ECONOMETRIC ANALYSIS OF RON/EUR EXCHANGE RATE EVOLUTION IN THE PERIOD 2005-2011

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Abstract: The paper analyzes the evolution of RON/EUR exchange rate from March 2005 to February 2011, a period marked by increases and decreases of the Romanian economy and European economies alike.
In the first part of the paper are summarized the main features of the series of linear discrete time of random processes, characteristics taken into consideration throughout the paper. Also, are presented the models of the linear stationary random processes (AR, MA, ARMA) and linear no stationary (ARIMA).
In the second part of the paper is analyzed the evolution of RON/EUR exchange rate between March 2005 February 2011. Seasonality and trend of the series are tested.Because the data series analyzed is non-stationary, is applied time finite difference operator $\left(\Delta^{m+1}\right)$, resulting a stationary process. Series of stationary random process is analyzed as mixed linear stationary ARMA(p,q).
Finally is determined a model, that approximates the dynamics of RON/EUR exchange rate during the analyzed period.

1. BRIEF METHODOLOGICAL CONSIDERATIONS

Characterization of the time evolution of business processes can be done by developing dynamic models. Of these many types, for the analysis presented in this paper, we stopped, at first, on autoregressive models with the general form:

$$y = f\left(x_t, y_{t-k}\right) + \varepsilon \tag{1}$$

Autoregressive models are models that allow description of the evolution of a stationary random process function according to its previous values.

A stationary series $\{y_t\}_{t\in Z}$ follows a $AR(p)$ process where is met the condition:

$$y_t - \sum_{k=1}^{p} \phi_k y_{t-k} = \varepsilon_t, \quad \forall t \in Z \tag{2}$$

where $\varepsilon_t \sim N\left(0, \sigma_\varepsilon^2\right)$ is a stationary series, with:

$$M\left(\varepsilon_t\right) = 0,\ M\left(\varepsilon_t^2\right) = \sigma^2 \text{ şi } \operatorname{cov}(\varepsilon_t, \varepsilon_i) = 0\ \forall t \neq i\,. \tag{3}$$

In (2), p is the number of previous values of y which are taken into account to predict its current value, and the term ε_t represents that part of the variable y_t which is not predictable.

Using the delay operator L and noting with

$$\Phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \ldots - \phi_p L^p \tag{3}$$

relationship (2) may be made in the form:

$$\Phi(L) y_t = \varepsilon_t \tag{4}$$

Characteristic polynomial attached AR(p) process is:

$$P(\lambda) = \lambda^p - \phi_1 \lambda^{p-1} - \phi_2 \lambda^{p-2} - \ldots - \phi_p \tag{5}$$

The process is stationary if the absolute values of its characteristic polynomial roots are strictly less than 1.

In addition to the series that can be modeled as autoregressive processes, there are time series following other types of processes. Some of these are processes of moving averages (MA). A set of data $\{y_t\}$ follows a moving average process of order q, if defined by the equality:

$$y_t = \varepsilon_t - \theta_1 \varepsilon_{t-1} - \ldots - \theta_q \varepsilon_{t-q} \tag{6}$$

where $\varepsilon_t \sim N\left(0, \sigma_\varepsilon^2\right)$ is a stationary series.

A significant improvement of methods of analysis can be obtained by combining AR and MA processes.

Thus, we obtain a generalized model, the autoregressive moving average ARMA. The equation of such model with p autoregressive terms and q moving average terms, denoted ARMA (p, q) is:

$$y_t = \phi_0 + \sum_{i=1}^{p} \phi_i y_{t-i} + \varepsilon_t + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} \tag{7}$$

If a random process $\{x_t\}_{t \in Z}$ has a uniform comportment highlighting, for example, a polynomial trend, we are dealing with a stochastic process whose average depends on the time. In these circumstances, removing trend and process stationary may be obtained, for example, through differentiation.

No stationary process $\{x_t\}_{t \in Z}$ for which $d \in N^*$ exist, so that the transformed process $y_t = \Delta^d x_t$ is a stationary ARMA (p, q), process is called ARIMA(p, d, q)

Reconstitution of no stationary process x_t is obtained from the corresponding y_t stationary, by operation of integration:

$$x_t = S^d y_d \tag{8}$$

where $S = \Delta^{-1}$ is the operator of integration.

