

**Estimating the Real Equilibrium Exchange Rate of the Algerian Dinar
During the Period (1990-2022) Using the Autoregressive Distributed Lag
Model (ARDL)**

تقدير سعر الصرف الحقيقي التوازني للدينار الجزائري خلال الفترة (1990-2022)

باستخدام نموذج الانحدار الذاتي للإبطاء الزمني الموزع (ARDL)

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Abstract:

This study aims to estimate the real equilibrium exchange rate of the Algerian dinar during the period of (1990-2022), relying the Behavioral Equilibrium Exchange Rate (BEER) model and using the Autoregressive Distributed Lag (ARDL) model. The results reveal that factors such as oil price, productivity, trade openness, and US dollar have a significant impact on real exchange rate in Algeria in the long run. Additionally, the results identified periods where the real exchange rate deviated from its equilibrium level. And this study recommends the adoption of structural reforms to boost productivity in the non-oil sector and to unify the foreign exchange market in order to stabilize the real exchange rate in Algeria.

Keys words: real exchange rate ; equilibrium; Algeria; BEER model; ARDL model.

JEL classification codes: E58, F31, F33.

ملخص:

تهدف هذه الدراسة إلى تقدير سعر الصرف الحقيقي التوازني للدينار الجزائري خلال الفترة (1990-2022)، بالاعتماد على نموذج سعر الصرف التوازني السلوكي (BEER) وباستخدام نموذج الانحدار الذاتي للإبطاء الزمني الموزع (ARDL). وقد دلت نتائج الدراسة إلى أن العوامل المتمثلة في كل من سعر النفط، الإنتاجية، معدل الانفتاح التجاري وسعر صرف الدولار تؤثر على المسار التوازني لسعر الصرف الحقيقي للدينار الجزائري على المدى الطويل. كما توصلت الدراسة إلى تسجيل انحراف لسعر الصرف الحقيقي عن مستواه التوازني، تراوح بين التقييم المفرط والمتدني للدينار الجزائري. وأوصت الدراسة بضرورة تبني إصلاحات هيكلية لرفع الإنتاجية في القطاع الانتاجي خارج النفط، وتوحيد سوق الصرف الأجنبي لضمان استقرار سعر الصرف الحقيقي للدينار الجزائري.

الكلمات المفتاحية: سعر الصرف الحقيقي؛ توازني؛ جزائر؛ نموذج BEER؛ نموذج ARDL.

تصنيف JEL: F33, F31, E58 .

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1-Introduction

The real exchange rate is one of the important indicators used to measure the competitiveness of exports in foreign markets, and it is also an indicator for the optimal allocation of resources among economic sectors. Its deviation from the long-term equilibrium level is a central concern in economic discussions due to the negative effects it has on various economic variables such as growth, employment, inflation, and balance of payments equilibrium.

Therefore, all countries aim to address the imbalance of the real exchange rate, as it is one of the basic conditions for improving economic performance and ensuring its stability. This process requires estimating the real equilibrium exchange rate by identifying the factors that explain its behavior in the long term.

Considering Algeria as a developing country suffering from excessive dependence on the oil sector and significant geographical concentration on the European Union, where it serves as a launchpad for exports and a source of imports, this creates difficulties in managing the exchange rate by increasing the risks of its value deviating from its equilibrium level. Therefore, the importance of this study emerges in estimating the equilibrium path of the real exchange rate of the Algerian dinar by identifying the factors controlling its behavior in the long term.

Study Problem:

The study's problem is highlighted in the following fundamental question:

- What are the determinants of the real equilibrium exchange rate of the Algerian dinar during the period (1990-2022)?
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Hypotheses:

To answer this question, we formulated the following hypotheses:

- The price of oil has a positive effect on the real equilibrium exchange rate of the Algerian dinar.
- Trade openness negatively affects the real equilibrium exchange rate of the Algerian dinar.

Study Objectives:

The study aims to estimate the real equilibrium exchange rate of the Algerian dinar using the Behavioral Equilibrium Exchange Rate (BEER) model, by estimating the actual real exchange rate as a function of the fundamentals explaining it using the Autoregressive Distributed Lag Model (ARDL).

