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Quality evaluation of enterprise environmental accounting information disclosure based on projection pursuit model

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ABSTRACT

To strengthen China's supervision of the quality of environmental accounting information disclosure and improve this quality, this paper established a set of evaluation systems. Based on the principles of "relevance" and "reliability", 28 evaluation indicators were selected, and a projection pursuit model was innovatively introduced according to the characteristics of the evaluation data in this study. This model can not only overcome the artificially weighted interference and restrictions on the data structure of the traditional evaluation method but also can achieve better robustness, anti-interference ability and accuracy when processing high-dimensional nonlinear data. To test whether the method is simple and effective, the study selected 34 thermal power listed companies in China as a sample. The evaluation results of the key quantitative indicators showed that the disclosure level of the whole sample is low, which indicates that the information disclosed by each enterprise is not substantial. After verification, the results are basically consistent with the original data. Finally, this paper analyzed the problems in the disclosure of the evaluation results and proposed feasible suggestions.

1. Introduction

Since China's reform and opening up and with its rapid economic development, environmental problems have become increasingly prominent. China's environmental protection has made some progress, but the situation is still not optimistic. The environmental accounting information disclosure (EAID) is the first method to provide essential information on an enterprise's environmental protection work, which means that environmental issues are included in an enterprise's accounting information. In terms of the system, the *Encouragement of Environmental Information Disclosure in Listed Companies in the Shenzhen Stock Exchange Guidelines to Enterprise Social Responsibility* and the *Guide to Environmental Information Disclosure of Listed Companies (Draft for Comment)* require that heavily polluting industries should regularly disclose their environmental accounting information and encourage voluntary disclosure in other industries, reflecting the gradual improvement of the disclosure system. Nevertheless, the current lack of a regulatory system for the content of an EAID in China has resulted in a relatively arbitrary disclosure and the quality has been uneven. At present, scholars have conducted little systematic research on evaluating EAID quality, and there is no consensus on the establishment and selection of the evaluation indicators and method. Wang (2008), Luo et al. (2019), and Kong and Tang (2016) used the EAID as a variable to study its influencing factors in order to find a way to improve EAID quality. However, the reliability of EAID quality directly affects the results of the above studies. Therefore, from the perspective of strengthening supervision and improving EAID quality or providing a research basis for other research, it is necessary to establish a scientific and practical evaluation system.

Regarding the selection of the evaluation indicators, Newell et al. (1997) classified the environmental information disclosed by the enterprise into ten categories such as environmental plans, environmental strategies, environmental accidents, and environmental litigation. Patten and Trompeter (2003) believed that listed enterprises should disclose their compliance with environmental protection laws and regulations, their environmental risks, and their pollution control actions in annual environmental information. Aerts et al. (2007) scored the environmental information disclosure of sample enterprises in Europe. The content mainly includes environmental restoration, environmental expenditures, risk, land restoration, and law enforcement. Shen et al. (2014) proposed evaluating enterprise EAID quality using three aspects:

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pollution emissions, environmental management and social impact. Chaklader and Gulati (2015) believed that the evaluation should be based on five aspects: the disclosure of the environmental system of the enterprise's location, environmental governance strategies, environmental costs, specific environmental protection programs, and enterprise environment-related rewards or penalties. Wang and Zhang (2018) said that the evaluation must include environmental accounting financial information, environmental performance information and three other categories. Ren (2019) concluded that Chinese theoretical circles have the following four views on the content of environmental accounting information and its elements: the three-element theory, the four-element theory, the five-element theory, and the six-element theory; furthermore, the six elements ensure consistency with traditional accounting systems. Generally, the scholarly research on the selection of environmental accounting information quality evaluation indicators is lacking, the classification lacks logic, and the descriptions are rough or even difficult to define, resulting in incompleteness or overlap. As the evaluation indicators become more comprehensive and clearer, the results of the evaluation will become more accurate.

