A Novel Fuzzy Financial Investment Algorithm based on Combinatorial Entropy Value Method

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Abstract. According to the multi-objective and multi-decision problem of traditional financial investment, a Financial Fuzzy Investment model based on Combinatorial Entropy Value Method is proposed. The company financial index system and index calculation model are constructed, an improved entropy method is proposed to calculate the index weight value, which can comprehensively consider the influence of historical evaluation data and current evaluation data, and the fuzzy membership function for investment satisfaction is proposed. Finally, an example is used to verify the effectiveness of the Investment model.

1. Introduction
There are many factors affecting stock investment model. Typical methods of stock prediction models include GARCH-M model [1], neural network model [2], wavelet analysis model [3], which predict future stock prices using nearly historical stock price data. However, the stock investment method relies on the historical stock price information, which is only suitable for the short-term stock forecast. For long-term financial investments, it relies more on the analysis of companies' finances indexes. Ball and Brown[4] found a strong correlation between corporate financial indexes and the long-term stock prices. Subsequently the correlation analysis of the company's financial indexes and stock price volatility had researched. with optimal regression analysis of large number of the company's stock price data and the company’s financial indexes, shows that the company’s financial indexes, such as current ratio, earnings per share, have higher correlation with the stock price. Recently some methods based on Fuzzy decision algorithm are used to predict stock prices, but most of them use subjective scoring method and lack of quantitative analysis process[5-6].

To solve the combined investment improblems included multi-objective multiple-decision decisions, this paper puts forward a fuzzy investment decision method based on combinatorial entropy value method. The company's financial indexes system is constructed, the index membership functions, fuzzy decision algorithm framework and the calculation process are given. According to fuzzy weights calculation problem, the combination entropy value method is proposed, which using analytic hierarchy process (AHP) method to calculate the company's history index weight values, using entropy value method (EV) to calculate the current financial index weight values. This method comprehensively considers the influence factors of historical data and current data, which can adjust the weight values with time changes.

2. The financial index system for financial stock investment
It sure that investing a company stock is investing the development of the company. Therefore, the company's financial stock prices can be evaluated from the company's profitability, growth ability,
debt financing ability, operating ability and so on. The company's profit indexes mainly reflect the company's operating income, including EPS, BVPS, ROE etc. The growth ability indexes of the company mainly reflects the growth of the main business of the company, including the growth rate of operating income, net assets growth rate, net profit growth rate etc.; Debt financing ability refers to the company's ability to repay debts, including asset-liability ratio, asset-current ratio and other indicators; The company's operating ability mainly reflect the company's resource utilization and management ability, including inventory turnover, accounts receivable turnover, total asset turnover.

3. Research on Fuzzy Financial Investment Model

In the stock market investment process, it is difficult to use a quantitative model to evaluate the stock prices because of its fuzziness. For example, Even in the same industry, the correlation of financial indexes and stock prices in different years are different, due to changes in company development prospects, market psychology and other factors. However, The fuzzy set evaluation method can be used to solve the uncertainty of evaluation factors.

Fuzzy decision is suitable for the decision making with multiple indexes and variables are fuzzy factors. It has been widely used in control field, scheduling field, command and decision field, etc. The fuzzy decision-making theory which used to the field of financial stocks, the first thing is to establish the fuzzy indexes of stock investment decision set, second establish the corresponding weight set of the fuzzy membership function, finally calculate the fuzzy membership function matrix, the different combination investment decisions can be evaluated by the fuzzy decision results.

4. Research on Fuzzy Financial Investment Model

4.1. Establish the set of financial stocks indexes

Establish the set of company's financial indexes \( U = \{u_1, u_2, ..., u_n\} \) which affect the company’s stock prices. The element \( u_i \) represent the important indexes, such as earnings per share, return on equity, net assets per share, growth rate of net assets.