This approach is particularly useful because it allows the study of a no stationary process x_t using models ARMA(p, q) applied to the stationary transform y_t, which by integrating (8) is x_t.

2. THE EVOLUTION OF RON/EUR RATE DURING MARCH 2005 - FEBRUARY 2011

Analysis of exchange rate RON/EUR was performed on a series containing 1586 records. Graphic exchange rate is shown in Figure 1. As can be seen, in the graphic representation of the series, a significant change in the exchange rate, in terms of its increasing, was in mid-2007. After a slight recovery, recorded in autumn 2008, the exchange rate continued to increase, exceeding in 2009, and threshold of 4 RON.

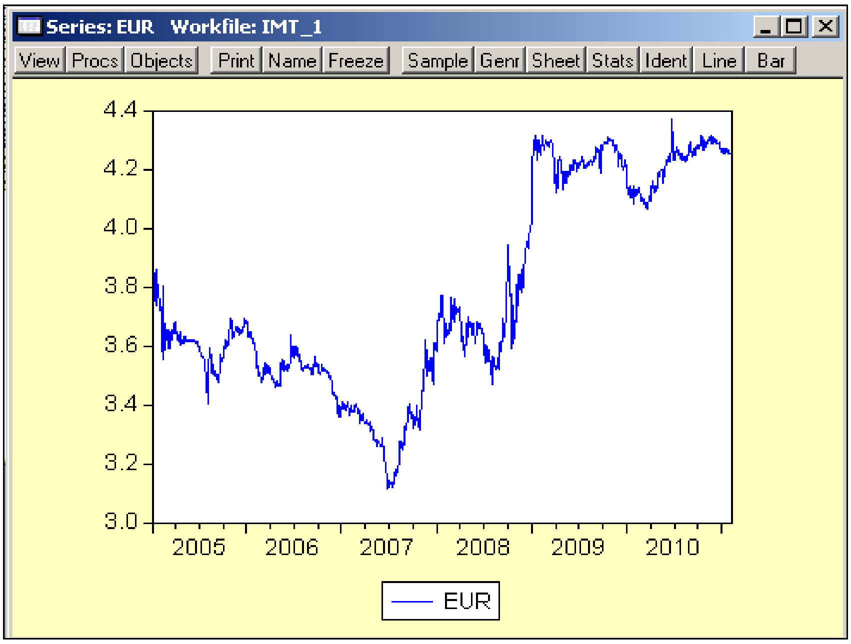

Figure 1 The exchange rate evolution in 2005-2011 periods

Series has a polynomial trend which leads to the conclusion that this is a stochastic process whose average depends on the time.

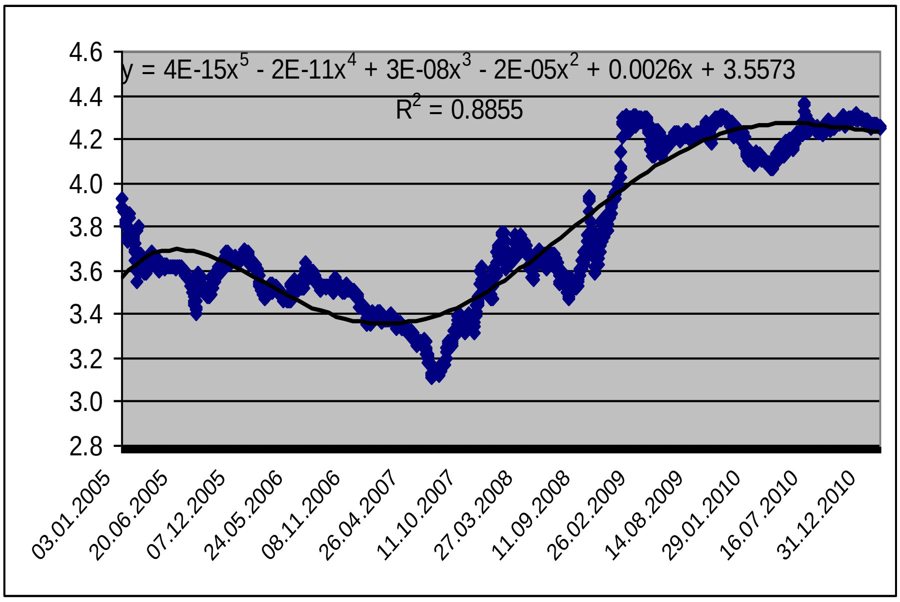

Figure 2 Polynomial trend of exchange rate RON / EURO
in the period March 2005 - February 2011.

