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Construction and Application of Comprehensive Evaluation Model for Corporate Profit Quality: Data from Chinese Listed Companies

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***Abstract*:**
The high quality of enterprise profits is crucial for the high-quality development of the economy. This paper proposes a comprehensive evaluation model for corporate profit quality based on the Decision Making Trial and Evaluation Laboratory based Analytic Network Process (DANP) technique and variable weights theory. The model is applied to Chinese listed companies, analyzing their profit quality from 2018 to 2022. The results indicate that the growth rate of profit quality declined in 2019-2020, and profit quality has been consistently decreasing since 2020. Upon further analysis of specific dimensions, it is observed that the profit structure and stability of listed companies have shown a continuous decline after 2019, with other dimensions also displaying unfavorable trends accompanied by significant fluctuations. Furthermore, an industry-specific analysis reveals that although the overall profit quality of Chinese listed companies has been declining since 2020, the profit quality of the scientific research and technical services industry has remained relatively high. This can be attributed to the impact of the COVID-19 pandemic, which resulted in poor and unstable profits for the core businesses of listed companies, leading to a weakened profit structure and stability, and an overall decrease in profit quality. During the pandemic, there was an increased demand for scientific research and technology, which drove the development of the scientific research and technical services industry and contributed to its higher profit quality.

Keywords: *Profit quality, Comprehensive evaluation model, Variable weights theory, DANP*

1. Introduction

As a significant economic entity, the high-quality profits of enterprises play a vital role in promoting high-quality economic development. However, existing literature primarily concentrates on studying financial performance, which only reflects the quantity of corporate profits but fails to capture the quality aspect. Financial performance alone cannot provide insights into the health and sustainability of an enterprise's development. Moreover, with the rise of prominent issues like financial fraud and manipulation of financial statements in listed companies, such as the Lucky Coffee incident, the importance of profit quality has gained widespread attention from both academia and industry. This has led to a growing recognition of the need to assess and understand the quality of profits to ensure the transparency and reliability of financial information.

Profit quality reveals a company's genuine profitability, providing a comprehensive reflection of its fundamental ability to generate profits over a specific period and offering insights into the company's true financial health (Li, Wen, and Jiao, 2019). Thus, this paper aims to delve into the comprehensive evaluation of corporate profit quality, with the objective of contributing to the promotion of high-quality economic development. Additionally, it seeks to provide a theoretical basis and practical guidance for enterprises to conduct scientific and rational evaluations of their profits.

In existing research, there is no consensus on the concept of profit quality. Scholars have defined profit quality from various perspectives, including performance correlation, information transmission, authenticity, profit composition, cash flow, predictability, value reflection, sustainability, and stability. From the perspective of performance correlation, profit quality refers to the degree of correlation between reported profits in a given period and the future performance of a company. A higher correlation indicates that current profits better reflect future performance, thus indicating higher profit quality. From the perspective of information transmission, profit quality refers to the extent to which a company's book accounting profits convey potential internal information. Profit quality, from the perspective of profit composition, reflects whether a company's profit composition is reasonable, whether it can generate profits after taxes, and the degree of correlation between its profits and its own performance. From the perspective of cash flow, profit quality refers to the degree of synchronization between recognized profits and cash flows in a company. Higher correlation between profits and cash flows indicates better profit quality. Dewi, Djaddang, and Supriyadi (2021) argued that profit quality reflects a company's true profit-generating ability and can be measured by the correlation between accounting profits and cash flows. Higher correlation signifies better profit quality. Chu and Wang (2000) posited that the quality of profits should be closely related to the inflow of cash in a company. If profits are accompanied by corresponding cash inflows, it indicates higher profit quality, while the absence of cash inflow suggests lower profit quality. From the perspective of cash flow and sustainability, profit quality encompasses an enterprise's current profitability, cash generation situation, and growth potential of profits. Hakim and Naelufar (2020) analyzed profit quality based on profit growth, profitability, capital structure, liquidity, and company size. From the perspective of cash flow and stability, Zhou (2004) noted that in the short term, profit quality refers to the ability to achieve book accounting profits based on the accrual basis. In the long term, profit quality refers to the stability of continuous profit generation by an enterprise. From the perspectives of predictability and value reflection, profit quality should reveal the operational status of the enterprise, its true intrinsic value, and the ability to predict future profits.

Based on the analysis provided, it appears that existing literature only offers partial insights into the concept of profit quality and lacks comprehensiveness. However, Li, Wen, and Jiao (2019) have presented a comprehensive definition of profit quality. They define it as the analysis of the essence of profits, which reveals an enterprise's fundamental ability to consistently generate profits over a specific period. Their definition encompasses five dimensions: profit level, profit structure, cash generation ability, profit stability, and profit sustainability. Given the comprehensive nature of this definition, this paper adopts it as the basis for defining profit quality.

