# EUR/RON EXCHANGE RATE PREDICTION BASED ON BOX-JENKINS TECHNIQUE

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## ABSTRACT

The aim of this study consists in analyzing the importance of the exchange rate forecast using the Box-Jenkins models, also known as Auto Regressive Integrated Moving Average (ARIMA) models. The first part of the paper presents the main research in this field, which can be classified in two categories (studies applying classical methods, such as Box-Jenkins models and studies which rely on sophisticated prediction tools), and summarizes the main findings of some of the studies applying Box-Jenkins models. In the second part of the paper we performed a EUR/RON exchange rate analysis and forecasting, based on testing several AR, MA and ARMA candidate processes, in order to find out the best fitting model specification. We adopted the following strategy: i) an initial time series had been used for testing various model specifications, identify the best performing one and making a forecast of the EUR/RON exchange rate; ii) after comparing the accuracy of this forecast with the real level recorded by the exchange rate at end of May 2018, we conducted a second forecast, for the period May 2019 – November 2019. The initial time series employed has daily frequency and covers the timeframe July 4, 2005 – December 5, 2017, while the second time series used covers the period July 4, 2005 – May 6, 2019. The empirical findings have passed the goodness-of-fit tests and show a good predictive power. The first forecast performed for a six month period (December 2017 – May 2018) has indicated a slow pace, persistent increase of the EUR/RON exchange rate, which was confirmed by the expectations of market participants (financial analysts, banks' research departments). The second forecast, which covers the period May 2019 – November 2019, indicates a similar rising trend and the ongoing depreciation of the national currency.

Keywords: exchange rate, Romania, descriptive statistics, Box Jenkins, forecast errors

## INTRODUCTION

The exchange rate is one of the most important economic variables. Its evolution influences the broad prospects of an economy, the price level, the international trade, the balance sheet of the companies, but also the wealth of each individual. The evolution of the exchange rate influences not only the wealth and the purchasing power of individuals, but also the wealth of the whole economy. On the other hand, the exchange rate is a variable strongly influenced by the dynamics of other macroeconomic indicators (such as inflation rate, interest rates, economic growth etc.) but also by mar-



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ket participants' expectations regarding future macroeconomic developments. The expected result of the forthcoming elections, the central bank governor' decisions, the oil price on the international market, are just a few factors influencing the exchange rate. For these reasons, the exchange rate is an extremely volatile economic variable, and its evolution is closely monitored by market participants.

The recent financial crisis and the monetary decisions taken by some major central banks have generated strong turbulence in the Romanian economy. The sustained economic growth and the favorable exchange rate evolution until the 2008 crisis had encouraged foreign currency lending. The depreciation of the Romanian national currency (RON) correlated with the austerity measures adopted by the authorities had determined, for many debtors, the impossibility of repaying debts. In this context, the exchange rate prediction is important for any economy, but at the same time a multitude of problems are generated (Which forecasting method is more effective? The historical path of the exchange rate evolution has the ability to influence the future level of the exchange rate? The result of the exchange rate forecast is correct and consistent with the economic reality?). Our paper tries to answer to some of these questions and is structured as follows: the second part briefly reviews the literature related to exchange rate forecasting, the third part presents the methodology applied in the paper, the fourth part illustrates the empirical findings obtained and their interpretation while the last part concludes.

## LITERATURE REVIEW

Economic literature is the field of broad debates related to the best predictive model to be used for the exchange rate forecast. There is no consensus regarding the use of a particular methodology, that's why research in this field can be classified in two categories: studies applying classical methods, such as Box-Jenkins models, and studies which rely on neural networks, fuzzy algorithms and other sophisticated prediction tools.

Only two papers have investigated the future dynamics of the EUR/RON exchange rate. [1] have uncovered that the exchange rate over the time period March 2005 – February 2011 is best modeled by an autoregressive AR(3) process. A slightly different research direction belongs to [2] which examined the changes in the volatility of daily returns recorded by EUR/RON exchange rate over the period January 1999 - June 2016. They tested first the specification of an ARIMA process and found out that EUR/RON time series is best described by an AR(3) process. Then they used the residuals of the AR process for testing the presence of ARCH effects.

[3] have developed a new predictive model, by combining ARMA architecture with differential evolution-based training. They tested its predictive performance for three exchange rates, namely Indian rupees, British Pound and Japanese yen with respect to US dollar.

