International Journal of Electrical and Computer Engineering (IJECE)
Vol. 7, No. 5, October 2017, pp. 2782~2790
ISSN: 2088-8708, DOI: 10.11591/ijece.v7i5.pp2782-2790

The Decision-making Model for the Stock Market under Uncertainty

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Article Info

Article history:

Received Mar 21, 2017
Revised May 26, 2017
Accepted Aug 11, 2017

Keywords:

Decision-making
Expert's knowledge
Information support
Model
Prediction parameters
State
The stock market
Uncertainty

ABSTRACT

The main purpose of this research is developing methods and models of decision-making to assess the stock market state, and predict the possible changes in the RTS index value. This article shows that the analytical models for assessing the stock market state do not give reliable results. The absence of the reliable estimates associated with the high degree of uncertainty, random, nonlinear and non-stationary process with a significant degree of aftereffect. In this paper, to formalize the securities market parameters it's proposed the fuzzy sets method. To assess the stock market current state and make decisions the fuzzy situational analysis model (situational model) is applied. The analytical prediction results of the stock market and graph of the RTS index expected return changes in 2014-2016 are showed. The model of calculating the fuzzy inference rules truth degree to predict the RTS index is developed. The market parameters linguistic definition is given and the expert's rules construction to predict the RTS index growth is shown. The program in Matlab environment is designed to perform research. The study result showed that the model allows for the RTS index prediction in the condition of incomplete initial data with a confidence level about 90%.

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1. INTRODUCTION

The stock market or Securities Market reflects the economy state in the world, frequently works with the changing rules (in their application) and reacts as economic nature events and political. Particularly it illustrates well the effect of the events in recent years, in particular with regard to political decision-making in a number of countries. These political decisions show instability of the stock market. Changes in the world economy, politics of leading banks, making decisions about changing the main interest rates and others are showed the effect on the stock market state. There are a large number of players in the stock market, a variety of unforeseen factors make the non-stationary and random market state. The market processes show the presence of aftereffect and nonlinear. The observing practice for the stock market state has shown that the linear and steady changes in market parameters can exist only in small time intervals. The stock market works in conditions of uncertainty, appropriate analytical models to determine the stock value at any time does not exist. There are not analytical models to determine the change in the stock market state sufficiently.

There are many studies to predict the stock market state by using the analytical models, however, the famous models with the trends extrapolation methods for prediction of the stock market state [1-3] do not give good results in conditions of uncertainty (market volatility) [4]. The stock market state prediction by using the neural networks requires a long time interval with fixed changes that is also unacceptable, since the stock market changes occur over small time intervals.

The decision-making models depends on the expert's knowledge can be applied [5-6] to assess the stock market state. Formalization of the stock market parameters is performed by the fuzzy sets methods and using linguistic variable [7-9]. The situational analysis model from the decision-making models is applied [5-6], [10]. This model gives better results for the stock market current state assessment as compared to the famous analytical models.

The prediction problem of the stock market state is actual and very important problem. This problem is not solved in conditions of uncertainty; despite there are many studies in this field of research. Find a good mathematical model is not possible. There is only one option to develop models based on the knowledge activation from the specialists' experts.

The importance of the stock market state assessment problem is defined by the fact that Russia is part of the global financial market system; it has an international credit rating. The prediction problem of price dynamics is particularly relevant for Russia at the moment. Now the Russian stock market is developing well, therefore it is necessary to use models and program for information support for investments planning. Investment planning depends on the market situations analysis.

2. PREDICTION CRITERIA FOR THE STOCK MARKET

There are four groups of prediction methods in the stock market: Technical prediction method [11]; fundamental prediction method [12]; methods based on the gambling approach; intelligent method for prediction in the stock market [13].

The technical prediction methods use the technical indicators for analysis and prediction the stock market state. However, during the experience it was showed that the technical analysis does not give effective results [4]. Fundamental analysis is based on the prediction of the prices behaviour. When performing fundamental analysis Expert appears. The expert must be specializing in the global economy. Expert's experience applied to create intelligent methods for prediction in the stock market. In fact, the intelligent methods are using the technical and fundamental analysis, although the experts can carry out it on a subconscious level. The numerous experiences for experts allow making the right decisions.