Existing scholars have conducted analyses on various factors that influence profit quality from multiple perspectives. These include corporate governance, environmental, social, and governance (ESG) factors, risk management, energy supply, digitalization of the economy, working capital management, liquidity, and growth. From the perspective of corporate governance, Almashhadani and Almashhadani (2022) conducted a review on the impact of ownership on profitability, focusing on the agency theory. Almashhadani (2021) examined the implications of corporate governance structure on corporate profitability in both industrialized and emerging economies, also utilizing an agency theory standpoint. Furthermore, Alabdullah, Ahmed, and Ahmed (2021) discovered that the size of the board of directors significantly influences the profitability of nonfinancial companies in Jordan, while organization size has an insignificant impact on organizational profitability. From an ESG perspective, Aydoğmuş, Gülay, and Ergun (2022) observed that the combined score of ESG factors, as well as individual Environment, Social, and Governance scores, exhibit positive and significant relationships with firm profitability. Regarding risk management, Alabdullah (2022) found a significant relationship between the risk management committee and return on equity (ROE). Additionally, in a study by Alabdullah, Ahmed, Almashhadani, Yousif, Almashhadani, Almashhadani, and Putri (2021), it was found that the size of the board of directors has a negative impact on profitability, whereas risk management was found to have no impact on profitability. From the perspective of energy supply, Xu, Akhtar, Haris, Muhammad, Abban, and Taghizadeh-Hesary (2022) concluded that energy supply plays a critical role in business profitability. Regarding the digitalization of the economy, Romanova, Maryanova, and Naumov (2021) found that it opens up new avenues for optimizing production costs and expanding the range of products and services at enterprises, thereby creating favorable conditions for financial stability. This, in turn, has a positive effect on the quality of business profit. In terms of working capital management, Alvarez, Sensini, and Vazquez (2021) highlighted a positive and statistically significant relationship between all components of working capital and profitability. However, Sensini and Vazquez (2021) found a negative relationship between working capital and firms' profitability. With respect to liquidity and growth, Lim and Rokhim (2021) discovered strong and positive relationships between liquidity, sustainable growth rate, and profitability as measured by ROE and return on assets (ROA). On the other hand, Yadav, Pahi, and Gangakhedkar (2022) found a negative relationship between firm size and profitability, suggesting that initially, profitability increases with firm growth but eventually diminishes over time as the firm size expands, indicating the presence of inefficiency in large-sized firms.

Existing scholars primarily focus on studying the construction of a profit quality evaluation system from perspectives such as profit structure, cash flow, profit level, and sustainability. Qian and Zhang (2008) developed a new analysis system for profit structure quality, considering asset appreciation quality, intrinsic quality, and cash acquisition quality. Building upon this framework, Qian, Zhang, and Zhou (2009) constructed an evaluation index system for profitability structure quality based on core profit capability. When considering both cash flow and sustainability, the evaluation framework for profit quality should incorporate indicators that reflect the company's cash flow and its ability to sustain profitability growth over time. From the perspective of profit level, Xu, Akhtar, Haris, Muhammad, Abban, and Taghizadeh-Hesary (2022) measured profitability using metrics such as ROE and ROA. Alvarez, Sensini, and Vazquez (2021) also utilized these two variables to assess profitability. Yu, Chen, and Chen (2022) examined the efficacy of the profitability effect using ROE as a proxy. Wang (2022) selected ROE as an indicator reflecting profitability. Li, Wen, and Jiao (2019) developed a comprehensive evaluation index system for profit quality comprising five dimensions: profit level, structure, cash generation ability, sustainability, and stability. Accordingly, this paper adopts this evaluation index system to construct a model for evaluating the profit quality of Chinese listed companies.

Existing scholars employ various evaluation methods for assessing profit quality, including TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), grey relational analysis (GRA), cost-benefit analysis, and factor analysis. To address the issue of subjective weighting of indicators, Dai and Wang (2011) evaluated the profitability of power listed companies using an entropy improved TOPSIS method. Suvvari and Goyari (2019) conducted a financial performance assessment using GRA. Venkateswarlu and Bhishma Rao (2016) evaluated the profitability of Indian non-life insurance firms using both GRA and TOPSIS. Soltero, Quirosa, Rodríguez, Peralta, Ortiz, and Chacartegui (2023) proposed a new index for evaluating profitability based on cost-benefit analysis. In Wang's study (2022), factor analysis was employed to evaluate the financial performance of listed Chinese medicine companies.

This paper makes several contributions in comparison to the existing literature. Firstly, it utilizes DANP technology and the theory of variable weights to construct a comprehensive evaluation model for assessing corporate profit quality. This model takes into consideration the interdependence and coordinated development among different evaluation dimensions and indicators. Secondly, the constructed model is applied to analyze the profit quality status of Chinese listed companies during the period from 2018 to 2022. Additionally, specific reasons are analyzed with the goal of contributing to the promotion of high-quality development within listed companies.

The rest of this paper is organized as follows: Section 2 presents a comprehensive evaluation model for assessing corporate profit quality. Section 3 reports the empirical analysis and describes the results of applying the model. Finally, Section 4 concludes the paper.

2. Model

2.1 Evaluation index system

Profit quality is an analysis of a company's true profitability, reflecting its fundamental ability to generate profits over a specific period. It encompasses five dimensions: profit level, profit structure, cash generation ability, profit sustainability, and profit stability. Profit level refers to the accounting profit generated by the company during a particular accounting period using the accrual accounting method, indicating the amount of profit obtained by the company. Profit structure pertains to the proportion of profits derived from the company's core production and operating activities as well as other activities. It reveals the primary sources and composition of profits, highlighting the distinctiveness of the company's core business. Cash generation ability represents the net cash flow corresponding to the accounting profit earned by the company. It reflects the company's capacity for generating cash flow. Profit sustainability refers to the growth of profits resulting from the company's production and operational activities, demonstrating the company's ability to achieve sustained and healthy development. Profit stability refers to the range of fluctuations observed in the company's realized profits, indicating its resilience to risks. Companies with significant profit fluctuations often exhibit less stable profitability and face greater business risks.