Given the value of the parameter $R^2 = 0.8856$, the polynomial function:

$$EUR = 4 \cdot 10^{-15} \cdot t^5 - 2 \cdot 10^{-11} \cdot t^4 + 3 \cdot 10^{-8} \cdot t^3 - 2 \cdot 10^{-5} \cdot t^2 + 0.0026 \cdot t + 3.5573 \qquad (9)$$

is a good approximation of the trend series.

3. THE ANALYZING OF RON/EUR RATE AS ARMA STATIONARY PROCESS

Before attempting to identify an as best ARMA model, we checked whether the series is stationary applying Dicley-Fuller Unit Root Test (Figure 3).

Series: EUR Workfile: IMT_1

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Augmented Dickey-Fuller Unit Root Test on EUR

Null Hypothesis: EUR has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic based on SIC, MAXLAG=23)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.544682	0.8799
Test critical values:	1% level	-3.434278	
	5% level	-2.863162	
	10% level	-2.567681	

Figure 3 Dickey-Fuller test applied to the EUR series

It is noted that the calculated value of $t\_Statistic = -0{,}544682$ test in relation to any relevant critical values of significance thresholds of 1%, 5% and 10% (-3.43, -2.86, -2.57), leading to acceptance of the null hypothesis, which means that it is a no stationary process.

Correlogram of EUR

Date: 03/29/11 Time: 17:01
Sample: 1/03/2005 2/04/2011
Included observations: 1586

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.998	0.998	1582.9	0.000
		2	0.996	-0.156	3158.8	0.000
		3	0.993	0.101	4728.5	0.000
		4	0.991	0.084	6293.6	0.000
		5	0.990	-0.002	7854.2	0.000
		6	0.988	0.007	9410.4	0.000
		7	0.986	0.009	10962.	0.000
		8	0.985	-0.008	12509.	0.000
		9	0.983	-0.020	14051.	0.000
		10	0.981	-0.005	15589.	0.000
		11	0.979	0.004	17121.	0.000
		12	0.977	-0.038	18648.	0.000
		13	0.975	0.013	20170.	0.000
		14	0.973	0.034	21688.	0.000
		15	0.971	-0.001	23201.	0.000
		16	0.970	0.022	24709.	0.000
		17	0.968	0.001	26214.	0.000
		18	0.966	-0.034	27714.	0.000
		19	0.964	-0.022	29208.	0.000

Figure 4 The correlogram of EUR series

The same results analyzing the 0.87 probability value corresponding to $t\_Statistic = -0{,}544682$ and from correlogram (figure 4).

