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Research Article

Entropy Weight TOPSIS Evaluation of Corporate Internal Control Quality Based on Fuzzy Matter-Element Model

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One of the core objectives of domestic and foreign regulation policies is to strengthen internal control and improve corporate risk management ability. To evaluate corporate internal control quality (CICQ), this paper constructs a composite fuzzy matter-element model based on the fuzzy matter-element theory and the data on 781 listed enterprises in China. By the entropy weight method, five evaluation indices of internal control were weighed and compared with the positive and negative ideal indices. Next, the internal control of the listed enterprises was measured by TOPSIS. The results show that the indices of laws and regulations (LR), financial statements (FS), assets safety (AS), operation (OP), and strategy (ST) are of different weights in terms of CICQ evaluation. The LR, OP, and ST indices are more important than the FS indices. Among the secondary indices, the most important indices, namely, major litigation and arbitration cases, turnover of total assets, and Tobin's Q account for 66% of total weights. In addition, the CICQ varies with industries: the top-10 enterprises in terms of CICQ mostly belong to industries with strict requirements on work safety. The research findings lay a methodological and practical basis for the CICQ evaluation of Chinese enterprises.

1. Introduction

Since the enactment of Sarbanes–Oxley (SOX) Act in 2002, corporate internal control quality (CICQ) has raised worldwide concern among practitioners and researchers [1, 2]. The Chinese government released the *Basic Standard for Corporate Internal Control* in 2008 and issued the *Supporting Guidelines for Corporate Internal Control* two years later. In addition to dividing internal control into five interrelated elements: internal environment, risk assessment, control activities, information and communication, and internal supervision, the above-mentioned documents also require enterprises to formulate specific internal control evaluation methods and carry out internal control evaluation work in an orderly manner. The corporate internal control is no easy task, for the internal structure of an enterprise involves a dazzlingly array of operational and management factors [3, 4]. The fat finger trading incident that broke out at Everbright Securities in 2013 aroused heated discussions quickly. China Securities Regulatory Commission (CSRC) punished Everbright Securities for insider trading, including the confiscation of all their illegal income, and a fine of more than 5 times the illegal income. The fat finger trading incident not only brought huge economic losses and serious negative impacts to Everbright Securities, it also reflected the serious problems existing in the internal control quality of Chinese companies. After the 2013 Everbright fat finger trading incident, many Chinese scholars turned their attention to CICQ.

Precise evaluation is the premise to CICQ improvement. How to evaluate CICQ precisely, the existing research has achieved certain results. For example, Han and Wang [5] evaluated CICQ comprehensively through analytic hierarchy process (AHP). Li and Dai [6] established evaluation systems for corporate internal control environment, using the Delphi method. However, neither AHP nor the Delphi method is objective and scientific enough to derive a standard judgement matrix. To overcome the defect, some researchers introduced fuzzy comprehensive evaluation (FCE) to the CICQ analysis. For instance, Zhu et al. [7] combined FCE with a backpropagation (BP) neural network to evaluate the design of corporate control activities, operational risks, and safety level. Yang [8] employed FCE to evaluate the internal control of a construction material producer. However, when FCE finally determines the results, the principle of maximum membership degree is usually adopted. The principle overemphasizes the extreme value and fails to make full use of the vector obtained by FCE, resulting in the loss of data information. There may even be unfair evaluation results. This motivates researchers to evaluate CICQ by the fuzzy matter-element model. With explicit concept and simple operation, the fuzzy matter-element model greatly promotes the evaluation of CICQ [9].

To sum up, the evaluation system of CICQ has been gradually perfected, and insights have been provided for CICQ improvement. Nevertheless, the existing studies face several disadvantages: the approach is too subjective, the indices are not diverse, and the index attributes/positions are often not considered. To address these disadvantages, this paper resorts to three cutting-edge technologies: fuzzy matter-element model, which solves the incompatibility of multiple indices; TOPSIS, which easily compares objects both horizontally and vertically; entropy weight method, which assigns an objective and real weight to each index according to the original data. Based on the fuzzy matter-element model, this paper constructs an entropy-weight TOPSIS evaluation system for CICQ and systematically analyzes the CICQ of 781 listed enterprises in China. The research results shed new lights on CICQ evaluation.