In the study conducted by Li, Wen, and Jiao (2019), they developed a profit quality evaluation index system called the "Profit Quality Pyramid." This system comprises five dimensions and 20 indicators. The five dimensions are profit level, profit structure, cash generation ability, profit sustainability, and profit stability. Under the profit level dimension, there are two indicators: ROA and ROE. These indicators measure the company's profitability in terms of its assets and equity. The profit structure dimension includes four indicators: Main Business Profit Margin, Gross Profit Margin, Operating Profit Proportion, and Operating Gross Profit Margin. These indicators assess the composition and sources of profits derived from the company's main business operations, gross profits, and operating profits. The cash generation ability dimension consists of five indicators: Net Profit Cash Content, Operating Profit Cash Content, Operating Revenue Cash Content, Operating Capital Turnover Ratio, and Accounts Receivable Turnover Ratio. These indicators reflect the company's ability to generate cash flow based on its net profit, operating profit, operating revenue, capital turnover, and management of accounts receivable. The sustainability dimension covers five indicators: Net Asset Return Rate Growth, Net Profit Growth Rate, Operating Profit Growth Rate, Net Cash Flow Generated from Operations Growth Rate, and Sustainable Growth Rate. These indicators examine the company's ability to achieve sustained growth in net assets, net profit, operating profit, cash flow generated from operations, and overall sustainable growth. Finally, the stability dimension includes four indicators: Coefficient of Variation of ROA, Coefficient of Variation of ROE, Coefficient of Variation of Main Business Profit Margin, and Coefficient of Variation of Operating Profit Margin. These indicators measure the fluctuation range or stability of key profitability metrics such as ROA, ROE, main business profit margin, and operating profit margin. Using this evaluation index system, we combined DANP technology with variable weight theory (VWT) to construct a profit quality evaluation model.

2.2 DANP-VWT model

DANP, which stands for DEMATEL-based ANP, is a method used in multicriteria decision analysis. It combines two techniques: the Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP). This approach allows for the consideration of mutual influences among criteria at different levels within a decision system (Chen, 2015). By using DANP, one can calculate the hybrid weights of criteria at different levels in relation to the decision objectives at the target level (Shen and Tzeng, 2016).

Variable weight theory (VWT) is another concept that comes into play. This theory, as proposed by Li, Li, Wang, Mo, and Li (2004) and further developed by Liu and Li (2019), overcomes the limitations of constant weight comprehensive models (CWCM). VWT suggests that the weight assigned to an evaluation factor should be a function of the factor's state value, meaning that the weight can change depending on the fluctuation of the factor. This approach provides a better reflection of the role of a factor in comprehensive evaluations.

In summary, DANP combines DEMATEL and ANP to account for mutual influences among criteria, while variable weight theory (VWT) addresses the dynamic nature of weight assignment based on factors' state values, enhancing the accuracy of comprehensive evaluations. Based on the profit quality pyramid, we utilize DANP technology and VWT to construct a comprehensive evaluation model for assessing the profit quality of enterprises. The specific steps are as follows:

3.2.1 Calculate the hybrid weights using DANP technique

(1) Obtain the direct influence matrix

We distributed a questionnaire to 8 experts to collect their opinions on the mutual influence indices between evaluation dimensions and indicators. This enabled us to obtain the dimension direct influence matrix $\mathbf{A}_d^t = (a_{ij}^{dt})_{5\times 5}$ and indicator direct influence matrix $\mathbf{A}_c^t = (a_{ij}^{ct})_{20\times 20}$,

$$\mathbf{A}_d^t = \begin{bmatrix} a_{11}^{dt} & \cdots & a_{1j}^{dt} & \cdots & a_{15}^{dt} \\ \vdots & & \vdots & & \vdots \\ a_{i1}^{dt} & \cdots & a_{ij}^{dt} & \cdots & a_{i5}^{dt} \\ \vdots & & \vdots & & \vdots \\ a_{51}^{dt} & \cdots & a_{5j}^{dt} & \cdots & a_{55}^{dt} \end{bmatrix}_{5\times 5}, \quad \mathbf{A}_c^t = \begin{bmatrix} a_{11}^{ct} & \cdots & a_{1j}^{ct} & \cdots & a_{1,20}^{ct} \\ \vdots & & \vdots & & \vdots \\ a_{i1}^{ct} & \cdots & a_{ij}^{ct} & \cdots & a_{i,20}^{ct} \\ \vdots & & \vdots & & \vdots \\ a_{20,1}^{ct} & \cdots & a_{20,j}^{ct} & \cdots & a_{20,20}^{ct} \end{bmatrix}_{20\times 20},$$

where t represents the index of the expert, $t=1,2,\cdots 8$, a_{ij}^{dt} and a_{ij}^{ct} represent the direct impact of the $i-th$ dimension on the $j-th$ dimension and the direct impact of the $i-th$ indicator on the $j-th$ indicator, respectively.

(2) Calculate the average direct influence matrix

If the average direct impact matrices of dimensions and indicators are $\mathbf{B}_d = (b_{ij}^d)_{5\times 5}$ and $\mathbf{B}_c = (b_{ij}^c)_{20\times 20}$, then

$$\mathbf{B}_d = \frac{1}{8}\sum_{t=1}^{8}\mathbf{A}_d^t = \begin{bmatrix} b_{11}^{d} & \cdots & b_{1j}^{d} & \cdots & b_{15}^{d} \\ \vdots & & \vdots & & \vdots \\ b_{i1}^{d} & \cdots & b_{ij}^{d} & \cdots & b_{i5}^{d} \\ \vdots & & \vdots & & \vdots \\ b_{51}^{d} & \cdots & b_{5j}^{d} & \cdots & b_{55}^{d} \end{bmatrix}_{5\times 5}, \quad \mathbf{B}_c = \frac{1}{8}\sum_{t=1}^{8}\mathbf{A}_c^t = \begin{bmatrix} b_{11}^{c} & \cdots & b_{1j}^{c} & \cdots & b_{1,20}^{c} \\ \vdots & & \vdots & & \vdots \\ b_{i1}^{c} & \cdots & b_{ij}^{c} & \cdots & b_{i,20}^{c} \\ \vdots & & \vdots & & \vdots \\ b_{20,1}^{c} & \cdots & b_{20,j}^{c} & \cdots & b_{20,20}^{c} \end{bmatrix}_{20\times 20}.$$

(3) Consistency test

We conducted a consistency test on the direct influence results obtained from the 8 experts. The consistency test values for dimensions con_d and indicators con_c should satisfy the following conditions:

$$con_d = \frac{1}{20}\sum_{i=1}^{5}\sum_{j=1}^{5}\left|\frac{b_{ij}^{d8} - b_{ij}^{d7}}{b_{ij}^{d8}}\right| \le 5\%, \quad con_c = \frac{1}{380}\sum_{i=1}^{20}\sum_{j=1}^{20}\left|\frac{b_{ij}^{c8} - b_{ij}^{c7}}{b_{ij}^{c8}}\right| \le 5\%,$$

where b_{ij}^{dn} and b_{ij}^{cn} are elements in the average direct influence matrix calculated by n experts for dimensions and indicators, respectively. If these conditions are not satisfied, we would need to return the questionnaire to the experts for further completion.

