

Real equilibrium exchange rate modeling: Econometric study using the ARDL methodology over the period (1986-2018)

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Abstract:

This study aims to identify the determinants of the real equilibrium exchange rate of the Algerian dinar using the ARDL approach during the period (1986-2018). The results of the long-term model estimation have shown that oil prices and productivity differentials have a positive effect on the real effective exchange rate, while inflation and trade openness have a negative effect on it, and the results of the error correction model showed that the deviation of the exchange rate from the equilibrium rate is corrected each year by 28.36%.

Keywords: Real equilibrium exchange rate; Real effective exchange rate; ARDL model; Algeria.

JEL Classification: F31; C51.

نمذجة سعر الصرف الحقيقي التوازني

دراسة قياسية باستعمال منهجية الـ ARDL خلال الفترة (1986-2018)

ملخص :

تهدف هذه الدراسة إلى التعرف على محددات سعر الصرف الحقيقي التوازني للدينار الجزائري باستخدام منهجية الـ (ARDL) خلال الفترة الممتدة من 1986 إلى 2018. أظهرت نتائج تقدير النموذج طويل الأجل أن أسعار النفط وفروق الإنتاجية لهما تأثير إيجابي على سعر الصرف الفعلي الحقيقي، بينما لكل من معدلات التضخم والانفتاح التجاري تأثير سلبي. وأظهرت نتائج نموذج تصحيح الخطأ أن انحراف سعر الصرف عن معدل التوازن يصحح خلال كل وحدة زمن بـ 28.36%.

الكلمات المفتاحية : سعر الصرف الحقيقي التوازني، سعر الصرف الفعلي الحقيقي، نموذج الـ ARDL، الجزائر.

تصنيف JEL : F31، C51.

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1. Introduction :

Increased inflation rates in countries over the world have led to the use of the real exchange rate to analyze economic phenomena. Also, the trade openness made countries interested in the external balance of their economies in addition to the internal balance. For that, reaching the real equilibrium exchange rate has become the goal of all countries.

Algeria, like other countries, has known several deviations in the real equilibrium exchange rate of the Algerian dinar, these deviations has known two important stages. In the first stage, the Algerian dinar was overvalued, and the official exchange rate did not reflect the equitable exchange rate which excludes the balance of payments from the deficit, in the second stage, the dinar was devaluated in order to rebalance the balance of payments.

Based on the above, the problematic of this study can be formulated in the following question: **What are the most important determinants of the real equilibrium exchange rate in Algeria?**

2. Equilibrium exchange rate modeling approaches

2.1. The fundamental equilibrium exchange rate approach:

The FEER of Williamson (1983, 1994) is defined as the real exchange rate that simultaneously attains internal and external balances. Internal balance is reached when the economy is at full employment output and operating in a low inflation environment, and external balance is characterized as a sustainable balance of payments position over the medium term, insuring desired net flows of resources and external debt sustainability (Jongwanich, 2009,p03).

The balance of payments identity indicates that the current account balance (CA) is equal to the opposite of the capital account balance (KA), so, to determine the FEER we have the following equation (Lopez-Villavicencio and al, 2012,p61):

$$CA = -KA \dots\dots\dots(1)$$

Since the current account balance is a sum of the net trade balance (ntb) and returns of net foreign assets (nfar), we have:

$$CA = ntb + nfar \dots\dots\dots(2)$$

The net trade balance is a positive function of the real effective exchange rate (q) and full employments output of foreign economies (yfpot), and a negative function of domestic full employments output (ydpot).

$$ntb = b_0 + b_1 q + b_2 ydpot + b_3 yfpot \dots\dots\dots(3)$$

with : $b_1 > 0$; $b_2 < 0$; $b_3 > 0$

We observe a real effective depreciation when (q) increases, so :

$$nfar = f(q) \dots\dots\dots(4)$$

The combination of equation (1) and (4) gives:

$$CA^* = f(q^{feer}, ydpot, yfpot) = -KA^* \dots\dots\dots(5)$$

With CA^* is the level of equilibrium current account at medium term.

