Fuzzy logic decision support for long-term investing in the financial market

Abstract

This paper discusses the use of fuzzy logic and modeling as a decision making support for long-term investment decisions in financial markets. A simple model is proposed to calculate recommendations for investors. This research required thorough analysis of historical data that lead to discovery of interesting dependencies between the Dow Jones index, currency pairs, oil price and the VIX volatility index. The fuzzy model uses several input variables that are used to simplify the complex conditions in the financial markets. The purpose of the model is to evaluate the current market situation, compare the current situation to similar situations in the past and to provide investment recommendations for long-term investing.

1. Introduction

This paper describes the use of soft computing as a decision making support for long-term investment in the financial markets. It is very difficult to predict the development of financial markets. Markets are dynamic and there are many complex factors and complicated relationships that influence indexes, currencies and commodities these makes investing complicated and risky. The processes in economy are nonlinear. If the system is nonlinear and dynamic, it can generate randomly looking behavior but it can include the permanent trends and cycles. Investing in the financial markets is difficult because of globalized economies - there are different crises, bubbles, rising debts and prices of commodities, energy etc. These problems randomly escalate and create extreme imbalances in the market. These imbalances are both great opportunities and threats for the investors. Psychology also plays an important role in the financial markets - investors often do not recognize these opportunities because they are afraid of the future development. This research is facing very actual and yet at the same time classic problem of investing – when to buy and sell stocks while minimizing the risk. Understanding the markets and being able to predict what will happen in the near future are the key skills that every successful investor has to have. This research uses a simple model with a few variables that simplifies the complex market environment to make reliable recommendations for the investors and so provides a valuable decision making support tool.

This research has several objectives. The first objective is to analyze the past development of the Dow Jones index and to find extreme imbalances that occurred in the past. These situations are opportunities for the investors. The second objective is to define a set of variables that reliably describe the situation in the market. The third objective is to research the dependencies

and relationships between these variables. The final objective is to design a very simple and reliable fuzzy model that uses these variables to calculate recommendations for the investor.

2. Literature review

This research focuses on the use of soft computing and fuzzy logic in finance. Investors and decision makers have to decide when, where and how to invest. This problem is very complex and decision makers always try to use methods, tools and algorithms that allow them to limit risk (Rais & Doskočil, 2007). Fuzzy model designed in this research is intended as a decision making support tool for investors in the financial markets (Rejnuš, 2008). This research deals with extreme situations that occur in the financial markets and that are very difficult to predict (Bernice, 1997). Many researchers in the past used soft computing in business and finance (Altrock, 1996), (Dostál, 2011), (Kohout, 1998), (Peters, 1996). This research helps to identify current imbalances in the market based on similarity to past known events. The fuzzy model then processes several input variables to calculate recommendations for investors. Instead of promoting short term speculation this research aims to provide a decision making support model that helps to identify long-term critical imbalances and helps the investor to find possibilities for making long-term profits with low risk.

3. Methods

This research is based on modeling, analysis, synthesis and simulation. The main component of this research is the fuzzy model implemented in the MATLAB mathematical software. The proposed model is based on fuzzy logic and fuzzy sets. A fuzzy set A is defined as (U, μ_A), where U is the relevant universal set and $\mu_A: U \to \langle 0,1 \rangle$ is a membership function, which assigns each elements from U to fuzzy set A. The membership of the element $x \in U$ of a fuzzy set A is indicated $\mu_A(x)$. We call $F(U)$ the set of all fuzzy set. Then the "classical" set A is the fuzzy set where: $\mu_A: U \to \{0, 1\}$. Thus $x \in A \Leftrightarrow \mu_A(x) = 0$ and $x \notin A \Leftrightarrow \mu_A(x) = 1$. Let U_i, $i = 1, 2, ..., n$, be universals. Then the fuzzy relation R on $U = U_1 \times U_2 \times ... \times U_n$ is a fuzzy set R on the universal U.

The creation of the model was preceded by a thorough statistical analysis of the historical data. It was necessary to identify ideal moments in the past when the investor could buy or sell stocks to generate profit – these moments are often characterized as maximum or minimum values of the Dow Jones index. To increase the reliability of the designed model it was necessary to use not only the data from the long-term time series of the Dow Jones index but also variables that are not directly related to the index itself. Therefore it was necessary to find more variables that have a relationship with the Dow Jones index and describe the situation in the financial market. After the maximum and minimum values were found it was necessary to collect information about all the variables that are used in the model. The fuzzy model uses five input variables. These variables are discussed in detail in this chapter.

