Innovative Techniques in Instruction Technology, E-learning, E-assessment, and Education

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A Fuzzy Approach to Solving Multicriteria Investment Problems

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Abstract—Financial managers have to make decisions under many restrictions and often have to deal with vague and imprecise information. In multicriteria problems, the best solution is sought in a set \( X \) of alternatives under certain constraints with rates of contentment \( \mu_i : X \rightarrow [0,1] \). Considering these rates as membership functions, the tools that fuzzy logic provides is adequate to solving a multicriteria investment problem. In this paper, a fuzzy approach for assessing the quality of an asset and making an investment decision based on this assessment is proposed.

I. INTRODUCTION
Assessing the characteristics of potential assets is a key issue in managing individual finance investments as well as in managing finance portfolio investments. Since an investor seeks maximal possible return combined with minimal possible risk, the decision making process at least two criteria have to be taken into consideration. Return and risk are the most common measurements in different models. They are obtained either from historical data or by subjective probabilities [1], [2], [3], [6], [8]. The precise determination of these characteristics is the basis for a good initial investment and proper investment in time. Investors' decisions are based on the degree of satisfaction of certain criteria often in conditions of vague and imprecise available economic information and are an optimal solution in a set \( X \) of alternatives [4]. This optimization problem could be solved with the tools of fuzzy logic if the degrees of satisfaction of the criteria are treated as membership functions of fuzzy variables \( \mu_i : X \rightarrow [0,1] \).

In this paper, a fuzzy logic based model for assessing financial assets and taking an investment decision is proposed. The input variables are the key characteristics of an asset \( K_1 = \{ \text{return} \} \), \( K_2 = \{ \text{Risk} \} \) and an additional one \( K_3 = \{ \text{r / R ratio} \} \). The decision about asset valuation is an output variable \( Q = \{ \text{quality} \} \).

II. MODEL

Return
Let \( A \) be a financial asset and \( P_1, P_2, ..., P_T \) is a sequence of historical data for the price of this asset in moment \( t \), \( t = 1, 2, ..., T \) (\( P_t \) is the market price of the asset at the end of each of \( T \) subsequent periods).

Then the return of the asset for the moment \( t \) is \( r_t = \frac{P_t}{P_{t-1}} - 1 \), \( t = 2, ..., T \).

The Annual Norm of Return (ANR) is calculated as

\[
ANR = AR - 1, \quad \text{where} \quad AR = \frac{1}{T} \prod_{t=2}^{T} r_t = \frac{P_T}{P_1},
\]

is the geometric mean of the returns.

Despite of the fact that the geometrical mean of returns \( AR \) is an accurate measurement for how the invested capital has changed the logarithms of returns and then arithmetic mean of log-returns is more suitable for examining the dynamic changes in return and risk:

\[
\bar{r}_e = \ln(AR) = \ln \left( \frac{P_T}{P_1} \right) = \frac{1}{T-1} \sum_{t=2}^{T} \ln r_t \quad (1)
\]

The following equality holds:

\[
AR = e^{\bar{r}_e}.
\]

In the proposed model the quantity \( r = ANR - \bar{r}_e \) is used, where \( \bar{r}_e \) is an additional constraint and it could be the
required minimal rate of annual return, or the return of the risk-free asset, or any other threshold parameter.

Risk
The common measure of risk in investment theory is the variability of returns. Different statistical tools, based on probability distributions and most often the variance of the returns, are used to calculate the variability [2], [3], [7]. In the proposed model, the estimator of variance is the arithmetic mean of log-returns:

\[ s^2 = \frac{1}{T-2} \sum_{t=3}^{T} \left( \ln(r_t) - \bar{r} \right)^2 \]  

(2)

As a measure of the risk the quantity \( \sigma = s - \sigma_o \) is used, where \( \sigma_o \) is the upper limit of the risk that the investor can take.

