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MODELING THE EXCHANGE RATES OF ALGERIAN DINAR PER UNITED STATES DOLLAR USING A MARKOV-SWITCHING AUTOREGRESSIVE MODEL

[*] **Assia MERABET**
FSEG Blida2 University
amerabet99@gmail.com

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ABSTRACT: This paper aims to model the Algerian dinar per United States dollar exchange rates using a regime Markov switching model. Firstly, we detect if nonlinear model suits the data at hand, the BDS test and CUSUM of squares test were used and the results indicates that a nonlinear model suits the data. Then, we proceed by using a two state Markov switching autoregressive model (MS-AR) developed by (Hamilton, 1989), Engle, Hamilton, 1990) for a period from January 1994 to March 2018. The empirical evidence indicates strong transition probabilities suggesting that only extreme events can switch the series from an appreciation regime to depreciation regime vice versa. Furthermore, the MA (2)-AR (3) is well suited to capture the nonlinearity in exchange rates.

Keywords: Exchange rates, Nonlinearity, Transition probabilities, Markov switching autoregressive model

JEL Classification: C32, C4

1. INTRODUCTION:

The exchange rate is a macroeconomic variable, key to which national economies are expected to adjust to each other; it has long been a focus of attention for economists, particularly econometricians. Therefore, exchange rate modeling remains at the center of interest for many researchers. Some of the field include monetary exchange models, while the others focus on time series models, such as (AR, ARMA, ARIMA, ARCG, GARCH,). Time series models are a class of specifications, where we try to model and forecast variables using only the information contained in their history, and were developed in response to the specification difficulties of structural models. The exchange rate fluctuations in the foreign exchange markets have shown that most macroeconomic variables are unable to explain the dynamics of exchange rate movements.

[*] Corresponding Author

Since the work of (Hamilton, J. D, 1989), there has been considerable interest in the development of Markov switching modes, which take into account the possibility of non-linearity in the exchange rates. (Hamilton J. D, Engle C, 1992), (Engle C, 1994) have shown that the Markov switching model can describe exchange rates movements over time.

In the case of Algeria, it is very important to study the econometric aspect of the Algerian dinar per United States dollar exchange rate.

2. LITERATURE REVIEW :

The Markov switching model was pioneered by (Hamilton, 1989, p 358). A Markov switching autoregressive (AR) model (MS-AR) of states with an AR process of order p is written as follow:

$$y_t = \begin{cases} c_1 + \alpha_{11} y_{t-1} + \cdots + \alpha_{p1} y_{t-p} + \varepsilon_{1(t)} & S_t = 1 \\ c_2 + \alpha_{12} y_{t-1} + \cdots + \alpha_{p2} y_{t-p} + \varepsilon_{2(t)} & S_t = 2 \end{cases} \quad (1)$$

Where the regimes in equation (1) are index by S_t. In this model, the parameters of the autoregressive part and the intercept are dependent on the regime at time t. The regimes are assumed discrete unobservable variable. Those, in this study, regime one (1) describes the periods of downward trending of the exchange rates and regime two (2) denotes period of upward trending of the exchange rates. The transition between the regimes is assumed to follow an ergodic and irreducible a first order Markov process. This implies influences of all past observations for the variables and the state is fully encapsulated in the current observation of the state variable are denoted as bellow:

$$P_{ij} = Pr(S_t = j / S_{t-1} = 1) \qquad \forall i, j = 1,2 \quad and \ \sum_{i=1}^{2} P_{ij} = 1 \quad (2)$$

The probability of switching is captured in the matrix P known as a transition matrix.

$$P = \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} \quad (3)$$

Where $P_{11} + P_{12} = 1$ and $P_{21} + P_{22} = 1$

The maximum likelihood estimator MLE was used to estimate the parameters of the MS-AR, thus, the log likelihood function is written as follow:

$$LnL = \sum_{t=1}^{T} Ln\left\{\sum_{S_t=1}^{2} f(y_t / S_t, \Psi_{t-1}) P(S_t / \Psi_{t-1})\right\} \quad (4)$$

Where. $\Psi_{t-1} = \{y_1, y_2, \dots, y_T\}$ and $P(S_t / \Psi_{t-1})$ denotes the filtered probabilities.

Given that MS-AR model allows in making an inference about the observe regime value, through the behavior of exogenous Y_t .thus the calculated filtered probabilities by a simple iterative algorithm is written as:

$$P(S_t = j / \Psi_t) = \sum_{S_t=1}^{2} P(S_t = j, S_{t-1} = i / \Psi_t) \qquad for\ t = 1, \dots T \quad (5)$$

Similarly, the smoothed probabilities are obtained if the data set is used as a whole.