(4) Calculate the normalized average direct influence matrix

If the normalized average direct influence matrices of evaluation dimensions and indicators are $\mathbf{E}_d$ and $\mathbf{E}_c$, then $\mathbf{E}_d = \mathbf{B}_d / m_d$, $\mathbf{E}_c = \mathbf{B}_c / m_c$, where $m_d = \max_{i,j}\{\sum_{i=1}^{5} b_{ij}^d, \sum_{j=1}^{5} b_{ij}^d\}$, $m_c = \max_{i,j}\{\sum_{i=1}^{20} b_{ij}^c, \sum_{j=1}^{20} b_{ij}^c\}$.

(5) Calculate the total influence matrix

If the total influence matrix of evaluation dimensions and indicators are $\mathbf{F}_d$ and $\mathbf{F}_c$, then $\mathbf{F}_d=\mathbf{E}_d+\mathbf{E}_d^2+\cdots+\mathbf{E}_d^\infty=\mathbf{E}_d(\mathbf{I}-\mathbf{E}_d)^{-1}$, and $\mathbf{F}_c=\mathbf{E}_c+\mathbf{E}_c^2+\cdots+\mathbf{E}_c^\infty=\mathbf{E}_c(\mathbf{I}-\mathbf{E}_c)^{-1}$, where $\mathbf{I}$ is identity matrix. Let $\mathbf{F}_d=(f_{ij}^d)_{5\times5}$, and express $\mathbf{F}_c$ as a block matrix composed of $\mathbf{F}_c^{ij}$, then

$$\mathbf{F}_c=\begin{bmatrix}\mathbf{F}_c^{11} & \cdots & \mathbf{F}_c^{1j} & \cdots & \mathbf{F}_c^{15}\\ \vdots & & \vdots & & \vdots\\ \mathbf{F}_c^{i1} & \cdots & \mathbf{F}_c^{ij} & \cdots & \mathbf{F}_c^{i5}\\ \vdots & & \vdots & & \vdots\\ \mathbf{F}_c^{51} & \cdots & \mathbf{F}_c^{5j} & \cdots & \mathbf{F}_c^{55}\end{bmatrix}_{20\times20},\quad \mathbf{F}_c^{ij}=\begin{bmatrix}f_{11}^{ij} & \cdots & f_{1k_j}^{ij} & \cdots & f_{15_j}^{ij}\\ \vdots & & \vdots & & \vdots\\ f_{k_i1}^{ij} & \cdots & f_{k_ik_j}^{ij} & \cdots & f_{k_i5_j}^{ij}\\ \vdots & & \vdots & & \vdots\\ f_{5_i1}^{ij} & \cdots & f_{5_ik_j}^{ij} & \cdots & f_{5_i5_j}^{ij}\end{bmatrix}_{5_i\times5_j},$$

where $i,j=1,2,\cdots5$, $\mathbf{F}_c^{ij}$ is a $5_i\times5_j$ matrix, 5_i is the number of indicators under the $i-th$ dimension, and $\sum_{i=1}^{5}5_i=20$.

(6) Calculate the unweighted supermatrix

First, block normalize the total influence matrix $\mathbf{F}_c$ to obtain the matrix $\mathbf{F}_c^\alpha$. Then, transpose the matrix $\mathbf{F}_c^\alpha$ to obtain the unweighted supermatrix $\mathbf{W}^\alpha$, where

$$\mathbf{W}^\alpha=(\mathbf{F}_c^\alpha)'=\begin{bmatrix}\mathbf{W}_{11} & \cdots & \mathbf{W}_{i1} & \cdots & \mathbf{W}_{51}\\ \vdots & & \vdots & & \vdots\\ \mathbf{W}_{1j} & \cdots & \mathbf{W}_{ij} & \cdots & \mathbf{W}_{5j}\\ \vdots & & \vdots & & \vdots\\ \mathbf{W}_{15} & \cdots & \mathbf{W}_{i1} & \cdots & \mathbf{W}_{55}\end{bmatrix}_{20\times20},$$

$$\mathbf{F}_c^\alpha=\begin{bmatrix}\mathbf{F}_{c11}^\alpha & \cdots & \mathbf{F}_{c1j}^\alpha & \cdots & \mathbf{F}_{c15}^\alpha\\ \vdots & & \vdots & & \vdots\\ \mathbf{F}_{ci1}^\alpha & \cdots & \mathbf{F}_{cij}^\alpha & \cdots & \mathbf{F}_{ci5}^\alpha\\ \vdots & & \vdots & & \vdots\\ \mathbf{F}_{c51}^\alpha & \cdots & \mathbf{F}_{c5j}^\alpha & \cdots & \mathbf{F}_{c55}^\alpha\end{bmatrix}_{20\times20},\quad \mathbf{F}_{cij}^\alpha=\begin{bmatrix}f_{11}^{ij}/f_1^{ij} & \cdots & f_{1k_j}^{ij}/f_1^{ij} & \cdots & f_{15_j}^{ij}/f_1^{ij}\\ \vdots & & \vdots & & \vdots\\ f_{k_i1}^{ij}/f_{k_i}^{ij} & \cdots & f_{k_ik_j}^{ij}/f_{k_i}^{ij} & \cdots & f_{k_i5_j}^{ij}/f_{k_i}^{ij}\\ \vdots & & \vdots & & \vdots\\ f_{5_i1}^{ij}/f_{5_i}^{ij} & \cdots & f_{5_ik_j}^{ij}/f_{5_i}^{ij} & \cdots & f_{5_i5_j}^{ij}/f_{5_i}^{ij}\end{bmatrix}_{5_i\times5_j},$$

$f_{k_i}^{ij}=\sum_{l=1}^{5_j}f_{k_il}^{ij}$, 5_i and 5_j are the number of indicators under the $i-th$ and $j-th$ dimension, respectively, $\sum_{i=1}^{5}5_i=20$.

