

Analysis of the Behavioral Equilibrium Exchange Rate in Algeria (1994-2024): A BEER Approach Using the ARDL Model

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Abstract :

This study investigates Algeria's Behavioral Equilibrium Exchange Rate (BEER) using the ARDL modeling framework. The findings indicate that the Real Effective Exchange Rate (REER) exhibits strong persistence, responding significantly to short-term fluctuations in oil prices, whereas foreign exchange reserves show no immediate impact. Over the long term, the REER gradually converges to its equilibrium level, contributing to macroeconomic stability.

The ARDL-BEER approach demonstrates its usefulness in analyzing the key determinants of the exchange rate and supporting policy decisions. Additionally, the examination of misalignment highlights Algeria's exposure to external shocks, particularly oil price volatility, emphasizing the importance of policy measures aimed at stabilizing the exchange rate under such conditions

Keywords: BEER, ARDL, REER, Foreign Exchange Reserves, Oil Prices.

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Introduction:

The exchange rate is a pivotal variable in open economies, influencing external competitiveness, the allocation of resources, and the balance of payments. In economies heavily reliant on commodity exports, this role becomes even more pronounced, as exchange rate movements often reflect external shocks and the economy's adaptive capacity (MacDonald & Clark, Exchange rates and economic fundamentals: A methodological comparison of BEERs and FEERs, 1998, pp. 03-05)

Algeria's economy is structurally dependent on its hydrocarbon sector, with oil exports representing the main source of foreign currency earnings and a substantial portion of government revenue. This dependence makes the country particularly sensitive to fluctuations in international oil prices. Periods of high oil prices typically lead to an accumulation of foreign exchange reserves and improved external balances, whereas price downturns put pressure on liquidity and challenge the stability of the national currency (Abdenadir, 2025, pp. 315-317)

The Algerian exchange rate regime, characterized by administrative management and capital controls, limits the influence of market forces. Additionally, the presence of a parallel currency market indicates a divergence between the official and market-driven rates, raising important questions regarding the dinar's real equilibrium level.

Assessing the equilibrium exchange rate is therefore essential. An overvalued currency can undermine the competitiveness of non-hydrocarbon sectors and increase import dependence, while an undervalued rate could trigger inflation and internal imbalances. Identifying misalignment periods provides valuable guidance for economic policy and enhances macroeconomic coherence.

This study employs the Behavioral Equilibrium Exchange Rate (BEER) methodology, which links the real exchange rate to observable economic fundamentals and focuses on actual macroeconomic behavior rather than purely theoretical long-term projections.

The specific objectives are to:

- Identify the structural determinants of Algeria's real exchange rate.
- Estimate the long-term relationship between the dinar and its fundamentals using the ARDL model, capturing both short-term and long-term dynamics.
- Quantify the degree of exchange rate misalignment and assess its response to major economic shocks over recent decades.

By updating the equilibrium exchange rate estimates for Algeria in the context of volatile oil prices, fiscal adjustments, and shifting international conditions, this paper aims to contribute to discussions on the sustainability of the current exchange rate regime and offer insights for macroeconomic policy.

The remainder of the paper is structured as follows: the next section presents a theoretical and literature review, followed by the methodology and model specification, and then the empirical results and their implications.

I. Theoretical Framework and Literature Review:

This section outlines the theoretical foundations for analyzing the Behavioral Equilibrium Exchange Rate (BEER). It begins by reviewing both traditional and contemporary exchange rate theories, emphasizing models that link the real exchange rate to key macroeconomic determinants (MacDonald & Clark, Exchange rates and economic fundamentals: A methodological comparison of BEERs and FEERs, 1998, pp. 03-04)

Subsequently, the section examines previous empirical studies applying the BEER methodology to commodity-dependent economies, with particular attention to Algeria. This review highlights the existing research gaps that the current study seeks to address (Cashin, Céspedes, & Sahay, 2003, pp. 02-04).

1.Exchange Rate:

1.1. Approaches to the Equilibrium Exchange Rate:

In the economic literature, various methodologies have been proposed to determine the equilibrium level of the real exchange rate, each aiming to identify a value that is consistent with macroeconomic fundamentals and ensures external sustainability (Peter I. , 2007, pp. 10-20)

One of the classical approaches, Purchasing Power Parity (PPP), posits that, over the long term, the exchange rate adjusts to equalize the purchasing power between two countries. According to this theory, differences in inflation rates are the main drivers of changes in the nominal exchange rate (Taylor, 2002, p. 139)

However, in developing economies that experience structural rigidities and sector-specific specialization, PPP often fails to accurately capture the real equilibrium exchange rate (Corden & Neary, 1982, pp. 825-835)

The Fundamental Equilibrium Exchange Rate (FEER) approach, by contrast, defines the equilibrium exchange rate as the level that simultaneously achieves internal balance full employment without excessive inflation and external balance a sustainable current account position. While normative in nature and based on policy targets, FEER requires strong assumptions regarding the economy's equilibrium levels to be fully applicable (MacDonald, Concepts to calculate the equilibrium exchange rate, July 2000, p. 37).

