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Explicative determinants of real exchange rate volatility in Morocco: An econometric approach

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Abstract. This paper aims to present a theoretical framework regarding the determinants of Moroccan Real Effective Exchange Rate (REER) volatility and to define the influential factors affecting it for the Moroccan economy between 1980 and 2020. This objective is primarily motivated by the recent changes adopted by Moroccan authorities towards a flexible exchange rate regime, which includes a progressive widening of the fluctuation range of the exchange rate. In this study, we used a GARCH(1,1) model and applied an Error Correction Model (ECM) with an estimation of the Autoregressive Distributed Lag (ARDL) approach. We found strong evidence that, in the long run, foreign direct investments, commercial openness, and terms of trade have a statistically significant negative impact on the volatility of the Moroccan REER, while the latter has a positive influence. Additionally, external debt, public expenditure, and the applied exchange rate regime positively affect REER volatility; in other words, they contribute to increased volatility in the foreign exchange market and the Moroccan economy. Conversely, the money supply has a negative impact, and the inflation rate has a positive effect on the studied volatility; however, these last results are not statistically significant.
Keywords. Real Effective Exchange Rate; Exchange Rate Volatility; GARCH Model; Error Correction Model; ARDL; Monetary Policy.
JEL. F31, F41, C22, C53, E52, C32.

1. Introduction

Over the last few decades, the real exchange rate has emerged as a critical tool for governments implementing counter-cyclical economic policies. It serves as a key indicator of a country's economic performance, with a stable real exchange rate reflecting a robust and sustainable economy. Consequently, achieving stability in the real exchange rate is essential for effective policy-making. Understanding the determinants of real exchange rate volatility is crucial for decision-makers in both developing and developed countries, as it enables them to formulate strategies that enhance economic stability and growth.

The economic literature has extensively explored the topic of real exchange rate volatility, leading to the development of several key theories (Fleming & Mundell, 1964; Balassa, 1964; Samuelson, 1964). These theories identify numerous factors influencing exchange rate volatility, with the most commonly cited being public expenditure, external debt, foreign direct

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investment, money supply, trade openness, GDP, interest rates, and the exchange rate regime. Notably, the impact of these factors varies significantly depending on the prevailing economic conditions, the specific time frame analyzed, and the unique characteristics of the economy, ceteris paribus. This study focuses on Morocco, aiming to identify the most influential factors affecting the volatility of the Moroccan Real Effective Exchange Rate (REER) from 1980 to 2020. This objective is driven by recent changes in Moroccan policy towards a more flexible exchange rate regime, characterized by a progressive widening of the fluctuation range. Understanding the determinants of REER volatility in Morocco is crucial for policymakers, as it will enhance their decision-making processes regarding monetary policy. This study is structured as follow: the first section brings an overview about the economic literature on the mater. The second section presents the used methods and applied models for the study. The third section discusses the results and the last section concludes.

2. Literature review

Kilicarslan (2018) applied the empirical techniques of ARCH modeling to measure the volatility of the exchange rate, as well as the application of the vector error correction model, for the period from 1974 until 2017 in Türkiye. He found that the increase in investment, money supply, and trade openness of the economy can lead to an increase in volatility of the real effective exchange rate; also, the increase in foreign investment and government spending can decrease the volatility studied.

Calderon & Kubota (2018) used the panel data methodology for 82 countries; the sample studied was 1974-2017. They found that trade operations in the manufacturing sector can generate less volatility in the real exchange rate, while the other sector studied, that is, non-manufacturing, could cause more volatility.

Khin et al. (2017) applied the ARDL model estimates for the period 2010-2016. These authors found that there is a positive impact on the long-run dynamics between the exchange rate and the price index, while the effect of the exchange rate on the money supply was found to be negative.

Adusei & Gyapong (2017) adopted structural modeling via equations over the period 1975-2016 to study the explanatory factors of the volatility of the exchange rate. The authors found that the variables that significantly explain this volatility are inflation, money supply, current account balance, GDP growth rate, and total external debt.