2. Materials and Methods

2.1. Design Principles of Evaluation System. The CICQ evaluation indices must be comprehensive, systematic, objective, applicable, and valid [10]. According to the comprehensive and systematic principle, the CICQ evaluation system should cover the contents of business activities, as well as all design factors of internal control, such as to reflect internal control comprehensively and systematically. According to the objective and applicable principle, the evaluation system should take account of the actual situation and operating condition of each enterprise. According to the principle of validity, the evaluation system should manifest the relationship between internal control and corporate management and pinpoint the weak links of internal control.

2.2. Index Selection. Following the above design principles, the provisions of Chinese regulations, and the ideas of Hwang et al. [11], this paper establishes an evaluation system for CICQ from the perspectives of laws and regulations (LRs), financial statements (FSs), assets safety (AS), operation (OP), and strategy (ST).

2.2.1. Laws and Regulations. The LR, essential to the survival of an enterprise, is the fundamental indicator of internal control. The sustainable development of an enterprise hinges on the observation of the laws, regulations, and policies of the host country, as well as the criteria of the market and the industry. Any violation of the LR will be penalized. Hence, two secondary indices were designed for LR: penalty for LR violation and major litigation and arbitration cases.

2.2.2. Financial Statements. The FS, another fundamental indicator of internal control, provides an effective channel for stakeholders to understand the business condition of an enterprise. In this paper, FS is measured by audit opinion of FS.

2.2.3. Assets Safety. The AS, a basic indicator of internal control, reflects the asset risks of an enterprise, and the executives' demand for the enterprise. This paper chooses asset-liability ratio, assets impairment loss ratio, and non-business expenditure to measure AS.

2.2.4. Operation. The OP, the core indicator of internal control, manifests the goal of production and business activities. Hence, this indicator was measured by operating profit margin, net return on equity, and turnover of total assets.

2.2.5. Strategy. The ST, a prospective indicator of internal control, reveals the overall operation and development direction of an enterprise. Here, ST was measured by Tobin's Q, growth rate of total assets, and rate of net return on total assets.

Through the above analysis, an CICQ evaluation system was established, involving 12 secondary indices and 5 primary indices. The details of the system are listed in Table 1.

2.3. Sampling and Data Sources. To measure CICQ in China comprehensively, this paper selects the CICQ data on 1,700 A-share listed enterprises in 2018, after fully considering data availability and sample representativeness. The enterprises receiving special treatment (ST) or with incomplete data were removed from the sample set. To evade the influence generated by the extreme values of samples on the results, double-sided 1% Winsorization processing was performed for all continuous variables. The remaining data involve 781 listed enterprises. The original data were acquired from China Stock Market & Accounting Research Database (CSMAR) and the 2018 financial statements of these enterprises.

2.4. Features of Fuzzy Matter-Element Model and Entropy-Weight TOPSIS Method. The CICQ system is a complex internal management system of enterprises. The various indices involved in the CICQ evaluation are very likely to be incompatible with each other. The fuzzy matter-element model can make systematic evaluation with multiple indices and solve complex incompatible problems.

As an objective weighting approach, the entropy weight method is widely adopted in management science to weigh different indices based on their variability. This method treats entropy as a measure of information uncertainty, which is negatively correlated with the information size of

Table 1: CICQ evaluation system.