To determine the FEER, which realizes simultaneously the external and internal equilibrium, we solve the following equation:

$$q^{feer} = f(KA^*, ydpot, yfpot) \dots\dots\dots(6)$$

2.2. The behaviour equilibrium exchange rate approach:

The original BEER approach of Clark and MacDonald (1998) is not based on any specific exchange rate model, so it is regarded as a very general approach to modelling equilibrium exchange rates (MacDonald and Dias, p04). It focuses on modeling the behavioural link between real exchange rates and the appropriate economic variables, and

this method aims to identify statically significant long-term drivers of the REER and modeling the exchange rate in a behavioural context (Melvin and Meshach, 2020, p05).

The reduced form of the equation may be expressed as follow (idem):

$$REER_t = \beta' F_t + \varepsilon_t \dots\dots(7)$$

Where:

- REER : is the real equilibrium exchange rate.
- F : represents a vector of values of economic fundamentals that have long-run persistent effects on equilibrium real exchange rate.
- ε_t : is the random disturbance term.

2.3. The Natural equilibrium exchange rate approach:

The NATREX approach of Stein (1994,1999) tries to link the real exchange rate to a set of fundamental variables explaining savings, investment and the current account. It is based upon a rigorous stock-flow interaction in a macroeconomic growth (Stein, 2000,p88).

In the NATREX approach, the real exchange rate can be depicted into three different phases (Siregar Reza, 2011, p39-40):

- **The actual/spot rate:**

$$q_t = q_t(k_t, F_t, \varepsilon_t : Z_t) \dots\dots\dots(8)$$

with : (k_t) is the stock of capital, (F_t) is the stock of debt, (ε_t) is a random error which is assumed to capture speculative forces, (Z_t) is a vector of fundamentals.

- **The medium-run NATREX:**

$$q = q(k_t, F_t : Z_t) \dots\dots\dots(9)$$

the speculative flows do not influence the medium-run NATREX.

- **The long-run NATREX:**

$$q^* = q^*(Z_t) \dots\dots\dots(10)$$

The spot real exchange rate is, therefore, not necessarily an equilibrium rate and it can be decomposed as it follows:

$$q_t(k_t, F_t, \varepsilon_t : Z_t) = [q_t(k_t, F_t, \varepsilon_t : Z_t) - q(k_t, F_t : Z_t)] + [q(k_t, F_t : Z_t) - q^*(Z_t)] + [q^*(Z_t)] \dots\dots\dots(11)$$

Note:

○ $[q_t(k_t, F_t, \varepsilon_t : Z_t) - q(k_t, F_t : Z_t)]$ captures the trajectory from the spot rate to the medium-run rate.

○ $[q(k_t, F_t : Z_t) - q^*(Z_t)]$ captures the trajectory from the medium-run equilibrium position to the long-run static equilibrium rate.

3. Literature review

There are several studies that tried to estimate the real equilibrium exchange rate using different approaches, methods and variables, among them we find:

- **“A new method of estimating equilibrium real exchange rate in Developing countries”**: This study aims to discuss the limitations of the Purchasing Power Parity (PPP) approach for estimating equilibrium exchange rate and how the fixed or managed floating exchange rate regimes in developing countries make the estimation more difficult. The author introduces the new method adjusted PPP approach which includes the human development index (HDI) and estimated the exchange rate in China using annual data for the period (1985-2013). The explanatory variables used were the ratio of GDP growth rate, ratio of HDI and the ratio of china net foreign assets to GDP, and the estimation’s results have shown that all those variables are significant (Renhong Wu,2016).

- ” **The real effective exchange rate misalignment: Application of Behavioural equilibrium exchange rate BEER to Algeria 1980-2009**”: this study aimed to demonstrate the effect of some fundamental factors on the real equilibrium exchange rate of the Algerian dinar during the period 1980-2009 using quarterly data. The results of the vector error correction model (VECM) showed that oil price, government consumption, liquidity, total reserve include gold, net capital flows, trade openness and terms of trade have a significant influence in the long run (Abbes Hiri,2014).

- ” **Assessing interdependence among countries fundamentals and its implication for exchange rate misalignment estimates: An empirical exercise based on GVAR**”: this study seeks to determine the real equilibrium exchange rate using the Global vector autoregression model (GVAR) proposed by Pesaran, Schuermann and Weiner in 2004. The sample consisted of 27 countries, the data were annual and covers the period (1970-2012). The estimation results have shown that the explanatory variables are not the same for all countries (Emerson and others,2018).