The first two input variables can be determined from the Dow Jones index. The first is the current value to long-term average ratio. This variable describes the situation in the market by comparing the current value to the long-term index average. The first four input variables have values from -100 to 100. A low value means that the index decreased in the past and is currently for some reason under its average. This variable is simple and it describes the very complex situation in the market clearly. The next variable is related to the past trend. If the values of the index decreased quickly in the past this variable has a negative value. The sharper decrease the lower the value. If the past trend was stable this variable has a value close to zero and when the index increased sharply in the past it has high positive value. For the purpose of this research these two simple variables describe the index well enough. This model does not directly predict the future development but it gives the investor a recommendation based on known information and comparison to the past situations in the market. Another important variable that has a complex relationship to the Dow Jones index is the EUR/USD currency ratio. USD in particular is closely related to the Dow Jones index. When USD is compared with other important world currencies (especially the Euro currency) very interesting and useful information can be read from the long-term development of this currency pair. The designed model does not use the value itself directly but it uses again the current value to long-term average ratio. This ratio is expressed again by values ranging from -100 to 100.

The next input variable is related to the current oil price. Prices of oil and energy in general are very important for the economy. Demand for oil is growing steadily. The fuzzy model has to be simple so the complex relations between oil production, supply, demand, oil price and the Dow Jones index have to be simplified. Instead of using the absolute price of oil a current price to long-term average price ratio is used. This ratio records information about the price during the last several months. Changes in the global financial market are not instant but take several days or weeks. And that is the reason why it is better to use this ratio to average price instead of the price itself in the model. An interesting correlation can be observed between the price of oil and the Dow Jones index in the last two decades. This correlation signifies the existence of a relationship even if this relationship is very complex. It is not the objective of this paper to analyze this and other complex relationships – instead the model uses input variables and calculates the recommendations for investors. It is known that high prices of energy and oil have a very negative impact on economic growth. Another input variable of the model is the Chicago Board Options Exchange Market Volatility Index often shortened to VIX. This index allows investors to observe the implied volatility of the S&P index options. The VIX index was proposed by Professor Robert Whaley in 1993. The VIX index was added into the designed model because it records the measure of uncertainty of the investors. When long-term development of the Dow Jones index is compared with the long-term development of the VIX index many interesting situations can be observed. High values indicate potential problems in the market which may cause the majority of the investors to sell and the Dow Jones index decreases. Statistical analysis of the long-term development of Dow Jones index showed that all major crises in the last two decades could also be observed as peaks in the VIX index. This finding is interesting and useful for this research.

The fuzzy model requires a set of rules that capture the important relationships between the input variables. These relationships have to be researched from the past data. A key step in this research even before the work on the fuzzy model began was to find extreme imbalances of the Dow Jones index in the past two decades. To find these imbalances it was necessary to analyze carefully the historical data. The long-term time series was analyzed many times with different methods in order to find key moments in the past that were opportunities for the investors. A very simple and reliable method to find these past moments is to compare the historical prices with the long term averages. When the historical price is very high in a certain time period and above both calculated long-term averages then this moment in time is a good opportunity for the investor to sell. When the price is the lowest in a certain time period and well below both long-term averages it is an ideal opportunity to buy. These two rules were used to determine the moments in time that were used in the model. When these dates were found the values for all the input variables were calculated. After all the values of the input variables had been determined the work on the fuzzy model started.
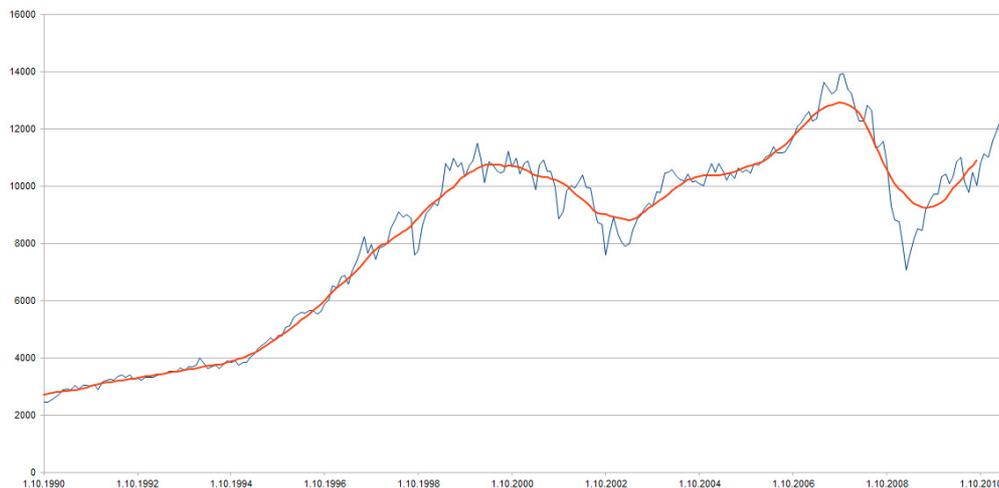