4.2. Establish the computational model of corporate financial indexes

Establish the computational model of corporate financial indexes, such as the return on equity per share, net assets per share, return on equity, growth rate of net assets, inventory turnover, etc. For example, earnings per share rate can be calculated as

\[
\text{Earnings per share rate (EPSR)} = \frac{\text{Current net profit}}{\text{Number of common shares}} \times 100\% \quad (1)
\]

4.3. Establish the index weight set of corporate financial stock

Establish the index weight set \( U = \{u_1, u_2, ..., u_n\} \). The weight value of \( u_i \) is dynamic, which need to be considered comprehensively with historical corporate financial data and current corporate financial data.

4.3.1 Evaluation of the index weight set using historical corporate financial data based on AHP method

The correlation between historical financial corporate data and stock price can be calculated by multiple linear regression analysis methods, thus the degree of correlation of financial index can be ranked. The AHP method is applicable to the weight calculation of indicators with ranked conclusions. Therefore, this paper uses the analytic hierarchy process to calculate the weight value based on historical financial indexes.

According to the statistics of historical data, the influence degree of the corporate financial indexes (such as net income per share, net asset per share, return on equity.) and the stock price can be calculated. Then, the judgment matrix can be constructed according to the "1-9" scale method[7].

4
Where, \( C_{ij} \) represents the importance of index \( C_i \) relative to index \( C_j \). Calculate the product of each row of elements in the judgment matrix

\[
M_i = \prod_{j=1}^{n} c_{ij} (i = 1, 2, ..., n)
\]

The weight value is calculated by normalization

\[
W_i = \frac{\sqrt[n]{M_i}}{\sum_{j=1}^{n} \sqrt[n]{M_j}}
\]

Where, \( W = (W_1, W_2, ..., W_n)^T \) is the weight set of each index. Calculate the maximum eigenvalue of the judgment matrix

\[
\lambda_{\text{max}} = \sum_{i=1}^{n} (CW)_i / nW_i
\]

Calculated consistency index

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1}
\]

Calculate the random consistency ratio

\[
CR = \frac{CI}{RI}
\]

Where, \( RI \) is the average consistency index. If \( CR < 0.10 \), then it indicates that the judgment matrix has acceptable satisfactory consistency, and the consistency check is passed.

### 4.3.2 Evaluation of the index weight set using current corporate financial data based on EV method

Since it is impossible to directly count the ranking of importance based on current corporate financial data, this paper uses the EV method to calculate the weight value. EV method is widely used to calculate weight, which can evaluate the weight value according to the information entropy.

Because the dimensions and units of each company's financial indexes may vary, it is necessary to conduct standardized processing of the evaluation index data, and the standardized formula is as follows:

\[
r_{ij} = \begin{cases} 
\frac{r_{ij} - \min(r_{ij})}{\max(r_{ij}) - \min(r_{ij})} & \text{max}(r_{ij}) \neq \min(r_{ij}) \\
1 & \text{max}(r_{ij}) = \min(r_{ij})
\end{cases}
\]

Where, \( r_{ij} \) is the \( j \)th index of the \( i \)th evaluation object, \( \min(r_{ij}) \) is the minimum value of the \( j \)th index, and \( \max(r_{ij}) \) is the maximum value of the \( j \)th index. Then normalize \( r_{ij} \)
standard matrix $R$ can be calculated. According to the calculation method of entropy value, the entropy value $H_j$ of the $j$th index is calculated

$$H_j = -k \sum_{i=1}^{m} r_{ij} \ln r_{ij}, \quad j = 1, 2, ..., m$$

(10)

Calculate the coefficient of difference of the $j$th index

$$g_j = 1 - H_j, \quad j = 1, 2, ..., m$$

(11)

Calculate the weight value of the $j$th index

$$v_j = \frac{g_j}{\sum_{j=1}^{m} g_j}, \quad j = 1, 2, ..., m$$

(12)

Where, $V = (V_1, V_2, ..., V_n)^T$ is the weight set of each index.