(7) Calculate the weighted supermatrix

Normalize the total influence matrix $\mathbf{F}_d$ to obtain matrix $\mathbf{F}_d^\alpha$, and multiply $\mathbf{F}_d^\alpha$ with $\mathbf{W}^\alpha$ to obtain the weighted supermatrix $\mathbf{W}$, where

$$\mathbf{W}=\mathbf{F}_d^\alpha\mathbf{W}^\alpha=\begin{bmatrix}f_{11}^{d\alpha}\times\mathbf{W}^{11} & \cdots & f_{i1}^{d\alpha}\times\mathbf{W}^{i1} & \cdots & f_{51}^{d\alpha}\times\mathbf{W}^{51}\\ \vdots & & \vdots & & \vdots\\ f_{1j}^{d\alpha}\times\mathbf{W}^{1j} & \cdots & f_{ij}^{d\alpha}\times\mathbf{W}^{ij} & \cdots & f_{5j}^{d\alpha}\times\mathbf{W}^{5j}\\ \vdots & & \vdots & & \vdots\\ f_{15}^{d\alpha}\times\mathbf{W}^{15} & \cdots & f_{i5}^{d\alpha}\times\mathbf{W}^{i5} & \cdots & f_{55}^{d\alpha}\times\mathbf{W}^{55}\end{bmatrix}_{20\times20},$$

$$\mathbf{F}_d^{\alpha}=\begin{bmatrix} f_{11}^d/d_1 & \cdots & f_{1j}^d/d_1 & \cdots & f_{15}^d/d_1 \\ \vdots & & \vdots & & \vdots \\ f_{i1}^d/d_i & \cdots & f_{ij}^d/d_i & \cdots & f_{i5}^d/d_i \\ \vdots & & \vdots & & \vdots \\ f_{51}^d/d_5 & \cdots & f_{5j}^d/d_5 & \cdots & f_{55}^d/d_5 \end{bmatrix}_{5\times5}=\begin{bmatrix} f_{11}^{d\alpha} & \cdots & f_{1j}^{d\alpha} & \cdots & f_{15}^{d\alpha} \\ \vdots & & \vdots & & \vdots \\ f_{i1}^{d\alpha} & \cdots & f_{ij}^{d\alpha} & \cdots & f_{i5}^{d\alpha} \\ \vdots & & \vdots & & \vdots \\ f_{51}^{d\alpha} & \cdots & f_{5j}^{d\alpha} & \cdots & f_{55}^{d\alpha} \end{bmatrix}_{5\times5},$$

and $d_i=\sum_{j=1}^{5} f_{ij}^d$.

(8) Calculate constant weights

The weighted supermatrix converges after being multiplied by itself for n times. Therefore, any column vector of matrix $\lim_{n\to\infty}\mathbf{W}^n$ represents the global constant weights of each evaluation indicator. Based on this, we can calculate the weights of each evaluation dimension and the local weights of each indicator.

3.2.2 Dimensionless normalization of evaluation indicators

Since we will calculate the comprehensive evaluation value of profit quality using variable weight theory, it is necessary to achieve dimensionless normalization of the evaluation indicator values. Among the five dimensions of profit level, profit structure, cash generation ability, sustainability, and stability, stability is the only inverse dimension, while the other four are positive dimensions. This paper utilizes the extreme value method to normalize the indicator values within the range of $[0,1]$. The specific procedure is as follows:

For positive indicators: $x_{ij}=\dfrac{u_{ij}-m_{ij}}{M_{ij}-m_{ij}}$, For reverse indicators: $x_{ij}=\dfrac{M_{ij}-u_{ij}}{M_{ij}-m_{ij}}$.

Here, u_{ij} and x_{ij} represent the original value and processed value of the $i-th$ indicator under the $j-th$ dimension, while M_{ij} and m_{ij} denote the maximum and minimum values of the original indicator value u_{ij} .

3.2.3 Calculate the comprehensive evaluation value of profit quality based on VWT

For the evaluation index system of profit quality, enterprises can achieve high-quality profits only when the five dimensions of profit level, structure, cash generation ability, sustainability, and stability develop in a coordinated manner. The CWCM exhibits attribute value transfer phenomenon, which leads to an overestimation of the "goodness" of the evaluated objects. Based on VWT (Liu and Li, 2019), the penalty-based variable weight vector emphasizes the balanced development among dimensions and indicators. It shows a sensitive response to reducing lower indicator values and a delayed response to increasing higher indicator values. By adjusting the weights and applying penalties to counteract the overestimated "goodness", the penalty force becomes stronger as the lack of coordination among evaluation dimensions or indicators increases (Li and Hao, 2009).

Li and Zeng (2016) pointed out that the penalty variable weight vector calculated using a balance function constructed with a power function summation exhibits the strongest penalty force. In this paper, a power function summation is utilized as the balance function, and with reference to the optimal penalty coefficients proposed by Li, Wen, and Jiao (2019), a penalty variable weight vector is constructed. Subsequently, the comprehensive evaluation value of profit quality is calculated following the specific steps outlined below:

(1) Construct the balance function

The balance function for the overall evaluation of profit quality is $B(x_1,x_2,\cdots,x_5)=\sum_{i=1}^{5}x_i^{0.3}$, where x_i is the value of the $i-th$ dimension in the evaluation system. The balance functions for the dimensions of profit level, structure, cash generation ability, sustainability, and stability are $B_1(x_{11},x_{12})=x_{11}^{0.6}+x_{12}^{0.6}$, $B_2(x_{21},x_{22},x_{23},x_{24})=\sum_{i=1}^{4}x_{2i}^{0.8}$, $B_3(x_{31},x_{32},\cdots,x_{35})=\sum_{i=1}^{5}x_{3i}$, $B_4(x_{41},x_{42},\cdots,x_{45})=\sum_{i=1}^{5}x_{4i}^{0.9}$, $B_5(x_{51},x_{52},x_{53},x_{54})=\sum_{i=1}^{4}x_{5i}^{0.7}$.