- ” **Real equilibrium exchange rates: A panel data approach for advanced and emerging economies**”: To examine the determinants of the real effective exchange rate and evaluate the degree of misalignment of a group of seventeen currencies since 1980 Q1 to 2005 Q4 the author used a set of economic fundamentals such as the sectoral productivity differential and the net foreign assets. The cointegration tests proposed by pedroni (1999) point to cointegration between variables and the use of the pooled mean group (PMG) for the estimation showed that the variables are significant and correctly signed (Antonia Lopez-Villavicencio, 2006).

- ” **Equilibrium exchange rate in the Czech Republic: How good is the Czech BEER?** “: in this paper the authors used the reduced form equation of the stock-flow approach which is tantamount to the behavioral equilibrium exchange rate (BEER), so both productivity differential and the net foreign assets position were used as explanatory variables. Monthly time series were employed from 1993:M1 to 2004:M9, and the estimation was made by two cointegration techniques (DOLS and ARDL). The results showed that there is a positive relationship between productivity differential and the real exchange rate (Ian Babetskii and Balazs Egert, 2005).

- ” **Equilibrium exchange rates and misalignments: The case of Homogeneous emerging countries**”: the BEER definition was also used in this article to compute the exchange rate misalignment for a set of emerging economies between 1980 and 2013, the results of panel cointegration showed that the East Asian countries, specializing in processing trade, keep their exchange rates at artificially low levels in order to remain competitive (Marthinus Breitenbach and others, 2017).

- ” **The determinants of ASEAN-5 real effective exchange rate vis-à-vis the UK pound**”: fundamentals like domestic and foreign interest rate, inflation rate, domestic money supply, net foreign assets and terms of trade were used in this study, beside of the quarterly data time series between 1991: Q1 to 2006: Q2. The results of the ARDL model showed that domestic money supply is the only variable that had a positive and a significant impact (Abdalrahman AbuDalou and others, 2014).0

- ” **Remittances and real effective exchange rate: An empirical exercise with Indian data**”: by using annual data from 1980 to 2015, the authors of this article added workers remittances to some other macro-variables to determine the REER of India, the

results showed that there is a cointegration and that the deviations adjust towards the equilibrium level in the long run (Ujjal Protim Dutta and Partha Pratim Sengupta, 2018).

- “**Equilibrium real exchange rate estimates across time and space**”: this study differs because of the use of all panel estimation methods, and the results showed that the conventional panel estimation methods (pooled OLS, fixed, random and between effects) can be interpreted as restricted version of a correlated random effects (CRE) model (Christoph fischer, 2019).

4. The evolution of the real effective exchange rate in Algeria

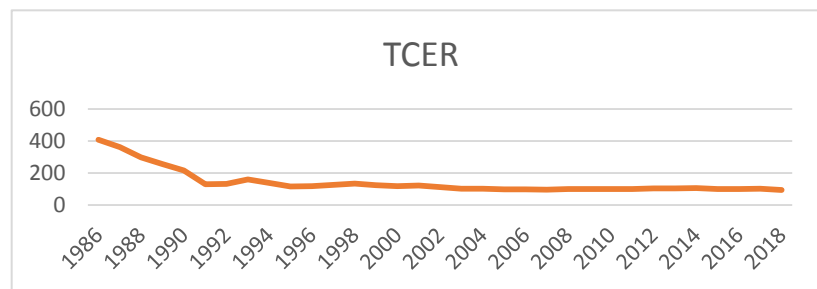
The real exchange rate index depends only on bilateral exchanges, this leads us to use the real effective exchange rate which is known as a nominal effective exchange rate weighted by the relative prices between the concerned country and its most important trading partners, so it indicates the evolution of the country’s exchange rate not against just one foreign currency but rather the currencies of the most important trading partners. We can measure the real effective exchange rate according to (Goujon, 2007, p06) from the following equation:

$$Reer_m = \prod_{i=1}^n \left\{ E_{i/m} \times \frac{p_i}{p_m} \right\}^{w_i} \dots\dots\dots(12)$$

Where:

- $Reer_m$: is the real effective exchange rate for the country (m);
- $E_{i/m}$: is the index of bilateral nominal exchange rates between the country (m) and its partner’s currency (i);
- P_i : is the consumer price index for the partner country (i);
- P_m : is the consumer price the country (m);
- $\sum_{i=1}^n w_i = 1$ and (n) is the number of trading partner countries.

The evolution of the real effective exchange rate in Algeria can be illustrated through the figure below.



Source: Based on the World bank data.