The criteria analysis of technical and fundamental methods of prediction was performed and some examples of their application were shown. First of all, let's see try for predicting by using correlation analysis (the work of scientists under the auspices of the World Bank and the IMF [14]); trend extrapolation methods: the moving average method, exponential smoothing method, method of trend correlation parabolic [15]. The most commonly used correlation analysis to evaluate the stochastic relations between the different global stock markets. The correlation analysis methods are used most often, but these methods are ineffective in non-stationary conditions and numerous uncontrolled disturbances in the securities market.

To describe the stock market current state, the following situations were introduced: stable; transient; market growth; unstable; stagnation.

Each of the situations can be determined by applying the following criteria (characteristic factors):

- The average change in prices of a stock set (index), for example, SP500, NASDAQ, RTS, MICEX and the other;
- The current transactions volume (trading volume indicators);
- Volatility, for example, the VIX index or RTSVX for RTS;
- The stock market capitalization (monetary volume);
- The oil price.

These factors are based on the exchange trading data in the stock market and determined on heuristic formulas.

The Russian Federation stock market used two major exchange indexes-MICEX [16] and RTSI [17]. These indicators show the average trading for the most liquid shares of the MICEX-RTSI Russian stock exchanges. Moreover, the RTS index today is the second most important indicator. The indices data shows the current status of certain sectors of the stock market. For example, RTSI2 index shows the prices dynamics of less liquid stock of the 2nd tier, and the index MICEX10 shows price movements T10- of the most liquid shares.

Market volatility was determined based on the amplitude of the price fluctuations for the selected period of time. Market volatility is indicator shows how much the price jumping and how active of these

securities trading [18]. The volatility calculates in the market by using the ATR indicator, it is for selected time of VIX volatility index and its Russian analogue RTSVX. The stock market capitalization is the amount of capital, expressed in the form of income securities. Market capitalization is the total capitalization of revenues generated by individual marketable securities [19].

3. THE PREDICTION ANALYSIS FOR STOCK MARKET IN RUSSIA

In [20] it's presented the analysis of the stock market indices and attempted to use the technical prediction method for the period 2014–2016, the prediction results were interesting.

In [20] it's implemented the analysis of the stock market development in the period 2005–2013. To construct the model, the following macro-economic factors are taken: the oil prices growth rate; the growth rate of non-cash money supply; the GDP growth rate. These factors are correlated with the resulting index is significantly different from zero, alleged in [20]. As a result, in [20] it's developed a three-factor model [14] with use the analysis of regression and correlation for prediction the RTS index returns value. If the model's parameters are distributed randomly and their distribution is statistically stationary, then it can get a linear three-factor model of observations [21].

Three-factor model parameters were calculated, the yield of the RTS index was determined by the formula

$$y=ln(RTS1/RTS0)\times 4, \quad (1)$$

Where y - the yield of the RTS index; RTS1, RTS0 - the last values of RTS index the current and the previous quarter respectively.

The oil price growth pace at an annual rate is determined by the formula

$$x_1=ln(P_1/P_0)\times 4, \quad (2)$$

Where x1 - the oil price growth pace on an annualized basis; P1, P0-the closing price of Brent crude oil (NYMEX) the current and previous quarter respectively.

The growth rate of non-cash money supply at an annual rate is calculated by the formula

$$x_2=ln(DM_1/DM_0)\times 4, \quad (3)$$

Where x3 - GDP growth at an annual rate, TGDP1, TGDP0-GDP real growth in the current and previous quarter respectively, as a GDP percentage in 1995, t_y and t_q-the number of working days per year and quarter, respectively.

In [20] it's carried out these studies in the period of 2005-2013, an explanation of the expected growth in Russian fuel and energy companies' revenue, the RTS index growth increases the investment activity of institutional investors and corporations, the growth of the stock market. The graph of the expected return for RTS index in 2014-2016 is shown in Figure. 1. In [20] it's carried out verification of the Russian stock market prediction.