In addition to the evaluation indicator system, the choice of the evaluation method also affects the accuracy of the evaluation. Li (2015) stated that the empirical analysis of the evaluation of EAID quality mainly adopts research methods ranging from the initial comprehensive evaluation model of a single indicator to the weighted average evaluation model of a single indicator. Cai (2017) and Qin (2018) summarized that the analytic hierarchy process combined with fuzzy evaluation method is one of the most widely used methods in recent years. This method has the advantages of simplicity and clarity, strong layering and systematization, and strong operability. However, authoritative experts need to determine the weight of each indicator, and so subjective experience cannot be avoided. In recent years, Gallego-Alvarez et al. (2018), Xie (2013), Bian (2009) and Kosajan et al. (2018) used the factor analysis method, the principal component analysis method, the entropy weight method, an evaluation method based on the BP artificial neural network, and an entire array polygon, respectively. These methods aim to find the internal structure and regularity of data through mathematical methods to improve the objectivity of the results. However, they have higher requirements on the amount and structure of the sample data such as a sufficient sample size and a normal distribution. If the assumptions are not met, the analysis results cannot fully cover the internal relationships of the data. Therefore, the projection pursuit model is innovatively introduced. It is used to process and analyze high-dimensional data, especially a class of statistical methods from nonnormal populations. The basic idea is to project high-dimensional data onto a low-dimensional subspace and determine what can reflect the high-dimensional data structure or feature projection to achieve the purpose of researching and analyzing high-dimensional data. Su and Yu (2018) explained that it not only reduces the requirements for sample data, but it also has the advantages of good robustness, a strong anti-interference ability and high accuracy. At present, Wen and Huang (2019), Pei et al. (2019), Liu et al. (2019), Wang et al. (2018), and Zhao et al. (2017) have widely used the projection pursuit model in industry, agriculture, water conservancy, geology, medicine, etc. and have achieved a series of results. In recent years, Yao (2019), Guo et al. (2019) and Shi (2018) have used it in some social sciences. In the field of accounting, Wu et al. (2012) first proposed a projection pursuit model in evaluating accounting information. Apart from this, the literature on the application of this model in the field is still blank. I find that the model can be applied to evaluate multidimensional, nonlinear, and non-normally distributed data with an insufficient sample size. This method can not only can objectively search for the inherent laws of data and avoid subjective experience interference, but it also requires a low data structure. It is very suitable for evaluating EAID quality using this paper's multidimensional nonlinear indicators.

In summary, the research on EAID quality evaluation in China is in its infancy. No unified conclusion has been reached on the evaluation indicators and evaluation methods. Therefore, the main contributions of this paper are as follows:

(1) Broaden the breadth and depth of evaluation indicators. First, using "relevance" and "reliability" as the basic principles, a total of 28 indicators in six categories were selected, including qualitative and quantitative indicators, covering almost all important information related to environmental accounting, and detailed descriptions are given for each indicator. Second, the evaluation of the qualitative indicators from the three aspects of significance, quantitativeness and timeliness extends the depth of the evaluation indicators. This common metric helps to improve the comparability of the EAIDs among enterprises, thereby strengthening the supervision.
(2) Innovatively introduce the projection pursuit model. This method requires a low sample data structure and is particularly good at processing high-dimensional nonnormal data. It can comprehensively and objectively find the internal laws of data and avoid interference from subjective experience. The mathematical model is simple and clear, and the operability is strong. This study fills the gaps in the literature on the application of this model in the field of environmental accounting.

The samples selected are listed enterprises in the thermal power industry in China. *The Environmental Information Disclosure Guide for Listed Companies* clearly classified thermal power as one of the sixteen types of heavily polluting industries and forced them to disclose environmental accounting information. The power industry is China's basic pillar industry. The thermal power industry is a typical industry in terms of its pollutant types and emissions. According to relevant statistics, as of the end of 2017, the amount of electricity generated nationally was 64179 billion kilowatt-hours, of which the thermal power generated 451.3 billion kilowatt-hours, accounting for more than 70%, which shows that thermal power generation is still the most important form of power generation in China. Therefore, as an industry with a large amount of pollutants and emissions, its environmental information disclosure status can truly and reasonably reflect the current status of environmental information disclosure in China's heavily polluting enterprises. This study selects 34 thermal power listed enterprises, excluding ST* enterprises, according to the statistics of the Ruisi database as cases, and it collects the enterprises' 2014–2018 annual reports, social responsibility reports and investment prospectuses. (The data are from the official website of Juchao Information.) The evaluation system evaluates the EAID quality therein, analyzes the problems existing in the evaluation results, and proposes countermeasures.

2. Design of quality evaluation indicators for EAID

2.1. Principles of indicator design

According to the requirements of the FASB and IASB accounting information quality characteristics framework, from the perspective of decision-making usefulness, it is proposed that relevance and reliability are important characteristics of investigating the quality of enterprise accounting information. Environmental accounting, as a branch of traditional accounting, can also reflect the

quality of information according to its relevance and reliability. The Accounting Standards Committee (UK) believed that the quality of accounting information is mainly reflected in the reliability and relevance of disclosures and the timeliness, comparability, understandability and consistency of disclosures in financial statements. The *Enterprise Accounting Standards* formulated by the Ministry of Finance of China also show that relevance and reliability are the main characteristics of the quality of accounting information. Ren and Feng (2016), Li (2016), and Peng (2016) combined the characteristics of China's economy, reviewed the content of the framework, and emphasized the role of "relevance" and "reliability" in the quality of accounting information in China. In this paper, after referring to previous studies, the two levels of "relevance" and "reliability" were selected for evaluation.