Index	Primary index	Secondary index	Code	Definition
CICQ	LR	Penalty for LR violation	X1	1, if an enterprise is penalized for violating LR; 0, otherwise
		Major litigation and arbitration cases	X2	1, if an enterprise has major litigation and arbitration cases; 0, otherwise
	FS	Audit opinion of FS	X3	1, if an enterprise faces standard unqualified opinion; 0, otherwise
	AS	Asset-liability ratio	X4	Ratio of total liabilities to total assets
		Assets impairment loss ratio	X5	Ratio of the asset impairment loss to operating income
		Nonbusiness expenditure	X6	Various nonoperating expenses
	OP	Operating profit margin	X7	Ratio of operating profit to operating income
		Net return on equity	X8	Ratio of net profit to net assets
		Turnover of total assets	X9	Ratio of the sales revenue to average asset balance
	ST	Tobin's Q	X10	Ratio of market value to replacement value
		Growth rate of total assets	X11	Ratio of growth of total assets to total assets
		Rate of net return on total assets	X12	Ratio of net profit to average total assets

the sample. Highly uncertain information contributes little to the comprehensive evaluation. The inverse is also true.

Proposed by Hwang and Yoon [12], the TOPSIS is a multiobjective decision method capable of multi-index evaluation. The main ideas of TOPSIS are as follows: firstly, the positive and negative ideal solutions are constructed. Then, the closeness of each object to the two solutions is computed. After that, the multiple objects are ranked in descending order of the closeness. TOPSIS can produce very reasonable results on a small sample size.

Entropy-weight TOPSIS combines the merits of both entropy weight method and TOPSIS. This composite approach can overcome the disadvantages of traditional evaluation methods and effectively quantify multiple objects.

2.5. Flow of Entropy-Weight TOPSIS Method Based on Fuzzy Matter-Element Model. Firstly, a composite fuzzy matter-element model is constructed. Secondly, the evaluation indices are weighed by the entropy weight method and used to set up a weighted normalization matrix. Finally, TOPSIS was applied to sort the samples by CICQ. The flow of our approach is summarized as follows.

Step 1. Establish a composite fuzzy matter-element model.

A is the fuzzy matter element, C is the thing, M is the characteristic of the thing, X is the magnitude, and then the fuzzy matter element $A = (\mathrm{C, M, X})$.

$$A_{mn} = \begin{bmatrix} & C_1 & C_2 & \cdots & C_n \\ M_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ M_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ M_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}, \tag{1}$$

where M is the first to m-th enterprises; C is the first to n-th CICQ indices; x_{mn} is the original data of the n-th index of the m-th enterprise.

Step 2. Normalize the composite fuzzy matter-element model to obtain a normalized matrix R.

The different dimensions and units hinder the comparison between indices. Hence, all indices are normalized. The indices positively correlated with CICQ (positive indices) and those negatively correlated with CICQ (negative indies) are normalized by different formulas.

Positive indices

$$x^*_{mn} = \frac{x_{mn} - \min(x_{mn})}{\max(x_{mn}) - \min(x_{mn})}. \tag{2}$$

Negative indices

$$x^*_{mn} = \frac{\max(x_{mn}) - x_{mn}}{\max(x_{mn}) - \min(x_{mn})}. \tag{3}$$

Then, the normalized data are summarized to obtain the normalized fuzzy matter-element matrix R.

$$R = \begin{bmatrix} x^*_{11} & x^*_{12} & \cdots & x^*_{1n} \\ x^*_{21} & x^*_{22} & \cdots & x^*_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x^*_{m1} & x^*_{m2} & \cdots & x^*_{mn} \end{bmatrix}, \tag{4}$$

where R is the normalized evaluation matrix; x_{ij} and x^*_{mn} are the initial and normalized values of the n-th index of the m-th enterprise, respectively.

Step 3. Determine the entropy value of each index.

Firstly, the weight f_{mn} of x_{mn} is calculated by the following equation:

$$f_{mn} = \frac{x_{mn}}{\sum_{m=1}^{i} x_{mn}}. \tag{5}$$

Then, the entropy e_n of n indices is calculated by the following equation:

$$e_n = -\frac{1}{\ln n}\left(\sum_{n=1}^{j} f_{mn} \ln f_{mn}\right). \tag{6}$$

Step 4. Weigh each index.

The weight w_n of each index is calculated by the following equation:

$$w_n = \frac{1 - e_n}{n - \sum_{n=1}^{j} e_n}. \tag{7}$$

Step 5. Establish the optimal fuzzy membership matrix.