Therefore, using all the information in the sample that is $\Psi_{t-1} = \{y_1, y_2, \dots, y_T\}$, the calculated smoothed probabilities are written as:

$$P(S_t = j / \Psi_t) = \sum_{k=1}^{2} P(S_t = j, S_{t-1} = k / \Psi_t) \quad (6)$$

Finally, from the transition matrix in equation (3) above, the expected duration of the i^{th} regime is extracted. This implies that the closer the probability P_{ij} is to one, it takes long time to shift to next regime. The unconditional probabilities that the switching process will indicate either regime 1 or 2 can be calculated with the following formulas:

$$P(S_t = 1) = \frac{1 - P_{22}}{1 - P_{11} - P_{22}} \quad (7)$$

$$P(S_t = 2) = \frac{1 - P_{11}}{1 - P_{11} - P_{22}} \quad (8)$$

In short the expected duration written as:

$$Expected\ duration = \frac{1}{1 - P_{ij}} \quad (9)$$

The empirical procedure used in this study is as follow:

- Firstly, the specifications of an appropriate autoregressive AR model of the lag order p which includes all of the time series data under investigation.
- Secondly, The test of null hypothesis of linearity against the alternative of nonlinearity.
- Thirdly, estimate the parameters in the selected model, and evaluate model using diagnostic test, these parameters include the AR parameters, and transition probabilities as well as the probabilities with each stat occurs at time t.

3. METHODOLOGY :

Given that observed nominal exchange rate data may follow different sub-sample, a complete description of the data generating process should involve understanding the different regimes that the process may follow. The Markov chain methodology was employed to analyze the possibility of regime changes in the nominal exchange rates. The different processes that a variable may follow over different sub-samples are referred to as states or regimes. So, (Bazdresch and Werner, 2005) employed the technique to examine appreciation and depreciation episodes of the nominal exchange rate of the Mexican peso. When, (Ismail and Isa, 2006) employed it to examine appreciation and depreciation episodes of the nominal exchange rate of the ringgit of Malaysia, the Singapore dollar and Thailand bath.

The data under study are monthly exchange rates of Algeria over the period from January 1994 to march 2019for a total of 303 observations. The exchange rates are the Algerian local currency dinar against the united state dollar. The data are sourced from www.bank-of-Algeria.dz. The variable under study are exchange rates returns in percentage (Engel, Hamilton, 1990, p 691), $Y_t = 100 \times \left(Ln(er_t) - Ln(er_{t-1})\right)$; where $Ln(er_t)$ and $Ln(er_{t-1})$ are logarithm of exchange rates at time *t* and *t-1* respectively.

3.1 Data description:

The analysis presented in this article makes use of econometric modeling that was possible with Eviews 11 program. The series of exchange rate is depicted in Figure N°1:

Figure N°1: Graphical representation of exchange rates series

It is possible to notice periods of higher and lower fluctuations, which can be attributed to structural changes, and the series is stationary because the graphical representation does not show a trend, we will check it by using the augmented Dickey-Fuller test and the Philips-Perron test as shown in Table N°1:

TableN°1 Augmented Dicky-Fuller test and Philips- Perron test results

Variables / test	**In level**					
Exchange rate	None		Constant		Constant, linear trend	
	t_{cal}	**Prob**	**t_{cal}**	**Prob**	**t_{cal}**	**Prob**
ADF test	-11.36	0.00	-11.75	0.00	-11.90	0.00
Philips-Perron test	-11.28	00	-11.95	00	-10.35	00

Source: (Eviews 11 outputs)

From the results of ADF test and Philips-Perron test all the probabilities are less than the 5%, so, we conclude that the exchange rate series is stationary. The descriptive statistics for the exchange rates time series is presented in table N°2:

Table N°2: Descriptive statistics of the exchange rates time series

Variables	**value**
Mean	0.528063
Median	0.229811
Maximum	31.35984
Minimum	-6.761702
Sd.Dev	2.375758
Skewness	0782
Kurtosis	96.76327
Jacque-Bera	113540.02
Probability	0.00000.

Source : (Eviews11 outputs)

According to the descriptive statistics, we notice that compared to the normal law, the kurtosis is 96.76327, it is greater than 3 (excess of flattening) and the value of the skewness is 7.607826, it is different from the zero

In probability theory and statistics, an excess of flattening corresponds a sharp distribution, while the skewness of the distribution is positive if the tail is longer, i.e in our sample, a large number of observations have a positive value.