Study Methodology:

In our research, we relied on the descriptive analytical approach when presenting the various approaches used in estimating the reference level of the real exchange rate, alongside quantitative methods using the Autoregressive Distributed Lag Model (ARDL) to estimate the equilibrium path of the real exchange rate of the Algerian dinar during the period (1990-2022).

2- (Theoretical Framework and Literature Review:**2-1 Look at Approaches to Estimating the Real Equilibrium Exchange Rate:**

The behavior of the real exchange rate is determined by a suitable set of nominal and real variables, where the latter, known as economic fundamentals, play a crucial role in determining the long-term real equilibrium exchange rate that achieves internal and external balances. This is often estimated using three different approaches.

The Fundamental Equilibrium Exchange Rate (FEER) Approach:

In 1985, J. Williamson proposed a new concept for the equilibrium exchange rate called the Fundamental Equilibrium Exchange Rate (FEER), which is defined as the actual real exchange rate that simultaneously achieves internal and external balance in the medium term. Internal balance is achieved when output reaches the level of full utilization of production factors without causing inflationary pressures, while external balance is achieved by reaching a sustainable level of the current account.

This approach aims to estimate the equilibrium exchange rate under a set of ideal economic conditions, abstracting from short-term cyclical factors and primarily focusing on the ideal level of economic fundamentals, thus considering the Fundamental Equilibrium Exchange Rate as an ideal benchmark for estimating the equilibrium exchange rate.

This approach requires estimating sustainable values for transactions, which necessitates imposing self-imposed restrictions on estimating these values. As a result, this process can lead to an inaccurate estimation process for the Fundamental Equilibrium Exchange Rate. Moreover, the approach assumes that the current real exchange rate is approaching its fundamental equilibrium level without explaining how this convergence occurs.

The Dynamic Approach: The Natural Real Exchange Rate (NATREX)

Stein and Allen in 1997 developed the approach of the Natural Real Exchange Rate. The natural real exchange rate is defined as the normal rate of exchange that ensures the balance of payments equilibrium in the absence of

cyclical factors (output at its potential level), speculative capital flows, and changes in foreign exchange reserves (bouveret & Sterdyniak, 2005, p. 253).

This approach does not rely on a single model for the natural real exchange rate but on a set of models adapted according to the characteristics of the economy under study. These models depend on a rigorous theoretical framework using principles of intertemporal optimization under uncertainty to describe the behavior of economic agents.

Although the NATREX approach allows for the estimation of the long-term equilibrium real exchange rate process, which helps measure the extent of deviation of the real exchange rate from its equilibrium level and identify periods of overvaluation and undervaluation of the currency, its assumptions are sometimes vague and unfounded, such as the assumption of labor market equilibrium, wage and price adjustment dynamics, and the assumption of exchange rate stability expectations by economic agents.

The Econometric Approach: The Behavioral Equilibrium Exchange Rate (BEER)

The Behavioral Equilibrium Exchange Rate (BEER) approach is an extension of the work by Edwards during 1989 and 1994, proposed by Clark & MacDonald (1999) as a basis for measuring the equilibrium exchange rate based on estimating the actual real exchange rate as a function of the current important values or fundamentals explaining it using econometric methods.

In this approach, the concept of equilibrium is not derived from the macroeconomic equilibrium as in previous approaches but is determined by a suitable set of variables explaining its behavior. According to this approach, the real exchange rate reaches equilibrium when its movements reflect changes occurring in its determinants (Zhang, 2001, p. 83).

The model for the Behavioral Equilibrium Exchange Rate approach can be succinctly represented as follows:

$$\mathbf{RER}_t = \beta_1 \mathbf{Z}_{1t} + \beta_2 \mathbf{Z}_{2t} + \beta_3 \mathbf{T}_t + \epsilon_t$$

where:

RER_t : The current real exchange rate;

Z₁ : Vector of economic fundamentals expected to continue affecting in the long term;

$\mathbf{Z}_2$: Vector of economic fundamentals affecting the real exchange rate in the medium term;

$\mathbf{T}_t$: Vector of factors affecting the real exchange rate in the short term;

$\beta_1, \beta_2, \beta_3$: Vectors of parameters for the simplified model;

ϵ_t : The random error.