In matrix R, the data on characteristic C can be divided into two types: the-bigger-the-better index, and the-smaller-the-better index. For the first type, CICQ increases with the numerical value of indices; for the second type, CICQ decreases with the numerical value of indices. The optimal fuzzy membership T of the-bigger-the-better index and the-smaller-the-better index can be, respectively, calculated by the following equation:

$$\begin{aligned} \theta(x_{mn}) &= \frac{x_{mn} - \min(x_{mn})}{\max(x_{mn}) - \min(x_{mn})}, \\ \theta(x_{mn}) &= \frac{\max(x_{mn}) - x_{mn}}{\max(x_{mn}) - \min(x_{mn})}, \end{aligned} \tag{8}$$

where $\theta(x_{mn})$ is the optimal fuzzy membership of the n-th eigenvalue of the m-th object; $\max(x_{mn})$ and $\min(x_{mn})$ are the maximum and minimum eigenvalues of the characteristic index, respectively.

Step 6. Establish the weighted optimal fuzzy matter-element membership matrix, and positive and negative ideal solutions.

The weight w_n is multiplied with R to obtain the weighted optimal membership matrix Y.

$$Y = Wn \times R. \tag{9}$$

Furthermore, the positive and negative ideal solutions (Y^+ and Y^-) in Y are determined. Specifically, Y^+ is the maximum of the n-th index of the m-th enterprise in the evaluation data. It is the most preferred scheme and thus called the positive ideal solution. Y^- is the minimum of the n-th index of the m-th enterprise in the evaluation data. It is the least preferred scheme and thus called the negative ideal solution. The two solutions can be, respectively, calculated by the following equation:

$$\begin{aligned} Y^+ &= \{\max_{1\le m\le i} y_{mn} | m = 1, 2, \ldots, i\} = \{y_1^+, y_2^+, \ldots, y_i^+\}, \\ Y^- &= \{\min_{1\le m\le i} y_{mn} | m = 1, 2, \ldots, i\} = \{y_1^-, y_2^-, \ldots, y_i^-\}. \end{aligned} \tag{10}$$

Step 7. Calculate the Euclidean distance.

Out of the various distance metrics, this paper chooses the Euclidean distance [10]. The distance S_n^+ between the m-th index and y_m^+, and that S_n^- between that index and y_m^- can be, respectively, calculated by the following equation:

$$\begin{aligned} S_n^+ &= \sqrt{\sum_{m=1}^{i} (y_m^+ - y_{mn})^2}, \\ S_n^- &= \sqrt{\sum_{m=1}^{i} (y_m^- - y_{mn})^2}, \end{aligned} \tag{11}$$

where y_{mn} is the normalized weighted value of the n-th index of the m-th enterprise; y_m^+ and $y_m^- y_i^-$ are the values of the most and least preferred schemes in the m-th index.

Step 8. Compute the closeness between each object and the ideal solutions.

Let $Z_m \in [0, 1]$ be the closeness of the m-th CICQ to the optimal quality. The greater the closeness, the nearer the CICQ is to the optimal quality. The CICQ reaches the maximum at $Z_m = 1$ and reaches the minimum at $Z_m = 0$. Here, the closeness represents the level of CICQ. The Z_m value can be calculated by the following equation:

$$Z_m = \frac{S_n^+}{S_n^+ + S_n^-}. \tag{12}$$

3. Results and Discussion

3.1. Index Weighting. Based on the proposed CICQ evaluation system, the weights of primary and secondary indices were determined by the entropy weight method and fuzzy matter-element model. The results in Table 2 show that LR (0.359871), OP (0.2510953), and ST (0.2163799) had relatively high weights among the five primary indices. Among them, LR accounts for 35.98% of total weights, indicating that this fundamental index directly manifests CICQ. OP accounts for 25.1% of total weights, suggesting that this core index mirrors the realization of business goals of enterprises. ST accounts for 21.64% of total weights, which implies that the index reflects the development direction of the enterprises and the sustainability of CICQ. The weights of these three primary indices are basically in line with the actual situation of enterprises and consistent with the conclusions of relevant studies.

