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A Hybrid Value Investing Method for the Evaluation of Banking Stocks

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***Abstract*—Stock market is regarded as a highly dynamic and complex environment consisting of opportunities and risks. All participants want to earn profits by adopting their investment strategies. One of the most famous investment strategies is value investing, which attracts both practitioners and researchers' attention all over the world. Empirical studies have consistently found that value stocks outperform the market in the long run, but it often encounters obstacles to implement this strategy in practices. Due to the need of in-depth analysis of financial statements, investors not only need accounting knowledge but also investment expertise. Among previous studies, the accounting-based fundamental analysis (F-score) has been a widely accepted model for value investing. The F-score model proposed nine fundamental signals to measure a firm's financial prospect. However, it is difficult to acquire the implicit knowledge and interactive considerations of senior experts. Thus, the evaluation processes of investment experts cannot be revealed for the others' reference. To improve the limitations, this paper integrates fuzzy set theory and decision methods to propose an innovative model for distinguishing strong financial prospect stocks within high book-to-market (B/M) banking stocks. Our empirical study shows the practicability of our proposed method. It also provides the relative weights and the interdependence of each measurement variables for the value investing strategy.**

***Index Terms*—investing style, F-score, fuzzy, ANP.**

I. Introduction

The value investing strategy can be traced back to the work of Graham and Dodd [1] in 1934. They argued that out-of-favor stocks are sometimes under-priced, and investors could make profits by identifying this phenomenon. This philosophy is now widely known as value investing, which is also encouraged by the world-class investor Warren Buffett, through his outstanding investment records [2]. The whole world encountered financial turmoil during 2008 and experienced strong bounce back in the following years. It would have been useful if investors could have had a practical investment method to distinguish underpriced financial stocks during 2008. To attain this goal, this research proposes a hybrid Fuzzy-MCDM (Multiple Criteria Decision Making) method and examines how investment experts evaluate banking stocks through the value investing approach.

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According to Fama and French [3], value stocks have higher returns than growth stocks in markets around the world. Both in academic and practice fields, firms that have higher ratios of book-to-market equity (B/M) are often classified as value stocks [4],[5]. Lakonishok, Shleifer, and Vishey [6] showed that there is a strong value premium in average returns for US stocks. Although many studies revealed similar findings, Piotroski [7] argued that not all high B/M stocks can earn above average returns. By examining whether a simple accounting-based fundamental analysis can separate winners from losers, F-score model aims to examine the "value-investing" strategy. F-score model shows that investors can use relevant historical information to eliminate stocks with poor future prospects from a generic high B/M portfolio. The result shows 23% annual return between 1976 and 1996 by buying expected winners and shorting expected losers. Although the findings of [7] contributed to identify relevant financial information regarding value investing, F-score model chose a simplified approach to transform relevant financial information into binary inputs in its regression model. The limitation of regression model is that all of the chosen variables should not have too close relationships, which might yield multi-collinearity. But in reality, financial variables in the original F-score model seem to have close relationships. For example, the change of a firm's margin might have influence on its return-on-asset (ROA). Also, the F-score approach also fails to integrate experts' knowledge for better modeling in a dynamic market.

Therefore, this research proposes an integrated fuzzy-MCDM method to extend the boundary of the original F-score model. Through literature review and re-examination of the F-score model, this research identified sub-factors of profitability, leverage/ liquidity, and operating efficiency. In addition, through a survey of experts and DEMATEL-ANP processing, this research determined the level of importance and weights of factors as well as their interdependence degree for stocks selection. For better understanding of how investment experts' consideration could be evaluated in the calculation process, the VIKOR technique was also conducted for further analysis. The rest of the research is organized as follows: in section 2, this research reviews the concept of value investing and F-score model. Also, analytical network process (ANP) and fuzzy set theory are introduced for model development. In section 3, an integrated fuzzy-DEMATEL-ANP framework is proposed for supporting banking stocks' selection. Section 4 provides an empirical example to rank 5 selected banking stocks and comparing their ex post performance with the output that our method suggests. Section 5 concludes this paper.

II. Literature Review

This section briefly reviews the concepts adopted by this research, such as the definition of value investing, fundamental analysis and the 3 evaluation dimensions that F-score model proposed.