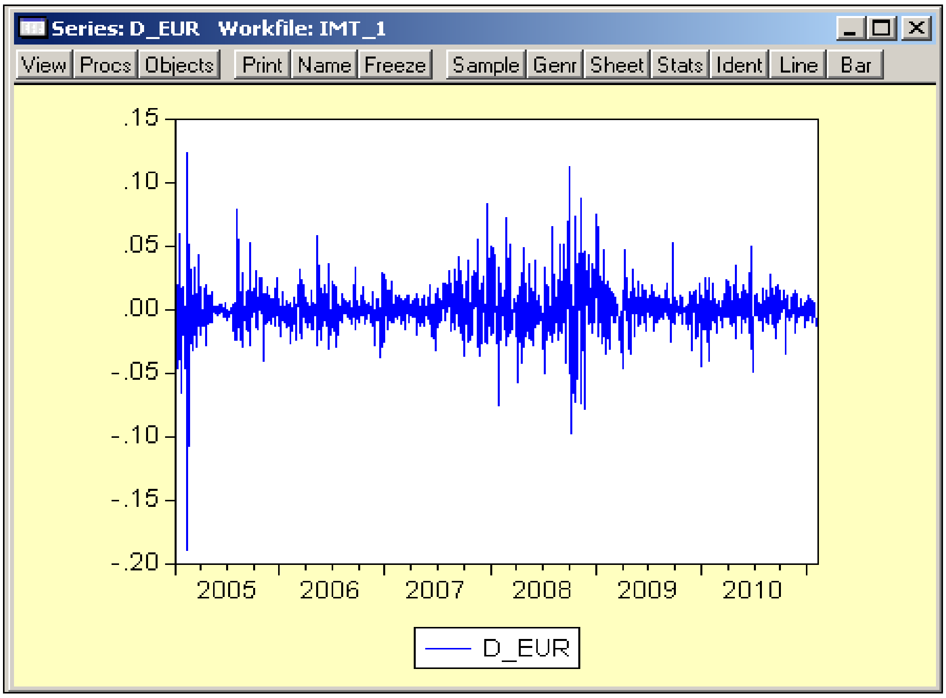

Figure 5 The graph of D_EUR series

Since the original series (EUR) is not stationary, was generated first-order difference of this series (denoted D_EUR). D_EUR series was subjected to the same checks as the original series. Test result is presented in Figures 5.

Series: D_EUR Workfile: IMT_1

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Augmented Dickey-Fuller Unit Root Test on D_EUR

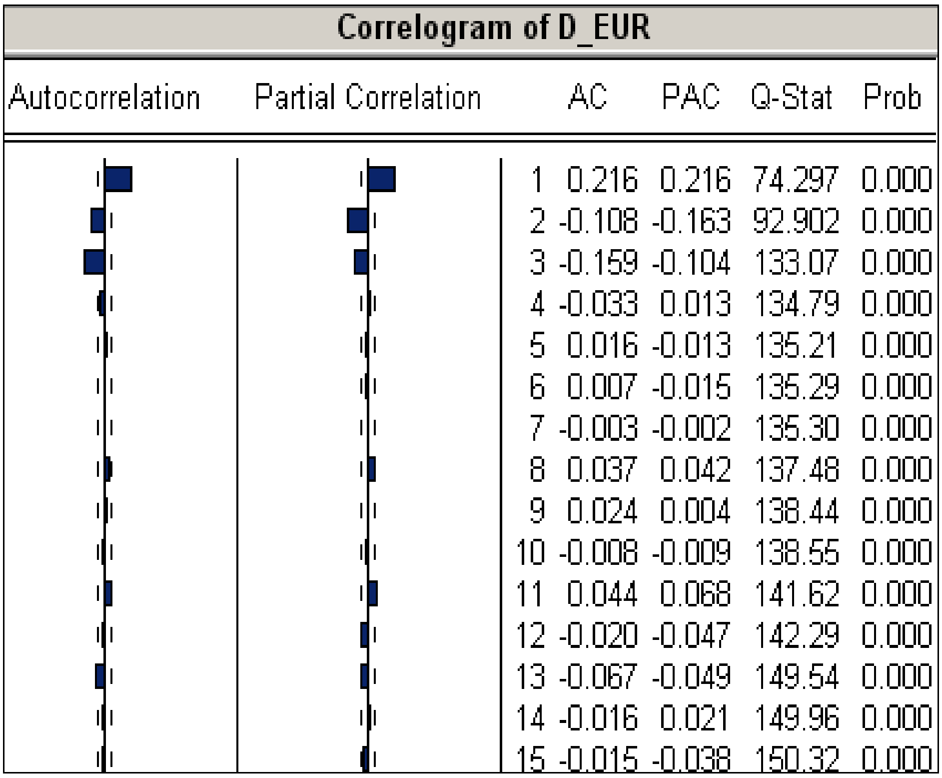
Null Hypothesis: D_EUR has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic based on SIC, MAXLAG=23)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-26.17067	0.0000
Test critical values:	1% level	-3.434278	
	5% level	-2.863162	
	10% level	-2.567681	

Figure 6 Dickey-Fuller test for D_EUR

Also, we checked whether the series is stationary applying Dicley-Fuller Unit Root Test (Figure 6). For D_EUR series, the calculated value of $t\_Statistic = -26{,}17067$, leading to reject the null hypothesis and accept the hypothesis: D_EUR series is a stationary process.

The same conclusion of no stationary series, results analyzing from correlogram (figure 7). We can used the correlogram of D_EUR series for obtain a initial ARMA model.


