The Introduction of a Fuzzy Parameter to Predict the Devaluation of the Local Currency Caused by the Fall in World Oil Prices

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***Abstract* - In the presented article, the forecast of the USD / AZN currency quotation is considered using fuzzy time series (FTS). It provides a step-by-step description of the methodology, which is the construction of fuzzy sets of terms for the linguistic variable "exchange rate", the use of input data as numerical values and the calculation predicting future states.**

The novelty of this study in the introduction of the new parameter, to reflect the devaluations of 2015 and 2016, resulting from a sharp drop in oil prices. In particular, it takes into account the fact that Azerbaijani manat is a commodity currency, and the against the dollar to manat depends on the cost of oil and is regulated by the state. FTS is predicted in the direction of applying new methods based on Fuzzy Times-Series Data Mining.

***Keywords*. Currency quotation, devaluation, discrete fuzzy sets, fuzzy time series, fuzzy relations, forecasting trends.**

I. Introduction

Forecasting of the currency market is always in the attention of such market participants as banks, investment companies, brokerage houses, etc. and people who track the trend of the course in order to minimize the loss of their own savings. Since the developing trend of the exchange rate is affected by variant or unknown factors, it is not realistic to establish a single forecasting model that can take all the unknown factors into account.

The analysis of time series plays an important role in solving many urgent problems. At present, it is necessary to develop forecasting methods that will provide an adequate assessment of the forthcoming changes in the economy [2], [9].

In presented article to forecast the exchange rate the technical analysis, which is the accumulation of a real history of price changes and the construction of conclusions about a possible future trend is used. A sequence of time-ordered data forms time series that can be used to predict a currency quote based on observations relating to the present and past time points [8].

However, the data that form the time series, or the character of the trend change, can be fuzzy and presented in verbal form. To solve this problem, in recent years new methods of solution based on fuzzy theory have been proposed.

As most real events are characterized by some uncertainty, each observation of the time series can be associated with a fuzzy variable with some membership function. Fuzzy time series allow to overcome the problem, allowing processing both numerical and linguistic data.

The idea of fuzzy modeling of the behavior of complex systems by TS is based on the basic model of a fuzzy dynamic process, called the "fuzzy time series". [1], [3].

In fuzzy time series (FTS), the conditions of the dynamic process are associated with fuzzy values modeled by parametric membership functions, and the relationship between them are constructed by observations and are represented by the basis of fuzzy "If-To" rules, numerically expressed by the fuzzy relationship matrix. [4], [5], [9].

Analysis of the possibilities and shortcomings of the methods of fuzzy modeling of TS revealed a number of unresolved problems: the problem of increasing the accuracy and informativity of the forecast, the lack of identification methods and mathematical models of fuzzy FTS tendencies, the problem of the lack of efficiency criteria and the methodology for estimating the of results of fuzzy modeling. Among them, the most interesting is the scientific and practical analyzes of fuzzy trend. This problem includes the tasks of formalization, identification and construction of TS models based on a fuzzy trend. Solving these problems will allow us to find new patterns and extract knowledge that is inaccessible to other models.

Thus, the present state of TS modeling and forecasting is characterized by further development towards the application of methods called Times-Series Data Mining and models based on artificial intelligence technologies.

The fuzzy time series model was first proposed by Song and Chissom [7], who applied the concept of fuzzy logic to develop the foundation of fuzzy time series. Thereafter, the fuzzy time series model had drawn much attention to the researchers. For model modifications, Chen [7] simplified the arithmetic calculations and introduced fuzzy logical groups to improve the forecast; Huarng [10] made a study of the effective length of intervals to improve the forecasting; Tsaur [7] made an analysis of fuzzy relations in fuzzy time series.

In 2015, a devaluation of the national currency took place in Azerbaijan. Unfortunately, the forecasting methods did not justify themselves; they could not take into account the sharp fall in the manat against the dollar.

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The AZN / USD relationship plays a crucial role in international trade and investment and may influence Azerbaijan's economy, the forecasting analysis for exchange rates is an important topic. Especially, during the global financial crisis, there was a tremendous change in the exchange rate of the AZN against the USD in 2015 and 2016.

There are statistical data on currency quotations from 2006 to 2014. It is necessary to build a fuzzy model for forecasting currency quotes for 2015 and 2016. It should be noted that in 2015 there was a devaluation of the Azerbaijani manat as a result of a sharp drop in the cost of oil.

The methods proposed by previous authors are looking for the predicted value between the highest and the lowest dollar rates in the time interval under consideration. But the predicted value of the exchange rate can vary greatly and come out of this interval.

