence on hydrocarbons, and curtail monetary expansion to enhance resilience against future adverse shocks. Conversely, in times of declining oil prices, close coordination among monetary, fiscal, and exchange rate policies is essential to avert disorderly adjustments in the exchange rate.

Lastly, these findings advocate for a macroeconomic policy framework that explicitly recognizes asymmetries, rather than adhering to implicit linear guidelines. Acknowledging the differentiated impacts of both positive and negative shocks would serve to improve exchange rate management and bolster macroeconomic stability in an economy that remains

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