Hassan, Abubakar, & Dantama (2017) applied the ARDL model for the period ranging from 1989 until 2015. They found that net foreign assets and interest rates have a positive and significant impact on exchange rate volatility. In addition, fiscal balance, economic openness, and oil prices have a positive and statistically insignificant effect on volatility, while real GDP has a negative effect on the volatility studied.

Alagidede & Ibrahim (2017) adopted and applied the vector error correction model to estimate the factors explaining exchange rate volatility. These authors found that capital outflow has a strong effect on exchange rate fluctuations in the very short term, while in the long term, the volatility was explained by the following variables: government spending, money supply, trade openness, FDI, and GDP.

Cevik, Harris, & Yilmaz (2016) applied generalized method of moments for 115 countries for the period 1996-2015 to study the explanatory factors of exchange rate volatility in the studied economies. These authors found that in most emerging economies there is a very high degree of exchange rate volatility; they also found that soft power variables influence the studied volatility.

Oaikhenan & Aigheyisi (2015) applied the EGARCH model to estimate the volatility of exchange rates. The ARDL model was then estimated to check the effect of explanatory variables on the volatility studied in Nigeria for the period 1970-2014. The authors found that trade openness, government spending, and interest rates are determinants that can well explain exchange rate volatility.

Insah & Chiaraah (2015) were able to apply the ARDL methodology for the period from 1980 until 2012. The authors found that there is a positive impact between government spending and exchange rate volatility. In addition, money supply, domestic debt, and external debt had a negative effect on exchange rate volatility.

Ajao & Igbokoyi (2013) sought to identify the explanatory causes of exchange rate volatility over the period from 1981 until 2008. They applied GARCH econometric techniques and an error correction model, finding that trade openness, domestic spending, and interest rates have a positive and significant influence on the volatility studied.

3. Data and methodology

This part will include the presentation of the data, the selected variables and the empirical model while basing on the particularity and characteristics of the Moroccan economy. Then, the econometric methodology adopted and applied will be presented.

3.1. Data and variables

In the following, we will present the dependent and explanatory variables of our empirical study.

Dependent variable:

Real Effective Exchange Rate Volatility (REERV): is the exchange rate of a currency area, measured as a weighted sum of the exchange rates with different trading partners and competitors. The nominal effective exchange rate is measured with nominal parities (without taking into account the differences in purchasing power between the two currencies), and the real effective exchange rate, with the price indices and their changes taken into account for the latter.

Explanatory variables:

External debt as % of GDP (ED): in economics, external debt refers to all debts that are owed by a country, including governments, firms and individuals to foreign lenders. It is important to distinguish between gross external debt (what a country borrows externally) and net external debt (the difference between what a country borrows externally and what it lends externally).

Government expenditure as % of GDP (GE): the impact of government expenditure on the RER is ambiguous and depends on the sectoral composition of expenditure. If government spending is higher on tradable goods, demand for imports increases.

Foreign direct investment, net inflows as % of GDP (FDI): A direct investment from one country to another is the export of capital to another country in order to acquire or create a business or to take a stake in it. The aim is to acquire effective decision-making power in the management of the enterprise. We take into account the balance of entries and exits.

Money supply as % of GDP (MS): refers to the amount of money in circulation in a given economy to meet its current monetary needs. The volume of money supply is controlled by central banks. They have a direct influence on the quantity of money in circulation through their control of the (monetary base), also called (monetary base).

Trade openness of the economy as a % of GDP (TO): This is simply the total value of exports of goods and services added to the total value of imports of goods and services, as a useful indicator for observing the trade openness of a given economy with respect to foreign countries (ROW).

Domestic Gross Domestic Product (GDP) in (purchasing power parity): is a macroeconomic product aggregate that measures the economic activity of a given economy. This indicator, although complex, is one of the most appropriate for comparing economies.

Terms of trade (TOT): All theoretical models in general stress the importance of terms of trade disturbances as a potential source of fluctuations in the TCR. Changes in the terms of trade generate inter-temporal and intra-temporal substitution effects as well as income effects.