Fig. 1. Long-term statistical analysis of the Dow Jones index

The fuzzy model is implemented in the Fuzzy logic toolbox in MATLAB. First the input variables are defined. The model then calculates the value from these input variables based on the defined rules and returns an output variable called Position. This variable is the recommendation for the investor. In order to keep the model as simple as possible only three attributes were used for each variable – low, medium and high. Also a small number of rules were defined to keep the fuzzy model as simple as possible. These rules record the basic relationships that have been determined from the analysis of the past data and from the values of input variables in the key past situations. Before the work on this research the authors were looking for a simple algorithm or method that could be used by investors who are not skilled enough to use complicated financial software. Many of the decision support methods were not reliable or simple enough. That led the authors to this research with a simple model with a few input variables. After the rules have been defined the surface viewer can be used to visualize the dependency between input variables and the output variable.
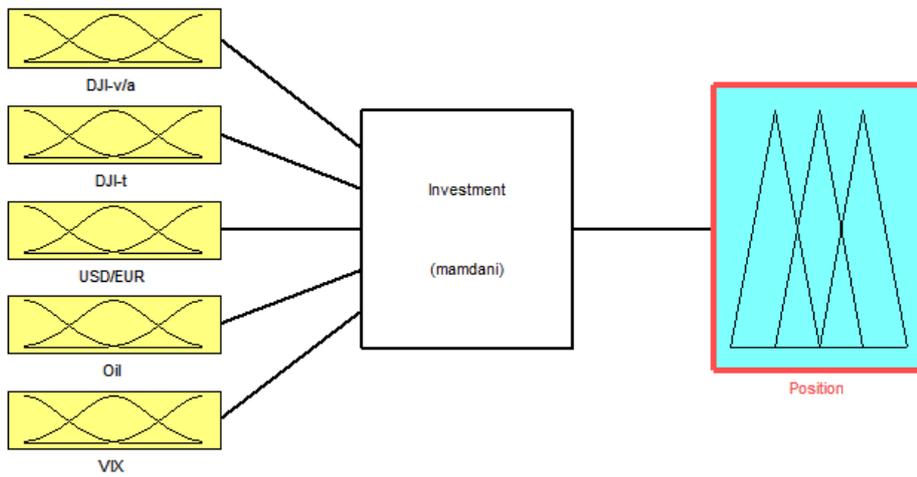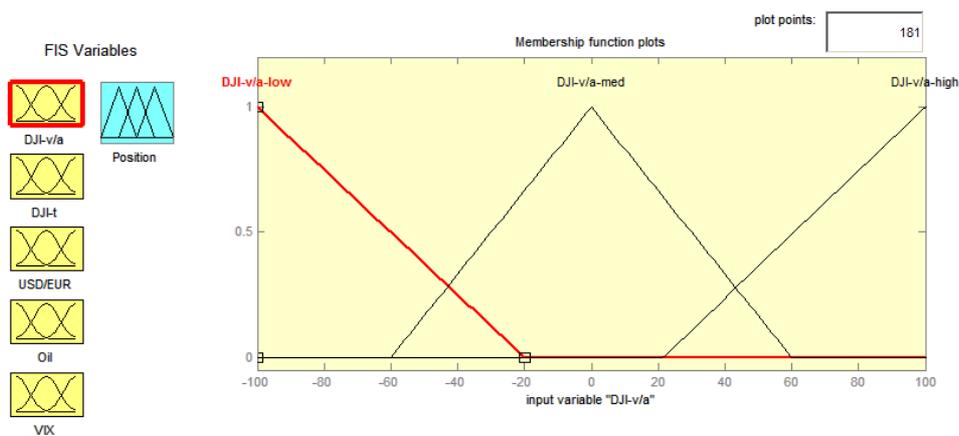
Fig. 2. FIS editor – input and output variables
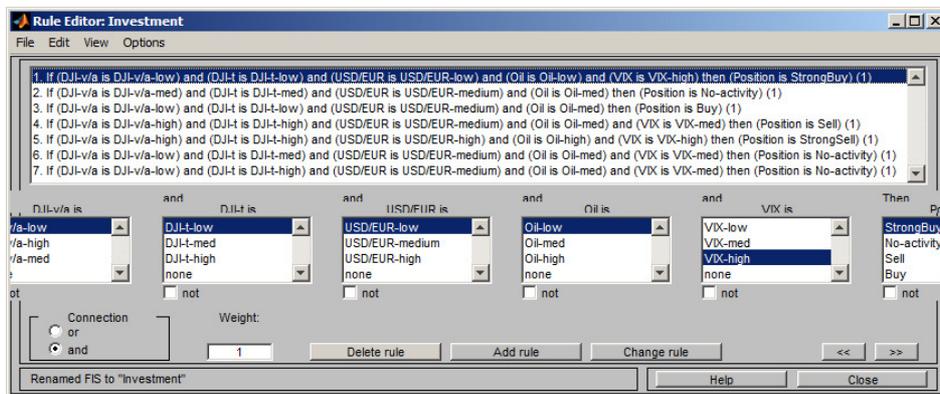