Recognizing the limitations of normative approaches, empirical methods have been developed to estimate the equilibrium exchange rate using observed macroeconomic behavior. These techniques provide a more flexible framework that can adapt to the actual conditions of the economy, allowing for a context-specific assessment of exchange rate fundamentals.

1.2. The Behavioral Equilibrium Exchange Rate (BEER) Approach:

The Behavioral Equilibrium Exchange Rate (BEER) framework posits that the real exchange rate is fundamentally determined by macroeconomic variables that affect the economy in a sustainable way. Unlike the FEER approach, which is based on normative targets for the current account balance, BEER relies on econometric techniques to estimate the long-term relationship between the real exchange rate and its underlying determinants (MacDonald, Concepts to calculate the equilibrium exchange rate, July 2000, pp. 44-45) .

Key factors commonly incorporated in BEER models include terms of trade, relative productivity levels, net foreign assets, government spending, real interest rate differentials, and monetary indicators.

In economies highly dependent on commodities, the international price of the main export such as oil plays a particularly important role. Increases in commodity prices enhance the terms of trade, raise foreign currency inflows, and place upward pressure on the domestic currency. Conversely, declines in prices tend to reduce reserves and exert depreciation pressures (Sidi Mohammed & Abderrahim, 2016, pp. 02-10) .

One of the main advantages of the BEER approach is its flexibility, as it can be integrated with co-integration methods. This allows researchers not only to

capture a stable long-term relationship between the exchange rate and its fundamentals but also to examine short-term dynamic adjustments in response to economic shocks (MacDonald, Concepts to calculate the equilibrium exchange rate, July 2000, pp. 12-16).

1.3. Review of Empirical Studies and Specificities of Oil-Exporting Countries:

Empirical evidence from oil-exporting countries generally indicates a strong link between real exchange rate movements and fluctuations in oil prices. During periods of rising oil prices, the real exchange rate often appreciates, a phenomenon frequently associated with the so-called "Dutch disease". Conversely, extended periods of declining prices tend to exert downward pressure on the currency and necessitate macroeconomic adjustments. In countries where the exchange rate is administratively managed, such adjustments may occur gradually or only partially, leading to episodes of imbalance. In the case of Algeria, research emphasizes the central role of oil revenues, foreign exchange reserves, and fiscal policies in shaping the dynamics of the dinar (Abbes, 2014, pp. 278-282). Nevertheless, the findings vary depending on the period examined, the frequency of the data, and the methodologies employed.

The existence of a parallel currency market further underscores a divergence between the official exchange rate and the rate determined by market forces, highlighting the importance of empirically estimating the equilibrium exchange rate to detect potential distortions (Peter & Jonathan, 1993, pp. 1-3).

Against this backdrop, the present study applies the BEER methodology to the Algerian context, incorporating key external and monetary variables. The aim is to examine whether a stable long-term relationship exists between the real exchange rate and its underlying fundamentals, and to assess the magnitude and evolution of any observed misalignments.

2. Model Specification and Data Description:

Before introducing the econometric model, it is important to outline the empirical framework and the methodological choices that guide this analysis.

2.1. Choice of the Empirical Framework:

Given Algeria's strong reliance on hydrocarbon exports, the estimation of the equilibrium exchange rate is based on the Behavioral Equilibrium Exchange Rate (BEER) approach, which is particularly well-suited for rentier economies. Oil revenues constitute the main source of foreign currency, implying that fluctuations in global oil prices have a direct impact on foreign exchange reserves, external liquidity, and consequently, the behavior of the dinar (Souhir, 2024, pp. 19-20).

The analysis employs the Real Effective Exchange Rate (REER), a composite indicator that captures inflation differentials relative to Algeria's main trading partners. This choice provides a broader measure of external competitiveness than a simple bilateral exchange rate.

Within this framework, the real exchange rate is modeled as a function of key macroeconomic fundamentals that reflect both the structural characteristics of the Algerian economy and its external environment.

2.2. Econometric Specification:

The long-term relationship can be formulated as follows:

$$\text{LOG}(\text{REER}_t) = \alpha_0 + \alpha_1 \text{LOG}(\text{OIL}_t) + \alpha_2 \text{LOG}(\text{RES_US}) + \alpha_3 \text{LOG}(\text{GOV}_t) + \alpha_4 \text{LOG}(\text{M2}_t) + \varepsilon_t \dots \dots (1)$$

- REER: Real Effective Exchange Rate of the dinar,
- OIL: International oil price (Brent) (USD/baril) ,
- RES_US: Official foreign exchange reserves (USD billion),
- GOV: Government expenditures,
- M2: Money supply (USD billion).

All variables are expressed in natural logarithms (*LOG*) to interpret the coefficients as elasticities.

The statistical data employed in this study are primarily sourced from established international macroeconomic databases and official national institutions. Key variables, including the real effective exchange rate of the Algerian dinar (REER), the money supply (M2), and official foreign exchange reserves, were obtained from the World Bank's World Development Indicators and the International Monetary Fund's International Financial Statistics. (Bank, 2025) (Fund, 2025) (Algeria, 2025) ((ONS), 2025) (Bank, Commodity prices database (Brent crude oil), 2025)

To complement these series, additional national data published by the Bank of Algeria and the Office National des Statistiques were utilized, particularly for monetary and fiscal indicators. Data on the international Brent crude oil price (in USD per barrel) were collected from international commodity and energy statistics databases, including those maintained by the World Bank and other reputable global institutions.