Inflation rate (IR): This variable is widely considered in the theoretical literature as one of the determinants of the RCR. Most economists consider a country's inflation rate to be a fundamental variable of the RCR.

Exchange rate regime adopted and applied by the monetary authorities (ERM): An exchange rate regime is the set of rules that determine the intervention of the monetary authorities in the foreign exchange market in a given economy, and therefore the behavior of the exchange rate. There is a very wide variety of exchange rate regimes, which are distributed between two extremes: fixed and flexible exchange rates.

To carry out this empirical study, we used statistical data from the World Bank. These data are annual and cover a period of 39 years, from 1980 to 2019.

First of all, and while basing ourselves on the economic theory, we find that there are several explanatory determinants of the volatility of the real exchange rate, in what follows and within the framework of this empirical study, we tried to take the explanatory variables of this volatility while basing ourselves on the particularity and the characteristics of the Moroccan economy.

The equation for our econometric model is as follows

$$REERV = \alpha_0 + \alpha_1 ED_t + \alpha_2 GE_t + \alpha_3 FDI_t + \alpha_4 MS_t + \alpha_5 TO_t + \alpha_6 GDP_t + \alpha_7 TOT_t + \alpha_8 IR_t + \alpha_9 ERM_t + \varepsilon_t \quad (1)$$

Where,

REERV: Real Effective Exchange Rate Volatility

α_0 : Model constant

α_0 .... α_9 : Parameters and elasticities of the model to be estimated

ED: External debt

GE: Government expenditure

FDI: Foreign direct investment; MS: Money supply

TO: Trade openness of the economy

GDP: Gross Domestic Product
TOT: Terms of trade
IR: Inflation rate
ERM: Exchange rate regime adopted and applied by the monetary authorities
ε_t : Error term.

3.2. Econometric methodology

This part is presented in four subsections. The first subsection is devoted to the stationarity test of the variables. The second subsection presents the results of the ARCH test. The third subsection will estimate the ARMA(p,q) model of the mean. And finally, the last subsection, will present the results obtained from the estimation of the GARCH(p,q) model of the volatility.

The stationarity analysis is the first step before estimating our econometric model, it consists in checking the order of integration of the variables used. The method applied allows us to analyze the level of stationarity and the existence of cointegration between all the variables.

Table 1. *Results of the ADF and PP stationarity test*

	ADF (% 5)		Phillips-Perron (% 5)		
Variable	Level (Intercept)	1st. Difference (Intercept)	Level (Intercept)	1st. Difference (Intercept)	Level
REERV	-1.918019 (-2.941145)	-6.114089 (-2.943427)	-1.818019 (-2.941145)	-6.116659 (-2.943427)	I (1)
ED	-0.990368 (-2.847145)	-6.036969 (-2.945842)	-0.673979 (-2.846145)	-7.907398 (-2.744427)	I (1)
GE	-9.546998 (-2.941145)	-13.93640 (-2.943427)	-11.29062 (-2.941145)	-64.02190 (-2.943427)	I (0)
FDI	-2.673305 (-1.949856)	-8.828530 (-1.950117)	-2.673929 (-1.949856)	-8.828530 (-1.950117)	I (0)
MS	-1.181894 (-3.533083)	-7.183667 (-3.536601)	-1.431397 (-3.533083)	-7.053542 (-3.536601)	I (1)
TO	-0.627117 (-2.941145)	-7.311897 (-2.943427)	-0.200111 (-2.941145)	-7.682831 (-2.943427)	I (1)
GDP	-2.140374 (-3.540328)	-3.700055 (-3.540328)	-1.443613 (-3.533083)	-10.21700 (-3.536601)	I (1)
TOT	-3.721265 (-3.533083)	-5.815902 (-3.544284)	-5.644081 (-3.533083)	-10.07401 (-3.536601)	I (0)
IR	-5.140096 (-3.533083)	-11.66844 (-3.536601)	-5.120197 (-3.633083)	-30.51902 (-3.596601)	I (0)
ERM	-6.989788 (-2.941145)	-8.067464 (-2.945842)	-6.942037 (-2.941145)	-15.51919 (-2.943427)	I (0)

Notes: The numbers in the table are statistical t values, and critical values are indicated in parentheses.The significance level is 5% (i.e. 0.05).
Source: Authors, from EViews 10 software.