In particular, the fact that Azerbaijani manat is a commodity currency is taken into account and the dollar exchange rate for manat depends on the cost of oil and is regulated by the state. In 2015, the drop in prices of oil increased so much that the state settlement was powerless. As a result, the dollar exchange rate changed a lot and came out of the interval under consideration. To take into account this fact and correctly predict the dollar's rate, a fuzzy parameter is introduced into the model.

First, based on statistical data on currency quotations from 2006 to 2014, we will build a forecasting model for the currency quotation USD / AZN [7-9]. Then, in order to teach the devaluation of 2015 and 2016, we introduce a fuzzy parameter.

II. CONSTRUCTİON AND SOLUTİON OF THR PROBLEM

Step 1. Based on the calculated exchange rate increments during the considered time interval, we denote the set U (the problem definition area) as the exchange rate, which takes values in the positive numeric axis, taking into account during the considered time interval. The highest dollar exchange rate in relation to the Azerbaijani manat during 2006-2014 is 0,893125 and is observed in 2006. The lowest rate is observed - 0.784411 in 2014. As a result, the resulting boundary values (0.784411, 0, 893125), correcting for the sake of simplifying the decomposition, can be taken as the segment U = [0.78, 0.90].

Step 2. The set U is divided into intervals of the same length.

Suppose that we work with six fuzzy sets. Then the set U is also divided into 6 intervals, i.e. $u_1 = [0.78, 0.80]$, $u_2 = [0.80, 0.82]$, $u_3 = [0.82, 0.84]$, $u_4 = [0.84, 0.86]$, $u_5 = [0.86, 0.88]$, $u_6 = [0.88, 0.90]$.

Step 3. Fuzzy sets A_i are identified for the linguistic variable "exchange rate" with the support [0.78, 0.90].

Let's assume that the variable "exchange rate" is characterized by a term set consisting of the following values: A_1 (significantly low rate), A_2 (low rate), A_3 (average rate), A_4 (slightly high rate), A_5 (a very high rate), A_6 (very high rate).

For the constructed intervals $u_i,\ i=\overline{1,6}$, the fact that each concrete u_i belongs to a certain set $A_j,\ j=\overline{1,6}$, is expressed by a real number from the unit interval [0,1], that is, for each term-set, the membership function is given in a discrete form:

$$\begin{aligned}
A_1 &= \{1/u_1 + 0.5/u_2 + 0/u_3 + 0/u_4 + 0/u_5 + 0/u_6\} \\
A_2 &= \{0.5/u_1 + 1/u_2 + 0.5/u_3 + 0/u_4 + 0/u_5 + 0/u_6\} \\
A_3 &= \{0/u_1 + 0.5/u_2 + 1/u_3 + 0.5/u_4 + 0/u_5 + 0/u_6\} \\
A_4 &= \{0/u_1 + 0/u_2 + 0.5/u_3 + 1/u_4 + 0.5/u_5 + 0/u_6\} \\
A_5 &= \{0/u_1 + 0/u_2 + 0/u_3 + 0.5/u_4 + 1/u_5 + 0.5/u_6\} \\
A_6 &= \{0/u_1 + 0/u_2 + 0/u_3 + 0/u_4 + 0.5/u_5 + 1/u_6\},
\end{aligned} \quad (1)$$

where $u_i \in U$, $i=\overline{1,6}$ and the numbers preceding u_i - the degrees of belonging of these elements corresponding to the set A_j, $j=\overline{1,6}$.

Step 4. The exchange rate obtained in step 1 is fuzzified (the degree of belonging of the initial data are determined).

If for any year a course belonging to one of the intervals is given and there is a linguistic value with the maximum degree of belonging to this interval, then it is fuzzy

If for any year t a course ρ belonging to one of the intervals $u_i,\ i=\overline{1,6}$ is given and there is a linguistic value A_j with the maximum degree of belonging to this interval u_i, then ρ is fuzzified as A_j (Table 1). For example, the dollar exchange rate against manat in 2007 will be 0.8581 - this value falls into the interval u_4 and the fuzzy rate becomes equal to A_4.

In the same way, each element of the time series is determined (see table 1, 4th column).

Step 5. Formation of logical relationships $A_i \to A_j$.

Pairwise sequentially fuzzy courses are considered to construct logical relationship sequences (2006 → 2007, 2008 → 2009, etc.), defined in step 4 (if recurring combinations occur, they must be excluded). The list of relations of our example will look like this:

$$\begin{gathered} A_1 \to A_1 \\ A_2 \to A_2,\ A_2 \to A_1 \\ A_3 \to A_2 \\ A_4 \to A_3 \\ A_6 \to A_4 \end{gathered} \qquad (2)$$

Following , it is assumed that fuzzy implicative relations $D = B \to C$ for arbitrary vectors B and C are treated as a fuzzy implication of Mamdani [5], that is, the elements of the matrix D are calculated by the formula $d_{ij} = b_i^T \times c_j = \min(b_i, c_j)$, where b_i and c_j denote i-th and j-th elements of the vectors B and C.