2.2. Selection and description of the indicators

2.2.1. Design of "relevance" level indicators

2.2.1.1. Environmental policy and responsibility information. Environmental policy and responsibility information mainly refers to the relevant disclosures such as environmental protection rules and regulations, environmental protection measures and the implementation of compulsory laws and regulations of relevant countries in order to enable enterprises to achieve their intended environmental protection purposes (see Table 1).

2.2.1.2. Environmental performance information. Environmental performance information refers to the impact of the production and operating activities of the enterprise on the environment and the governance of negative impacts (see Table 2).

2.2.1.3. Environmental financial information. Environmental financial information refers to the information used to calculate and supervise environmental accounting elements based on financial accounting (see Table 3).

2.2.2. Design of "reliability" level indicators

2.2.2.1. Environmental information compilation process. The environmental information compilation process is mainly evaluated using the production link of the enterprise's environmental accounting information. Whether the principle of reliability is met in the process of forming the environmental accounting information is reflected in the various internal control descriptions and information reliability levels of the enterprise in its related reports (see Table 4).

2.2.2.2. Environmental information disclosure process. The environmental information disclosure process mainly examines the relevant quality assurance provided by the internal management and external independent third-party organizations to the environmental accounting information disclosed by the enterprise to ensure the reliability of the final information (see Table 5).

2.2.2.3. Completeness of environmental information disclosure. The completeness of enterprise environmental accounting information content mainly examines the disclosure of negative information related to the enterprise environment. Specific indicators include the following: major environmental accidents, environmental litigation, and negative media reports on an enterprise's environment (see Table 6).

Through the design of the evaluation indicators above, the quality evaluation system for EAID is obtained (see Table 7).

3. Method

3.1. Model introduction

U.S. professors Kruskal and Shepard (1974) first used projection pursuit models in the early 1970s. These models are mainly used to process high-dimensional data, especially high-dimensional data whose overall distribution is nonnormal. Fu et al. (2003) indicated that these models combine computer technology to project complex high-dimensional data and convert it to a low-dimensional space; the models then optimize the projection function to find the best projection vector that can reflect the structure or characteristics of the original data so that the data can be transformed into a low-dimensional space for analysis. Since the projection pursuit model needs to solve the characteristics and structure of the best high-dimensional data, Ouyang (2012) showed that the first solution methods were some traditional optimization calculation methods such as the gradient descent method and Gauss-Newton method, and then the current genetic algorithm was used. Lin et al. (2006) stated that the genetic algorithm is an adaptive global optimization probability search algorithm formed by simulating the genetic and evolutionary processes of living things in their natural environment. However, the standard genetic algorithm's process is cumbersome and computationally intensive, and the output is slow. It easily experiences problems such as falling

Table 1
Environmental policy and responsibility information indicators.

Indicator name	Comment
Independent social responsibility report	–
Environmental protection principles, goals and systems	Specific norms formed by the strategic summary of the enterprise environmental protection work
Disclosure and implementation of environmental laws and regulations	Including the environmental laws and regulations formulated by enterprises and their implementation
Environmental protection plans and environmental issues	–
Environmental management system certification	Professional certifications in the current environmental field
Environmental management structure and status	Including whether the enterprise has established an environmental protection department or whether there is a special person engaged in environmental protection work
Evaluation and supervision of environmental issues of stakeholders	Stakeholders mainly include enterprise creditors, debtors, investments and investees, and upstream and downstream enterprises of the enterprise
Environmental impact of production and sales activities	Including the degree of resource consumption and the degree of environmental pollution
Propaganda and education on environmental protection concepts	Relevant activities organized by the enterprise to promote environmental protection concepts and environmental education
Environmental policy risk	Refers to the negative impact of current or newly introduced relevant laws on the current environmental protection status of enterprises

Table 2
Environmental performance information indicators.