From this table, we notice that the variables (REERV, ED, MS, TO and GDP) are integrated oforder one [I(1)], so this shows that these variables are stationary in first differences. While, concerning the variables (GE, FDI, TOT, IR and ERM) are stationary in level, in other words they are integrated of order zero [I(0)].

Thus, for the estimation period, no statistical series is integrated of order two [I(2)] which is essential for the application of the ARDL model. In the

following, we will present the ARCH test and the ARMA-GARCH modeling before estimating the co-integration relation and the parameters of our empirical model. In the following we will present the ARCH test and then the estimation of the chosen ARMA(p,q) and GARCH(p,q) model.

ARMA models (autoregressive and moving average models), also known as Box Jenkins models, are the main time series models. Given a time series Xt, the ARMA model is a tool to understand and predict, eventually, the future values of this series. The model is composed of two parts: an autoregressive part (AR) and a mean-moving part (MA). The model is generally noted ARMA(p,q), where p is the order of the AR part and q the order of the MA part.

Using a program to generate the orders (p,q) here are the results obtained:

Table 2. *Estimation results of the ARMA(1,0) model*

	Coefficient	P-value
Constant	0.91	0.00
AR(1)	0.03	0.00

Source: Authors, from EViews 10 software

It is simply an ARMA (1; 0) model. In other words, it is an AR(1) model. Moreover, the results obtained are significant.

Table 3. *Results of the Lagrange Multiplier Test*

F-statistic	6.001612	Prob. F(1,28)	0.0193
Obs*R-squared	5.429821	Prob. Chi-Square(1)	0.0198

Source: Authors, from EViews 10 software

As seen in Table 2, the probability value is equal to 0.01 according to the result of the ARCH LM test is considered significant at the 5% level. This result indicates that the H 0 hypothesis should be rejected, in other words, there is the ARCH effect and therefore has a volatility of the series. Thus, the GARCH variance series shows that it can be used as a measure of the volatility of real effective exchange rates.

Table 4. *Selection results for the optimal GARCH (p,q) model*

		AIC	BIC	HQ
GARCH	Normal (Gaussian)	6.062923	6.190889	6.108836
	Student's t	6.114205	6.284826	6.175422
	Generalized Error (GED)	4.689499	4.860121	4.750717
TGARCH	Normal (Gaussian)	6.114205	6.284826	6.175422
	Student's t	6.165517	6.378794	6.242039
	Generalized Error (GED)	4.741649	4.954926	4.818171
EGARCH	Normal (Gaussian)	6.114200	6.284822	6.175418
	Student's t	6.168598	6.381875	6.245120
	Generalized Error (GED)	4.766841	4.980118	4.843363

Source: Authors, from EViews 10 software.

From this table we can see that the optimal model for measuring volatility is the GARCH(1.1) model, based on the selection criterion AIC, since the model that minimizes AIC is the GARCH model with a value of 4.6894.

Staying within this framework, the GARCH model (1.1) allows us to represent in a simplifiedway the conditional volatility processes, the latter can be represented as follows: $Rt = u + \varepsilon t$ With, εt follows a normal distribution with mean equal to 0 and variance equal to ht whichrepresents a conditional error variance. Here is the estimate of the GARCH(1,1) model formeasuring volatility:

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} \quad (2)$$

Where :

α_0 : is a constant;

α_1 : the coefficient relating the past value of the square of the residuals to the current level of variance;

β_1 : the coefficient relating the current variance to that of previous periods.

Table 5. *Results of the estimations of the GARCH(1,1) model*

	Coefficient	P-value
α_0	3.87	0.00
α_1	1.02	0.00
β_1	0.20	0.00

Source: Authors, from EViews 10 software

The constant is equal to 3.87, moreover, the coefficient linking the past value of the square of the residuals to the current level of the variance is equal to 1.02, thus, the coefficient linking the current variance to that of the previous periods, is negative, with a value equal to 0.20.