The equation above shows that the real exchange rate is explained by a set of real variables, another set of nominal variables, in addition to the random error.

This approach is significant for countries experiencing radical changes in economic fundamentals in the short term, making it a go-to for economic policymakers in many developing countries to estimate the appropriate exchange rate level for achieving macroeconomic equilibrium. However, the lack of a theoretical framework defining the determinants of the equilibrium exchange rate reduces the use of this approach.

2-2 Previous Empirical Studies

Numerous empirical studies have addressed the topic of estimating the long-term equilibrium real exchange rate path by identifying the factors that explain it. These studies have yielded varied results in determining these factors.

(Madouri, 2022) estimated the real equilibrium exchange rate of the Algerian dinar for the period (1980-2019) using the Autoregressive Distributed Lag Model (ARDL) and concluded that the factors controlling the long-term behavior of the real exchange rate include: oil prices, trade openness, productivity differentials, and government consumption expenditure. The study also found that the Algerian dinar deviated from its equilibrium level, ranging between overvaluation and undervaluation of the Algerian dinar.

The study by (Mahfoud & ben mazzouz, 2021) attempted to estimate the long-term path of the real exchange rate of the Algerian dinar for the period (1986-2019) using the Autoregressive Distributed Lag Model (ARDL). The study revealed a statistically significant long-term effect of oil prices, trade openness, productivity differentials, and the exchange rate of the dinar in the parallel market on the real exchange rate of the Algerian dinar.

The study by (Benaou jaafr, 2017), using Johansen's (1988) cointegration test and the Error Correction Model (ECM) for the period (1980-2015), found a

significant long-term effect of the terms of trade, trade openness, and government spending on the real exchange rate of the Algerian dinar against the US dollar.

(Koranchelian, 2005) estimated the real equilibrium exchange rate for Algeria during the period (1970-2003), based on the model by (Cashin, Céspedes, & Sahay, 2002) and using Johansen's (1988) cointegration test and the Error Correction Model (ECM). The results indicated that the real equilibrium value of the Algerian dinar is affected by changes in the real oil price and productivity differentials. The study also recorded periods of deviation of the real exchange rate from its equilibrium level, although it remained close to its equilibrium level at the end of 2003.

3- Estimating the Real Equilibrium Exchange Rate of the Algerian Dinar

3-1 Method and Tools:

The Behavioral Equilibrium Exchange Rate (BEER) model is most suitable for developing countries like Algeria, where comprehensive and complex models are not feasible due to the scarcity of long-term statistical data for variables. Based on previous studies and the specifics of the Algerian economy, the following variables were selected:

The actual real exchange rate of the Algerian dinar (REER), (100=2003), indicating an increase in the real value of the Algerian dinar, sourced from the International Financial Statistics (IFS) database;

Oil price, given the dominance of oil in exports, uses the OPEC basket price (POIL) as a proxy for the terms of trade, obtained from the OPEC database;

Trade openness, usually represented by the trade openness index (TO), to show the effect of foreign trade policy on the real exchange rate, data extracted from the World Bank database;

Productivity, using real per capita income as a proxy for Algerian individual productivity (PROD), obtained from the World Bank database;

The exchange rate against the US dollar (US), representing the number of US dollar units per Special Drawing Rights (SDR) unit, chosen due to the dominance of the dollar in Algeria's export revenues, extracted from the International Financial Statistics (IFS) database.