Indicator name	Comment
"Three wastes" emissions	The "three wastes" comes from the *Trial Standards for Industrial "three wastes" emissions*
"Three simultaneities" implementation	Means that during the construction of the project, the pollution prevention facilities accompanying the project shall be designed, constructed and put into use simultaneously with the main project.
Energy consumption and efficiency	–
Recycling situation	Refers to the recovery and reuse of production residues, wastes and pollutants by enterprises

Table 3
Completeness of environmental information disclosure.

Indicator name	Comment
Major environmental accidents	Refers to a serious environmental accident that has not been filed by an enterprise
Environmental litigation	Refers to a serious environmental accident that violates the law and is prosecuted
Negative media reports on enterprise environment	–

Table 4
Environmental information compilation process.

Indicator name	Comment
Internal control of environmental work	For enterprises that establish environmental management regulations or have separate environmental management departments, they should disclose the development of relevant systems and their supervision during the reporting period, such as the implementation of environmental management systems by various departments of the enterprise, and whether there are any violations.
Statement on environmental information compliance	The enterprise shall explain in detail the principles for compiling environmental accounting information, such as whether the measurement of capitalized environmental investment and expensed environmental expenditures meets the corresponding recognition criteria, whether the measurement of various environmental subsidies received by the enterprise follows the recognition of revenue guidelines, etc.
Other instructions to confirm the reliability of environmental information	–

Table 5
Environmental information disclosure process.

Indicator name	Comment
Government audits	–
Third party audits	Mainly refers to an unqualified audit report issued by a certified public accountant on the audit of the enterprise
Internal audits	Refers to management's evaluation and guarantee of enterprise environmental accounting information

Table 6
Completeness of environmental information disclosure.

Indicator name	Comment
Major environmental accidents	Refers to a serious environmental accident that has not been filed by an enterprise
Environmental litigation	Refers to a serious environmental accident that violates the law and is prosecuted
Negative media reports on enterprise environment	–

into the local optimum and premature convergence, which leads to poor solution accuracy. Therefore, this paper chose an improved genetic algorithm, that is, an accelerated genetic algorithm based on real number coding, to solve the problem of optimizing the projection pursuit model. This algorithm can greatly increase the optimization performance, improve the operating quality, and obtain the optimal solution. For the purpose of this topic, the best projection vector is essentially the weight of each evaluation indicator.

3.2. Model building

Step 1: Normalize the sample evaluation indicator set. Let the sample set of each indicator value be $\{x^*(i,j)|i = 1,2,\ldots,n;j = 1,2,\ldots,p\}$. To eliminate the dimension of each indicator value and unify the change range of each indicator, the following formula can be used to normalize extreme values.

For larger and better indicators:

$$x(i,j) = (x^*(i,j) - x_{min}(j)) \,/\, (x_{max}(j) - x_{min}(j)) \tag{1}$$

$x_{max}(j)$ and $x_{min}(j)$ are the maximum and minimum values of the j indicator values, respectively, and $x(i,j)$ is a normalized sequence for the indicator eigenvalues.

Step 2: Construct a projection indicator function. The projection pursuit method is $\{x^*(i,j)|j = 1,2,\ldots,p\}$. This is synthesized into a one-dimensional projection value $z(i)$ with $a = \{a(1),a(2),a(3),\ldots,a(p)\}$ as the projection direction, that is:

Table 7
Quality evaluation system for EAID.

Target layer *A*	Criterion layer *B*	Subcriterion layer *C*	Indicator layer *D*
EAID quality evaluation (*A*)	Relevance (B_1)	Environmental policy and responsibility (C_1)	Independent social responsibility report (D_1)
			Environmental protection principles, goals and systems (D_2)
			Disclosure and implementation of environmental laws and regulations (D_3)
			Environmental protection plans and environmental issues (D_4)
			Environmental management system certification (D_5)
			Environmental management structure and status (D_6)
			Evaluation and supervision of environmental issues of stakeholders (D_7)
			Environmental impact of production and sales activities (D_8)
			Propaganda and education on environmental protection concepts (D_9)
			Environmental policy risk (D_{10})
		Environmental performance information (C_2)	"Three wastes" emissions (D_{11})
			"Three simultaneities" implementation (D_{12})
			Energy consumption and efficiency (D_{13})
			Recycling situation (D_{14})
		Environmental financial information (C_3)	Environmental assets (D_{15})
			Environmental liabilities (D_{16})
			Environmental rights (D_{17})
			Environmental costs (D_{18})
			Environmental income (D_{19})
	Reliability (B_2)	Environmental information compilation process (C_4)	Internal control of environmental work (D_{20})
			Statement on environmental information compliance (D_{21})
			Other instructions to confirm the reliability of environmental information (D_{22})
		Environmental information disclosure process (C_5)	Government audits (D_{23})
			Third party audits (D_{24})
			Internal audits (D_{25})
		Environmental information disclosure integrity (C_6)	Major environmental accidents (D_{26})
			Environmental litigation (D_{27})
			Negative media reports on enterprise environment (D_{28})

Table 8
Indicator weights.