4. Results and discussion

This part is presented in two subsections. The first subsection is devoted to present the results obtained from the cointegration test of the econometricians Pesaran et al. (2001) The second subsection will present the result of the estimation of the parameters of the empirical model.

4.1. Results

First of all, before estimating the parameters of the model, it is necessary to go through the statistical test of cointegration of Pesaran et al. (2001) We will use the AKAIKE econometric information and selection criterion (AIC) to be able to select the optimal ARDL (auto- regressive distributed lag) model, the one that offers significant statistical results. Here are the results of the statistical tests performed.

Table 6. *ARDL model specification*

Model	LogL	AIC*	BIC	HQ	F-statistic	Specification
1	11.45610	0.186521	0.832937	0.416511	9.432799 (0.0000)	ARDL(1, 1, 0, 1, 1, 0, 0, 0,1, 0)

Source: Authors, from EViews 10 software

Table 7. *Validation of the optimal ARDL model and diagnostic tests for residuals*

	DW	LM	ARCH	R	R2

ARDL(1, 1, 0, 1, 1, 0, 0, 0,1, 0)	2.382049	1.290794 (0.2960)*	0.108861 (0.7434)*	0.851670	0.791381

Note: *denotes significance at the 5% level
Source: Authors, from EViews 10 software

According to the results presented in the previous table, we find that the coefficient of determination (R2) is equal to 79.13%, i.e., the chosen explanatory variables do have an impact on the dependent variable. In other words, over the period studied from 1981 to 2019, the exogenous variables explain the volatility of the REER by 79.13%.

Moreover, with regard to the statistical tests that help to diagnose and properly analyze the estimated ARDL model, namely the serial correlation test of the econometricians Breusch- Godfrey (LM) and Durbin-Watson (DW) confirm the existence of serial correlation, if the probability associated with the F-LM statistic is greater than 0.05, this means that there is an absence of auto-correlation. Indeed, this is verified in our case because simply the probability associated with the F-LM statistic is equal to 0.2960 which is greater than 5%. Similarly for the ARCH heteroscedasticity detection test, the probability is assumed to be greater than 0.05 to speak of the absence of heteroscedasticity. Indeed, in our case the probability is equal to 0.7434 so it is simply the absence of this phenomenon.

The results obtained allow us to confirm the absence of correlation and the absence of heteroscedasticity, we can conclude that the optimal ARDL model estimated for the period studied is validated, and it could be the subject of economic analysis and reflection. Thus, we can proceed to the evaluation of the cointegration test at the bounds.

According to Pesaran et al. (2001), the statistical test of cointegration at the boundaries confirms the existence of a cointegrating relationship between the variables, which makes it possible to estimate the long-term and short-term impacts of the explanatory variables on the dependent variable. However, the calculated test statistic, Fisher's F, will be compared to the critical values, as follows

Fisher's F < Lower bound (LB): Cointegration does not exist
Fisher's F > Upper bound (UB): Cointegration exists
Lower bound < Fisher's F < Upper bound: No cointegration.

Table 8. Results of the cointegration test at the bounds of Pearsan et al. (2001)

F-statistic calculated	REERV	2.9931
Critical Threshold	Lower bound	Upper bound
10%	1.8	2.8
5%	2.04	2.08
2.5%	2.24	2.35
1%	2.5	2.68

Source: Authors, from EViews 10 software

The results of the bounds test above show that the Fisher F-statistic (F = 2.9931) for REERVis greater than the upper bound for the different significance levels, which makes it possible to estimate the short- and long-term effects of the explanatory variables on the dependent variable by using the error correction model (ECM). Then, it is found that there is an integration, thus a long term equilibrium relationship and consequently the ECM must be

applied. The model is based on the Autoregressive Distributed Lag (ARDL) model in order to estimate the impact of explanatory variables to explain the sources of volatility.