After converting all variables to natural logarithms, the general formulation of the model for estimating the real equilibrium exchange rate is given by the following expression:

$$\text{LREER} = \alpha_0 + \alpha_1 \text{LPOIL} + \alpha_2 \text{PROD} + \alpha_3 \text{LTO} + \alpha_4 \text{LUS} + \epsilon_t$$

The Autoregressive Distributed Lag (ARDL) model is used to estimate the long-term relationship and the error correction model, after confirming the existence of an equilibrium relationship between the real exchange rate and its determinants using the Bounds Testing approach to cointegration. This approach, proposed by (Pesaran, Shin, & Smith, 2001), has become widely used in recent years due to its advantages compared to traditional cointegration tests (Johansen (1988), Johansen-Juselius (1990), Engle and Granger (1987)).

3-2 Results and Discussion:

Before applying the Bounds Testing methodology for cointegration to test for an equilibrium relationship between the study variables, it is necessary to determine the integration order of each variable. This ensures that the variables do not exhibit stability at their second differences, meaning they are not integrated of order two [I(2)]. The Zivot-Andrews (ZA) test (1992) for unit root with a structural break is used to determine the integration degree of the variables under study.

This is because traditional unit root tests (Augmented Dickey-Fuller (ADF, 1981), Phillips & Perron (PP, 1988), Ng and Perron (2001)) may provide misleading results by excluding the possibility of a structural change in the variables during the study period (Remember, Festus, & Murat, 2019, p. 544). The results are shown in the following two tables:

Table 1: Unit Root Test with Structural Break for Variables at Level

Variables	Level				
	t_{za}	Critical Values			Structural Break Year
		%1	%5	10%	
LREER	-3.83	-5.75	-5.08	-4.82	2002
LPOIL	-4.22	-5.34	-4.93	-4.58	2015
LTO	-2.70	-5.34	-4.93	-4.58	2000
LPROD	-3.78	-4.80	-4.42	-4.11	2015
LUS	-3.11	-5.34	-4.93	-4.58	2004

Source: Prepared by the researcher based on Eviews 10 outputs.

Table 2: Unit Root Test with Structural Break for Variables after First Difference

Variables	First Difference				
	t_{za}	Critical Values			Decision
		1%	5%	10%	
LREER	-11.44	-5.34	-4.93	-4.58	I(1)
LPOIL	-5.71	-5.34	-4.93	-4.58	I(1)
LTO	-7.22	-5.34	-4.93	-4.58	I(1)
LPROD	-4.83	-4.80	-4.42	-4.11	I(1)
LUS	-6.16	-5.34	-4.93	-4.58	I(1)

Source: Prepared by the researcher based on Eviews 10 outputs.

The ZA test results shown in Tables (01) and (02) above indicate that the time series of the study variables are not stable at the level but become stable after the first difference. This means that the time series of the study variables are integrated of order one (I(1)) at a significance level of 1%, with structural changes occurring in different years for all the economic variable time series under study.

Bounds Testing for Cointegration:

Before applying the bounds test for cointegration, the optimal lag length for the model's variables will be determined using the Akaike Information Criterion (AIC) (see Appendix No. 01). It was found that the optimal model is: ARDL(2,0,0,1,1).

The results of the cointegration test using the bounds test, as shown in Table No. (03), indicate that the calculated F-statistic (F-Stat) value is above the upper bound I(1) at the 1% significance level. This rejects the null hypothesis of no cointegration relationship between the real exchange rate and its determinants. Consequently, there is a long-term equilibrium relationship between the real exchange rate of the Algerian dinar and its determinants.

Table No. 3: Bounds Testing Approach to Cointegration

Statistic (F-Stat)	15.5554	
Critical Value	Higher Bound I(1)	Lower Bound I(0)
1% Significance Level	6.64	5.205
5% Significance Level	4.878	3.715
10% Significance Level	4.118	3.097

Note: Critical values for F-statistic are taken from Narayan (2004): Case III with unrestricted Intercept and restricted Trend.

Source: Prepared by the researcher based on Eviews 10 outputs.