Step 6. Joining to the logical relationship groups.
The logical relations R_1 having the same left-hand sides are combined and the ratios for each of the obtained, i-th groups, $i = \overline{1,6}$ are computed.

In our example, the grouping will only take place when A_1, since only this linguistic variable has a not the only relation:

$$A_2 \to A_2, A_1$$

Step 7. The process of predicting the results.
The resulting ratio R_i, $i = \overline{1,6}$ is computed by combining the logical relationships of the ones found in the i-th group, i.e.

$$\begin{gathered} R_1 = A_1^T \times A_1 \\ R_2 = A_2^T \times A_2 \cup A_2^T \times A_1 \\ R_3 = A_3^T \times A_2 \\ R_4 = A_4^T \times A_3 \\ R_6 = A_6^T \times A_4 \end{gathered} \qquad (3)$$

The obtained relations R_i are used in the forecasting model (Model of Song and Chisoma [7]):

$$A(t+1) = A(t) \circ R(t) \qquad (4)$$

where $A(t)$ the known course of the year t; $A(t+1)$ is a fuzzy set expressing the forecast rate, i.e. the exchange rate of the next forecast year (t+1); $R(t)$ the corresponding ratios for the year t and the sign '$\circ$' denotes the 'max-min' operator.

Step 8. Conversion of the fuzzy forecast obtained in step 7 into an integer. Applying the method of the center of gravity according to the formula:

$$I = \frac{\sum_{i=1}^{k} u_i \mu(u_i)}{\sum_{i=1}^{k} \mu(u_i)}, \qquad (5)$$

we will get the forecasted value.

In table 1, the fifth column shows the results of the forecast for 2007-2014, and the sixth column reflects the relative errors of the forecasts.

TABLE 1. The data of the exchange rate from 2006 to 2014 were taken from the website http://www.cbar.az/) and average annual price of Brent crude oil from the website http://www.rustock.info/oil-gas/87-tablica-cen-na-neft-po-godam.html

1 Years	2 Oil prices	3 Actual value (p)	4 Fuzzy sets	5 Forecasted value	6 Relative Error (%)
2006	65.4	0,8931	A_6		
2007	72.7	0,8581	A_4	0.850	0.9439
2008	97.7	0,8216	A_2	0.830	1.0223
2009	61.9	0,8039	A_2	0.810	0.7588
2010	79.6	0,8027	A_2	0.806	0.4111
2011	111.0	0,7897	A_1	0.806	2.0640
2012	111.4	0,7853	A_1	0.796	1.3625
2013	108.8	0,7845	A_1	0.796	1.4659
2014	98.9	0.7843	A_1	0.796	1.4917
2015	52.4	1.0500			
2016	46.1	1.6204			

In 2015, a devaluation of the national currency took place in Azerbaijan. Forecasting the USD/AZN currency quote for 2015, we should take into account the fact that the

Azerbaijani manat is a commodity currency and the US dollar exchange rate against the Azerbaijani manat depends directly on the cost of oil and is simultaneously regulated by the state. With a sharp change in the cost of oil, of course, the rate of manat also goes down. If the oil price does not fall below a certain value, or if the oil price is very low for a short time, then the USD/AZN exchange rate is supported by the state, or the national currency is reduced by a targeted policy to adjust the budget execution indicators. In order to take this fact into account in forecasting, we introduce a coefficient q , $0 \le q \le 1$, which correct the forecast results: $A_i = A_i^* \times (1+q)$ where $0 \le q \le 1$. If the cost of oil is greater than the value b , then the USD / AZN rate is supported by the state and $q = 0.$ (As in 2006-2014). But if the cost of oil falls lower b and holds for a sufficiently long period of time, then the USD / AZN rate rises to $A_1 \times q,$ where $0 \le q \le 1.$

Analyzing the statistical data, we can draw the following conclusion:

q is a fuzzy indicator with support [0,1], which can be described by the spline function. That is, the membership function for this parameter can be described as follows:

$$\mu_q(x) = \begin{cases} 1, & x \le a \\ 1-2\left(\frac{x-a}{b-a}\right)^2, & a < x \le \frac{a+b}{2} \\ 2\left(\frac{b-x}{b-a}\right), & \frac{a+b}{2} < x < b \\ 0, & b \le x \end{cases} \qquad (6)$$

Where, a and b determined experimentally. (by analyzing statistical data)

Note that the definition of the membership function for the description of a fuzzy parameter can be different and affects the adequacy of the forecast.

The indicator b can be determined by the expert, reflecting the conclusions of his analysis of statistical data. Note that only a global change in the price of oil can have an impact on a sharp change in the exchange rate. Therefore, average annual statistics are considered.