Table 9. *Estimation results of the coefficients of the short-term ECM model*

Variable	Coefficient	Std. Error	t-Statistic	Prob
C	2.947219	7.385780	0.399040	0.6935
D(ED)	0.283586	0.335192	0.846040	0.4062
D(GE)	0.088033	0.086908	1.012940	0.0216**
D(FDI)	0.034681	0.032730	1.059609	0.3003
D(MS)	0.466513	1.484067	1.661996	0.0101**
D(TO)	-0.179434	0.726485	-0.246990	0.8071
D(GDP)	0.168438	0.663241	1.761711	0.0914***
D(TOT)	0.019582	0.086303	0.226904	0.2225
D(IR)	0.394301	0.750148	0.525631	0.6042
D(ERM)	0.226723	0.128569	1.763430	0.0911***
CointEq(-1)	-0.410702	0.059754	-6.873160	0.0000**

D is the first difference of the variables considered
Note: *;**and *** denote significance at the 1%; 5% and 10% threshold
Source: Authors, from EViews 10 software

Table 10. *Estimation results of the coefficients of the longterm ECM model*

Variable	Coefficient	Std. Error	t-Statistic	Prob
ED	0.128019	1.419344	1.499297	0.1474
GE	0.214348	0.187935	1.140541	0.2658
FDI	-0.119026	0.095822	-1.242156	0.0267**
MS	-0.256761	0.960108	-0.267429	0.7915
TO	-0.436897	1.725024	-0.253270	0.0023*
GDP	0.844981	2.283586	1.245839	0.0454**
TOT	0.047680	0.219307	0.217414	0.8298
IR	-0.397767	1.836442	-1.305659	0.0046*
ERM	0.552039	0.359672	1.534840	0.1385
C	7.176059	15.52569	0.462205	0.6483

Note: *;**and *** denote significance at the 1%; 5% and 10% threshold
Source: Authors, from EViews 10 software

4.2. Discussion

Finally, this last section will allow to develop the analysis and the economic reflection on the treated subject, moreover, it is presented in two subsections. The first sub-section is devotedto analyze the results obtained. The second subsection is devoted to the presentation of the statistical test of the stability of the dependent variable.

In what follows, we will interpret and comment on the results obtained explaining the different effects of the explanatory variables on the volatility of the real exchange rate in the short and long term.

Concerning the short-term dynamics

The error correction coefficient is equal to (-0.41< 0), it is negative and significant, because its probability is equal to (0.00< 0.05). The value of this coefficient represents the speed of adjustment of the short-term relationship to the long-term equilibrium. In other words, this coefficient represents the speed of adjustment of the dependent variable towards the equilibrium to correct the long-run deviation.

First, the constant is equal to 2.94 which is statistically insignificant.

Indeed, the elasticity of external debt is equal to (0.2835) this result is positive, in fact, an increase of 1% of the ED in the short term will lead to an increase of 0.28% of the volatility of the REER. The same is true for the elasticity of public expenditure, which is equal to (0.0880). This result is also positive, so it is simply a positive impact, i.e. an increase of 1% in short-term PDs will lead to an increase of 0.08% in the volatility of the REER, even if the impact remains small.

Concerning the elasticity of FDI, we find that it is equal to (0.0346), which is simply a positive impact in the short term, in other words, a 1% increase in FDI will lead to a 0.03% increase in the volatility of the REER, so this effect remains weak.

As for the elasticity of the money supply, we find that it is positive (0.4665), which means that a 1% increase in this economic monetary variable will lead to a 0.46% increase in the volatility of the REER, this effect is high from a statistical perspective. Moreover, the elasticity of trade openness is negative with a value equal to (-0.1794) which means that the improvement of trade openness will generate in the short term a decrease in the volatility of the REER.

So, regarding the elasticity of domestic GDP, we find that it has a positive value equal to (0.1684) which reflects that the influence of this real economic variable will cause in the short term an increase in the volatility studied. The same is true for the estimated elasticities of the trade term and the inflation rate, which have positive values of (0.3943) and (0.0195) respectively, thus increasing the volatility of the REER in the short run.