(2) Calculate the penalty state variable weight vector

The penalty state variable weight vector for the overall evaluation of profit quality is $\mathbf{S}(x_1,x_2,\cdots,x_5)=\left(S_i(x_1,x_2,\cdots,x_5)\right)_{1\times5}$, where $S_i(x_1,x_2,\cdots,x_5)=\frac{\partial B(x_1,x_2,\cdots,x_5)}{\partial x_i}$. The penalty state variable weight vector for the dimensions of profit level, structure, cash generation ability, sustainability, and stability are $\mathbf{S}_1(x_{11},x_{12})=\left(S_{1i}(x_{11},x_{12})\right)_{1\times2}$, $\mathbf{S}_2(x_{21},x_{22},x_{23},x_{24})=(S_{2i}(x_{21},x_{22},x_{23},x_{24}))_{1\times4}$, $\mathbf{S}_3(x_{31},x_{32},\cdots,x_{35})=\left(S_{3i}(x_{31},x_{32},\cdots,x_{35})\right)_{1\times5}$, $\mathbf{S}_4(x_{41},x_{42},\cdots,x_{45})=\left(S_{4i}(x_{41},x_{42},\cdots,x_{45})\right)_{1\times5}$, $\mathbf{S}_5(x_{51},x_{52},x_{53},x_{54})=\left(S_{5i}(x_{51},x_{52},x_{53},x_{54})\right)_{1\times4}$, where $S_{1i}(x_{11},x_{12})=\frac{\partial B_1(x_{11},x_{12})}{\partial x_{1i}}$, $S_{2i}(x_{21},x_{22},x_{23},x_{24})=\frac{\partial B_2(x_{21},x_{22},x_{23},x_{24})}{\partial x_{2i}}$, $S_{3i}(x_{31},x_{32},\cdots,x_{35})=\frac{\partial B_3(x_{31},x_{32},\cdots,x_{35})}{\partial x_{3i}}$, $S_{4i}(x_{41},x_{42},\cdots,x_{45})=\frac{\partial B_4(x_{41},x_{42},\cdots,x_{45})}{\partial x_{4i}}$, $S_{5i}(x_{51},x_{52},x_{53},x_{54})=\frac{\partial B_5(x_{51},x_{52},x_{53},x_{54})}{\partial x_{5i}}$.

(3) Calculate the penalty variable weight vector

Let ω_i and ω_{ij} represent the constant weight of the $i-th$ dimension and the $j-th$ indicator under the $i-th$ dimension in profit quality evaluation system. Then the penalty variable weight vector for the overall evaluation of profit quality is $\mathbf{W}(x_1,x_2,\cdots,x_5)=\left(w_i(x_1,x_2,\cdots,x_5)\right)_{1\times5}$, where $w_i(x_1,x_2,\cdots,x_5)=\frac{\omega_i S_i(x_1,x_2,\cdots,x_5)}{\sum_{i=1}^{5}\omega_i S_i(x_1,x_2,\cdots,x_5)}$. The penalty state variable weight vector for the dimensions of profit level, structure, cash generation ability, sustainability, and stability are $\mathbf{W}_1(x_{11},x_{12})=\left(w_{1i}(x_{11},x_{12})\right)_{1\times2}$, $\mathbf{W}_2(x_{21},x_{22},x_{23},x_{24})=\left(w_{2i}(x_{21},x_{22},x_{23},x_{24})\right)_{1\times4}\ x_{24}))_{1\times4}$, $\mathbf{W}_3(x_{31},x_{32},\cdots,x_{35})=\left(w_{3i}(x_{31},x_{32},\cdots,x_{35})\right)_{1\times5}$, $\mathbf{W}_4(x_{41},x_{42},\cdots,x_{45})=\left(w_{4i}(x_{41},x_{42},\cdots,x_{45})\right)_{1\times5}$, $\mathbf{W}_5(x_{51},x_{52},x_{53},x_{54})=\left(w_{5i}(x_{51},x_{52},x_{53},x_{54})\right)_{1\times4}$, where $w_{1i}(x_{11},x_{12})=\frac{\omega_{1i}S_{1i}(x_{11},x_{12})}{\sum_{i=1}^{2}\omega_{1i}S_{1i}(x_{11},x_{12})}$, $w_{2i}(x_{21},x_{22},x_{23},x_{24})=\frac{\omega_{2i}S_{2i}(x_{21},x_{22},x_{23},x_{24})}{\sum_{i=1}^{4}\omega_{2i}S_{2i}(x_{21},x_{22},x_{23},x_{24})}$, $w_{3i}(x_{31},x_{32},\cdots,x_{35})=\frac{\omega_{3i}S_{3i}(x_{31},x_{32},\cdots,x_{35})}{\sum_{i=1}^{5}\omega_{3i}S_{3i}(x_{31},x_{32},\cdots,x_{35})}$, $w_{4i}(x_{41},x_{42},\cdots,x_{45})=\frac{\omega_{4i}S_{4i}(x_{41},x_{42},\cdots,x_{45})}{\sum_{i=1}^{5}\omega_{4i}S_{4i}(x_{41},x_{42},\cdots,x_{45})}$, $w_{5i}(x_{51},x_{52},x_{53},x_{54})=\frac{\omega_{5i}S_{5i}(x_{51},x_{52},x_{53},x_{54})}{\sum_{i=1}^{4}\omega_{5i}S_{5i}(x_{51},x_{52},x_{53},x_{54})}$.