Thus the positive value of the skewness indicates that the distribution of the exchange rates is skewed.

This asymmetry shows that there are two states of the exchange market, the appreciation phase and the depreciation phase. Therefore, it is important to take into account the non-linear effect of the exchange rates series, which is caused by this difference between two regimes.

According to the model specification, the detected asymmetry can be decomposed into a regime that corresponds to the appreciation phase and another regime that corresponds to the depreciation phase i.e the Hamilton (1989) regime-switching model.

To test for a non-linearity effect of Algerian Dinar per US Dollar exchange, we will use the nonparametric method known as the BDS test developed by (Brock, Dichert and Scheinkman, 1987). The BDS test is based on an integral correlation of the series, and it is defined as follow:

$$BDS_{m,T}(r) = \sqrt{T}\,\frac{C_m(r) - C_1^m(r)}{\sigma_{m,T}} \qquad 10$$

Where:

T is the surrounded points of the space with m dimensions;

r denotes the radius of the sphere centered of the points x_i ;

$$C_m(r) = \frac{2}{(T-m+1)}\sum_{t<m} I_e\,(x_t^m - x_s^m) \qquad 11$$

and $$C_1^m = P(|x_t - x_s| < r)^m \qquad 12$$

$\sigma_{m,T}$ is the standard deviation of $C_m(r) - C_1^m(r)$

thus the null and alternative hypothesis of the BDS test for non-linearity is as follow:

H_0: The series are linearly dependent.

H_1: the series are not linearly dependent.

Hence, the null hypothesis is rejected at the 5% significance level whenever $|BDS_{m,T}| > 1.96$, or the probabilities are less than 5%..

Also, for detecting structural breaks, we employed the CUSUM of squares test developed by (Brown, Durbin and Evan 1975) based on a plot of cumulative sum of squared one step ahead forecast error resulting from recursive estimation between two crucial lines, in which any movement outside the crucial line is an indication that the parameter is unstable (Ismail, Isa (2006), p 59).

3.2. Test of non-linearity:

The table N**3** reports the results of the non-linearity test:

TableN°:3 BDS test for non-linearity

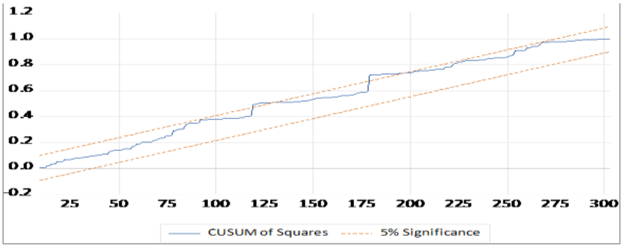
Dimension	BDS statistic	Std Error	z-Statistic	Prob
2	0.049906	0.005244	9.516603	0.0000
3	0.081399	0.008331	9.770798	0.0000
4	0.102419	0.009918	10.32702	0.0000
5	0.113876	0.010335	11.01904	0.0000
6	0.117154	0.009964	11.75716	0.0000

Source : (Eviews 11 outputs)

The BDS test results in table N°2 indicates that there is non-linearity effect in the Algerian dinar per United State dollar exchange rate, because all the probabilities in the table N°2 are less than 5%, thus implying a rejection of the null hypothesis that the series is linearly dependent.

The figure N°: 2 indicate structural breaks in the series as shown below:

Figure N°2: CUSUM of squares test



Source : (Eviews 11 outputs)

The results in figure N°2 indicate that some the cumulative sums of squares are outside the boundary of 5% significant level which implies instability. So, from the results in Table N°3 and Figure N°2, we conclude that the time series of Algerian exchange rates is non-linear and unstable; hence the data can be estimated using a non-linear model. The study proceeds with the Markov switching autoregressive model (MS-AR). However, before obtaining the final form of the models in this study, various form of lagged values of the Algerian dinar per United States dollar was considered in table N°3 compares the appropriateness of the various estimated Two-state Markov switching models.

3.3 Model estimation:

Before estimating the model, we have to select the optimal(MS- AR) model.