Thus, the last estimated parameter concerns the exchange rate regime adopted and applied by the monetary authorities in Morocco during the period studied, this qualitative variable which was constructed via binary values that vary from 0 to 1. We find that this variable has a positive impact on the volatility of the REER, allowing to increase this volatility, in fact, an improvement of this variable and the change of exchange rate regime leads to an increase of this volatility in the short term which is estimated at 0.22%.

Finally, we see that the parameters of the variables PE, MS, GDP and ERM are statistically significant at the 5% and 10% significance level, while the other estimated elasticities are not statistically significant.

Concerning the long term dynamics

First of all, the constant is equal to 7.17 this result is statistically insignificant. Moreover, based on these results, we conclude that the elasticity of external debts is equal to (0.1280)this result is positive, in fact, an increase of 1% of external debts in the long term will lead to an increase of 0.12% of the volatility of the REER.

Indeed, the same thing concerning the elasticity of public spending which is equal to (0.2143) this result is also positive, it is simply a positive impact, that is to say that an increase of 1% of public spending in the long term will lead to an increase of 0.21% of the volatility of the REER.

Concerning the elasticity of FDI, we find that it is equal to (-0.1190), which is simply a negative impact in the long term, in other words, a 1% increase in FDI will lead to a decrease of 0.11% in the volatility of the REER, so this effect remains weak. However, as regards the elasticity of the money supply, we find that it is negative (0.2567), i.e. an increase of 1% in this economic monetary

variable will lead to a reduction of 0.25% in the volatility of the REER, this effect is high from a statistical point of view.

On the other hand, the elasticity of trade openness is negative with a value equal to (0.4368) which means that the improvement of trade openness will generate in the long run a decrease in the volatility of the REER.

Then, regarding the elasticity of domestic GDP, we find that it has a positive value equal to (0.8449) which reflects that the influence of this real economic variable will cause in the long run an increase in the volatility studied. The same is true for the estimated elasticity of the inflation rate, which has a positive value of (0.0476) and will therefore cause the volatility of the REER to increase in the long term.

Then, the elasticity of the exchange term is evaluated at (-0.3977), which is simply a negative effect, in other words, a 1% increase in this economic variable will cause a decrease in the volatility of the REER by 0.39% in the long term. Thus, the last estimated parameter concerns the exchange rate regime adopted and applied by the Moroccan monetary authorities duringthe period studied, this qualitative variable which was constructed via binary values that vary from 0 to 1. We find that this variable has a positive impact on the volatility of the REER, allowing to increase this volatility, in fact, an improvement of this variable and the change of exchange rate regime causes in the long run an increase of this volatility which is evaluated at 0.55%.

Finally, we find that the elasticities of the variables FDI, TO, GDP and TOT are statistically significant at the 5% level, while the other remaining estimated parameters are not statistically significant.

The CUSUM and CUSUM square tests, which are based on the recursive regression technique, allow us to observe, through a graph, the existence of possible instability affectinga linear relationship over time. The procedure consists in calculating the recursive residual sum by progressively increasing the number of observations (by successive regressions) with the objective of determining by a test whether the calculated breakpoints are significant within a reliable threshold fixed at two distances (plus or minus two standard deviations) or not. It is simply a matter of checking whether the coefficients of the model evolve within a confidence interval. If not, the residual variations are not considered to be identical and their variation results from structural changes. Here are the results obtained from these statistical tests.