[4] have compared the predictive ability of three different methodologies, namely ARIMA, Neural Network and Fuzzy neuron models in forecasting the exchange rates of the Indian Rupee against the US Dollar, British Pound, Euro and Japanese Yen. The empirical findings show that the classical ARIMA model outperformed the other two complex methods.

Controversial results have been obtained regarding the forecast of US dollar/EUR exchange rate. [5] tested first an ARIMA model, but the presence of serial correlation between residuals made it inappropriate for further predictions. However, the author uncovered that the inflation differential between Europe and US is the main variable to be used for the dollar/euro exchange rate forecast. [6] failed to forecast the future path of the EUR/US dollar exchange rate by using ARIMA and exponential smoothing forecasting techniques. [7] had estimated an ARMA (4,4) model but with low predictive ability.

## METHODOLOGY OVERVIEW

Box-Jenkins models, known also as AutoRegressive Integrated Moving Average (ARIMA) models, are built on the assumption of a univariate time series model, whose main purpose is to model the behavior of a given variable by relying on its own past values. If the validated model shows a good predictive ability, then it can also be used for time series' forecasting. The specificity of ARIMA models is that they don't require the splitting of an initial dataset into dependent and explanatory variables. They simply focus on a single variable, by taking into account only past historical values recorded by the variable and stochastic error terms.

According to [8], Box-Jenkins models are based on the philosophy *let the data speak for themselves,* as their main purpose is to statistically identify and describe the persistence of a variable, by analyzing only the stochastic properties of the time series considered. [9] argues that ARIMA specific methodology for building forecasting models has provided reliable results and even superior ones when compared to other more sophisticated statistical techniques. The peculiarities of ARIMA methodology have been synthesized by [10], namely flexibility by successfully modeling trends and seasonal patterns, rooted on the analysis of autocorrelations (patterns in time) and good results for long and stable time series.

The broad range of ARIMA models comprises simpler time series models, represented by Autoregressive (AR) processes (self-regressive) and Moving Average (MA) processes, as well as compounded models, called ARMA. In AR (p) models of order *p* it is assumed that the current value of a variable is explained only by its preceding, lagged values and an error term:

$$y_t = \alpha + \sum_{i=1}^{p} \emptyset_i \times y_{t-i} + u_t \qquad (1)$$

where
$y$ is the variable considered
$\alpha$ is the intercept
$y_{t-i}$ are the past values of the variable
$p$ is the order of the AR model
$u_t$ is a white noise disturbance term

MA (q) models of order *q* start from the premise that the current value of a variable *y* can be explained by actual and lagged values of a white noise process:

$$y_t = \alpha + u_t + \sum_{i=1}^{q} \beta_i \times u_{t-i} \qquad (2)$$

where
$y$ is the variable considered
$\alpha$ is the intercept
$q$ is the order of the MA model
$u_t$ is a white noise disturbance term
Finally, an ARIMA (p, d, q) model specification can be developed by combining AR(p) and MA(q) processes, where *p* denotes the number of autoregressive terms, *d* is the number of times the series has to be differenced before it becomes stationary, and *q* the number of moving average terms. Theory states that an ARIMA


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(p, d, q) model is equivalent to applying an ARMA (p, q) model on the stationary variable.

The identification of a model's best specification is preceded by an analysis of the autocorrelation function (ACF) and of partial autocorrelation function (PACF). Their patterns will indicate whether a time series follows an AR, a MA or an ARMA process.

[11] emphasizes that it is particularly useful to jointly analyze the patterns of ACF and PACF. According to him, an autoregressive process depicts: i) a geometrically decaying ACF; and ii) a number of non-zero points of PACF = AR order. A moving average process has: i) a number of non-zero points of ACF = MA order; and ii) a geometrically decaying PACF. A combination of autoregressive moving average process depicts: i) a geometrically decaying ACF; and ii) a geometrically decaying PACF.

## CONFIGURATION OF BOX-JENKINS CANDIDATE MODELS, RESULTS AND INTERPRETATIONS

The purpose of the study is to model the future path to be recorded by the EUR/RON exchange rate by means of a Box-Jenkins method. The time series employed has a daily frequency, by covering the timeframe July 4, 2005 – May 6, 2019 and had been extracted from National Bank of Romania's database. The first stage of the empirical analysis consists in examining the intrinsic statistical properties of the initial, raw data series. *Figure 1* provides a synthesis of basic descriptive statistics for the EUR/RON exchange rate.