Return-to-Risk ratio
In the proposed model, a new characteristic is introduced - Return-to-Risk ratio \( q \). This ratio is calculated as

\[ q = \frac{r}{\sigma} \]  

(3)

and shows to what extend the risk taken by the investor is justified. Every investor aims at maximum return and minimum risk, thus for the Return-to-Risk ratio \( q \) maximal values are sought. There are other measures of the proportion between mean and variance, but in this model, a degree of quality of the asset is introduced and so Return-to-Risk ratio is an appropriate characteristic. Indeed, if Return-to-Risk ratio is small (e.g. small return, great risk) the asset is not attractive to the investors and vice versa.

Model description
In the process of investment decision making, uncertainty in data is an important condition that cannot be ignored. Besides an investment manager faces several criteria - either constraints or restriction and has to consider a decision problem finding the best decision in the set of feasible alternatives with respect to several criteria functions that are within the range [0, 1] (or could be mapped to this interval) and therefore fuzzy approach is applicable [4].

In the proposed model, the criteria are high return, combined with low risk and good quality of the asset.

The asset evaluation in the proposed fuzzy system is based on historical market prices. In the example, the prices of 12 arbitrary chosen assets listed on Bulgarian Stock Exchange are used. The period of the observations is from 10.09.2004 till 13.06.2007 and the data has been extracted by a real-time Perl based data acquisition system [10]. Return, risk and Return-to-Risk ratio are calculated. For each asset according to (1), (2) and (3). These values are fuzzified and thus they become input variables for the fuzzy system. Then the quality of the asset is derived by firing fuzzy rules in the FuzzyToolBox module in MatLab (fig. 1).

Fuzzy input variables description
The input fuzzy variable \( K_i = \{ \text{return} \} \) consists of five terms: very_low, low, neutral, high, very_high (fig.2).

Table 1

<table>
<thead>
<tr>
<th>Term</th>
<th>Type of membership function</th>
<th>Parameter 1</th>
<th>Parameter 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>very_low</td>
<td>sigmf</td>
<td>-30</td>
<td>-0.05</td>
</tr>
<tr>
<td>low</td>
<td>gaussmf</td>
<td>0.05</td>
<td>0</td>
</tr>
<tr>
<td>neutral</td>
<td>gaussmf</td>
<td>0.007</td>
<td>0.1</td>
</tr>
<tr>
<td>high</td>
<td>gaussmf</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>very_high</td>
<td>sigmf</td>
<td>30</td>
<td>0.25</td>
</tr>
</tbody>
</table>
The input fuzzy variable \( K_2 = \{\text{Risk}\} \) also consists of five terms: very _low, low, neutral; high; very _high (fig. 3), but with different parameters.

The fuzzy variable \( K_3 = \{r / R \text{ ratio}\} \) consists of three terms: low; neutral; high (fig. 4). The membership functions of the terms low and high are of sigmoid type, while the term none has Gaussian membership function of type 2.

Fuzzy output variable description

The output variable \( Q = \{\text{quality}\} \) has five terms: bad; not _good; none, good; very _good (fig. 5) all with membership functions of Gaussian type 1 with the corresponding parameters.

Rules for decision-making

For making the decision about the quality of the asset three criteria are taken into consideration – high return, low risk and high Return-to Risk ratio. The quality of an asset is assumed as very good if it has very high or high return, very low or low risk, and high Return-to Risk ratio that shows that the risk taken is justified by higher return. The Mamdani min operator is used for aggregation and defuzzification is done following the centroid method [9], [11]. In the model, 24 rules with corresponding weights are applied and the first 10 of them are shown in table 3.

For instance, rule 1 is:

IF \( K_1 \) is very _high) and \( K_2 \) is very _low) and \( K_3 \) is very _low) THEN \( Q \) is very _good

<table>
<thead>
<tr>
<th>Rule</th>
<th>( K_1 )</th>
<th>( K_2 )</th>
<th>( K_3 )</th>
<th>( Q )</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>very _high</td>
<td>very _low</td>
<td>high</td>
<td>very _good</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>very _high</td>
<td>low</td>
<td>high</td>
<td>very _good</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>high</td>
<td>very _low</td>
<td>high</td>
<td>very _good</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>high</td>
<td>low</td>
<td>very _low</td>
<td>high _good</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>very _high</td>
<td>very _low</td>
<td>high _good</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>very _high</td>
<td>neutral</td>
<td>high _good</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>high</td>
<td>low</td>
<td>high _good</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>high</td>
<td>neutral</td>
<td>high _good</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>very _high</td>
<td>very _low</td>
<td>neutral</td>
<td>good _good</td>
<td>0.8</td>
</tr>
<tr>
<td>10</td>
<td>very _high</td>
<td>low</td>
<td>neutral</td>
<td>good _good</td>
<td>0.8</td>
</tr>
</tbody>
</table>