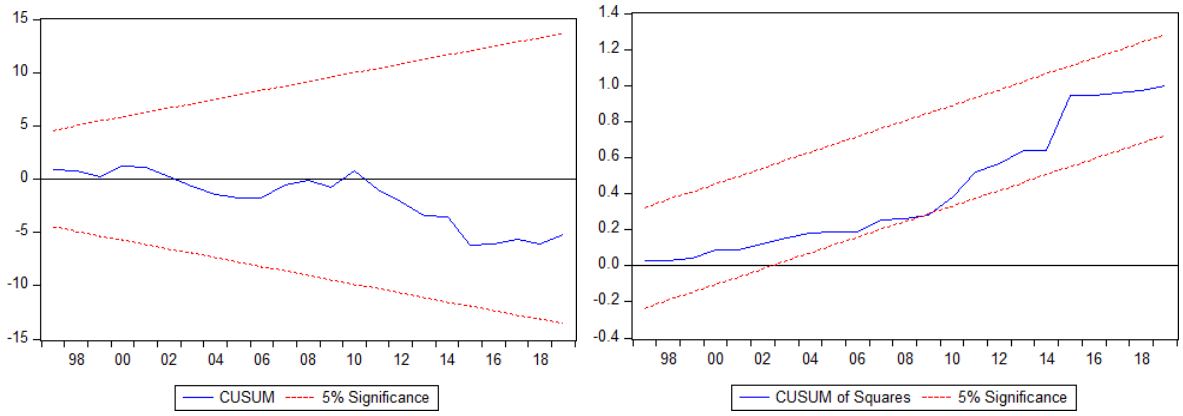

Figure 1. *Results of CUSUM and CUSUM squared tests of REER volatility*

The results of the CUSUM and CUSUM squared tests for the estimated empirical model allow us to say that the REER volatility function is stable in the period studied, because quite simply, the results of these tests are within the corridor, which allows us to say that the relationship is indeed stable. Given that this stability can be explained by several elements, in particular by the economic policies influencing the explanatory determinants presented in this empirical study.

5. Conclusion

The main objective of this theoretical and empirical study was to investigate the explanatory determinants of the volatility of the real exchange rate (RER), based on the explanatory economic theories and using econometric tools that allow estimating the parameters of the empirical model applied in a simplified way. Since it is very useful and important to know the factors that cause the volatility of exchange rates in a given economy, in order to adopt and apply effective economic policies to reduce this volatility. In this study, the explanatory determinants of the volatility of the RER that were estimated for the period 1981-2019 in Morocco are: external debts, government expenditures, foreign direct investments, money supply, trade openness of the economy, domestic gross domestic product, interest rate, term of trade, and the exchange rate regime applied by the monetary authorities.

In addition, the GARCH(1,1) model was used to measure the volatility of the REER, also a long term equilibrium relationship was found between the economic variables studied (Co-integration), given that the variables (volatility, external debts, money supply, trade openness and GDP) are stationary in first difference, while, the other remaining variables are stationary in level. For this reason, we applied the vector error correction model (ECM), while applying the ARDL econometric modeling.

Thus, according to the results obtained, it is concluded that in the long term, foreign direct investment, trade openness of the economy and the term of trade have negative and statistically significant impacts on the volatility of the REER, while domestic GDP has a positive influence, i.e., allowing to increase this volatility, also this result is statistically significant. Finally, the external debts, the public expenditure and the applied exchange rate regime have positive effects on the volatility of the REER, in other words, they allow to increase this volatility on the foreign exchange market and in the Moroccan economy, whereas, the money supply has a negative impact and the inflation rate has a positive effect on the studied volatility, but still these last obtained results are not significant from the statistical viewpoint.

Staying within this framework, the results obtained in this empirical study are consistent with other empirical works including, Kilicarslan (2018), Adusei & Gyapong (2017), Hassan, Abubakar & Dantama (2017), Alagidede & Ibrahim (2017), Mpofu (2016), Oaikhenan & Aigheyisi (2015), Insah & Chiaraah (2015), & Mirchandani (2015), as the Moroccan monetary authorities can design appropriate macroeconomic and monetary policies, while taking into consideration the impact of these explanatory determinants of REER volatility.

In future studies, while using theoretical and empirical arguments, it is preferable to develop an analysis and an economic reflection on the sources of asymmetry of the volatility of the nominal exchange rate of the Moroccan dirham (EUR-MAD and USD-MAD), and while studying the positive and negative shocks of this volatility in the Moroccan economy Finally, the

economic optimality of the exchange rate regime applied in Morocco, also remains a topical economic issue and it is very important to study the current exchange rate regime based on the widening of the optimal fluctuation band of the exchange rate from +/-2.5% to +/-5% in order to know if this widening is optimal while using non-linear models to know the impact of this economic decision making by the Moroccan monetary authorities on the volatility of the exchange rate.

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