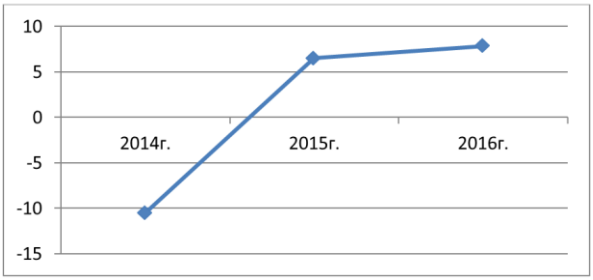

Figure 1. The expected return of the RTS index in 2014–2016

But now, it became obvious in 2016 that the prediction result is incorrect by using the technical analysis method. Therefore, it has to be considered to the intelligent analysis methods in the stock market.

4. THE PROPOSED RESEARCH MODELS

4. 1. Situational Model for Assessment the Stock Market State

In [5] it's used the situational model with fuzzy inference to study the stock market state. There are many other works [5-6] are using this model and give good results to solve the different problems. Also there are other famous methods to construct models for assessing the current state of the stock market [5-7], [10]. The assessment problem remains important, especially in the conditions of uncertainty and the instability of the stock market parameters.

The assessment problem of the stock market state is closely connected with the prediction problem of changes in the stock market parameters. The prediction is done at interval of time, but when the time interval of prediction is big, than the prediction result may be less accurate.

The experts knowledge was applied to solve the identification problems of the market state and predict its parameters. This is due to the fact that the results of stochastic forecasting methods are unsatisfactory [4]. The situational model for assessment the stock market current state is applied. In this model, the experts are given the Fuzzy reference situations to determine the stock market situations and their corresponding solutions.

It can be applied a variant, when a sets of fuzzy reference situations $S^* = \{\widetilde{S}_1^*, \widetilde{S}_2^*, ..., \widetilde{S}_R^*\}$ is divided into subsets $S_j^* \in S^*, S_i^* \times S_j^* = \varnothing, i, j = \overline{1,n}, i \neq j$ thus, each subset corresponds to one decision of stock market state: h_1 - stable; h_2 - transition; h_3 - growth; h_4 – unstable and h_5 - stagnation. The experts mapped each fuzzy reference situation to a particular state of the stock market.

The experts give the linguistic and fuzzy variables on the basic sets and define the characteristic factors parameters for decision making problem. The characteristic factors parameters are measured and the measurement results correspond to the values on basic sets X_i $i = \overline{1,n}$. The measured values of characteristic factors correspond to the membership degree values of fuzzy variables α_i^j. Measurements the stock market parameters and calculate the membership degree of fuzzy variables allow us to determine the real fuzzy situation in the stock market.

The situational models are comparing the real fuzzy situation with references fuzzy situations to determine the stock market state.

The formalization and implementation the situational models to assess the current state of the stock market exists the detail in [5].

The situational model has disadvantages. The main drawback is the lack of adequate guarantees of the experts to describe the references fuzzy situations, the drawback of classification model is that the experts must do exhaustive search for all decision-making rules in all combinations of fuzzy variables, the term-set of linguistic variables. Therefore, the composition model is applied to predict the change values (estimates) of the stock market parameters; it is also called the model of calculating the truth degree of fuzzy inference rules [22]. Let's consider the application of this model for prediction of the RTS index values for a given period of time (7 days). The value of "7 Days" is selected based on the recommendations of experts.

4.2. Model of Calculation the Truth Degree of Fuzzy Inference Rules for the RTS Index Prediction

As noted above, the classification model has a complex application [22], which can be avoided by limiting the number of rules for decision-making. As in in [5] to describe the stock market parameters on the verbal level applied linguistic variables (LP) to the term-set:

-α_1 – RTS index, which has a term-set T(α1)={ α_1^1 -Very Small; α_1^2 -Small; α_1^3 -Medium; α_1^4 -Big; α_1^5 -Very Big};

-α_2–The volume of current transactions, which has a term-set T(α_2)={ α_2^1 -Very Small; α_2^2 -Small; α_2^3 -Medium; α_2^4 -Big; α_2^5 -Very Big};

-α_3–Volatility in term-set of T(α_3)={ α_3^1 -Very Low; α_3^2 -Low; α_3^3 -Medium; α_3^4 -High; α_3^5 -Very High};

-α_4 – Capitalization, which has a term-set T(α_4)={ α_4^1 -Very Low; α_4^2 -Low; α_4^3 -Medium; α_4^4 -High; α_4^5 -Very High};

-α_5–The price of oil, which has a term-set T(α_5)={ α_5^1 -Low; α_5^2 -Medium; α_5^3 -High; α_5^4 -Very High};

Stock market defined states: h_1-stable; h_2-transition; h_3-growth; h_4-unstable; h_5–stagnation.