(4) Calculate the comprehensive value of profit quality

The dimension values of profit level, structure, cash generation ability, sustainability, and stability in the evaluation system are $x_1(x_{11},x_{12})=\sum_{i=1}^{2}w_{1i}(x_{11},x_{12})x_{1i}$, $x_2(x_{21},x_{22},x_{23},x_{24})=\sum_{i=1}^{4}w_{2i}(x_{21},x_{22},x_{23},x_{24})x_{2i}$, $x_3(x_{31},x_{32},\cdots,x_{35})=\sum_{i=1}^{5}w_{3i}(x_{31},x_{32},\cdots,x_{35})x_{3i}$, $x_4(x_{41},x_{42},\cdots,x_{45})=\sum_{i=1}^{5}w_{4i}(x_{41},x_{42},\cdots,x_{45})x_{4i}$ and $x_5(x_{51},x_{52},x_{53},x_{54})=\sum_{i=1}^{4}w_{5i}(x_{51},x_{52},x_{53},x_{54})x_{5i}$, respectively. Then the comprehensive value of profit quality

$$PQ=\sum_{i=1}^{5}w_i(x_1,x_2,\cdots,x_5)x_i(x_{i1},\cdots,x_{i5_i}),$$

where $\sum_{i=1}^{5}5_i=20$.

3. **Empirical analysis**

3.1 Data

This paper applies the constructed model to evaluate and analyze the profit quality of Chinese listed companies from 2018 to 2022. However, due to the specific characteristics of the financial and insurance industries, as well as Special Treatment (ST) companies, they were excluded from the analysis. Additionally, companies with missing data were also removed, resulting in a sample size of 24,046 companies. Specifically, there were 4,592 sample companies in 2018, 4,851 in 2019, 4,831 in 2020, 4,874 in 2021, and 4,898 in 2022. The data for evaluating the profit quality indicators in listed companies were obtained from the CSMAR database. Data processing for this study was conducted using Excel and SPSS software.

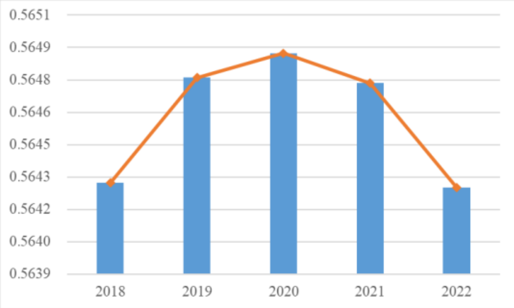
3.2 Empirical Results

The results of the evaluation of the profit quality of Chinese listed companies from 2018 to 2022, calculated using the established model, are presented in Table 1 and Figure 1. It can be observed that the overall profit quality of Chinese listed companies witnessed a significant increase from 2018 to 2019, followed by a smaller increase from 2019 to 2020, and a continuous decline starting from 2020. When analyzing specific dimensions, the profit level showed a continuous growth trend from 2018 to 2021, followed by a decrease from 2021 to 2022. On the other hand, the structure and stability aspects of profit have been consistently declining since 2019, while the cash generation ability and sustainability aspects exhibited greater fluctuations between 2018 and 2022.

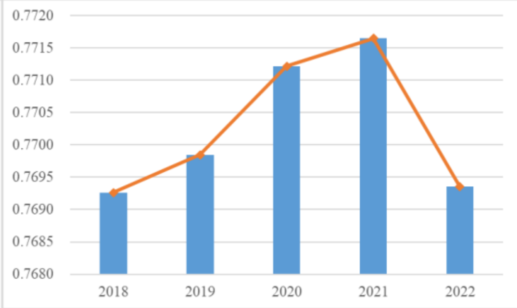
Table 1: Descriptive statistical of profit quality

PQ	2018	2019	2020	2021	2022
Mean	0.56427	0.56476	0.56487	0.56473	0.56425
95% confidence interval for mean lower bound	0.56388	0.56465	0.56476	0.56447	0.56396
95% confidence interval for mean upper bound	0.56466	0.56487	0.56499	0.56500	0.56453
5% trimmed mean	0.56495	0.56503	0.56506	0.56500	0.56448
Median	0.56488	0.56494	0.56495	0.56490	0.56450
Variance	0.00018	0.00001	0.00002	0.00009	0.00010
Std. deviation	0.01342	0.00385	0.00413	0.00955	0.01017
Minimum	0.00779	0.46293	0.44948	0.08460	0.08612
Maximum	0.62610	0.60759	0.59138	0.59139	0.62521
Range	0.61831	0.14466	0.14190	0.50678	0.53908
Interquartile range	0.00218	0.00229	0.00257	0.00277	0.00286

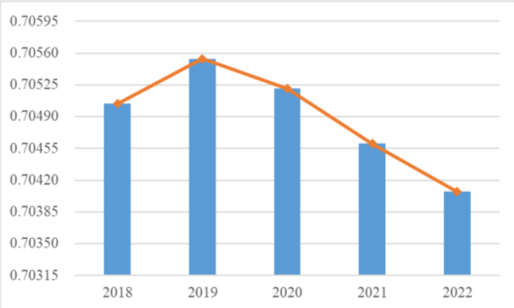
Upon further analysis, these changes can primarily be attributed to the impact of the COVID-19 pandemic. The pandemic, which started at the end of 2019, resulted in a continuous decline in the profit quality of Chinese listed companies starting from 2020. Although the profit level experienced growth from 2019 to 2021, the structure and stability aspects of profit have been continuously declining since 2019. This suggests that during the pandemic, the profit of listed companies did not mainly originate from their core business, which had poor and unstable profit performance. Consequently, both the structure and stability aspects of profit were relatively low, leading to an overall decrease in profit quality. As the pandemic comes to an end, it is crucial for Chinese listed companies to optimize resource allocation, improve the profitability and stability of their core business operations, and thereby promote the enhancement of profit quality.