Estimating the Long-Term Equilibrium Relationship:

After confirming the existence of a cointegration relationship between the actual real exchange rate and its determinants, the long-term relationship is estimated within the framework of the ARDL(2,0,0,1,1) model, as shown in the equation below. (see Appendix No. 02)

$$\text{LREER} = 0.13\text{LPOIL} + 0.42\text{LPROD} - 0.56\text{LTO} - 0.68\text{LUS}$$

prob (0.00) (0.03) (0.00) (0.00)

The estimation results can be analyzed as follows:

The parameter for oil price is estimated at (+0.13%), positive and significant at the 1% level. This indicates that a 1% increase in oil price leads to a 0.13% improvement in the actual real exchange rate. This result is consistent

with economic theory and the reality of the Algerian economy, where higher oil prices improve the real value of the currency through the spending effect. It aligns with the findings of (Koranchelian, 2005), which indicated that oil prices play a significant role in determining the long-term real exchange rate of the Algerian dinar.

The estimated parameter for productivity indicates a positive relationship between Algerian individual productivity and the actual real exchange rate, where a 1% increase in productivity in Algeria improves the actual real exchange rate by 0.42% at the 5% level.

This result is consistent with economic theory and the economic reality in Algeria, explained by the improvement in productivity represented by an increase in individual income resulting from better performance of the oil sector without an increase in productivity in other sectors such as industry and agriculture, leading to an increase in aggregate demand and hence an increase in local price levels, thereby improving the real exchange rate of the Algerian dinar. This is in line with the findings of (Chetbani & Mouhoubi, 2021), which found that productivity positively and significantly affects the real exchange rate of the Algerian dinar.

Regarding trade openness, it negatively affects the actual real exchange rate, where a 1% increase in trade openness leads to a 0.38% deterioration in the actual real exchange rate at the 1% level. This can be explained by the fact that trade openness leads to an increase in imports to meet domestic demand, which is financed from foreign exchange reserves, leading to a depreciation of the Algerian dinar. Previous empirical studies have confirmed the inverse relationship between trade openness and the real exchange rate of the dinar.

An improvement in the value of the US dollar against one unit of Special Drawing Rights (SDR) by 1% leads to a 0.68% improvement in the actual real exchange rate. This result is consistent with the study by (Chekouri, Chibi, & Benbouzian, 2022), which found that the Algerian dinar is closely linked to the US dollar in the long term.

Estimating the Error Correction Model:**Table No. 5: Error Correction Model Estimation Results for the ARDL(2,0,0,1,1) Model**

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.364090	0.128139	10.64537	0.0000
D(LREER(-1))	0.171916	0.051522	3.336760	0.0031
D(LPROD)	-0.151973	0.205071	-0.741075	0.4669
D(LUS)	-1.023014	0.139791	-7.318194	0.0000

Source: Prepared by the researcher based on outputs from Eviews 10.

The error correction model estimation results, shown in Table No. (50) above, confirm the existence of a long-term equilibrium between the real exchange rate of the Algerian dinar and its determinants. The error correction coefficient is estimated at (-0.88), which is negative and significant at the 1% significance level. This reflects a high speed of adjustment, where the actual real exchange rate takes approximately (1.13) years to return to its long-term equilibrium position after any shock in the model due to changes in one of the explanatory variables.

Figure No. (02) displays the process of the current actual real exchange rate and the estimated equilibrium rate. The evolution of their curves shows that both variables followed the same general trend during the study period, with periods of deviation reflecting situations of overvaluation and undervaluation of the currency.

4-Diagnostic Tests for Residuals:

The credibility of the aforementioned inference relies on the model's residuals being free from problems of autocorrelation, heteroscedasticity, non-normal distribution, and model misspecification. Therefore, the model's residuals are examined through the following diagnostic tests, and the results are shown in Table No. (06) below:

Table No. 6: Diagnostic Tests for the Estimated Model's Residuals

Test Hypothesis (Null)	Tests	Statistical Value	Probability Value
No problem of serial autocorrelation	Breusch-Godfrey (BG)	2.53	0.28
Constant variance of error term in the estimated model	Breusch-Pagan-Godfrey	9.06	0.43
Regression equation residuals are normally distributed	Jarque-Bera	0.43	0.80
No model specification error in the estimated model	Ramsey RESET	2.23	0.13