A. Fundamental Analysis

Prior researches show that investors have chance to gain positive abnormal returns by trading on useful financial performance signals [8]. Those approaches assume that market is not always in equilibrium, and sometimes the market cannot fully process the implications of a firm's financial signals, it fails to reflect its fair price in a timely manner. This approach suggests investors to find undervalued stocks and hold those value stocks until prices come back to fair level [1]. Ou and Penman [9] used a model to capture future change in earnings by using a set of historical financial ratios. Lev and Thiagarajan [10] choose 12 financial signals for similar purpose. Others [11] add expectation of future B/M and ROE (return on equity) as explanatory variables for future stock returns. Thus, this research adds ROE as an important factor to replace the original Accrual variable. Through literature review of accounting-based investing and utilizing financial signals for trading purposes reveals the possibility of selecting stocks with strong financial prospects for better investment decisions. Although previous researches aim to reach this goal, the limitations of previous methods rule out the plausible interrelationships between variables, and might mislead to inappropriate modeling.

B. Value Investing Strategy

According to Fama and French [4], investment managers classify firms that have high ratios of book-to-market equity (B/M), earnings-to-price (E/P), or cash flow-to-price (C/P) as value stocks. This strategy was initiated by [1], they argued that out-of-favor stocks are sometimes under-priced in the market. Intelligent investors may make profit by identifying this kind of stocks. Even in recent study, Elze [12] still finds this strategy to be useful in the European market. In this research, it defines value stock to generic high book-to-market (B/M) stocks. Therefore, this research defines value investing as focusing on high B/M stocks, while investing decisions are driven by selecting stocks with strong financial prospects through fundamental analysis approach.

C. F-score Model and Evaluation Process

Prior researches show that investors have chance to gain positive abnormal returns by trading on useful financial performance signals [9],[10]. Those approaches assume that market is not always in equilibrium, and sometimes the market cannot fully process the implications of a firm's financial signals, fails to reflect its fair price in a timely manner. To extend previous research, Abarbanell and Bushee [13] show that an investment strategy based on the 12 financial signals can generate positive abnormal returns. Clubb and Naffi [11] added expectation of future B/M and ROE (return on equity) as explanatory variables for future stock returns. ROE should be an important factor to be considered. To keep the F-score model's essence in this study, we only added ROE factor in the original framework. By focusing on high B/M firms, the F-score model claims to distinguish a firm's overall performance by examining 3 different financial aspects.

The literature review of value investing reveals the possibility of selecting stocks with strong financial prospects for better investment decisions [14]-[16]. Although previous researches aim to reach this goal, the limitations of previous methods ruled out the plausible interrelationships between variables, and which might mislead to inappropriate modeling. With the aim to improve previous method, we extend the core of F-score model and modify accordingly in order to adapt it to the proposed model.

F-score model chose nine fundamental signals to measure three aspects of a firm's financial condition: profitability, financial leverage/ liquidity and operating efficiency. Current profitability and cash flow generation show how firms can generate funds internally. F-score used ROA and CFO to measure profitability performances. It defined CFO as cash flow from operations. Unlike traditional definitions of ROA and CFO, if a firm's ROA (CFO) is positive, the variables ROA (CFO) in regression model equals 1, zero otherwise. F-score also defined the variable "Accrual" as return on asset before cash flow from operation deducted extraordinary items. The application of Accrual was originated from [17], but not too much attention was paid in the field of accounting research. Thus in this research, ROE variable is used to replace Accrual. This research applies ANP and expert's questionnaire to further examine the validity of those 9 variables. Nine financial signals are designed to measure financial leverage, liquidity and source of funds.

III. Constructing The Hybrid Value Investing Model

This section adopts F-score model as the conceptual framework, and it shows various dimensions of the original model that can be reorganized to allow for interdependence among factors.

A. Influential dimensions and sub-factors for ANP

According to the design of original F-score model, to evaluate a firm's financial prospect can be divided into three dimensions: profitability, financial leverage/ liquidity, and operating efficiency. These three dimensions have their own 2~4 extended sub-factors. The overall structure is shown in Fig.1:

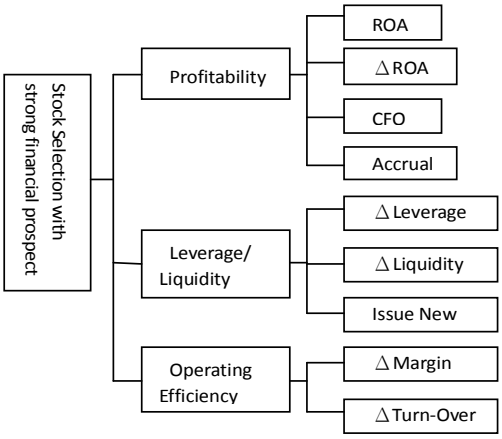

Figure 1. Hierarchical framework of original ANP structure

After the construction of conceptual model for analysis, this research adopts DEMATEL (Decision Making Trial and Evaluation Laboratory) method to analysis the degrees of influence of those criteria and illustrate the interrelations among criteria. It has been an applied method for various business decision makings, such as group decision making and management decisions [18]. The procedures of building an ANP model is described as below [19]-[20]:

Step1: Calculate the initial average matrix by scores. Respondents need to reply the degree of direct influence each dimension on each dimension, ranging from 0 (no influence) to 4 (very high influence), and get the average matrix A ($A=[a_{ij}]_{n\times n}$). In this paper, since there are 3 dimensions for fundamental analysis, n equals to 3.

Step2: Calculate the initial influence matrix. It can be obtained by normalizing the average matrix A to get X ($X=[x_{ij}]_{n\times n}$). Apply (1) & (2) to derive X.

$$s = \min\left[\frac{1}{\max\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{\max\sum_{i=1}^{n}|a_{ij}|}\right] \quad (1)$$

$$X = s \times A \quad (2)$$

Step3: Derive the total influence matrix T, where may be described as (3) & (4), while continuous decrease of indirect effects along the powers of x, e.g., x, x^2, x^3,…x^n.

$$T = X(I - X)^{-1} \quad (3)$$

when

$$\lim_{k\to\infty} x^k[0]_{n\times n} \quad (4)$$

Step4: Set a threshold value and obtain the NRM (network relationship map). Based on T, each factor t_{ij} of matrix T provide network information about how factor *j* affects factor *j*. After setting a discussed threshold to filter minor effects, it may reach the final NRM_f in the stage 1. In the stage 2, this research utilizes NRM to be integrated with ANP logics to build the overall priorities for ranking selected stocks. The procedures of building an ANP model from NRM is described as below:

Step5: Structuring a two layer networks of ANP as Fig. 1.

Step6: Collecting experts' questionnaires and calculating the scores by geometric average, and inputs the numbers to get pair-wise comparison matrices and priority vectors, and form an un-weighted super-matrix W. In a general form of super-matrix W, where C_n denote the *n*th cluster, e_{nm} denotes the *m*th criterion in the *n*th cluster (dimension), and w_{ij} is the principle eigenvector of the influence of the criteria in the *j*th cluster compared to the *j*th cluster.

Step7: Obtain the weighted supe-rmatrix(SM) by multiplying the normalized NRM_n matrix, which can be derived by transforming NRM_f, make its each column to sum to unity. To illustrate the final weighted super-matrix, (5) can be expressed as following:

$$\text{weightedSM} = \begin{bmatrix} t_{11}^f \times w_{11} & \cdots & t_{n1}^f \times w_{1n} \\ \vdots & \ddots & \vdots \\ t_{1n}^f \times w_{n1} & \cdots & t_{nn}^f \times w_{nn} \end{bmatrix} \quad (5)$$

where $NRM_f=[t_{ij}f]_{n\times n}$, and $W=[w_{ij}]_{n\times n}$ represents the un-weighted super-matrix.

Step8: Collecting each selected stock's pertaining ratios as a vector (since there are totally 8 criteria in our model, it should be a 1×8 vector) to multiple with the weighted super-matrix to get each stock's final scores.

In this research, DEMATEL is used to find the interrelationships among criteria to reflect more suitable super-matrix calculation in ANP [22]. Comparing with traditional F-score approach, this model allows interdependence among clusters, and it may take one step further to analysis the influence among clusters (dimensions), says "Profitability", "Leverage/ Liquidity" and "Operation Efficiency" in our conceptual framework. Investors can make future forecast toward each dimension/ criterion to adjust their evaluation, and find out the importance of influence among criteria more clearly.