In addition, the AS, accounting for 16.08% of total weights, has an important impact on CICQ. This index reflects the asset management quality in enterprise internal control. The growing asset risks can obviously suppress the overall operational safety. The FS accounts for 1.18% of total weight. The five primary indices interact and complement each other. Each of them not only affects the corporate internal control but also work with other primary indices to enhance the CICQ.

When it comes to secondary indices, the top three indices were major litigation and arbitration cases (X2) (0.2999216), turnover of total assets (X9) (0.2122838), and Tobin's Q (X10) (0.1518735). Together, the three secondary indices account for 66% of total weights and correspond to LR, OP, and ST, respectively. Considering the weight distribution, enterprises should enhance CICQ by observing

Table 2: Weights of CICQ evaluation indices.

Primary index	Secondary index	Nature	Entropy value	Weight	
LR	X1	Positive	0.9952843	0.0598953	0.359817
	X2	Positive	0.9763863	0.2999216	
FS	X3	Positive	0.9990674	0.011845	0.011845
	X4	Negative	0.9913721	0.1095845	
AS	X5	Negative	0.9991669	0.010581	0.1608628
	X6	Positive	0.9967958	0.0406973	
	X7	Positive	0.9976097	0.0303596	
OP	X8	Positive	0.9993346	0.0084519	0.2510953
	X9	Positive	0.9832863	0.2122838	
	X10	Positive	0.9880426	0.1518735	
ST	X11	Positive	0.9971212	0.0365638	0.2163799
	X12	Positive	0.9978	0.0279426	

Table 3: Top-10 enterprises in terms of CICQ.

Enterprise	Industry	S_j^+	S_j^-	Z_i
PetroChina	Oil and gas extraction	0.053538	0.046886	0.466877
Sichuan Tianyi	Chemical raw materials and chemical products manufacturing	0.061604	0.037512	0.378465
Hengrui Medicine	Pharmaceutical manufacturing	0.063343	0.033469	0.345708
Zhangzhou Pien Tze Huang	Pharmaceutical manufacturing	0.063929	0.030489	0.322911
Grinm Advanced Materials	Nonferrous metal smelting and rolling processing	0.0662	0.025111	0.275001
Kweichow Moutai	Liquor, beverage, and refined tea manufacturing	0.064633	0.02352	0.266809
Hundsun Technologies	Software and information technology service	0.064672	0.022155	0.255167
Chongqing Brewery	Liquor, beverage, and refined tea manufacturing	0.064414	0.02146	0.249898
M&G	Cultural, educational, industrial, sports, and entertainment products manufacturing	0.065066	0.020979	0.243815
Haili Biology	Pharmaceutical manufacturing	0.065626	0.020181	0.235189

laws and regulations, meeting the regulatory requirements on information supply and disclosure, improving the effectiveness of business activities, and formulating appropriate development strategies.

3.2. TOPSIS-Based CICQ Evaluation. After computing the weights of CICQ indices for Chinese listed enterprises, the authors quantized the CICQ of 781 samples and sorted their quality levels through TOPSIS. Firstly, the CICQ evaluation matrix was established by formula (9). Secondly, the maximums and minimums of all indices for the 781 samples were solved and taken as positive and negative ideal solutions. Thirdly, the distances (S_n^+ and s_j^-) from every sample to the positive and negative ideal solutions were estimated by the formula of Euclidean distance. Fourthly, the closeness (Z_m) of each sample to the optimal CICQ was computed and used to evaluate the CICQ of that sample. For the lack of space, only the top-10 enterprises in terms of CICQ are displayed (Table 3).

As shown in Table 3, the top-10 A-share listed enterprises in terms of CICQ are PetroChina, Sichuan Tianyi, Hengrui Medicine, Zhangzhou Pien Tze Huang, Grinm Advanced Materials, Kweichow Moutai, Hundsun Technologies, Chongqing Brewery, Morning Glory, and Haili Biology. These high-CICQ enterprises belong to industries with the strictest requirements on work safety, namely, mining, chemical engineering, medicine, etc.