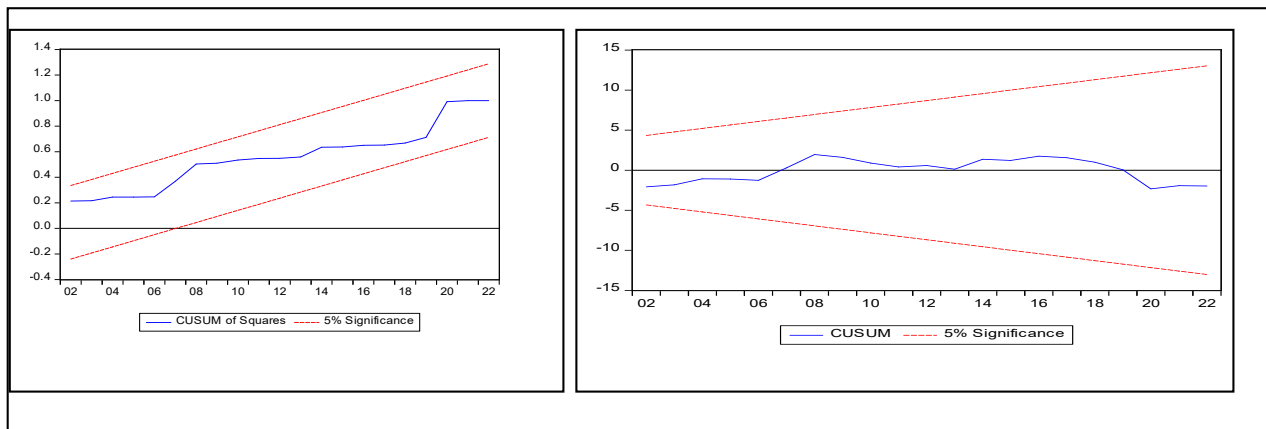
Source: Prepared by the researcher based on outputs from Eviews 10.

The diagnostic tests' results for the estimated model's residuals accept the null hypothesis for all tests at the 1% significance level (see Appendix No. 03). This indicates that the estimated model is statistically sound.

5-Structural Stability Test of the Estimated Model:

The structural stability test for short-term and long-term coefficients involves verifying that the data used in this study are free from any structural changes over time. Therefore, the Cumulative Sum (CUSUM) test and the Cumulative Sum of Squares (CUSUM of Squares) test are used to confirm the stability of the estimated ARDL(2,0,0,1,1) model.

The results shown in Figure No. (02) indicate that both the cumulative residuals and the squared cumulative residuals fall within the critical bounds, suggesting structural stability of the model at the 5% significance level.

Figure No. 02: Test for Structural Stability of the Model

Source: Prepared by the researcher based on outputs from Eviews 10.

6. Conclusion

Given the importance of estimating the long-term equilibrium level of the real exchange rate, which allows economic actors to form their predictions about future exchange rate trends and helps enhance the effectiveness of exchange rate policies in achieving their objectives, this study sought to estimate the long-term equilibrium path of the actual real exchange rate of the Algerian dinar using the Behavioral Equilibrium Exchange Rate (BEER) model.

By employing a set of economic fundamentals that control the internal and external equilibria of the Algerian economy and using the Autoregressive Distributed Lag (ARDL) model, the study found the following:

There is a positive effect of oil prices on the long-term actual real exchange rate of the Algerian dinar, indicating that the Algerian dinar suffers from the symptoms of the Dutch disease. Additionally, an improvement in productivity positively affects the real exchange rate of the Algerian dinar through the Balassa-Samuelson effect. Meanwhile, an increase in trade openness rates inversely affects the real exchange rate of the Algerian dinar, and the deterioration of the US dollar leads to a deterioration of the real exchange rate of the Algerian dinar.

The speed of adjustment from any real exchange rate disequilibrium to its long-term equilibrium level is high, reflecting the strength of the Bank of Algeria's intervention in the interbank exchange market as the sole provider of foreign currency. Its interventions aim to align the real exchange rate with its equilibrium level as a primary objective of the managed floating exchange rate system followed in Algeria.