All the rules (situations) to predict the RTS index by using the classification model is shown in Table. 1.

Table 1. All the Rules to Predict the RTS Index by using the Classification Model

Rules	RTS index	Volume of current transactions	Volatility	Capitalization	Price of oil	The current state	Forecast RTS
1	α_1^1	α_2^5	α_3^5	α_4^5	α_5^1	h_4	drop
2	α_1^1	α_2^5	α_3^5	α_4^5	α_5^2	h_4	drop
……	……	……	……	……	……	……	……
12499	α_1^5	α_2^5	α_3^1	α_4^5	α_5^4	h_1	strong growth
12500	α_1^5	α_2^5	α_3^1	α_4^5	α_5^3	h_1	strong growth

As shown in Table.1, If the first, second, third and fourth of linguistic variables have five fuzzy variables, and the 5th of linguistic variables has four fuzzy variables, then the total number of rules for the classification model will equal 5×5×5×5×4=12500.

Obviously, if every rule took from the expert 20 seconds, then the total time to fill the table. 1 will be 69.4 hours. This number is unacceptable to apply this approach to predict the state of the stock market parameters. When the expert works an 8-hour every day, then 69.4 hours will be 8.7 days, which it is more than a week. During this time, the situation of the stock market will change and no longer needed to such prediction.

Therefore, the model of calculating the truth degrees of inference fuzzy rules allow avoiding the disadvantages of classification model [22] related to the increase in the number of rules.

For example, the results of analysis the stock market situation for prediction the change of RTS index the expert only give the RTS index growth rules and uncertainties, which are shown in the Table. 2. Any other rules will be drop for the RTS index.

As shown in Table. 2 the number of rules is 118. Therefore, the expert drawing up the rules for 20 seconds, it will take for this work 39.3 minutes. It is an acceptable time to predict.

Table 2. The Experts Rules for Prediction the RTS Index Growth

Rules	RTS index	Volume of current transactions	Volatility	Capitalization	price of oil	The current state	Prediction RTS
1	α_1^5	α_2^5	α_3^1	α_4^5	α_5^4	h_1	strong growth
2	α_1^5	α_2^5	α_3^1	α_4^5	α_5^3	h_1	strong growth
….	….	….	….	….	….	….	….
22	α_1^5	α_2^5	α_3^2	α_4^5	α_5^4	h_1	growth
23	α_1^5	α_2^5	α_3^2	α_4^4	α_5^4	h_3	growth
….	….	….	….	….	….	….	….
117	α_1^4	α_2^3	α_3^2	α_4^5	α_5^3	h_2	weak growth
118	α_1^4	α_2^3	α_3^2	α_4^4	α_5^2	h_3	uncertainty

5. INFORMATION SUPPORT

The program in Matlab was developed to predict the changes of the RTS index in the stock market. The algorithm of the program is shown in Figure. 2. The difference from the working results [5] is presence the composition model (model calculation of the truth degree of fuzzy inference rules) in the algorithm for prediction the RTS index value.

The algorithm show the identifying process of the stock market state: measuring characteristic factors; fuzzification; inference; defuzzification; the current state of stock market; the prediction of RTS index.