2.3. Estimation Methodology: ARDL Approach

To examine the relationship between the real exchange rate and its fundamental determinants, the Autoregressive Distributed Lag (ARDL) modeling approach was selected. This decision is based on several features of the Algerian macroeconomic data:

- a. The time series under study exhibit a mixture of integration orders, including both I(0) and I(1) variables.
- b. The available dataset is relatively small, particularly since it consists of annual observations.
- c. The ARDL framework permits the joint estimation of long-term equilibrium relationships and short-term dynamics, and it is fully compatible with cointegration analysis.

The representation of the *ARDL model* is written as follows:

$$\text{LOG}(\text{REER}_t) = \alpha + \sum_{i=1}^p \beta_i \text{LOG}(\text{REER}_{t-i}) + \sum_{j=0}^{q_1} \gamma_j \text{LOG}(\text{OIL}_{t-j}) + \sum_{k=0}^{q_2} \delta_k \text{LOG}(\text{RES_US}_{t-k}) + \sum_{l=0}^{q_3} \theta_l \text{LOG}(\text{M2}_{t-l}) + \varepsilon_t \dots \dots (2)$$

The study period spans from 1994 to 2024, a relevant timeframe for analyzing the economic developments in Algeria, including:

- The devaluation and economic reforms of the 1990s,
- The period of sharp rise in oil prices (2000–2014),
- The oil shock of 2014,
- Recent economic adjustments.

The data used comes from reliable sources, including:

- Bank of Algeria for monetary statistics and foreign exchange reserves,
- National Office of Statistics,
- International databases.

2.5. Data Transformation:

In order to stabilize variance and allow for the interpretation of coefficients in elasticity terms, all quantitative variables used in this study have been converted into natural logarithms (LOG). This logarithmic transformation also mitigates the influence of extreme fluctuations and helps linearize the relationships among variables, thereby facilitating the estimation of the ARDL model and the analysis of both short-term and long-term dynamics.

2.6. Measurement of Misalignment:

Once the long-term relationship has been estimated, the equilibrium exchange rate is obtained from the adjusted ARDL model values. The degree of misalignment is then calculated as the difference between the actual exchange rate and the estimated equilibrium rate. This approach enables the identification of deviations of the currency from its theoretical equilibrium, highlighting periods of overvaluation or undervaluation. Such measures provide insights into existing imbalances and inform the assessment of potential corrective adjustments.

$$Mist_t = LOG(REER_t) - LOG(REER_t^{eq}) \dots \dots (3)$$

A positive gap indicates an overvaluation of the dinar, while a negative gap reflects an undervaluation.

3. Econometric Methodology:

The primary goal of this empirical study is to assess whether a stable long-term relationship exists between the Algerian dinar's real exchange rate and its macroeconomic determinants. Considering the particular characteristics of the Algerian time series and the relatively small sample size, the analysis employs the ARDL approach, complemented by cointegration testing and the estimation of an Error Correction Model (ECM) (Pesaran, Shin, & Smith, 2001, p. 291)

3.1. Stationarity Analysis of the Series:

Prior to estimation, it is essential to examine the statistical properties of the variables to determine their integration order. Macroeconomic series often exhibit non-stationary behavior, which can result in biased or inconsistent econometric outcomes if not properly addressed (Dickey & Fuller, 1979, p. 427) .

The stationarity of each variable was assessed using the Augmented Dickey-Fuller (ADF) test. applied both in levels and in first differences, taking into account the possible presence of a constant and a deterministic trend.

The ARDL framework is particularly useful as it accommodates variables integrated of order zero $[I(0)]$ and order one $[I(1)]$, but it is not suitable if any variable is integrated of order two $[I(2)]$. Therefore, this preliminary step is critical to ensure the data are compatible with the selected estimation methodology (Pesaran, Shin, & Smith, 2001, p. 291)

3.2. Specification and Estimation of the ARDL Model:

The Autoregressive Distributed Lag (ARDL) model is employed to capture the effects of both lagged values of the dependent variable and the explanatory variables simultaneously. This approach is particularly appropriate for analyses involving small datasets, such as the annual Algerian data used in this study (Pesaran, Shin, & Smith, 2001, pp. 292-295)

The procedure for estimating the ARDL model involves several key steps:

- Determining the optimal lag length for each variable based on information criteria, such as the Akaike Information Criterion (AIC) or the Schwarz Information Criterion (SIC) (Pesaran, Shin, & Smith, 2001, pp. 294-296).
- Estimating the ARDL model using the selected lag structure.
- Assessing the statistical significance of the estimated coefficients, both individually and collectively, to ensure robustness (Engle & Granger, 1987, p. 260).

This approach allows for the identification of short-term dynamics between the real exchange rate and its determinants, while accounting for potential interactions and adjustment processes among the variables.