Since in 2009 the average annual price of oil fell sharply to $ 61.9 per barrel (Fig. 1.) and this fact did not significantly affect the state-supported rate of USD / AZN. Therefore, $a < b < 61{,}9$.

Consider the case when: $a = 45, b = 58.$

Using formula (6) let's calculate the membership degree of the coefficient q for 2015:

$$\mu_q(52.4) = 0.37 \; . \qquad (7)$$

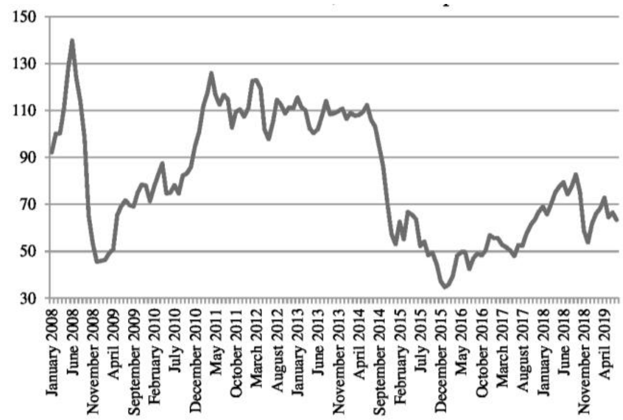

Fig. 1. Crude Oil Brent Futures, US dollars per barrel.
* investing.com

Applying the formulas (3), (4) and (7), we find the forecast rate for 2015:

$$A_{2015} = A_{2014} \circ R_{2014} = A_1 \circ R_1 = (1\ 0.5\ 0\ 0\ 0\ 0) \circ \begin{pmatrix} 1 & 0.5 & 0 & 0 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 1 \\ 0.5 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Applying the method of the center of gravity, we will get the forecast for 2015 equal to 0.7966.

$$A_{2015}^* = A_{2015} \times (1+q) = 0.7966 \times (1+0.37) = 1.08 \qquad (8)$$

At the same time, the actual value of the exchange rate for 2015 is 1.05, from which it follows that the relative error will be 2.85%, which indicates the adequacy of the proposed method.

Similarly, we forecast the average annual rate of USD for 2016:

$$\mu_q(46.1) = 1,$$

$$A_{2016}^* = A_{2016} \times (1+q) = 0.7966 \times (1+1) = 1.58$$

An average estimated value of the exchange rate for 2016 is 1.6204, from which it follows that the relative error will be equal to 2.46%.

TABLE 2. The data and forecasted values of the exchange rate for 2015-2016.

1 Years	2 Oil prices	3 Actual value	4 Fuzzy sets	5 Forecasted value	6 Relative Error (%)
2015	52.4	1.0500	A^*_{2015}	1.08	2.855%
2016	46.1	1.6204	A^*_{2016}	1.58	2,46%

Figure 2 graphically shows the changes in the calculated and projected values of the exchange rate from 2006 to 2016. It can be seen from the graphs that the forecasted values are close to the actual.

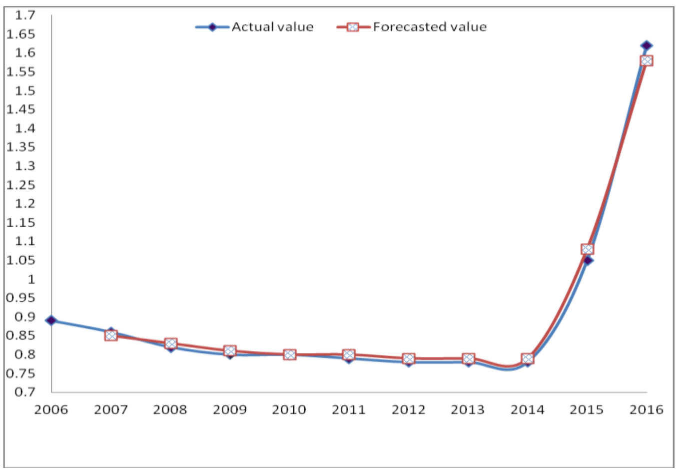

Fig. 2. Actual and forecasted values exchange rates.

CONCLUSİON

The proposed method of forecasting of currency quotations can mainly relate to short-term forecasting. The feature of the proposed method is the full availability of the initial data of time series, so that you can conduct a large number of experiments. Also this method differs from the others in sufficient simplicity and acceptable accuracy.

The introduction of a new fuzzy parameter for reflecting the national currency devaluation in the model and taking into account the dependence of the USD / AZN rate on the oil price was first proposed. The definition of the membership function for the description of a fuzzy parameter can be different and affects the adequacy of the forecast. The future trend of the course will make it possible to improve the proposed method.

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