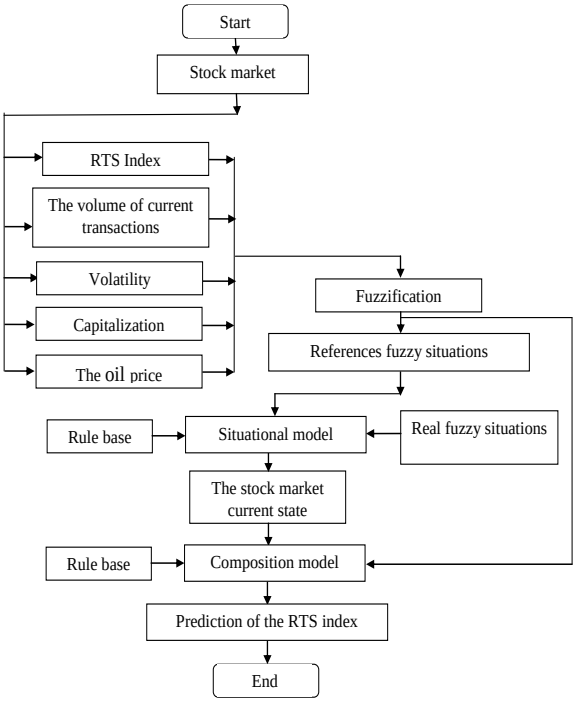

Figure 2. The program algorithm

6. RESULTS AND DISCUSSION

To perform the study the program is used. The program is shown in Figure. 3.

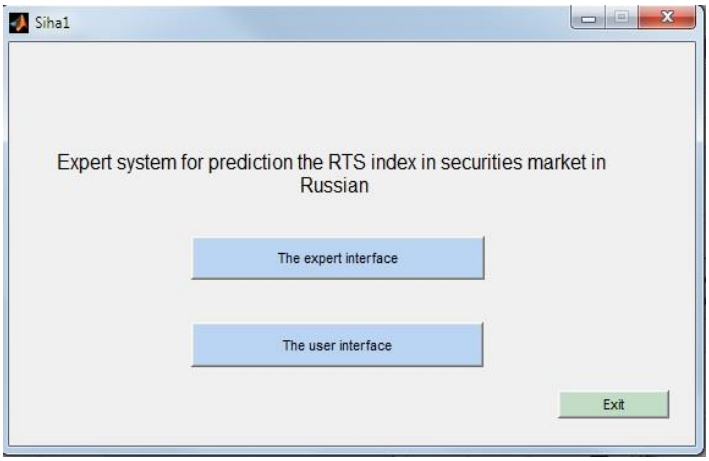

Figure 3. The main interface of program

To assess the stock market current state in the Russian Federation, it is identified five linguistic variables with their term-sets, references fuzzy situations of stock market, the decision-making rules of the stock market state as in [5].

The user enters the characteristic factors parameters to predict the RTS index: the RTS index values, transactions volume, the volatility, capitalization, oil prices. Figure 4 is shown the result of the input the characteristic factors values.

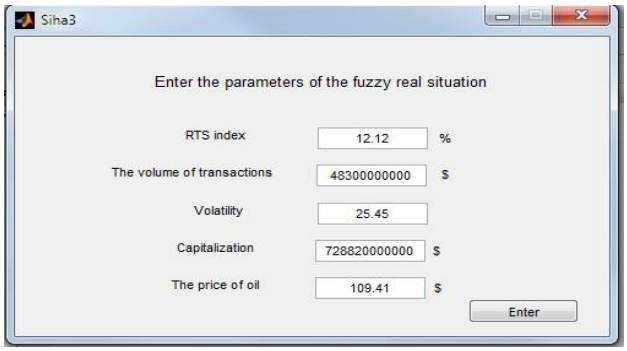

Figure 4. Specific the characteristic factors values

Firstly, the program generates the stock market current state and then predicts the RTS index as shown in Figure. 5.

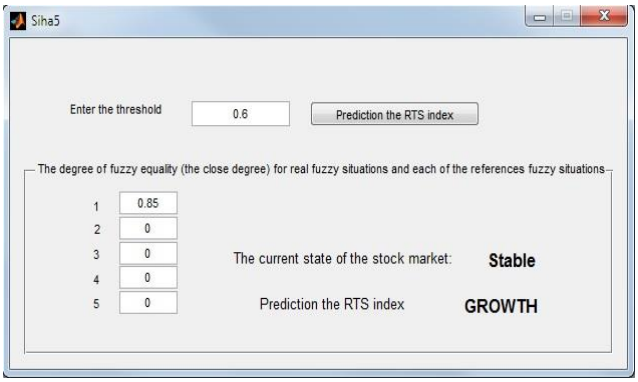

Figure 5. The current status of the stock market and prediction for the RTS index

As a test, the prediction for the RTS index of stock market from 05.2014 to 04.2016 is performed. The prediction results are shown in Table 3.