The mean and median values computed for a period of 15 years are not equal, which represent a first theoretical clue that the time series of EUR/RON isn't normally distributed. In absolute terms, the lowest value of 3.1112 had been recorded on 2nd July 2007 while the maximum value of EUR/RON exchange rate was of 4.7648 and had been recorded on 25 January 2019 (see figure 2 for the graphical evolution depicted by the exchange rate).

*Figure 2* illustrates the path of main exchange rates in the last 15 years. It can be noticed that the EUR/RON recorded a jump in January 2019 when it exceeded the psychological threshold of 4.7 RON for one EURO. The depreciation of the national currency against the other currencies wasn't as fast and sharp as for EURO. This negative impact on the national currency was an immediate result of fiscal and budgetary regulation changes with direct impact on large companies and financial institutions. Unpredictability and radical changes in the national regulation triggered a period of turmoil on the foreign exchange market, characterized by the persistent depreciation of the national currency.

On this background, the National Bank of Romania has conducted in December 2018 a survey [12] among major financial institutions in Romania to uncover banks' perception on the new threats to financial stability and exposure to systemic risks. For the first time banks had signaled as a major, difficult to manage risk the lack of predictability and uncertainty of financial regulations. One of the most important effects envisaged by banks is the depreciation of the national currency, which actually occurred in January 2019.

The fluctuation or variability of EUR/RON time series can be assessed by means of standard deviation statistics, which meas-