Correlogram of D_EUR

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.216	0.216	74.297	0.000
		2	-0.108	-0.163	92.902	0.000
		3	-0.159	-0.104	133.07	0.000
		4	-0.033	0.013	134.79	0.000
		5	0.016	-0.013	135.21	0.000
		6	0.007	-0.015	135.29	0.000
		7	-0.003	-0.002	135.30	0.000
		8	0.037	0.042	137.48	0.000
		9	0.024	0.004	138.44	0.000
		10	-0.008	-0.009	138.55	0.000
		11	0.044	0.068	141.62	0.000
		12	-0.020	-0.047	142.29	0.000
		13	-0.067	-0.049	149.54	0.000
		14	-0.016	0.021	149.96	0.000
		15	-0.015	-0.038	150.32	0.000

Figure 7 The correlogram of D_EUR series

Since D_EUR series is stationary, we test various ARMA models to identify an acceptable model to describe exchange rate RON/EUR as a stochastic process. After testing several models, and taking into account the values of Ficher and Student tests, was chosen two models, ARMA(4,5) and AR(3), presented in Table 1.

Table 1 Comparative presentation of ARMA(4,5) and AR(3) models

Dependent Variable D_EUR	ARMA(4,5)		AR(3)	
C	0.000325	0.4744	0.00023	0.5983
AR (1)	0.235219	0.4744	0.23498	0.0000
AR (2)	0.739793	0.0000	-0.13629	0.0000
AR (3)	-0.317843	0.0000	-0.10411	0.0000
AR (4)	0.130924	0.0000	-	-
MA (2)	-0.887529	0.0000	-	-
MA (5)	0.106616	0.0000	-	-
Log likelihood	4167.447		4163.144	
Durbin-Watson stat	1.992300		1.995542	
Schwarz criterion	-5.239300		-5.244515	
F-statistic	26.08294		47.09827	
Prob(F-statistic)	0.000000		0.000000	

Considering the data presented in Table 1, we can conclude that both models are valid. Thus, the $F\_statistic = 26.08294$ for ARMA (4,5) model, and $F\_statistic = 47.09827$ for AR (3) as well as $\mathrm{Prob}(F\_statistic) = 0.00$, for both models, we reject the null hypothesis (H0) and we accept the alternative hypothesis (H1): both the models are statistically valid

Also all the parameters of the models are statistically significant because both the values of corresponding probabilities lead to the rejection of the null hypothesis (H0: parameter values are not significantly different from zero) and accepting the alternative hypothesis (H1: parameter values are significantly different from zero, so they are statistically significant). The estimation equation with substituted coefficients for AR(3) is:

D_EUR = 0.00023 + [AR(1)=0.23498,AR(2)=-0.13629,AR(3)=-0.10411] (10).

Among these models we chose, given the simplicity, the AR(3) model (equation 10).

4. FORECASTING RON/EUR RATE FOR THE PERIOD JANUARY 2011 - MAY 2011

To use the model to forecast exchange rate RON/EUR for the coming period is necessary to test the linear regression model assumptions. To test the errors autocorrelation assumption was used Serial Correlation Breusch-Godfrey LM Test. The results of the test are illustrated in Figure 8.

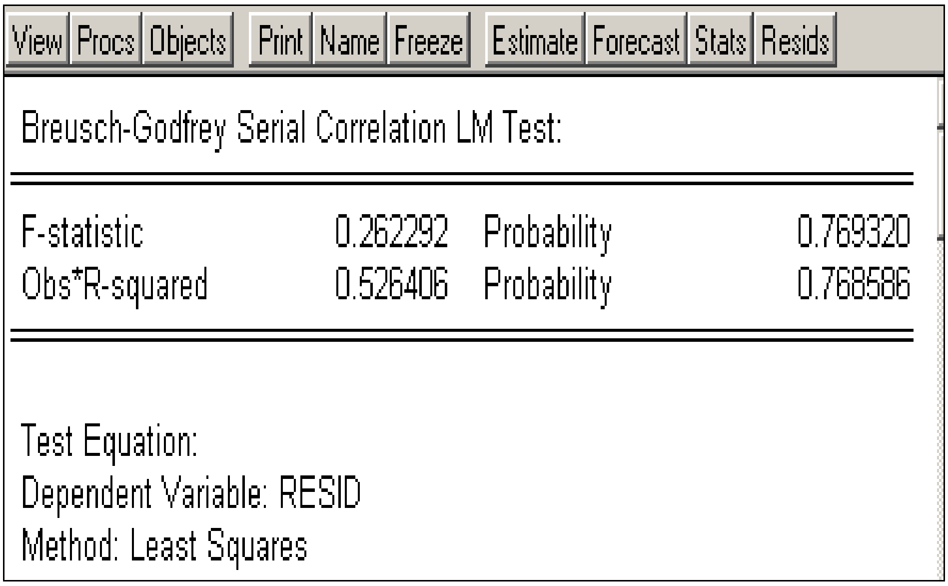


Figure 8 The Breusch-Godfrey LM Test for AR(3) model of D_EUR series

The statistic labeled "Obs*R-squared" is the LM test statistic for the null hypothesis (H_0) of no serial correlation. The value 0.768586 of probability is much higher than 0.05, leading to the conclusion that the null hypothesis is accepted. Errors are not in correlation.