4.3.3 Calculate the combinatorial Entropy weight value

By calculating the weight value of the historical index $W$ and the weight value of the current index $V$, the combined weight value $Z = (z_1, z_2, ..., z_j)$ can be obtained:

$$Z = \rho W + (1 - \rho) \cdot V$$

(13)

Where $\rho \in [0, 1]$ . If $\rho < 0.5$, the combined weight value is prefer to use current index data; if $\rho > 0.5$, the combined weight value is prefer to use of historical index data. If there is little difference between the current company's financial data and the historical company's financial data, indicating that the company's fundamentals have not changed, then the combined weight value tends to use the weight value of the historical index. If the difference is large, indicating that the fundamentals of the company have changed greatly, then the combined weight value tends to use the weight value of the current index.

If the historical financial index data of the company is $U^+ = [u_1^+, u_2^+, ..., u_n^+]$ and the current financial index data of the company is $U = [u_1, u_2, ..., u_n]$, then the distance measure of two sets can be calculated:

$$d(U^+, U) = \sqrt{\sum_{j=1}^{n} (u_j^+ - u_j)^2}$$

(14)

the maximum permissible distance is $d_{max}$, then

$$\rho = \begin{cases} 
0 & \text{if } d(U^+, U) \geq d_{max} \\
\frac{d_{max} - d(U^+, U)}{d_{max}} & \text{if } d(U^+, U) < d_{max} 
\end{cases}$$

(15)

4.4. The Fuzzy decision algorithm example

In this paper, the real estate industry of stock financial investment are chosen as an example, the corporate financial data between December 2018 and December 2019 are listed in table 1, while contain WK A(000002), LDKG(600606), BLDC(600048), JDJT(600383), TLXC(000809) five stocks, all data are collected from Shanghai stock exchange sites. According to literature [6], the correlation of
14 financial indexes and stock prices of the real estate industry from years 2015 to 2017 is analysed. The results showed that four indicators, including net assets per share (NAPS), liquidity ratio (LT), earnings per share (EPS) and return on equity (ROE), were highly correlated with stock prices. Therefore, table 1 selects the four indexes of 5 stocks of real estate companies from 2018 to 2019.

| Corporation | EPS    | NAPS   | ROE    | LT     | 2018 year Stock price | 2019 year Stock price | The growth rate |
|------------|--------|--------|--------|--------|------------------------|------------------------|-----------------|
| 000002     | 3.06   | 14.11  | 20.47% | 1.16   | 21.76                  | 31.16                  | 43%             |
| 600606     | 0.93   | 5.60   | 18.69% | 1.27   | 5.41                   | 6.55                   | 21%             |
| 600048     | 1.59   | 9.7    | 17.92% | 1.78   | 10.47                  | 15.36                  | 46.7%           |
| 600383     | 1.79   | 10.27  | 18.63% | 1.58   | 8.35                   | 13.83                  | 65.6%           |
| 000809     | 0.12   | 3.8    | -2.7%  | 3.26   | 5.06                   |                        | 21.1%           |

4.4.1 Establish the set of financial stocks indexes

Establish the set of financial stocks indexes \( U = \{u_1, u_2, u_3, u_4\} \), where, \( u_1 \) is earnings per share, \( u_2 \) is net asset per share, \( u_3 \) is return on equity and \( u_4 \) is current ratio.

4.4.2 Establish the weight value set of the financial stocks indexes

(1) Calculate the weight value of historic financial data

According to the statistical data of financial indexes and stock prices in the real estate industry from 2015 to 2017, the judgment matrix is constructed

\[
C = \begin{bmatrix}
1 & 3 & 2 & 7 \\
1/3 & 1 & 1/2 & 5 \\
1/2 & 2 & 1 & 6 \\
1/7 & 1/5 & 1/6 & 1
\end{bmatrix}
\]

Through the calculation of hierarchical ranking weight formula (4-7), \( \lambda_{max} = 4.0766 \), \( CR = 0.0287 \), \( W = \left[ \begin{array}{cccc}
0.4784 & 0.1801 & 0.2918 & 0.0497 \\
\end{array} \right]^T \).

\( CR \) is less than 0.10, indicating that the judgment matrix passes the consistency check.