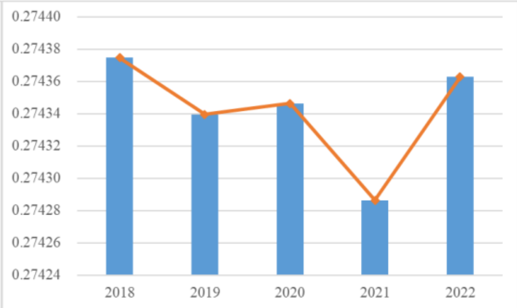
(a) Profit Quality



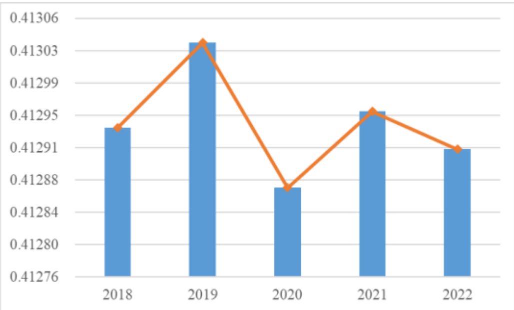
(b) Profit Level



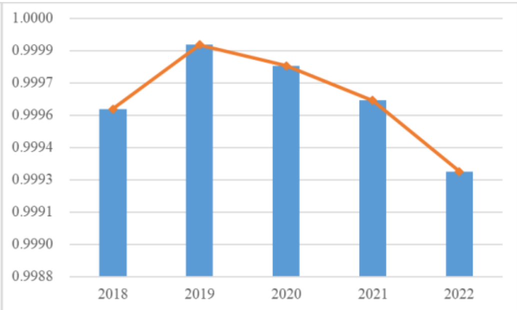
(c) Profit Structure



(d) Cash Generation Ability



(e) Profit Sustainability



(f) Profit Stability

Figure 1 The Profit Quality of Chinese Listed Companies

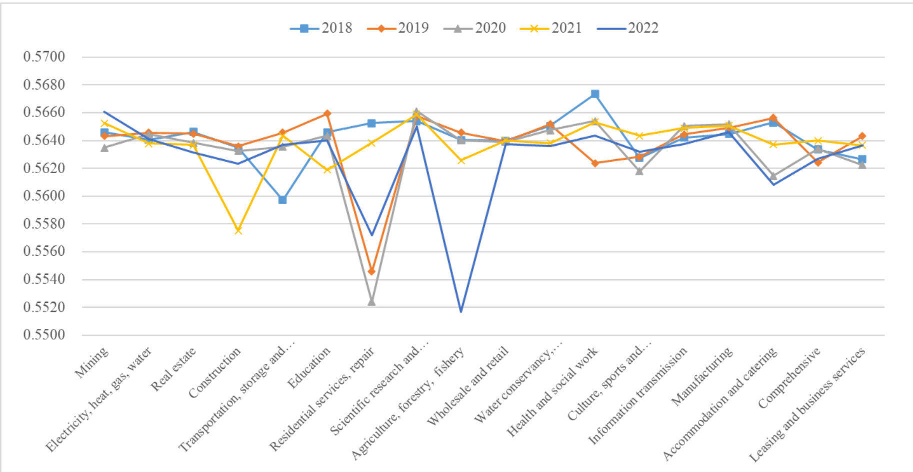


Figure 2 The Profit Quality of Chinese Listed Companies by Industr

Further industry analysis indicates that despite the general decline in profit quality among Chinese listed companies since 2020, the scientific research and technical services industry has maintained a relatively high level of profit quality, as depicted in Figures 2. Upon investigating the reasons for this trend, it can primarily be attributed to the heightened demand for scientific research and technology during the COVID-19 pandemic. This increased demand has propelled the growth and advancement of the scientific research and technical services industry, resulting in higher profit quality within this sector.

The COVID-19 pandemic has necessitated extensive research and technological solutions, driving the need for scientific expertise and technical services. Consequently, companies operating in the scientific research and technical services industry have been able to capitalize on this demand, contributing to their sustained high levels of profit quality. The industry's ability to adapt and innovate in response to the unique challenges posed by the pandemic has played a significant role in its success. It is important to recognize the positive impact of the scientific research and technical services industry during this period. By continuing to invest in research and development, leveraging technological advancements, and providing essential services, this industry has not only contributed to addressing the challenges posed by the pandemic but has also demonstrated resilience and potential for future growth.

4. Conclusions

This paper employs the DANP technique and VWT to establish a comprehensive evaluation model for enterprise profit quality. The model is applied to assess the profit quality of Chinese listed companies from 2018 to 2022. The findings indicate that the profit quality of Chinese listed companies has experienced a continuous decline since 2020, primarily influenced by the COVID-19 pandemic. When examining specific dimensions, the profit level demonstrated growth from 2019 to 2021. However, the profit structure and stability aspects have consistently deteriorated since 2019, while the cash generation ability and sustainability aspects exhibited significant fluctuations during this period. These results suggest that the profitability of the core business of listed companies has been severely impacted by the COVID-19 pandemic. Additionally, it indicates that the profits of listed companies are not primarily derived from their core business, which exhibits lower and more unstable profitability. Consequently, both the profit structure and stability aspects are relatively weak, contributing to a continuous decrease in profit quality. With the end of the pandemic, it is crucial for Chinese listed companies to enhance the profitability and stability of their core business operations in order to promote the improvement of profit quality.

Moreover, further industry analysis reveals that since the onset of the COVID-19 pandemic, the scientific research and technical services industry has maintained a relatively high level of profit quality. This can be attributed to the increased demand for scientific research and technology during the pandemic, which has facilitated the rapid development of the scientific research and technical services industry and contributed to its higher profit quality. Simultaneously, this observation indirectly confirms the effectiveness of the DANP-VWT profit quality model developed in this study.

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