The assumption of normality distribution errors, as shown in the figure 9, is also satisfied. Distribution of errors is relatively symmetric ($Skewness = 0.049688$), with the average (effectively) equal to 0 ($Mean = -0.87 \cdot 10^{-18}$) and $Std.Dev. = 0.017419$. The value of $Kurtosis = 13.35659$ indicates a leptokurtic distribution pattern.

To test the presence of heteroskedasticity in the residuals was used ARCH Test (Figure 10).

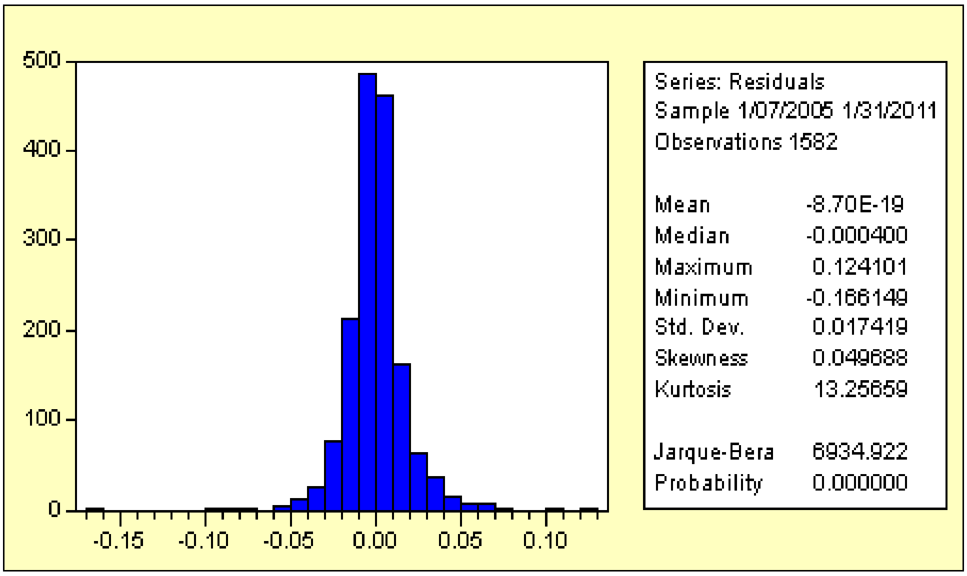


Figure 9 Histogram - Normality Test of Residuals

As can be seen, in this case, Obs*R-squared=50.25253 and Probability=0.000000, values strongly indicates the presence of autoregressive conditional heteroskedasticity (ARCH) in the residuals.

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ARCH Test:

F-statistic	51.83660	Probability	0.000000
Obs*R-squared	50.25253	Probability	0.000000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares

Figure 10 ARCH Test for initial AR(3) model

To remove heteroskedasticity we reformulate the model by integration. The new estimation equation of model is:

$$\begin{aligned} \text{D\_EUR} = & -0.09326 - 0.00268*(\text{@LOG(D\_EUR(-1))}) - 0.00821*(\text{@LOG(D\_EUR(-2))}) \\ & - 0.00582*(\text{@LOG(D\_EUR(-3))}) + [\text{AR}(1) = 0.65478] \end{aligned} \quad (11)$$

In this case, the null hypothesis (H_0): the presence of heteroskedasticity in the residuals is rejected and the alternative hypothesis (H_1) is accepted (Figure 11).