Figure(1): Real effective exchange rate in Algeria during the period 1986-2018

The oil shock of 1986 led to a crisis in the Algerian economy, since the deterioration of the main source of income and the overvaluation of the official exchange rate led to the deficit in the balance of payments. The Algerian government was forced to abandon the fixed exchange rate system in order to correct the exaggeration in its evaluation to achieve monetary stability at the internal and external levels.

The dinar's value was depreciated twice, the first time without being announce during the period (1987-1991), and the second was with the assistance of the International Monetary Fund (IMF) within the program of stability and adjustment over the period (1991-1994).

In 1994, the Algerian dinar has known an actual transformation with the inclusion of the fixing sessions system, and after it, the interbank exchange market appeared in preparation for the adoption of the managed floating system.

Increased oil prices in 1999 led to the accumulation of exchange reserves, which improved the external situation, and supported the implementation of an exchange policy centered on the stability of the real effective exchange rate.

As various evaluations of the exchange policy according to the Central Bank and the International Monetary Fund (IMF) showed, the actual real exchange rate of the Algerian dinar is close to its equilibrium value from 2003 to the present day.

5. Stability test and model selection

5.1. The study variables

Based on the (BEER) approach and the previous studies, a set of variables which can affect the real effective exchange rate of the Algerian dinar (Reer) has been chosen as it is shown in the following equation:

$$\text{Reer} = f(\text{Oil}, \text{Inf}, \text{Open}, \text{Dpro}) \dots \dots \dots (13)$$

Where:

- Reer : is the Real effective exchange rate of the Algerian dinar;
- Oil : represent oil prices ;
- Inf : is the inflation rate;
- Open : is the ratio of trade openness;
- Dpro : represent the productivity differentials.

The statistics of the real effective exchange rate and inflation rates were obtained from the World Bank database. The oil prices were obtained from the Organization of Arab Petroleum Exporting Countries (OAPEC) database. For the ratio of trade openness, which represents the ratio of total exports and imports to GDP, it was calculated based on the world bank data. Finally, the productivity differentials were calculated based on the GDP data extracted from the World bank database.

5.2. The unit root test

Before estimating the model, it is necessary to test whether the time series used in the study are stable or not, for that we employed the Augmented Dickey-Fuller (ADF) test and the results are shown in the following table.

Table (1): ADF test results

Variables	Level			1 st Difference		
	T and C	C	None	T and C	C	None
Reer	-2.558	-2.785	-1.116	-3.928*	-3.491*	-3.476*
Oil	-2.881	-0.949	0.147	-4.244*	-4.333*	-4.247*
Inf	-1.898	-1.592	-1.282	-3.919*	-4.741*	-4.827*
Open	-2.191	-2.182	0.614	-6.664*	-6.229*	-6.037*
Dpro	-5.044*	-4.361*	-2.960*	-	-	-
Level of significance	Critical Values at Level			Critical Values at 1 st difference		
	T and C	C	None	T and C	C	None
1%	-4.339	-3.699	-2.653	-4.356	-3.711	-2.660
5%	-3.587	-2.976	-1.953	-3.595	-2.981	-1.955
10%	-3.229	-2.627	-1.609	-3.233	-2.629	-1.609

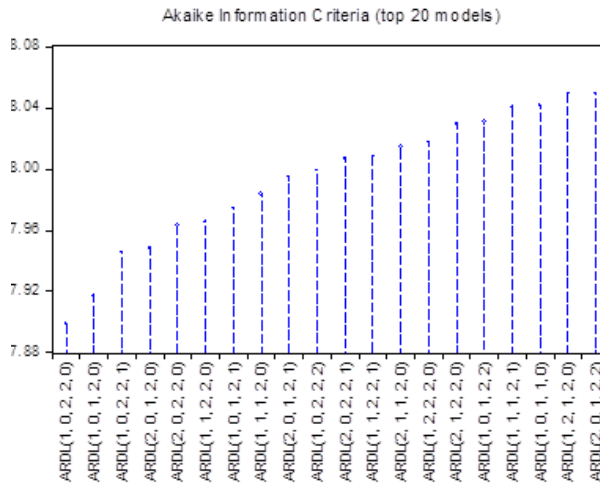
Source: Based on EViews 9 output.

Note: (*) denotes statistical significance at one of the levels (1%, 5%, 10%).