TableN°:4 Model estimation and selection

Model (MS-AR)	Number of states	Number of lag s	Log likelihood	AC
2	2	1	-505.6644	3.4244
3	2	2	-491.6351	3.3666
4	2	3	-473.0369	3.2443
5	2	4	-491.5802	3.3546
6	2	5	-481.6041	3.2969
6	2	6	-477.9700	3.2815

Source : (Eviews 11 outputs)

From Table N°3 above, using the specification measures such as the Log likelihood and the Akaike information criteria, among the six estimated Markov switching model from MS(2)-AR(1) to MS(2)-AR(6), the selected model was the lowest Akaike information criteria of 3.2443, and the highest Log likelihood of -473.36969. After model estimation and selection, the model MS(2)-AR(3), the results are reported in Table N°5:

Table N°:5 Estimation results of MS (2)-AR(3) model

Variable	Coefficient	Std-Error	Z-statistic	Prob
Regime1 (Appreciation)				
C_1	-0.31639	0.38661	-0.81838	0.4131
AR_{t-1}	3.35375	0.31844	10.5317	0.0000
AR_{t-2}	-1.01670	0.16496	-6.16331	0.0000
AR_{t-3}	-0.36473	0.26731	-1.36444	0.1724
Regime 2 (Depreciation)				
C_2	0.22243	0.07037	3.16109	0.0016
AR_{t-1}	0.34609	0.02892	11.6963	0.0000
AR_{t-2}	-0.03827	0.03256	-1.17521	0.2399
AR_{t-3}	0.02403	0.02922	.82259	0.4107
Transition probability				
	Regime1	Regime2		
Regime 1	0.907195	0.092805		
Regime 2	0.060711	0.939289		

Source : (Eviews 11 outputs)

In Table N°4, almost all the estimated coefficient of the MS (2)-AR (3) model is found to be significant at conventional level 5%. However, the estimated model is agree with the results found by (Hamilton and Engle, 1990), since the regime dependents intercepts for appreciation regime is negative and for depreciation regime is positive. The estimated transition probability shows that is a higher probability. that the system stays in the same regime thus implying few switches in the regime. For example, the results indicated a 91% probability of staying in an appreciation regime and a lower probability of 9% switching to the depreciation regime. Correspondently, when the system is in a depreciation regime, there is a 94% probability of staying in a depreciation regime and again a lower probability of 6% switching to the appreciation regime. The estimated transition probabilities indicated that none of the regime is permanent since all the estimated transition probabilities are less than one.

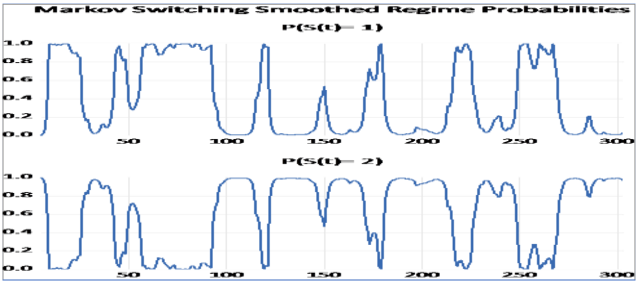
Also, there have been more episodes of depreciation of the Algerian dinar against the United States dollar than the counterpart appreciation during the period 1994(1) to 2018(3), the average duration of each regime supports this. Based on expected duration, the appreciation regime has an average duration 10.77528 months while depreciation has 16.47148 months duration. It implies that the Algerian dinar per United States dollar will be in appreciation regime for an average 10.77528 months and depreciation regime for an average of 16.47148 as shown in Table N° 6 and figure N°3:

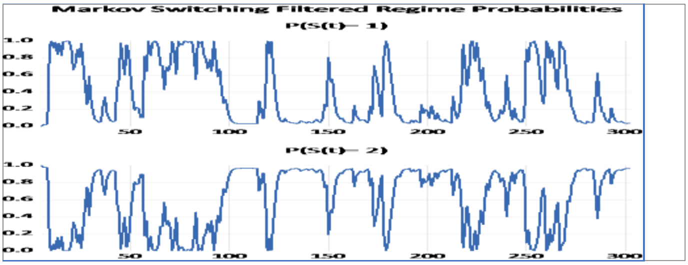
Table N° 6: Regime classification. Appreciation and Depreciation from 1994 to 2018

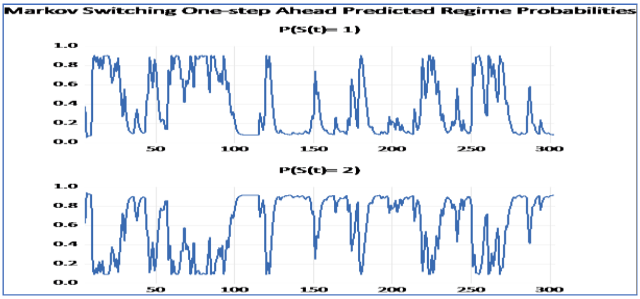
Regime1 (Appreciation)		
Range	Months	Average probability
1-129	129	0.907195
Total: 129 months (42.72%) , with an average duration of 10.78 months		
Regime 2 (Depreciation)		
Range	Months	Average probability
130-302	173	0.939289
Total: 173 months (57.28%) , with an average duration of 16.47 months		