Table 3. The Study Results

Date	RTS index %	Volume of current transactions (million. $)	Volatility	Capitalization (billion. $)	Price of oil	Prediction RTS
5.2014	12,12	39681	25,45	728,82	109,41	Growth
6.2014	5,43	39985	30,9	758,82	112,36	Strong growth
7.2014	-10,74	26221	36,39	707,71	106,2	Drop
8.2014	-2,39	23570	35,24	686,11	103,19	Drop
9.2014	-5,59	$28^{21}4$	33,26	656,76	94,67	Drop
10.2014	-2,87	25270	31,94	575,61	85,86	Drop
11.2014	-10,74	21215	40,21	556,52	70,15	Drop
12.2014	-18,84	26800	60,4	439,29	57,33	Drop
2.2015	21,60	26240	46,44	476,69	62,58	Growth
3.2015	-1,81	33700	40.78	465,12	55,11	Uncertainty
4.2015	16,91	30216	32,4	532,41	66,78	Uncertainty
5.2015	-5,88	29200	35,42	564,71	65,56	Drop
6.2015	-2,98	31200	33,83	518,18	63,59	Drop
7.2015	-8,63	28056	30,53	510,71	52,21	Drop
8.2015	-2,94	29200	37,68	455,38	54,15	Drop
9.2015	-5,26	31250	37,07	439,09	48,37	Uncertainty
10.2015	7,07	34200	34,24	473,02	49,56	Strong growth
11.2015	0,18	31200	38,53	465,25	44,61	Uncertainty
12.2015	-10,63	27170	34,23	418,58	37,28	Drop
2.2016	3,15	36180	43,63	393,51	35,97	Growth
3.2016	13,97	32200	34,02	461,72	39,60	Strong growth

As shown in Table. 3 the situational model determines the stock market current state, then the model of calculating the truth degree of inference fuzzy rules predicts the changes of the RTS index based on expert rules which are given in the table. 2. For example, to predict the RTS index for month 06.2014 the user enters the characteristic-factors parameters for the month 05.2014: the RTS index values, transactions volume, the volatility, capitalization, oil prices, and then the program determines the parameters of the fuzzy real situation as follows:

={<<0/VerySmall>, <0/Small>, <0/Medium>, <0,91/Big>, <1/VeryBig>/*RTSindex*>, <<0/VerySmall>, <0/Small>, <0/Medium>, <0,75/Big>, <0,94/VeryBig>/ *The volume of current transactions* >, <<0,85/VeryLow >, <0,95/Low>, <0/Medium>, <0/High>, <0/VeryHigh>/ *Volatility* >, <<0/VeryLow>, <0/Low>, <0/Medium>, <0/High>, <1/VeryHigh>/ *Capitalization* >, <<0/Low>, <0/Medium>, <0/High>, <1/VeryHigh>/ *The price of oil* >}.

For assessing the stock market current state in the Russian Federation, the five references fuzzy situations of stock market, decision-making rules of the stock market state are determined in [5].

According to the situational model $\tilde{S} = \dot{\tilde{S}}_1$, the decision was h_1 - the current state is stable and according to the model of calculation of the truth degree of fuzzy inference rules the prediction of the RTS index will increase.

The prediction results using this model are shown in Table. 3.

In Table 3 the prediction for RTS index in 06.2014 was incorrect, the prediction result was a weak growth, but in fact, it was noted a drop. Also, the prediction for RTS index in 02.2015 was wrong. The prediction result from the model was growth the RTS index, in fact was the drop (Table 3 the highlight line). The rest of the prediction results by using the proposed model were satisfactory, this corresponds with the real events in the stock market.

Comparison the obtained results (RTS index) with the actual proved that the developed model for prediction the changes of the RTS index has given good results compared with the famous models with the trends extrapolation methods, which do not give good results in conditions of uncertainty (market volatility) [4]. The reliability of the prediction results was approximately 90% of correct results.

7. CONCLUSION

In the article, the urgency of assessing the stock market current state to predict the index RTS of the stock market is showed. The differences in this study: Firstly, the stock market current state is determined: stable; transient; growth; unstable and stagnant by using the situational analysis model, then prediction for the RTS index by using the model of calculation the truth degree of fuzzy inference rules.

According to the program results, it can be concluded that the proposed model and the program allow predicting the RTS index of stock market in the condition of incomplete source data.

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