Fig. 3. Membership function editor
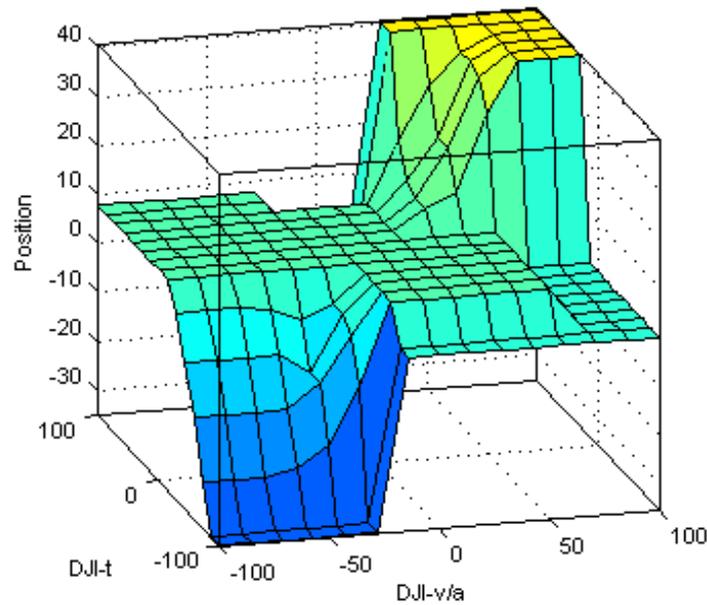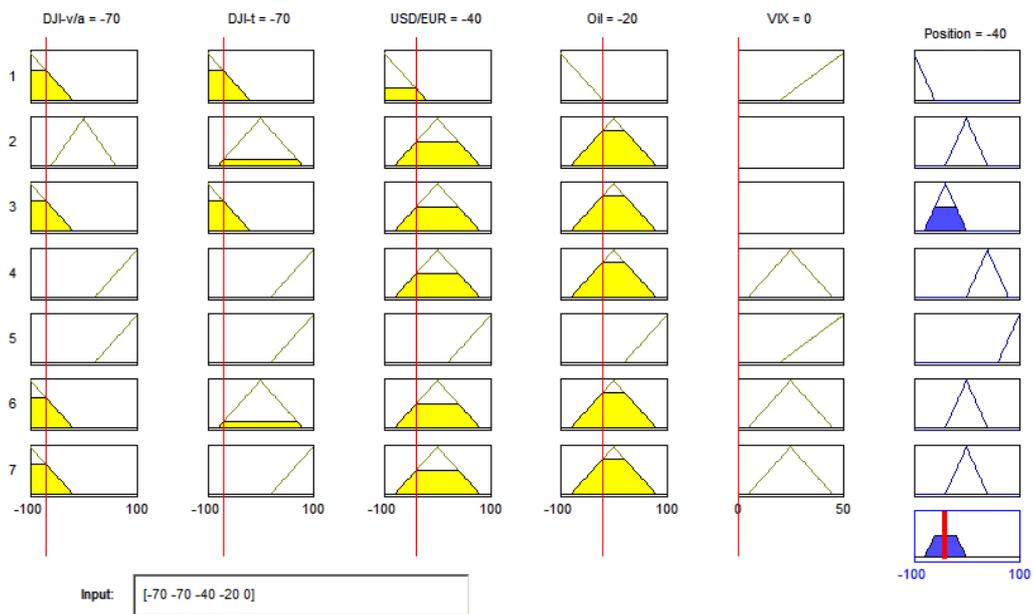