3.3. Cointegration Test: Bounds Approach:

After estimating the ARDL model, the existence of a long-term relationship among the variables is evaluated using the Bounds testing procedure proposed by Pesaran, Shin, & Smith (2001, pp. 279–313).

The procedure tests the joint significance of the variables in their level form within the regression equation. The calculated F-statistic is then compared against two critical thresholds:

- Lower bound:** assumes that all variables are stationary at level $[I(0)]$.
- Upper bound:** assumes that all variables are integrated of order one $[I(1)]$.

If the F-statistic exceeds the upper critical bound, the null hypothesis of no long-term relationship is rejected, indicating cointegration. Conversely, if the F-statistic falls below the lower bound, evidence for cointegration is inconclusive (Pesaran, Shin, & Smith, 2001, pp. 299-303).

This step is essential for verifying that the Algerian dinar's real exchange rate aligns with its fundamental macroeconomic determinants over the long term.

3.4. Estimation of the Long-Term Relationship and Error Correction Model (ECM):

After confirming the presence of a cointegrating relationship among the variables, the long-term coefficients can be extracted from the estimated ARDL model. These coefficients indicate the responsiveness (elasticities) of the real exchange rate to changes in the underlying macroeconomic fundamentals.

The short-term dynamics are subsequently analyzed using an Error Correction Model (ECM). This framework enables the examination of how deviations from the long-term equilibrium are corrected over time, capturing the speed and pattern of adjustment in response to short-term shocks (Engle & Granger, 1987, pp. 251-252). The ECM can be expressed as follows:

$$\Delta \text{LOG}(\text{REER}_t) = \beta_0 + \sum \beta_i \Delta X_{t-i} + \lambda \text{ECT}_{t-1} + u_t \dots \dots (4)$$

where the term ECT_{t-1} represents the deviation from the long-term equilibrium.

he adjustment coefficient (λ) is expected to be negative and statistically significant, reflecting the speed at which the real exchange rate returns to its equilibrium level following a shock. In the context of Algeria, this coefficient provides an estimate of how rapidly the exchange rate responds to changes in external fundamentals, particularly those related to fluctuations in oil prices.

3.5. Diagnostic Tests:

To confirm the reliability and robustness of the estimated model, a series of diagnostic checks are conducted. These tests assess the stability of the model over the sample period and evaluate the strength of the long-term relationship, ensuring that the empirical findings are dependable and that the conclusions drawn are well-founded (Pesaran, Shin, & Smith, 2001, pp. 304-308).

II. Applied Framework:

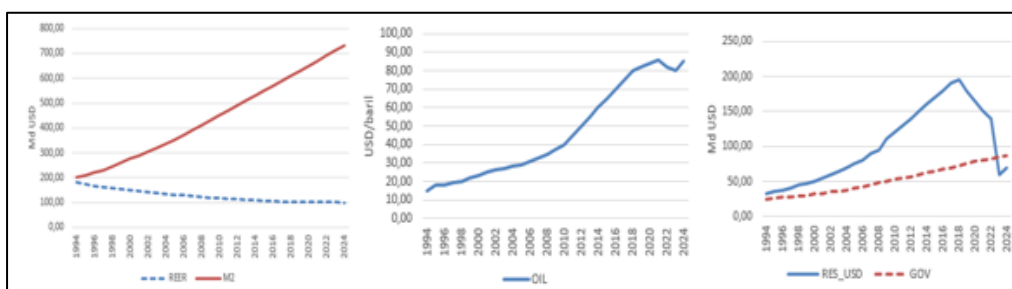
1. ARDL Modeling and Estimation:

This section focuses on the estimation of the ARDL model to investigate the dynamic interactions between the real exchange rate and its macroeconomic determinants. After defining the econometric framework and preparing the dataset, the objective is to capture both the short-term and long-term effects of the explanatory variables.

The ARDL methodology, well-suited for small sample time series, facilitates a clearer understanding of how the Real Effective Exchange Rate (REER) adjusts to changes in external factors, particularly fluctuations in oil prices. The analysis begins with the estimation of the ARDL model, followed by a detailed examination and interpretation of the results obtained.

1.1. Preliminary Descriptive Analysis:

The oil price, with an average around 50 USD/barrel and significant fluctuations reaching over 85 USD/barrel, illustrates the volatility of the global market and its direct impact on the Algerian economy. Foreign exchange reserves experienced steady growth until peaking at nearly 190 billion USD in 2017, before declining following the 2014 oil shock. The money supply (M2) also grew rapidly, reflecting the expansion of liquidity fueled by oil revenues and public spending, which nearly doubled over the period.

Graph 01: Overview of Raw Variables for Econometric Analysis.

Source : Graph produced by the authors using data from various sources (World Bank, IMF, Bank of Algeria, ONS).

This evolution reveals an economy heavily dependent on oil revenues, where monetary and fiscal policies closely follow the cycles of the energy sector. While the increase in public spending supported investments and growth, the volatility of oil prices exposes the country to macroeconomic and fiscal risks, particularly visible after 2014.