The idea of the compromised ranking method (VIKOR) [23] was also included in our study to analyze the ranking result. We may assume the alternatives to be expressed as A_1, A_2, …, A_m. The strength of the *j*th criterion is expressed by f_{ij} for alternative A_i, and w_j is the weight of the *j*th criterion, which expresses the relative importance of the criteria, where *j*=1, 2,…, n. The compromise alternative will be chosen while the group utility and individual regret will be considered according to different settings. A VIKOR based modification for adjusting ANP's matrix can be obtained as bellow [24]:

Step9: Normalize the original rating matrix. At first, choose the best f_j^* and the worst f_j^- for all criterion, *j*=1, 2,…, n, where *j* represents the *j*th criteria. While the *j*th criteria represents a benefit, the best implies $f_j^*=\max f_{ij}$ and $f_j^-=\min f_{ij}$ respectively. An original rating matrix can be transformed into a normalized matrix by (6):

$$r_{ij} = \left(|f_j^* - f_{ij}|\right)/\left(|f_j^* - f_j^-|\right) \quad (6)$$

Step10: Compute the value S_i and R_i by the following (7) & (8):

$$s_i = \sum_{j=1}^{n} w_j r_{ij} \quad (7)$$

and

$$R_i = \max_j\{r_{ij} | j = 1,2,\dots,n\} \quad (8)$$

where S_i and R_i show the mean of group utility and maximal regret respectively.

Step11: Compute the index values Q_i, i=1, 2,…,m, by (9):

$$R_i = v * \frac{(S_i - S^*)}{(S^- - S^*)} + (1 - v) * \frac{(R_i - R^*)}{(R^- - R^*)} \quad (9)$$

Where $S^*=\min S_i$, $S^-=\max S_i$, $R^*=\min R_i$, $R^-=\max R_i$. In which, v is introduced as a weight for the strategy of maximum group utility, (1-v) is the weight of the individual regret.

Step12: Rank the alternatives, by sorting the values of S_i, R_i and Q_i for i=1,2,…,m, in decreasing order.

Step13: Propose as a compromise the alternative $A^{(1)}$ which is ranked first by the measure min{Q_i | i=1,2,…,m} if the following two conditions are satisfied:

C1: $Q(A^{(2)})-Q(A^{(1)}) \geqq 1/(m-1)$; C2: $A^{(1)}$ must be ranked as the best choice by S_i or/and R_i.

B. The Synthetic Value of Fuzzy Judgment

Fuzzy set theory provides effective descriptions for highly complex, ill-defined, or difficult-to-analyze mathematical systems [25]-[27]. It can mathematically express vagueness and subjective relationships [28]. In the past decades, fuzzy set theory has been widely used when imprecise data or linguistic variables exist [29],[30]. In this research, each criterion has to be reviewed and subjectively evaluated by individual experts. Five benchmark banking stocks have individual numerical outputs of each criterion and experts are requested to rank these firms based on their numerical outputs of each criterion. The numerical outputs as well as

the performance of the stocks are ranked in five levels, excellent, good, fair, bad, and poor. For example, ROAs of the five firms are -131%, 9%, 19%, -218%, and -23% respectively and the experts rank the ROAs as poor, good, excellent, poor, and bad respectively. Since the experts' evaluation would be a linguistic variable, fuzzy set theory is needed to deal with the problem encountered. Among various membership functions, the triangular fuzzy number is one of the most popular functions in the previous applications. Each triangular fuzzy number has linear representations on its left and right side such that its membership function can be defined as (10)

$$\mu(x/M) = \begin{cases} 0, \text{if } x < 1 \text{ or } x > u; \\ \frac{(x-l)}{(m-l)}, \text{if } l \le x \le m; \\ \frac{(u-x)}{(u-m)}, \text{if } m \le x \le u \end{cases} \quad (10)$$

where l and u represent the smallest and the largest possible values and m represent the most promising value that describe a fuzzy event.

Based on given financial numbers, experts are requested to answer the question: "How good does the firm perform based on the result of factor A?" And the answer is one of the linguistic variables given in Table Ⅰ. Triangular fuzzy scale is adopted to determine the fuzzy value of experts' judgments as shown in the following Table I.

TABLE I. LINGUISTIC VARIABLES TO MEASURE JUDGMENTS

	Linguistic variables for performance evaluation	Triangular fuzzy scale
1	Poor	(1, 1, 2)
2	Bad	(1, 2, 3)
3	Fair	(2, 3, 4)
4	Good	(3, 4, 5)
5	Excellent	(4, 5, 5)

Once experts have made their judgments on the financial performance of the benchmark firms, the fuzzy values are calculated. The degrees of possibility for each convex fuzzy number are determined.

For each criterion, every expert' evaluation is transformed into fuzzy numbers and the fuzzified numbers are then compiled into a sum. Finally, the sum is defuzzied and generates an output for ANP analysis.