Source: (Eviews 11 outputs)

Figure N°3: Markov switching regime probabilities







Source : (Eviews 11 outputs)

Based on the graphical representation of regime probabilities of the MS (2)-AR (3) model exchange rates were classified into one of the two regimes Appreciation regime and depreciation regime, the Algerian dinar per United States dollar have the longest period of stability (173 months or 57.28% stability of the time), with an average duration of 16.47 months in regime of depreciation.

3.4. Regime classification measure:

According to (Ang, A and Bekeart G , 2002) , we can calculate a measure in order to assess the quality of the regime classification. This measure is called regime classification measure (RCM), and the formula for a model with two regimes is the following:

$$RCM = 400 \times \frac{1}{T}\sum_{t=1}^{T} P_t(1 - P_t) \qquad (10)$$

Where P_t the smoothed regime probabilities and T is is the number of regimes. When the regime switching model cannot successfully separate the regimes, then we have weak regime inference. If P_t is close to 1 or 0, the regime switching model is ideal and it classifies regimes a abruptly. The fixed term in the form is used to keep the RCM statistics between 0 and 100. Low RCM implies good regime classification. On the **Total: 129 months (42.72%) ,**

with an average duration of 10.78 months other hand, a value of denotes that we cannot observe any information about the regimes, now, in the analysis study find the following value:

$$RCM = 28.243481$$

The RCM statistic is low; therefore, we can conclude that the regime classification for the model is good.

4 THE QUALITY OF THE MODEL:

In order to study the quality of the model, we apply the following diagnostic tests as shown in table N° 7:

Table N° 7: Results of diagnostic testsof the model

Breuscg-Godfrey serial correlation LM test			
Null hypothesis (H_0)m there no no auto-correlation of residuals			
F-statistic	1.8435	prob F (3.292)	0.1393
Obs*Squared	5.5578	prob chi-squared	0.1352
Heteroskedasticity test ARCH			
Null hypothesis (H_0): stability of variance			
F-statistic	0.3506	prob F (3.292)	0.7887
Obs*Squared	1.0623	prob chi-squared	0.6862
Normality test			
Null hypothesis (H_0): Residuals are normaly distibutesd			
Jacque- Bera	2.8052	prob	0.2459
Linearity restriction LR test			
Null hypothesis (H_0): the model is linear			
F-statistic	25.7439	prob F (3.292)	0.0000
Obs*Squared	102.9757	prob chi-squared	0.0000

Source : (Eviews 11 outputs)

From the Table N°7, the results of diagnostic tests of the model confirm the following:

- The serial correlation LM test indicates that Fisher‘s probability 0.1393 is greater than the 5%, so, we accept the null hypothesis, there is no auto-correlation of residuals.
- The Heteroskedasticity test ARCH indicates that Fisher‘s probability 0.7887 is greater than the 5%, so we accept the null, the variance is stable.
- The Normality test of Jacques-Bera probability 0.2459 is greater than the 5%, so, we accept the null hypothesis, and the residuals are normally distributed.
- The linearity restriction LR test indicates that the Fisher’s probability 0.0000 is less than the 5 %, so, we reject the null hypothesis of normality in favour of the markov switching autoregressive model MS(2)-AR(3).

5 CONCLUSION;

A two state Markov autoregressive MA(2)-AR(3) model was employed in this study, using monthly Algerian dinar per United States dollar exchange rate covering the period January 1994 to March 2018, the parameters of the model were obtained using eviews 11. The BDS test and CUSUM of squares test were used, and both tests suggested that a non linear model was appropriate for modeling the Algerian dinar per United States dollar exchange rates. .

According to the descriptive statistics, we notice that compared to the normal law, so the distribution of the exchange rates is asymmetric. This asymmetry shows that there are two states of the exchange market, the appreciation regime and the depreciation regime

Our results validate the hypothesis that the time series of exchange rates of Algerian dinar per United States dollar was non linear and the Markov autoregressive switching model MA (2)-AR(3) was the best model, and plots of smoothed probabilities and filtered probabilities were able to report the appreciation and the depreciation of the Algerian dinar per United States dollar exchange rates.

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