The results of the unit root test indicate that the time series of the productivity differentials (Dpro) is stationary in its original level, which means that the series is integrated in I(0), while the other time series of the real effective exchange rate (Reer), inflation (Inf), trade openness (Open) and oil prices (Oil) are stationary after the first difference, therefore they are integrated in order one I(1).

5.3. the model selection

Since the time series used in the study are integrated in I(0) and I(1), the Autoregressive Distributed Lag approach (ARDL) will be used to estimate the model, but before the estimation, it is necessary to determine the best number of lags for each variable using the Akaike Information criterion (AIC) like it is shown in the following figure.



Source: EViews 9 output.

Figure (2) : Model criteria graph

By choosing the lowest value of the (AIC) criterion, the best model is ARDL(1.0.2.2.0) and it can be written as follow:

$$\Delta Reer_t = a_0 + \beta_1 Reer_{t-1} + \beta_2 Oil_t + \beta_3 Inf_t + \beta_4 Inf_{t-1} + \beta_5 Inf_{t-2} + \beta_6 open_t + \beta_7 open_{t-1} + \beta_8 open_{t-2} + \beta_9 Dpro_t + \pi_1 Reer_{t-1} + \pi_2 Oil_{t-1} + \pi_3 Inf_{t-1} + \pi_4 open_{t-1} + \pi_5 Dpro_{t-1} + \varepsilon_t \dots\dots\dots(14)$$

Where:

- Δ : is the first difference operator;
- ε : is the white noise residuals;
- $(\pi_1, \pi_2, \dots, \pi_5)$: represents the long-run parameters;
- $(\beta_1, \beta_2, \dots, \beta_9)$: represents the short-run dynamic of the model.

In order to determine if there is a long-run relationship between variables in the (ARDL) approach, we used the bounds test like it is shown.

Table (2): Bounds test results

F-statistic	Lower critical value	Upper critical value	Level of signifiacne
8.5549	2.45	3.52	10%
	2.86	4.01	5%
	3.25	4.49	2.5%
	3.74	5.06	1%

Source: Based on EViews 9 output.

The calculated F-statistic is greater than the upper critical values at all the levels of significance, so we reject the null hypotheses, therefore we conclude that there is a long-run relationship between the variables.

6. Model estimation

After confirming that the study variables are cointegrated, we can now estimate the model.

6.1. Long-run model.

We estimated the long-run relationship between the variables and the results were as shown in the table below.

Table (3): Long-run estimation results

Variables	Coefficient	Std.Error	t-statistic
Oil	0.006	0.0054	1.1044
Inf	-1.1058	1.0534	-0.1005
Open	-2.6345	1.6582	-1.5888
Dpro	0.000004	0.00001	0.3033
C	230.8575	88.4907	2.6088

Source: Based on EViews 9 output.

Through the results of (table 3) we can conclude that:

- The increase in oil prices (Oil) by 1% will lead to an increase of the real effective exchange rate (Reer) by 0.006%, which means that there is a positive relationship between the two variables and this confirms the control of the hydrocarbon sector in the Algerian revenue;

- The increase in trade openness (Open) by 1% will lead to a decrease in the (Reer) by 2.63%, and this negative relationship is due to the deterioration of the Dollar in 1986 which lead to a decrease in the export revenues between 1985 and 1986 by 56.5%, so the heavy dependence on hydrocarbons as a primary resource negatively affect the macroeconomic balances and of course the real effective exchange rate of the Algerian dinar;

- The expansionary monetary policy pursued by Algeria through the economic recovery program and for which huge sums were allocated contributed to the revitalization of the labor market and the reduction of the unemployment rate, but despite the encouraging results, this has led to an increase in inflation. From the estimation we notice that the increase of inflation by 1% will lead to a decrease by 1.10% in the real effective exchange rate;

- The increase of the productivity differentials by 1% will lead to the increase of the real effective exchange rate by 0.00004%, this variable is taken from the effect of Balassa-Samuelsson and its high value indicates the high incomes in Algeria due to the high prices of oil.

6.2. Short-run model.

We estimated the Error Correction Model to know the short-run relationship between variables and the results are in the following table.

Table (4): Short-run estimation results

Variables	Coefficient	Std.Error	t-statistic	Probability
D(Oil)	0.0017	0.0016	1.0605	0.3015
D(Inf)	-1.4158	0.4500	3.1460	0.0051***
D(Inf(-1))	-0.5887	0.4417	-1.3328	0.1976
D(open)	-1.1253	0.5258	-2.1400	0.0449*
D(open(-1))	1.1756	0.4991	2.3551	0.0288**
D(dprob)	0.000001	0.000004	0.3065	0.7624
CointEq(-1)	-0.2836	0.0596	-4.7568	0.0001***

Source: Based on EViews 9 output.