Table 01: Descriptive Statistics of Model Variables.

	Mean	Stan. Dev.	Min.	Max.	Variance
REER	130.90	19.27	98.50	183.10	371.39
OIL	50.47	21.84	15.00	86.000	477.11
RES_USD	122.89	47.27	32.90	190.0	2230.33
M2	434.67	152.29	200.00	730.00	23191.11
GOV	49.27	21.96	25.00	87.00	482.34

Source : Statistics computed by the authors using data from multiple sources (World Bank, IMF, Bank of Algeria, ONS).

In conclusion, this analysis highlights the need for Algeria to diversify its economy to reduce its vulnerability to oil shocks, while optimizing the management of foreign exchange reserves and monetary policy to maintain sustainable macroeconomic stability.

1.2. Multicollinearity Analysis:

The study of multicollinearity is crucial for ensuring the reliability of estimates in an econometric model. It helps detect highly correlated variables, whose influence on the dependent variable may be difficult to isolate, thus ensuring the validity of the conclusions drawn from the model.

The analysis of the correlation matrix reveals that LOG_OIL, LOG_GOV, and LOG_M2 are strongly correlated with each other (ranging from 0.988 to 0.998). This strong correlation suggests significant multicollinearity, meaning these variables evolve similarly. Therefore, their individual effects on the BEER would be difficult to isolate within the ARDL model.

On the other hand, LOG_RES_USD shows a moderate correlation with the other variables (ranging from 0.498 to 0.548). This moderate correlation allows LOG_RES_USD to retain an independent explanatory value, making it a key variable for analyzing the REER without introducing issues of redundancy.

Variables to Retain:

- Retain LOG_RES_USD: it provides a distinct and economically relevant effect on the REER.
- Retain LOG_OIL (or LOG_GOV / LOG_M2) as a representative of oil revenues and their macroeconomic impacts:
 - Justification: including all three would create multicollinearity.
 - LOG_OIL is often preferred as it directly reflects the origin of revenues that feed into M2 and GOV.

This selection helps to reduce multicollinearity while maintaining the essential economic information needed for analyzing the *REER*.

Table 02: Correlation Matrix of Model Variables

Variable	LOG_OIL	LOG_RES_USD	LOG_GOV	LOG_M2
<i>LOG_OIL</i>	1	0.498	0.992	0.988
<i>LOG_RES_USD</i>		1	0.526	0.548
<i>LOG_GOV</i>			1	0.998
<i>LOG_M2</i>				1

Source : Analysis performed by the authors using data from various sources (World Bank, IMF, Bank of Algeria, ONS).

1.3. Stationarity Test:

Before estimating the *ARDL model*, it is crucial to verify the stationarity of the series used to avoid misleading econometric results. Unit root tests, particularly the *ADF* test, were applied to the variables in their level form and in their first difference. The obtained results are satisfactory and confirm that the selected series are suitable for the *ARDL approach*.

The results of the ADF test at level for the LOG_REER, LOG_RES_USD, and LOG_OIL series show that all p-values are greater than 0.05:

- LOG_REER: p-value = 0.7531
- LOG_RES_USD: p-value = 0.6609
- LOG_OIL: p-value = 0.8747

This means that we do not reject the null hypothesis of a unit root. In other words, all the series are non-stationary at level, suggesting that they need to be differentiated to become stationary (most likely of type *I(1)*).

The results of the ADF test on the differenced series show:

- D(LOG_REER): p-value = 0.0037, less than 0.10 so stationary at 10% significance
- D(LOG_RES_USD): p-value = 0.0889, less than 0.10 so stationary
- D(LOG_OIL): p-value = 0.0129, less than 0.10 so stationary

Therefore, all the selected series (LOG_REER, LOG_RES_USD, and LOG_OIL) become stationary after the first difference (*I(1)*), making them suitable for ARDL model estimation.

1.4. Estimation of the ARDL Model:

Once the stationarity tests and multicollinearity checks have been performed, the next step is to estimate the *ARDL* model to analyze the short-term and long-term dynamics between the real exchange rate and its macroeconomic fundamentals. This approach allows for the simultaneous capture of both immediate effects and long-term adjustments, while considering the specificities of the Algerian economy.

The estimated model is an *ARDL*(1,0,1), where the real exchange rate is explained by its lagged values, foreign exchange reserves (*LOG_RES_USD*), and oil prices (*LOG_OIL*), with appropriate lags for each variable. This specification captures both the short-term dynamics (via the differenced variables) and the long-term relationships (via the level variables). We will now proceed with the analysis of the estimated coefficients, examining their significance and their impact on the real exchange rate, to better understand the immediate and durable effects of the explanatory variables.

Table 03: Analysis of the Coefficients:

Variable	Coefficient	p-value	Interpretation
LOG_REER(-1)	0.898	0.0000	Strong persistence effect of the <i>REER</i> : The long-term <i>BEER</i> depends heavily on its past value.
LOG_RES_USD	-0.0044	0.5289	Insignificant direct effect of foreign exchange reserves on the <i>BEER</i> in the short term.
LOG_OIL	-0.0871	0.0600	Marginally significant effect: An increase in oil prices tends to depreciate the <i>BEER</i> in the short term ($p \approx 0.06$).
LOG_OIL(-1)	0.0702	0.1995	Insignificant delayed effect.
Constant (C)	0.5597	0.1920	Insignificant, marginal interpretation.