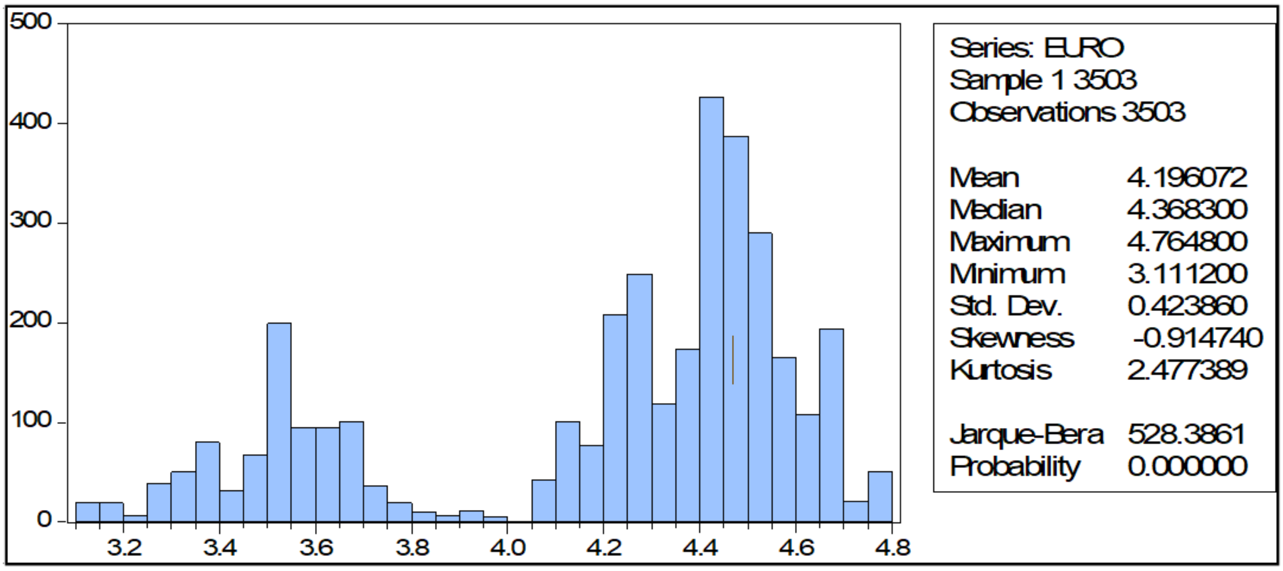


***Figure 1.*** *EUR/RON histogram and descriptive statistics*
Source: authors, by using Eview

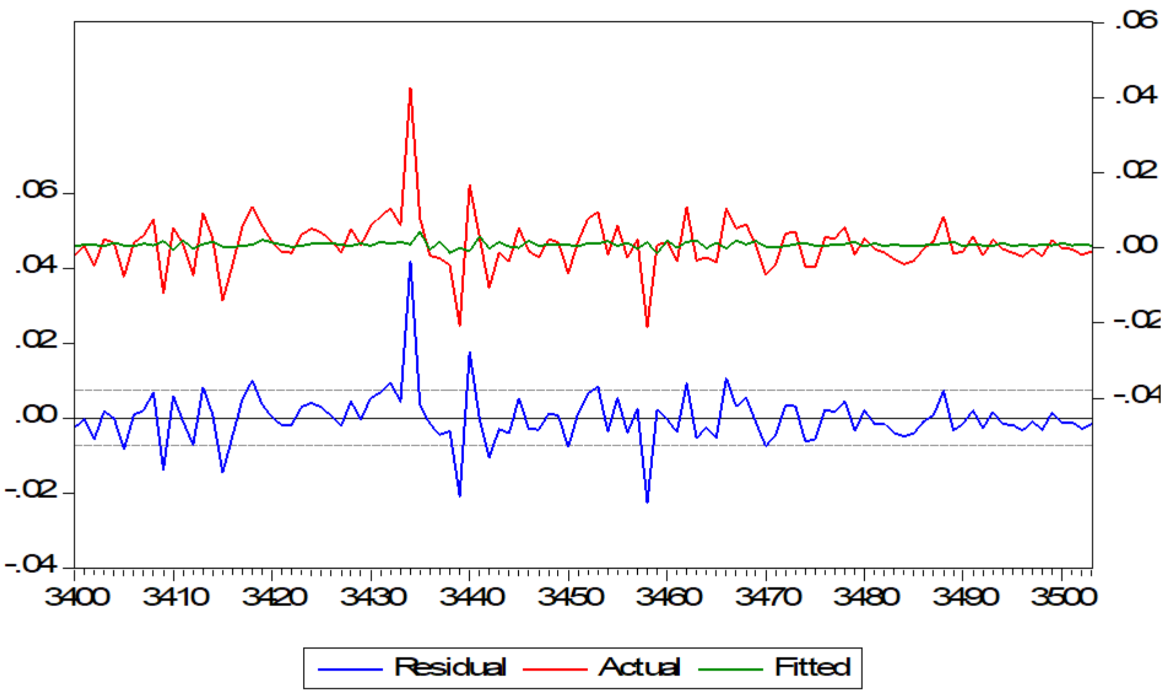


***Figure 2.*** *Dynamics of EUR/RON and other currencies' exchange rate*

ures the dispersion of the time series raw values around its mean. The theory states that a higher standard deviation indicates persistent extreme values (both smaller and higher) in the sample considered. In our case the values aren't too scattered around the sample's mean value.

Other two related statistics used for uncovering the shape of the distribution are represented by the skewness and kurtosis.


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Economic theory has established thresholds for both statistics to indicate the presence of a normal distribution: skewness equal to zero and kurtosis equal to 3. There is a negative asymmetry (skewness of -0.9147), meaning that EUR/RON time series depicts a longer tail towards left and hence smaller values of the variable under analysis predominate in the sample. Kurtosis lies below the theoretical threshold, and hence the time series is flatter than a normal distribution (platikurtotic).

A last test for detecting the presence of a normal distribution is the Jarque-Bera test. The implicit null hypothesis is that the series is normally distributed. In our case the probability assigned to Jarque-Bera statistic is of 0.000%, thus the null hypothesis is rejected meaning that EUR/RON time series doesn't follow a normal distribution.

Secondly, it has been applied a stationary test to detect the presence of unit root. The Augmented Dickey-Fuller test (see ***table 1*** below) indicated that the EUR/RON time series is stationary in first difference, as the null hypothesis stating that the series has a unit root is rejected with a probability of 0.000%.

Thus, in testing the various specifications of an ARIMA process it has to be taken into account that EUR/RON time series is integrated of the 1st order and follows an ARIMA process whose *d* equals 1. Or, in other words, the potential ARMA processes have to be estimated by first differencing the EUR/RON variable.

To gain an insight on the type of processes to be further tested it has been analyzed the correlogram of the time series, by estimating the coefficients of the autocorrelation function (ACF) and the partial autocorrelation function (PACF). The autocorrelation between current values of residuals and their past values provides guidance in selecting the proper specification of an ARMA process. The patterns of ACF and PACF functions indicate that EUR/RON time series declines smoothly at a geometric rate after one lag. Consequently, it is expected that EUR/RON exchange rate follows an autoregressive model (AR process) or an ARMA process of order (1,1).