C. Integrated Data Processing

Using integrated fuzzy evaluation to calculate the score of expert's questionnaire and multiply the weights of analytic network process (ANP) and then aggregate the scores of firm's financial performance. To calculate the priority of stock, we construct the formula as (11).

$$\text{SCORE}_{\text{stock}} = \sum_{i=1}^{9} w_i \times R_i \quad (11)$$

IV. EMPIRICAL EXAMPLE OF BANKING STOCKS

This research chooses nine fundamental signals to measure three aspects of a firm's financial condition, which uses integrated fuzzy evaluation to analyze the experts' questionnaires. After acquiring the average score of 9 financial signals, this research integrated the DEMATEL-ANP model with fuzzy performance calculation to have the final score of each firm. The detail procedures are illustrated in the following sections. Based on the aforementioned model, a set of high B/M banking stocks are selected for further analysis.

A. Building ANP structure and calculating weights

After collecting questionnaires from 10 experts in financial domain with more than 20 years experience in average, this research constructs the total influence matrix T of our application. By step 1 and 2, this research obtains the original average matrix A as Table II, and the initial influence matrix X in Table III.

TABLE II. THE ORIGINAL AVERAGE MATRIX A

	Cluster1	Cluster2	Cluster3
Cluster1	1	3.3	2.5
Cluster2	2.8	1	0.8
Cluster3	2.6	0.6	1

And the column-based normalization is conducted as Table III:

TABLE III. THE NORMALIZED TOTAL INFLUENCE MATRIX A

	Cluster1	Cluster2	Cluster3
Cluster1	0.3623	0.4428	0.4290
Cluster2	0.3330	0.2984	0.2914
Cluster3	0.3046	0.2588	0.2796

The result indicates that "Profit" dimension has the strongest influence over "Leverage/ Liquidity" dimension. Since all of the criteria hold significant importance, this numerical example doesn't conduct threshold–cut to eliminate minor effects. Through collecting experts' questionnaires, this research constructs the DEMATEL-ANP structure and gathers weights. Our interviewees have more than 20 years of working experiences related to investment, financial field, and more than half of the interviewees are responsible for investment decision making. The ranking & comparison of experts' perception of each criterion are listed as Table IV.

TABLE IV. LINGUISTIC VARIABLES TO MEASURE JUDGMENTS

Dimensions	Criteria	All Experts	
		Normalized Weight	*Ranking*
Profitability	ROA (P1)	0.2563	1
	ΔROA (P2)	0.0905	6
	CFO (P3)	0.1156	4
	ROE (P4)	0.2010	2
Leverage/ Liquidity	ΔLeverage (L1)	0.0804	7
	ΔLiquidity (L2)	0.0251	8
	Issue New (L3)	0.0101	9
Operating Efficiency	ΔMargin (O1)	0.1256	3
	ΔTurn-over (O2)	0.0955	5

B. Fuzzy Calculation for 5 Selected Banking Stocks

This research restricts analysis to banking stocks which categorized as value stock and has high book-to-market ratio (B/ M). By acquiring the 2008 annual financial data from TEJ (Taiwan Economic Journal Co., Ltd) database, this research selected the B/M ratio of Taiwan's banking firms around Mar_2009, and chose top 20% B/M banking stocks as value stocks. Then, this research further selected five firms among

the top 20% of the banking stocks. This research provides the numbers of nine financial signals in our questionnaire and requests experts to judge the performance from poor to excellent. Fuzzy logic was applied to transform the experts' judgments into calculative numbers for DEMATEL- ANP analysis.

The experts give the weights of nine financial signals based on five points Likert-scale and calculate the weights by applying integrated fuzzy evaluation. The score of each firm is ranked as table Ⅴ.

C. Forming Synthesized Ratings

The integrated data processing to form synthesized rating is based on the ANP method and integrated fuzzy evaluation as Table V:

TABLE V. SYNTHESIZED FINAL SCORES OF SELECTED COMPANIES

	ANP	A	B	C	D	E
ROA	0.2563	1.19	4.00	4.86	1.09	2.10
ΔROA	0.0905	1.19	2.10	3.98	4.20	1.71
CFO	0.1156	1.68	2.67	1.30	4.44	1.77
ROE	0.2010	1.54	3.34	3.77	1.19	2.45
ΔLeverage	0.0804	2.96	2.54	3.06	2.85	2.67
ΔLiquidity	0.0251	1.86	2.03	2.96	3.43	2.77
Issue New	0.0101	3.46	3.31	3.31	2.63	3.11
ΔMargin	0.1256	1.19	2.36	2.03	4.60	4.23
ΔTurn-over	0.0959	3.11	3.11	3.11	3.11	2.21
Scores	1	1.682	3.077	3.419	2.628	2.448