Source : Analysis performed by the authors using data from various sources (World Bank, IMF, Bank of Algeria, ONS)

This table provides an overview of the coefficient estimates for the *ARDL* model, interpreting their significance and economic implications. The real exchange rate (*LOG_REER*) shows a strong persistence effect, meaning that the past value of the exchange rate strongly influences its current level. On the other hand, foreign exchange reserves (*LOG_RES_USD*) have no significant direct impact on the *BEER* in the short term.

Oil prices (*LOG_OIL*) have a marginally significant negative impact on the *BEER*, indicating that an increase in oil prices tends to depreciate the exchange rate in the short term. The delayed effect of oil prices is insignificant. Lastly, the constant is not significant, indicating it does not have a meaningful impact on the model's results.

Also, the results of the *ARDL* model estimation show that the R^2 is close to 0.998, indicating that the model explains almost all of the *BEER* variation. The *Durbin-Watson* statistic is 1.52, suggesting a slight autocorrelation of the residuals, which requires careful attention. Finally, the F-statistic is highly significant,

confirming that the model is overall significant and that the included variables effectively explain the phenomenon being studied.

In general, the analysis of the model shows that the *REER* is highly autocorrelated, with its past level explaining almost entirely its current level. In contrast, foreign exchange reserves (*LOG_RES_USD*) do not have a significant short-term effect on the *REER*, suggesting that their immediate impact is limited. As for oil prices (*LOG_OIL*), their effect is marginal: an increase in oil prices tends to slightly depreciate the *REER*, but this effect is not robust at the 5% significance level. Despite this, the model is overall very effective in explaining the *REER* dynamics, although the economic interpretation of the explanatory variables is partially limited by the high persistence of the *REER*, which masks the individual impact of other factors.

1.5 Structural Breaks and Model Specification:

The Algerian economy over the period 1994–2024 has been subject to important structural changes, notably the 2014 oil price collapse and the COVID-19 shock in 2020, which may have affected macroeconomic relationships. To control for these potential regime shifts, two dummy variables (*D2014* and *D2020*) are introduced in the *ARDL* model.

The estimation results show that both dummies are not statistically significant, suggesting that their direct effect is limited once key fundamentals are included. However, their inclusion remains important to account for possible structural changes and to improve the robustness of the estimated relationships.

Overall, these controls ensure that the *ARDL* results are not biased by major economic shocks and reinforce the reliability of the model over the full sample period.

1.6. Cointegration Test (F-Bounds):

To confirm the existence of a long-term relationship between the real exchange rate and its macroeconomic fundamentals, a cointegration test is performed using the F-Bounds method. This test allows us to examine the joint significance of the variables in their level form and determine whether a stable relationship exists between the variables over the study period, taking into account the characteristics of their short-term and long-term dynamics.

The F-Bounds test provides an F-statistic of 15.11, which is greater than the upper bound *I(1)* for the 1%, 5%, and 10% significance levels in the finite sample ($n=30$). This indicates that we reject the null hypothesis of no cointegration.

The results of the cointegration test show that there is a significant long-term relationship between *LOG_BEER*, *LOG_RES_USD*, and *LOG_OIL*. This suggests that macroeconomic fundamentals have a lasting impact on the real exchange rate. Moreover, the estimated *ARDL* model shows long-term stability, allowing us to proceed to the next step: estimating an *ECM* model to analyze the short-term adjustment and observe how the *REER* responds to changes in short-term economic determinants.

1.7. ECM Estimation for D(LOG_REER):

Once the long-term relationship is confirmed, it is essential to analyze the short-term adjustment of the real exchange rate ($D(LOG_REER)$). This analysis is conducted through the estimation of an Error Correction Model (ECM), which captures the dynamic adjustment of the *REER* to short-term imbalances relative to its long-term equilibrium level. Estimating the *ECM* will allow us to examine the immediate effects of changes in the explanatory variables on the *REER* and measure the speed of adjustment towards equilibrium.

Table 04: Summary of Results of ECM Estimation.

Variable	Coefficient	p-value	Interpretation
D(LOG_OIL)	-0.0871	0.0084	Negative and significant short-term effect. A 1% increase in oil prices leads to a 0.087% decrease in the BEER.
ECT_{t-1}	-0.1023	0.0000	The Error Correction Term (<i>ECM</i>) is significant and negative, indicating that the model adjusts the <i>REER</i> to its long-term equilibrium at a rate of 10.23% per period.

Source : Analysis performed by the authors using data from various sources (World Bank, IMF, Bank of Algeria, ONS)

The global statistics of the ARDL model reveal an adjusted R^2 of 0.6877, meaning that the model explains 68.77% of the variation in the REER in the short term. The Durbin-Watson statistic is 1.518, indicating slight autocorrelation of the residuals, which warrants attention. Furthermore, the p-value for ECT_{t-1} is 0.0000, confirming the existence of a significant long-term relationship between the REER and its determinants.