In addition, two top-10 enterprises were found in the burgeoning industries of information technology and education, namely, Hundsun Technologies and M&G. This means enterprises in China's emerging industries can enhance their overall competitiveness by increasing CICQ.

PetroChina stands out clearly from the top-ranking enterprises. The CICQ gap from the 5^{th} to the 10^{th} enterprises is not very large. It can be seen that PetroChina has achieved world-class CICQ, and Chinese enterprises with high CICQ develop collaboratively.

Our ranking differs from the China Top 500 ranking. In the latter ranking, the top-10 Chinese enterprises in terms of CICQ include Sinopec, CNPC, CSCEC, Ping'an Insurance, SAIC Motor, China Mobile, ICBC, China Railway, CRCC, and China Life Insurance. The difference can be interpreted in two aspects: firstly, the two rankings focus on different attributes. Our ranking mainly considers the construction of CICQ, while the other ranking highlights the comprehensive strength. Secondly, some listed enterprises with high comprehensive strength still have a large space to improve CICQ.

3.3. TOPSIS-Based Industry Analysis of CICQ. The 781 samples were further divided into 14 industries. Those belong to the accommodation and catering industry and those

Table 4: Index weights and rankings of various industries.

Industry	Sample size	Mean	Standard deviation	Ranking
Real estate	11	0.118326	0.155665	1
Manufacturing	466	0.094434	0.028061	2
Agriculture, forestry, animal husbandry, and fishery	7	0.091194	0.024031	3
Wholesale and retail	49	0.089743	0.034077	4
Transportation, warehousing, and postal service	41	0.086753	0.048317	5
Water conservancy, environment, and public facilities management	10	0.084431	0.00718	6
Mining	30	0.080756	0.041164	7
Information transmission, software, and information technology service	83	0.077015	0.019875	8
Culture, sports, and entertainment	11	0.075936	0.014403	9
Resident services, repairs, and other services	8	0.073355	0.01713	10
Electricity, heat, gas, and water production and supply	36	0.069791	0.01339	11
Construction	24	0.068326	0.013761	12
Miscellaneous	4	0.06714	0.012981	13

with missing or abnormal data were eliminated. Then, the remaining 13 industries was processed by TOPSIS to obtain their distributions and rankings (Table 4).

As shown in Table 4, the different industries varied in terms of CICQ. The leading industries include real estate, manufacturing, agriculture, forestry, animal husbandry, and fishery, wholesale and retail, as well as transportation, warehousing, and postal service. Specifically, real estate had the highest CICQ, but the standard deviation was far greater than that of any other industry. Despite the high overall CICQ in the industry, real estate enterprises differ significantly in the construction of internal control. This reveals the great gap between these enterprises in CICQ management.

Resident services, repairs, and other services, electricity, heat, gas, and water production and supply, construction, and miscellaneous occupied the bottom positions in the ranking, a sign of the poor CICQ of these industries. However, the small standard deviations show that these industries are highly stable and not competitive. The smallest standard deviation was achieved by electricity, heat, gas, and water production and supply, indicating that the industry is highly monopolized.

4. Conclusions

Based on the fuzzy matter-element model, this paper sorts out the CICQ data on 781 A-share listed enterprises in China and establishes a CICQ evaluation system by the entropy-weight TOPSIS method, giving full consideration of Chinese policies on internal control, and the features of China's capital market and listed enterprises. The evaluation system makes full use of the information in the original data and determines weights objectively, providing an effective way to evaluate multiattribute factors comprehensively. The results show that CICQ evaluation is significantly affected by LR, OP, and ST. Specifically, major litigation and arbitration cases, turnover of total assets, and Tobin's Q account for 66% of total weights. The top-10 enterprises in terms of CICQ mostly belong to industries with strict requirements on work safety. Emerging industries also began to pay attention to the construction of CICQ. In view of industries, real estate achieved the highest overall CICQ, but had a high CICQ difference among its enterprises. The research results provide theoretical insights into reasonable measurement of the validity of internal control modes.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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