The next step is to define and test several AR, MA and ARMA candidate processes, in order to find out the best fitting model specification. It has been identified 6 candidate model specifications whose coefficients are highly statistically significant (see **table 2** below).

***Table 1.*** *Result of the ADF unit root test*

Null Hypothesis: D(EURO) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=29)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -35.4843 | 0 |
| Test critical values: | 1% level | -3.43203 | |
| | 5% level | -2.86217 | |
| | 10% level | -2.56715 | |

*MacKinnon (1996) one-sided p-values.
Source: authors, by using Eviews

***Table 2.*** *Results of autoregressive models*
Dependent Variable: D(EUR/RON)
Method: Least Squares

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.000329 | 0.00029 | 1.13522 | 0.2564 |
| AR(1) | 0.166189 | 0.01757 | 9.458866 | 0 |
| | | | | |
| C | 0.000329 | 0.000273 | 1.20775 | 0.2272 |
| AR(1) | 0.17633 | 0.01779 | 9.911761 | 0 |
| AR(2) | -0.06102 | 0.017791 | -3.42996 | 0.0006 |
| | | | | |
| C | 0.00033 | 0.000257 | 1.284495 | 0.1991 |
| AR(1) | 0.172692 | 0.017797 | 9.703383 | 0 |
| AR(2) | -0.05052 | 0.01804 | -2.80044 | 0.0051 |
| AR(3) | -0.05956 | 0.017798 | -3.34659 | 0.0008 |
| | | | | |
| C | 0.000333 | 0.000247 | 1.345149 | 0.1787 |
| AR(1) | 0.170359 | 0.01782 | 9.559868 | 0 |
| AR(2) | -0.05248 | 0.018054 | -2.90698 | 0.0037 |
| AR(3) | -0.05289 | 0.018054 | -2.92957 | 0.0034 |
| AR(4) | -0.03871 | 0.017821 | -2.17195 | 0.0299 |
| | | | | |
| C | 0.000329 | 0.000284 | 1.157135 | 0.2473 |
| MA(1) | 0.177061 | 0.017533 | 10.0985 | 0 |
| | | | | |
| C | 0.000333 | 0.000247 | 1.348348 | 0.1776 |
| AR(1) | 0.727526 | 0.141561 | 5.13931 | 0 |
| AR(2) | -0.16269 | 0.023453 | -6.93699 | 0 |
| MA(1) | -0.55358 | 0.142854 | -3.87511 | 0.0001 |

Source: authors, using Eviews

Each autoregressive model has been further tested by using several residual diagnostic tests, such as: residuals' correlogram which indicated the absence of any autocorrelation of residuals, the inverse roots of the AR/MA polynomials are placed inside the unit circle and the Breusch-Godfrey Serial Correlation LM Test which suggests that residuals aren't serially correlated. All the six models considered have passed these goodness-of-fit tests. In order to choose the most appropriate model it has been relied on several criteria, namely the values recorded by adjusted R-squared and the Akaike and Schwarz information criteria. ***Table 3*** synthesizes the three selection criteria upon which the decision had been made.

***Table 3.*** *Summary of candidate models' statistical indicators*

| | Adjusted R-squared | Akaike info criterion | Schwarz criterion |
|---|---|---|---|
| AR (1) | 0.02731 | -5.76208 | -5.7582 |
| AR (2) | 0.0306 | -5.76486 | -5.759 |
| AR (3) | 0.03375 | -5.76747 | -5.7597 |
| AR (4) | 0.03489 | -5.76812 | -5.7585 |
| MA(1) | 0.02941 | -5.76456 | -5.7607 |
| ARMA(2,1) | 0.03388 | -5.76791 | -5.7602 |

Source: authors, using Eviews

According to the three criteria simultaneously considered, the highest value for adjusted R-squared and the lowest values for the two information criteria have been recorded by an AR(4) process.

Therefore, this model specification will be


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further used for making predictions of EUR/RON exchange rate evolution. The initial version of our paper [13] had considered a forecast time horizon during 6 December 2017 – 31 May 2018. It has been chosen a period of 6 months because economic theory warns that the quality and reliability of forecasts based on time series' previous values diminishes when considering longer time periods. It has been performed an out-of-sample dynamic forecast which generated several measures of forecast accuracy (see ***table 4)***.