Note: (***, **, *) denotes statistical significance at levels (1%, 5%, 10%) respectively.

The estimation of the short-run relationship showed that:

- The coefficient of the error correction term (ECT) is negative and statically significant at all levels, And the value of the coefficient reveals that 28.36% of the disequilibrium in the real effective exchange rate of the Algerian dinar will be corrected in the following year.

7. Diagnostic test results

To find out if the estimated model above is reliable, we applied some diagnostic tests and the results are shown in the table below.

Table (5): Diagnostic test results

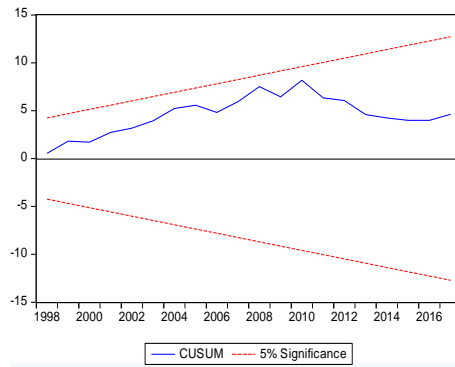
Test	Value	Probability
LM	0.0374	0.8487
Jarque-Berra	1.3159	0.5179
ARCH	0.0392	0.8445

Source: Based on EViews 9 output.

From the table above we note that all probabilities exceed 0.05, thus we accept the null hypotheses (H_0) in all tests at a 5% level of significance and we conclude that:

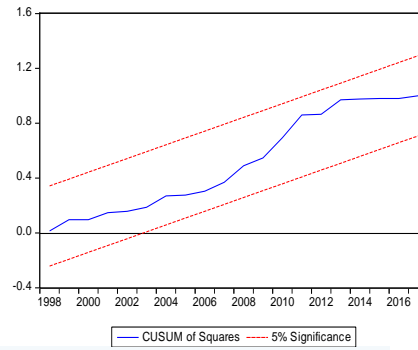
- LM test confirmed that there is no correlation in the model;
- Jarque-Berra test shows that the residuals are normally distributed;
- ARCH test shows that the model is not heteroscedastic.

To test the structural stability of the model the Cumulative sum (Cusum) test and Cumulative sum squares (CusumQ) test were employed and the results are shown in the following two figures.



Source: EViews 9 output

Figure (3): Cusum test



Source: EViews 9 output

Figure (4): CusumQ test

Since both curves are located inside the critical bounds of 5% significance, both long and short run models do not contain any structural changes.

8. Conclusion

This study aimed to determine the effect of some variables on the real effective exchange rate of the Algerian dinar over the period 1986-2018, and these are the major conclusions:

- According to the (Beer) approach we have choose oil prices (Oil), inflation rates (Inf), trade openness (Open) and productivity differentials (Dpro) as explanatory variables of the real effective exchange rate (Reer) of the Algerian dinar;
- The results of Augmented Dicky- Fuller (ADF) test showed that the time series used in the model are integrated in I(0) and I(1), which allowed us to use the (ARDL) approach for the estimation;
- Bounds test results showed that the variables are cointegrated;
- Diagnostics tests results proved that we can rely on the model's parameters for the analysis;
- The results of the long-run model have shown that oil prices (Oil) and productivity differentials (Dpro) have a positive effect on the real effective exchange rate, while inflation (Inf) and trade openness (Open) have a negative effect on it;
- The error correction model results showed that the speed of adjustment of the real effective exchange rate for the long-run equilibrium is 28.36%.

Through the findings, a set of suggestions and recommendations can be made:

- Economic policy must be directed towards the stability of the real exchange rate and around an equilibrium level that encourages economic growth.
- Commercial banks should be given freedom to manage the foreign exchange surplus in order to achieve balance in the exchange market.
- The parallel exchange market should be eliminated to give freedom to exchange rate in order to be determined in the interbank exchange market, and to establish the principles of transparent and flexible management.
- Exports outside hydrocarbons should be encouraged to protect the economy from external shocks, and this comes with restructuring the productive sector and rationalizing expenditures.

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