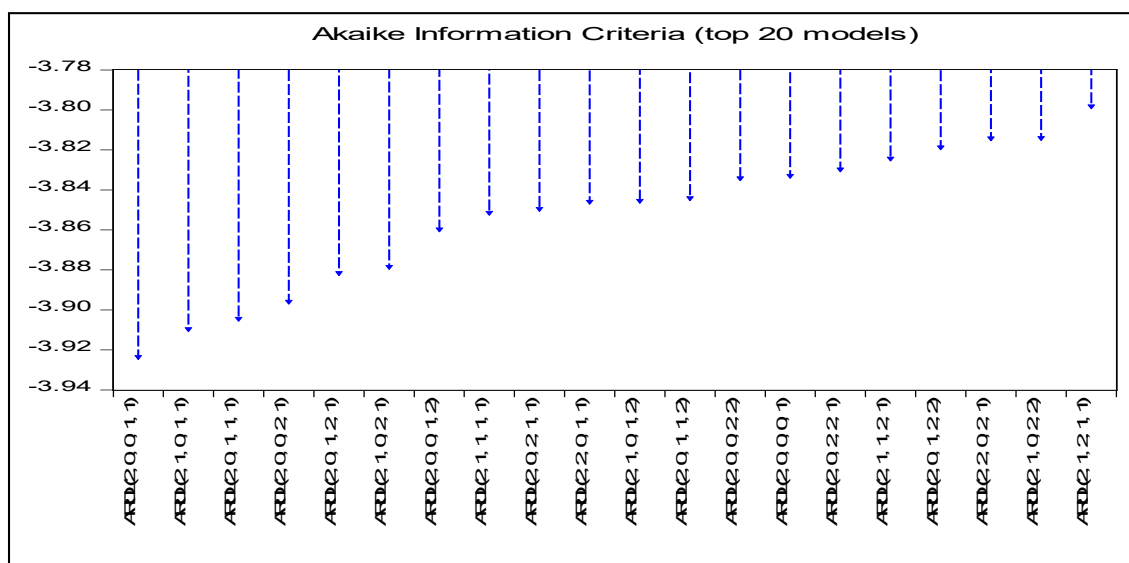
Based on the study's findings, the following recommendations are proposed:

The failure to achieve economic diversification and excessive dependence on the hydrocarbon sector have led to the deterioration of the currency's real value. Thus, it is imperative to:

- Adopt structural reforms targeting productivity enhancement, economic diversification, and boosting non-hydrocarbon exports to strengthen the currency's value and support its stability;
- Develop the forward exchange market for currencies by introducing financial instruments that enable investors to hedge against the risks arising from exchange rate volatility;
- Unify the parallel and official exchange markets to enhance investor confidence.

7-Appendices:

Appendix No.1: Akaike Information Criterion (AIC)



Appendix No.2: estimated values for Long-term

Levels Equation				
Case 4: Unrestricted Constant and Restricted Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LPOIL	0.133201	0.040059	3.325111	0.0032
LTO	-0.560406	0.101293	-5.532509	0.0000
LPROD	0.423260	0.182238	2.322569	0.0303
LUS	-0.683408	0.213156	-3.206142	0.0042
@TREND	-0.024671	0.003030	-8.142194	0.0000
EC = LREER - (0.1332*LPOIL - 0.5604*LTO + 0.4233*LPROD - 0.6834*LUS - 0.0247*@TREND)				

Appendix No.2:Diagnostic Test for residuals

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	0.847186	Prob. F(2,19)	0.4442
Obs*R-squared	2.538154	Prob. Chi-Square(2)	0.2811

Jarque-Bera	0.430200
Probability	0.806461

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.963589	Prob. F(9,21)	0.4955
Obs*R-squared	9.060348	Prob. Chi-Square(9)	0.4317
Scaled explained SS	2.966526	Prob. Chi-Square(9)	0.9656

LPROD(-1) LUS LUS(-1) C @TREND Omitted Variables: Powers of fitted values from 2 to 3			
	Value	df	Probability
F-statistic	2.236425	(2, 19)	0.1342

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