D. Discussion

To test the proposed model, this research collects real adjusted HPRs (holding period return) from April_2009 to Jan_2010 for the 5 banking stocks (from TEJ), and make comparison with the outcome generated from our method. Statistical Pearson correlation analysis was conducted to examine the relationship between the synthesized rating scores and HPRs. To test the robustness of the method, this research also conducts correlation analysis until Feb_2010 & Mar_2010, the result is illustrated as Table VI：

TABLE VI. MULTI-PERIOD'S CORRELATION RESULT

	04/09'~01/10'	04/09'~02/10'	04/09'~03/10'
Correlation	75.63%	78.38%	88.41%

The result indicates the correlation between HRP from April_2009 to Jan_2010 and the synthesized rating is about +75.63%. The correlation between HRP from period April_2009 to Feb_2010 and the synthesized rating is about 78.38%. The correlation result goes up to 88.41% after one month. The result shows that the proposed model can be applied to value investing in real practice.

Then, by following the step9-12, we used the VIKOR method to obtain the ranking index S_i, R_i and Q_i of the alternatives as in the TableⅦ. In this empirical example, we set v=0.3, which means that the group utility is less important than individual regret.

TABLE VII. MULTI-PERIOD'S CORRELATION RESULTS BY VIKOR

	A	B	C	D	E
S_i	1.281	1.852	2.003	1.952	1.585
v=1(ranking)	(1)	(3)	(5)	(4)	(2)
R_i	3.460	3.340	4.860	4.600	4.230
v=0(ranking)	(2)	(1)	(5)	(4)	(3)
Q_i	2.370	2.596	3.432	3.276	2.908
v=0.5(ranking)	(1)	(2)	(5)	(4)	(3)
Q_i	2.806	2.894	4.003	3.805	3.437
v=0.3(ranking)	(1)	(2)	(5)	(4)	(3)

TABLE VIII. 1 YEAR CORRELATION RESULT BY VIKOR

Indexs	A	B	C	D	E	Correlation by 1 year
S_i	1.281	1.852	2.003	1.952	1.585	68.94%
R_i	3.460	3.340	4.860	4.600	4.230	86.33%
Q_i(v=0.5)	2.370	2.596	3.432	3.276	2.908	88.74%
Q_i(v=0.3)	2.806	2.894	4.003	3.805	3.437	88.34%

TableⅦ presents the calculated S_i, R_i and Q_i indexes by the VIKOR technique. The four indexes' ranking sequences all indicated that stock A is the best choice except R_i, which corroborated the consistency of the VIKOR technique. The result shows that maximum group utility strategy (by S_i) generated the best result after 1 year. The correlation between the ranking of sample stocks and the index Q_i (v=0.5) reached up to 88.74% after 1 year as shown in TableⅧ. If we consider more minimum individual regret (Q_i, v=0.3), the correlation went down slightly to 88.34% in this example.

V. CONCLUSION

The world's financial markets have experienced financial turmoil during 2008. Most of the banking stocks dropped dramatically and yielded attractive buying price for banking stocks. It's critical to have a reliable value investing method to find out promising banking stocks during this period. Value investing heavily relies on analyzing historical financial information. But in practice, investment decision makers also need their extensive knowledge and experience to utilize relevant financial information. How to process and retrieve investment experts' knowledge becomes an important issue while building a system to support value investing. To retrieve investment experts' knowledge, this research proposes an integrated model to capture the implicit decision rules of experts when processing relevant financial information. The proposed DEMATEL-ANP model allows for interdependence among variables, improves the limitations of traditional ANP method by adding DEMATEL calculation [22]. It also extends the boundary of previous value investing model, namely the F-score model. Compared with the original F-score model, the interesting finding shows that ROE variable plays important role while applying this model to the stock market in Taiwan.

The synthesized rating scores of the 5 selected banking stocks are based on the DEMATEL-ANP method and integrated fuzzy evaluation. This study aims to select stocks with good financial prospects; hence, it conducts Pearson correlation analysis between the synthesized rating scores and the 5 stocks' HPRs. The correlation between synthesized rating scores and HPRs can reach +88.41%, which shows the validity of our proposed method. The combined VIKOR technique helps to integrate group utility and individual regret for analyzing the ranking's performance.

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