(2) Calculate the weight value of current financial data

Substitute the data in Table 1 into Equation (8-9), calculate the standard matrix:

\[
R = \begin{bmatrix}
0.4085 & 0.3245 & 0.2703 & 0.1281 \\
0.1241 & 0.1287 & 0.2468 & 0.1403 \\
0.2122 & 0.2230 & 0.2366 & 0.1745 \\
0.016 & 0.0873 & 0 & 0.3602
\end{bmatrix}
\]

The entropy value \( H_j \) is calculated according to Equation (10)

\[
H = \left[ \begin{array}{cccc}
0.735624318 & 0.848729179 & 0.750173818 & 0.873718194 \\
\end{array} \right]^T
\]

The coefficient of difference is calculated according to Equation (11)

\[
G = \left[ \begin{array}{cccc}
0.264375682 & 0.151270821 & 0.249826182 & 0.126281806 \\
\end{array} \right]^T
\]

The weight value of each index is:

\[
V = \left[ \begin{array}{cccc}
0.333911188 & 0.191057736 & 0.31553491 & 0.159496166 \\
\end{array} \right]^T
\]

(3) Calculate the combinatorial Entropy weight Value
According to the historical index data from 2015 to 2017, through the formula (14-15), the combinatorial parameter $\rho = 0.72$. According to Equation (18), the combined weight value can be calculated as $Z = \begin{bmatrix} 0.374368055 & 0.18798957 & 0.308889135 & 0.12875324 \end{bmatrix}^T$.

4.4.3 Establish the membership function of the financial stocks indexes

According to the characteristics of financial stock, fuzzy distribution method can be used to determine the membership function of financial stock. For the indexes such as earnings per share, return on equity and net assets per share, the value bigger the better. Therefore, a typical up-half distribution $\Gamma$ can be selected:

$$\mu(x) = \begin{cases} 0 & x \leq \alpha \\ 1 - e^{-k(x-\alpha)} & x > \alpha, k > 0 \end{cases}$$

According to the information of the four financial indexes, the coefficient $k = 1$, earnings per share parameter $\alpha = 0.05$, return on equity parameter $\alpha = 0.01$, net assets per share parameter $\alpha = 2$.

The current ratio index is used to measure the company’s solvency. If the index is too low or too high, it will affect the healthy financial development of the company. Generally, the optimal value is 2, and a typical symmetric tip distribution $\Gamma$ can be adopted:

$$\mu(x) = \begin{cases} e^{k(x-\alpha)} & x \leq \alpha \\ e^{-k(x-\alpha)} & x > \alpha \end{cases}$$

According to the information of the four financial indexes, the coefficient $k = 1$, $\alpha = 2$.

4.4.4 Establish the membership function matrix

By substituting the values of each index in Table 1 into the formula (18-19), the membership function matrix can be obtained as follows:

$$U = \begin{bmatrix} 0.95 & 0.59 & 0.78 & 0.82 & 0.07 \\ 0.99 & 0.97 & 0.99 & 0.99 & 0.83 \\ 0.18 & 0.16 & 0.15 & 0.16 & 0 \\ 0.43 & 0.48 & 0.80 & 0.66 & 0.28 \end{bmatrix}$$

4.4.5 Fuzzy comprehensive evaluation

$$E = Z \circ U = \begin{bmatrix} 0.652723 & 0.514451 & 0.627453 & 0.627491 & 0.218288 \end{bmatrix}$$

From the calculation results, 000002 stock is the best plan, 600383 stock ranks second, 600048 stock ranks third, 600606 stock ranks fourth, and 000809 stock ranks fifth. There is small distance between the three stocks of 000002, 600383 and 600048. Compared with the actual stock price rise from 2018 to 2019, the first three stocks rose significantly more than the other two stocks, basically meet the criteria for stock selection.

5. Conclusion

This paper constructs the index system that affects the stock investment, analyzes the influence of various indexes on the stock price, puts forward the membership function calculation method of various indexes, and gives the method of fuzzy investment decision. Aiming at the problem of calculating the weight value of stock indexes, a combined entropy method is proposed, which can evaluate the historical data and the current data comprehensively.

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