Fig. 4. Rules of the rule editor

Fig. 5. Visualization of dependence Position = f(DJI-t, DJI-v/a)
Fig. 6. Rule viewer and calculated output variable

4. Results

This chapter contains a simple table showing the input values for the five input variables for the selected key situations determined from the long-term Dow Jones index time series. The fuzzy model calculated the output value in each case from the input variables based on the simple set of rules. When the model outputs a value it can then be clearly translated to recommendations for the investor. Even without the fuzzy model very interesting and useful information can be learned from the values of the input variables. There are some quite strong dependencies and relationships between the input variables. Even when a long time has passed between two selected points in time this relationship is still present in the input data. It would of course be possible to add more input variables and make the model

more sophisticated but the objective of this research was to keep the set of input variables and the model itself as simple as possible.

Table 1: Input variables and calculated recommendations

Date	DJI	DJI-v/a	DJI-t	USD/EUR	Oil	VIX	Calculated value	Recommendation
30.8.1998	7640	-10	-40	-40	-30	45	-87,3	strong buy
1.1.2000	11722	90	90	50	50	25	40	strong sell
11.2.2002	9739,81	-70	-70	-40	-20	22	-40	strong buy
1.7.2007	13800	95	90	50	90	30	84	strong sell
9.3.2009	6625,74	-90	-70	-50	-100	80	-84	strong buy
1.5.2011	12600	80	80	80	-30	18	40	strong sell

5. Discussion

This chapter discusses the results obtained from the fuzzy model. It can be seen that the input variables have very different values for all the key moments in the past. These selected imbalances of the market were chosen to demonstrate the model. The financial market is dynamic and a very complex system so there is no simple way to predict the future development. The objective of the model is not to predict the future development but merely to identify opportunities and calculate recommendations from the input variables. Because this model focuses on the extreme imbalances of the market it can identify them safely. When the calculated recommendations are combined with other information and investing skills of the individual investor this decision support model is very valuable. This model promotes long-term investing strategy with low risk. That is a major difference when compared to most other methods that promote short-term speculation with high risk.

6. Limitations and implications

The designed model is intended as a decision making support for long-term investment. The financial market is a complex, dynamic and chaotic environment. A large number of factors influence the developments in the financial market each day. The reliability of the model would decrease significantly if it were used for short-term investing. Another limitation is that the model is designed for investing in large mutual funds that are highly correlated with the Dow Jones index. The model is designed to be as simple as possible and easy to use. Its reliability decreases significantly when it is used for investing in a single company due to the fact that events such as sudden changes in management, mergers, changes in the firm's focus and similar changes have a significant impact on the stock price of the individual company but not on the whole index that is composed of hundreds of companies. This simple model is designed to use specific combination of input variables. The combination of selected variables will provide significantly less reliable recommendations when it is used for other indexes due to the large change in conditions. The objective of this research is to develop an easy to use model that has a few simple input variables and yet is able to provide reliable recommendations to the investor. The accuracy of the model can be improved by adding more input variables and more rules but research has shown that at some point the model becomes too complex and the reliability of the model decreases. It is clear that no simple

fuzzy model can help the investor to identify all the short-term imbalances that can be used for investing this is because the current financial markets are interconnected and very complex due to globalization. In spite of this it is possible to reliably detect the long-term major imbalances of the financial markets which can then be used by investors to generate profits while maintaining low risk.

7. Conclusions

Investment decision making support based on the fuzzy model can prove to be very useful for investors who are looking for a path to manage risk when dealing with their long-term investment portfolio. The proposed model uses several input variables to evaluate the current situation in the market and calculate recommendations for the investor. The objective of this research is of course to limit risk and safely identify opportunities. This research does not promote risky short-term speculations. The designed model has been tested extensively on the historical data and it has proved to provide correct investment recommendations with high statistical probability. This research will be continued in the near future.