***Table 4.*** *Forecast evaluation statistics of the AR(4) model*

| | |
|---|---|
| Forecast: EUR/RONF | |
| Actual: EUR/RON | |
| Forecast sample: 12/06/2017 | 05/31/2018 |
| | |
| Root Mean Squared Error | 0.008073 |
| Mean Absolute Error | 0.006615 |
| Mean Absolute Percentage Error | 0.142746 |
| Theil Inequality Coefficient | 0.00087 |
| Bias Proportion | 0.661941 |
| Variance Proportion | 0.142384 |
| Covariance Proportion | 0.195676 |

Source: authors, using Eviews

Each evaluation statistics is meant to shed light on the presence of forecasting errors. The value recorded by Mean Absolute Percentage Error (14.2746%) is lower than the 100% theoretical threshold, indicating that the specification of the AR model is suitable for making forecasts, as it doesn't generate forecast errors. The forecast errors can be decomposed into three components: the bias, the variance and the covariance. The bias proportion statistics indicates that forecast errors are quite biased, in other words the mean of the forecasted values is quite far apart from the mean of the actual data. The small variance proportion indicates that the forecasts are tracking well the variation in the actual EUR/RON series. The covariance proportion (19.56%) shows the remaining unsystematic part of forecast errors. The value recorded by Theil Inequality coefficient is very low, close to 0, suggesting a very good fit. Best practice claims that for a forecast to be good, both bias and variance have to be quite small, which is partially accomplished by the model tested.

The forecast of the EUR/RON exchange rate suggests a persistent increasing path, although at a slow pace. From a value of 4.6344 recorded at the beginning of December 2017 it is expected that the forecasted exchange rate at end of May 2018 be of around 4.6539 RON for 1 EUR. Indeed, the real evolution of the exchange rate, published by the National Bank of Romania, indicated a value of 4.6485 recorded on May 31, 2018, closely related to the one forecasted by our model.

In the following as the reliability of the model configuration was proved by the previous forecast results, we proceeded to an update of the initial sample with data till May 2019 and then we've performed a second forecast based on the same model specification in order to making predictions of EUR/RON exchange rate evolution for a time horizon covering May 6, 2019 – November 29, 2019. As figure 3 shows, it had been obtained a forecasted value of 4.8754 RON for 1 EUR at end of November 2019 suggesting that the Romanian currency will continue its depreciation against EURO. (see ***figure 3***)

Looking at the forecast statistics one can notice that the value recorded by Mean Absolute Percentage Error (8.36%) is well below the 100% theoretical threshold, indicating absence of forecast errors. Subsequently, the forecast errors have been decomposed into three components. The bias