The short-term effect of LOG_OIL shows that oil prices have a negative and significant impact on the REER, suggesting that an increase in oil prices tends to depreciate the REER in the short term. The Error Correction Term (ECT_{t-1}) is also significant and negative, indicating that the economy adjusts the REER by 10.23% per period to return to long-term equilibrium after a shock. Finally, the ARDL model is generally very effective, explaining a substantial portion of the short-term variation in the REER (68.77%) and demonstrating strong long-term stability.

1.8. Short-Term Adjustments and Convergence to Long-Term Equilibrium:

This section focuses on the analysis of the short-term adjustments of the real exchange rate and its convergence to the long-term equilibrium. Using the Error Correction Model (ECM), we will examine how the REER responds to short-term economic shocks and the speed at which it returns to its long-term equilibrium level, particularly after external disturbances, such as fluctuations in oil prices.

a. Short-Term Adjustments: In our ECM model, the coefficient for D(LOG_OIL) is -0.0871 with a p-value of 0.0084, indicating that a 1% increase in the price of Brent oil leads to an immediate 0.087% decrease in the REER. This effect is statistically significant at 1%, confirming that the REER reacts quickly to changes in oil prices. On the other hand, D(LOG_RES_USD) does not appear in the final ECM model, suggesting that its short-term variations do not have a significant immediate effect on the REER.

In conclusion, in the short term, the REER is highly sensitive to oil price fluctuations, with shocks to the oil price leading to an immediate response in the real exchange rate. However, foreign exchange reserves do not have a direct short-term effect on the REER in this model.

b. Convergence to Long-Term Equilibrium: The coefficient of the error correction term (ECT(-1)) is negative (-0.1023) and statistically significant, confirming the existence of a stable long-run equilibrium relationship among the variables. This result indicates that any short-run deviation of the real effective exchange rate from its equilibrium path is corrected over time.

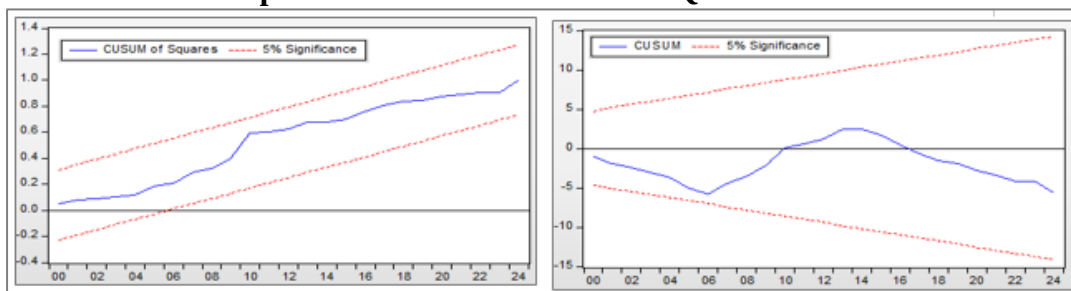
The magnitude of the coefficient implies a speed of adjustment of approximately 10.23% per period. In practical terms, this means that around one-tenth of any disequilibrium is eliminated within each period. Consequently, the full adjustment process toward long-run equilibrium requires approximately 9 to 10 periods to completely absorb the effect of an external shock.

This relatively moderate adjustment speed suggests that the Algerian real exchange rate exhibits partial but gradual convergence toward its equilibrium level following shocks such as oil price fluctuations. While the system is not fully instantaneous in its correction mechanism, it demonstrates a stable and self-correcting behavior in the long run, reflecting a degree of macroeconomic resilience.

1.9 Stability of the Model (CUSUM and CUSUMSQ Tests):

The stability of the estimated ARDL model is assessed through the CUSUM and CUSUM of Squares (CUSUMSQ) tests.

Graph 02: CUSUM and CUSUMSQ Tests results



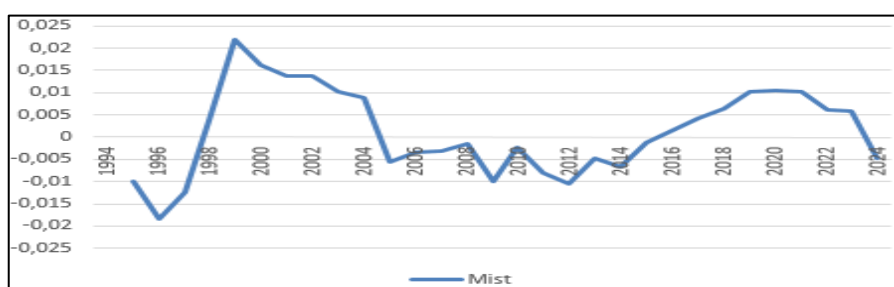
Source : Graph produced by the authors using data from various sources (World Bank, IMF, Bank of Algeria, ONS).