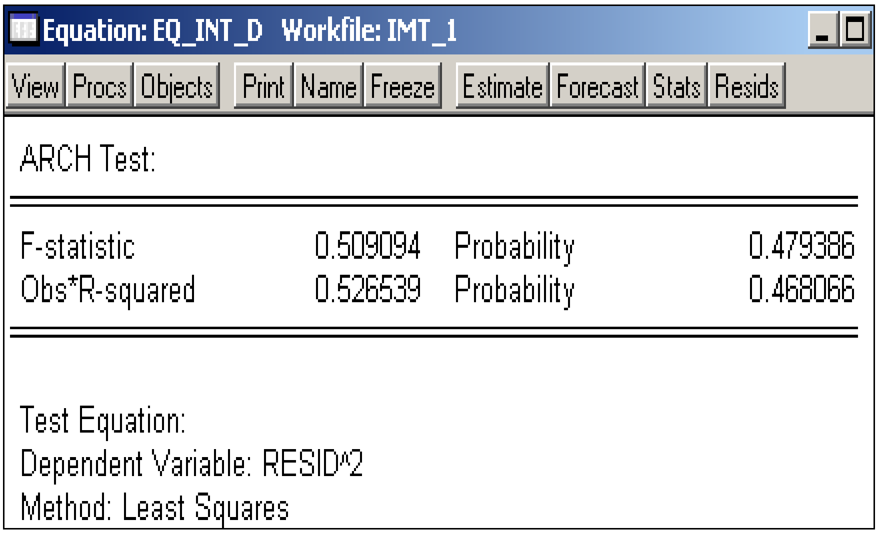

Figure 11 ARCH Test for initial AR(3) model

Now, the model can be used to forecast exchange rate RON/EUR for the period January 2011 - May 2011. The results are shown in Figure 12.

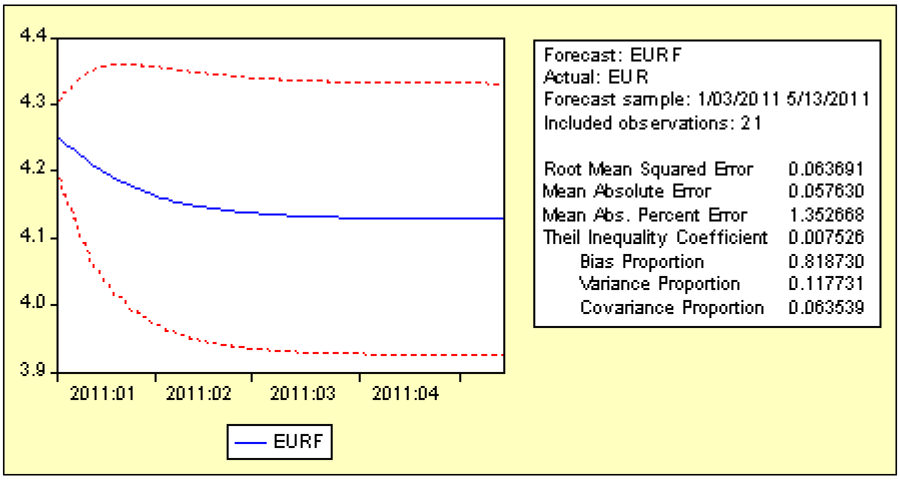

Figure 12 Forecasted RON/EUR rate for the period January 2011 - May 2011

According to the model used, in the period March-May 2011, the exchange rate will has a tendency to decrease to the 4.13, 4.14 RON / EUR.

5. CONCLUSIONS

In the period January 2005 - March 2011 exchange rate RON/EURO has fluctuated between a minimum de 3.1112 recorded July 2, 2007 and a maximum 4.3688 recorded on June 30, 2010. If in the period January 2005 - June 2007 the fluctuations had a general downward trend in the period June 2007 - January 2009 exchange rate had an almost explosive tendency, exceeding the threshold 4 RON/EUR. During the years 2009 and 2010 the exchange rate fluctuated around 4.2 RON/EURO, with a minimum of 4.0296 on January 5, 2009 and a maximum of 4.3688 on June 30, 2010.

After analyzing the data series, we obtained two models, one type ARIMA(4,5) and the second AR(3) type. For the forecast exchange rate RON/EURO in the period January to March 2011 was chosen AR(3) model, which, after the necessary transformations to meet assumptions of linear regression model is a good approximation of the exchange rate throughout the period analyzed.

With this model, for the period April-May 2011, the exchange rate forecasted will oscillate around 4.14 RON/EUR. Of course, this forecast is valid as long as the foreign exchange market will not be influenced by particular events.

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