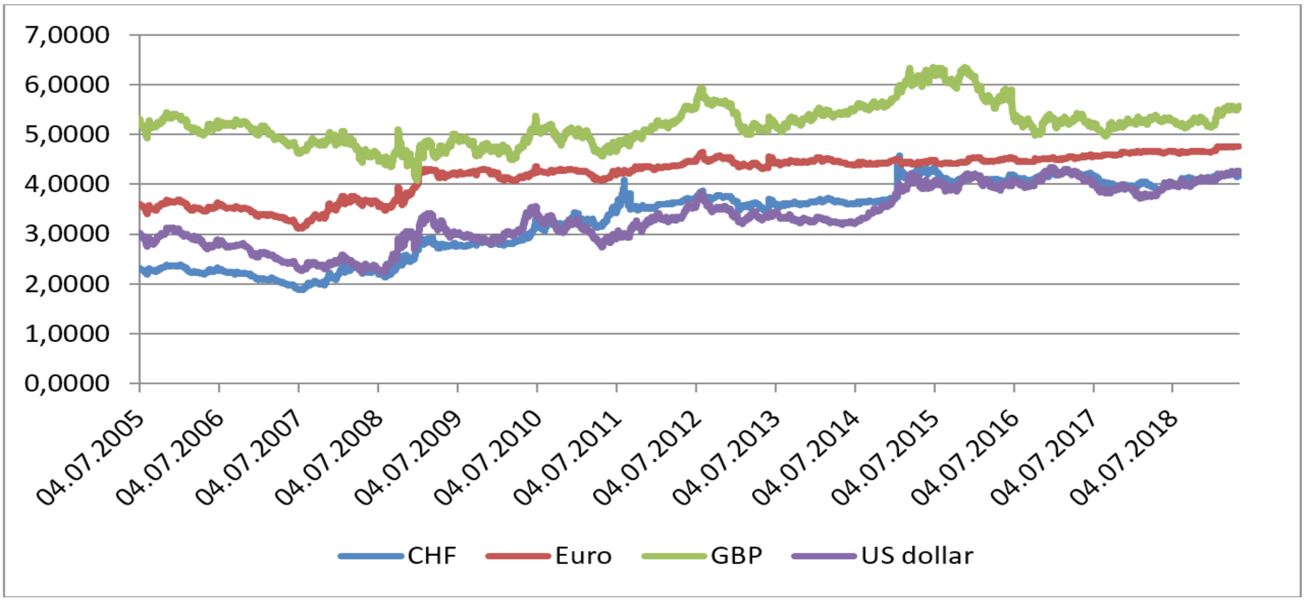


***Figure 3.*** *Forecast graph and evaluation statistics (May – November 2019 frame)*

Source: authors, based on Eviews results

proportion statistics of 74.36% shows that forecast errors are biased, the mean value of the forecasted values being significantly different than the mean of the actual data. The negligible variance proportion (0,09%) indicates that the forecasts are tracking well the variation depicted by the actual EUR/RON time series. The covariance proportion (25.53%) shows the remaining unsystematic part of forecast errors. The value recorded by Theil Inequality coefficient is close to 0, suggesting a very good fit.

Additional information on whether forecasted data are well fitting actual data is gained by generating residuals pattern graph (see ***figure 4)***.

As there are no sharp upward or downward jumps of fitted (forecasted) values against actual ones, or of residuals against the horizontal line one may conclude that the fitted values are matching the long run features of actual data. Also, the residuals exhibit a flatter pattern with the passing of time, which is beneficial for model's goodness-of-fit.

## CONCLUSION

The topic addressed by the paper is of importance not only for decision makers and financial institutions, but also for individuals and companies which have borrowed money from banks or intend to apply for a loan denominated in foreign currency. The latter are always concerned about the EUR/RON exchange rate fluctuations, as any depreciation of the national currency against EUR increases their monetary burden.

Our first short term forecast, which takes into account only the information embedded in the EUR/RON dynamics, indicates a rising trend for the EUR/RON exchange rate until May 2018, which is already confirmed by financial analysts and the Romanian Central Bank's quotations. The second forecast, made on the timeframe May 2019 – November 2019 indicates the same slow but persistent pace rise of the exchange rate, although it is possible to witness short term fluctua-


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tions of the exchange rate, due to external factors (macroeconomic prospects, political stability) than the historical path of the exchange rate, which might alter the real level of EUR/RON rate to be attained in end of November 2019.

Recent experience has shown that the interbank monetary markets are rapidly reacting to political instability or changes in regulation. According to a National Bank of Romania presentation [14], a coherent economic policy mix has to be maintained on long term, even in electoral years, as there is no substitute for it in order to achieve exchange rate stability and convergence towards euro adoption.

The more unpredictable is the political and economic environment, the larger the depreciation of the Romanian currency against Euro. This sensitivity isn't present in terms of RON exchange rate against CHF, US Dollar or GBP, most probably due to the heavily reliance on the EURO/RON exchange rate by both companies and households applying for a loan.

Therefore, the empirical analysis proposed in this study proves a high degree of reliability and accuracy. This is due not only to the good levels recorded by the forecast statistics related to the assessment of potential forecasting errors, but also to the very good match between our own results and those obtained by financial market analysts. Another indirect conclusion of our study is that basic, non-sophisticated statistical techniques are still valuable as they depict increased accuracy of forecasts, at least on short term.

In addition, our analysis might be complemented with a multivariate one, which investigates the impact various economic and financial variables have on EUR/RON prospects. The growth trend of the EUR/RON exchange rate envisaged for the forecasted period might be determined by the future evolution of several macroeconomic factors such as: the increase of the current account deficit correlated with the potential increase in the public budget deficit (the twin deficits), the ascending trend of the Romanian interest rates on the money market, the upward trend of inflation in Romania, or the expansionary fiscal policy which has begun in 2016 as well as by changing regulations and political instability.

It worth's to be mentioned that recently the National Bank of Romania [15] has launched the national plan for euro adoption in order to map the future path to be followed by decision makers in this regard, arguing that it is only a matter of timing for passing to euro. It is ascertained the complexity of this process and the careful assessment of the full accomplishment of all convergence criteria so as to witness a smooth euro adoption.

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