The result after firing the rules for a case with \( \text{return}_1 = 0.15, \text{risk} = 0.20, r / R \text{ ratio} = 75 \) is shown on figure 6. The obtained value for the quality of the asset is 0.727.
As can be seen from table III neither high return nor high Return-to-Risk ratio only guarantees good quality of the asset. For instance, RAZHL is not the best choice for investment no matter it shows excessive return. In the same time CHIM, though having the lowest return, shows best quality.

In financial world, it is important to know what happens with the amount of money invested in a particular asset. Assuming that an investor spends 100$ on each of the assets on 13.06.07, the change of this sum over time shows how good the investment is. In table IV the assets are sorted by their quality (column Quality*100%) and then the prices on 20.06.2007, 27.06.2007 and 04.07.2007 are used for calculating the change in each investment.

### Table IV

<table>
<thead>
<tr>
<th>Quality*100%</th>
<th>20.6.2007</th>
<th>27.6.2007</th>
<th>04.7.2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHIM</td>
<td>69.63</td>
<td>107.95</td>
<td>127.17</td>
</tr>
<tr>
<td>ADVANC</td>
<td>65.06</td>
<td>102.31</td>
<td>106.27</td>
</tr>
<tr>
<td>PETHL</td>
<td>64.34</td>
<td>103.23</td>
<td>119.02</td>
</tr>
<tr>
<td>ALBHL</td>
<td>61.98</td>
<td>103.47</td>
<td>108.78</td>
</tr>
<tr>
<td>CENHL</td>
<td>61.06</td>
<td>104.33</td>
<td>13.77</td>
</tr>
<tr>
<td>SOFBT</td>
<td>55.95</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>LEV</td>
<td>53.34</td>
<td>97.93</td>
<td>96.65</td>
</tr>
<tr>
<td>GAMZA</td>
<td>51.92</td>
<td>99.35</td>
<td>100</td>
</tr>
<tr>
<td>ZLP</td>
<td>51.46</td>
<td>98.14</td>
<td>n.a.</td>
</tr>
<tr>
<td>DOVUHL</td>
<td>50</td>
<td>100.15</td>
<td>108.91</td>
</tr>
<tr>
<td>RAZHL</td>
<td>50</td>
<td>91.4</td>
<td>83.78</td>
</tr>
<tr>
<td>BHC</td>
<td>49.08</td>
<td>101.94</td>
<td>99.78</td>
</tr>
</tbody>
</table>

The leaders in Quality (CHIM, ADVANC, PETHL and ALBHL) shows steady increase in price over time while the assets with Quality less than 60 either show decrease in price or have unstable prices over time. The only exception is CENHL, which had a dramatic fall in price at the end of June 2007.

### IV. Conclusion

There are different methods to approach and solve multi-criteria problems. In financial world, where the decisions have to be taken under many constraints with sometimes imprecise and vague information, acceptable results can be derived with fuzzy approach. In this paper a model based on fuzzy
reasoning is introduced. In the model, three criteria are used to support the investment decision-making process with a measure of the quality of a financial asset. The model is applied and tested to twelve arbitrary chosen assets from Bulgarian Stock Exchange. Results about the quality of these assets are obtained.

An investor can use the information about the quality of an asset in managing an individual asset - e.g. choosing the "best" asset.

The results from the proposed model can be used for asset allocation in investment portfolio management. In this point an investor can choose shares \( x_j \) of asset \( j \) to be equal to

\[
x_j = \frac{Q_j}{\sum_{k=1}^{n} Q_k},
\]

where \( Q_j \) is the Quality of the \( j \)-th asset,

\( j = 1, \ldots, n \).

Though the achieved results are satisfactory, the model can be developed in different directions - decision making in real time, predicting future returns and risks, adding new criteria.

REFERENCES