The results, graph 02, upper, indicate that both statistics remain within the 5% critical bounds over the entire sample period, suggesting that the estimated parameters are structurally stable. In particular, the CUSUM test confirms the stability of the regression coefficients, while the CUSUMSQ test indicates the absence of significant instability in the variance of the residuals. Overall, these findings provide strong evidence that the model is well specified and stable over time, reinforcing the reliability of the estimated short-run and long-run relationships for the period 1994–2024.

1.10. Measuring the Degree of Exchange Rate Misalignment and Analyzing Its Evolution in Response to Major Economic Shocks in Recent Years:

This section focuses on measuring the degree of misalignment of the real exchange rate (BEER) relative to its equilibrium level, by analyzing the gaps between the observed exchange rate and the exchange rate estimated from the model. The evolution of these misalignments is then examined in light of the key economic shocks that have affected the Algerian economy, such as oil price volatility and budgetary adjustments due to the decline in oil prices since 2014. This analysis helps assess the impact of external fluctuations on the REER and identify periods when the currency was overvalued or undervalued, as well as the necessary adjustments to restore equilibrium.

Graph 03: Evolution of REER Misalignment.



Source : Graph produced by the authors

The misalignment values (the gap between the observed and estimated exchange rates) show a fluctuating evolution of the REER over the years, indicating periods of both overvaluation and undervaluation of the dinar relative to its equilibrium level.

a. Periods of overvaluation (positive values):

a.1. 1998 to 2001, with positive gaps: This suggests a slight overvaluation of the dinar, indicating that the observed exchange rate was higher than the estimated equilibrium level.

a.2. 2003 to 2005 shows a similar trend with gaps ranging from 0.0037 to 0.0162.

b. Periods of undervaluation (negative values):

b.1. 1995 to 1997, marked negative misalignments suggest that the dinar was likely undervalued relative to its equilibrium level.

b.2. 2008 to 2014, the undervaluation continues, indicating a period when the real exchange rate was lower than the estimated level, likely in response to external shocks, particularly the decline in oil prices.

c. Recent periods (2016 to 2024):

c.1. The misalignment becomes more moderate, oscillating around 0.0016 to 0.0105, suggesting that the dinar is gradually adjusting towards its equilibrium level after the 2014 shocks. However, the slight persistent undervaluation observed may reflect macroeconomic adjustment processes in response to global oil market fluctuations, as well as policy responses aimed at maintaining external competitiveness and overall macroeconomic stability.

The periods of negative misalignment seem to coincide with oil price shocks or budgetary adjustments, especially during the decline in oil prices after 2014. Conversely, the periods of overvaluation may be associated with phases of higher hydrocarbon revenues and more expansionary macroeconomic conditions.

In conclusion, the misalignment of the REER shows significant volatility, heavily influenced by oil price fluctuations and internal economic adjustments. The analysis reveals an economy that remains sensitive to external shocks but that progressively adjusts towards a long-term equilibrium. This underscores the importance of economic diversification and prudent management of foreign exchange reserves to mitigate the effects of external volatility on macroeconomic stability, within the framework of national macroeconomic policy choices.

Conclusion:

The main objective of this study was to estimate the Behavioral Equilibrium Exchange Rate (BEER) for Algeria using the ARDL methodology, considering key macroeconomic variables such as oil prices, foreign exchange reserves, and other relevant economic indicators. This approach allows for the simultaneous assessment of short-term determinants and the adjustment process toward the long-term equilibrium of the Real Effective Exchange Rate (REER).

The empirical analysis highlighted strong interrelations among certain macroeconomic variables, necessitating a careful selection of explanatory variables to mitigate multicollinearity. Stationarity tests confirmed that the series were integrated of order one, supporting the application of the ARDL framework for examining long-term relationships.

Key findings from the ARDL and ECM estimations include:

- The REER exhibits high persistence, indicating that its past values play a significant role in explaining current levels.
- In the short term, fluctuations in oil prices exert a significant impact on the REER, demonstrating the direct effect of external shocks on the Algerian economy. In contrast, foreign exchange reserves did not show an immediate significant effect, suggesting that other macroeconomic instruments take longer to influence the exchange rate.
- Over the long term, the REER systematically converges toward its equilibrium, with the error correction mechanism gradually rectifying temporary deviations and maintaining currency stability.

The REER misalignment analysis shows alternating periods of overvaluation and undervaluation, mainly driven by oil price fluctuations. Overvaluation dominated during the oil boom period (2000–2014), while the 2014 oil shock led to a sustained undervaluation, highlighting Algeria's exposure to external commodity cycles. In recent years, the gradual narrowing of misalignment suggests a slow adjustment toward equilibrium, reflecting a moderate convergence process of the exchange rate within a macroeconomic stabilization framework.

Overall, the combination of the ARDL model and the BEER approach proves to be a robust framework for understanding the dynamics of Algeria's REER. The

findings provide valuable insights into the interactions between external shocks, foreign reserves, and macroeconomic adjustments, offering a solid foundation for guiding exchange rate policies and evaluating long-term economic stability. Moreover, the misalignment analysis underscores the importance of diversifying the economy and enhancing the management of foreign exchange reserves to reduce vulnerability to oil price shocks and promote sustainable macroeconomic stability.

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