Indicator	Weights	Indicator	Weights	Indicator	Weights	Indicator	Weights
D_1	0.0000	D_8	0.0000	D_{15}	0.1992	D_{22}	0.0000
D_2	0.1846	D_9	0.2350	D_{16}	0.1545	D_{23}	0.0000
D_3	0.0000	D_{10}	0.0558	D_{17}	0.2139	D_{24}	0.0000
D_4	0.3125	D_{11}	0.4454	D_{18}	0.0000	D_{25}	0.3741
D_5	0.1117	D_{12}	0.0000	D_{19}	0.0000	D_{26}	0.4814
D_6	0.0000	D_{13}	0.0132	D_{20}	0.2946	D_{27}	0.1236
D_7	0.1119	D_{14}	0.0000	D_{21}	0.0584	D_{28}	0.0000

$$z(i) = \sum_{j=1}^{p} a(j)x(i,j),\ i = 1, 2, \ldots, n \tag{2}$$

Then, the values are classified according to the one-dimensional walking graph of $\{z(i)|i = 1, 2, \ldots, n\}$. In Equation (2), a is a unit length vector. Therefore, the projection indicator function can be expressed as:

$$Q(a) = S_z D_z \tag{3}$$

$$S_z = \sqrt{\left(\sum_{i=1}^{n} (z(i) - E(z))^2\right) \Big/ \left(n - 1\right)} \tag{4}$$

$$D_z = \sum_{i=1}^{n} \sum_{j=1}^{p} (R - rIi,j)) \cdot u(R - r(i,j)) \tag{5}$$

In formula (4), $E(z)$ is the average value of the sequence $\{z(i)|i = 1, 2, \ldots, n\}$, R is the window radius of the local density, $r(i,j)$ represents the between samples distance $r(i,j) = |z(i) - z(j)|$, and $u(t)$ is a unit step function. When $t \geq 0$, $u(t)$ is 1; and when $t \leq 1$, $u(t)$ is 0.

Step 3: Optimize the projection indicator function.

Maximize the objective function:

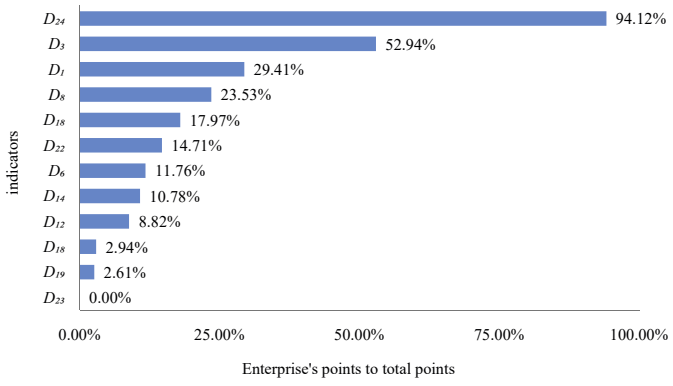

Fig. 1. Percentage of indicators with a weight of zero.

Table 9
Indicator evaluation mean and standard value.

Indicator	Mean	Standard Value (Full Scores)	Difference Between Standard and Mean	Indicator	Mean	Standard Value (Full Scores)	Difference Between Standard and Mean
D_2	0.1249	0.1846	0.0597	D_{15}	0.6678	1.7924	1.1246
D_4	0.1747	0.3125	0.1379	D_{16}	0.0409	1.3909	1.3500
D_5	0.0099	0.1117	0.1018	D_{17}	0.5223	1.9255	1.4032
D_7	0.0000	0.1119	0.1119	D_{20}	0.0087	0.2946	0.2860
D_9	0.0829	0.2350	0.1521	D_{21}	0.0069	0.0584	0.0515
D_{10}	0.0230	0.0558	0.0328	D_{25}	0.3191	0.3741	0.0550
D_{11}	1.7818	4.0090	2.2272	D_{26}	0.1416	0.4814	0.3398
D_{13}	0.0360	0.1185	0.0825	D_{27}	0.0618	0.1236	0.0618

$$Q(a) = S_z D_z \tag{6}$$

The restriction is:

$$\sum_{j=1}^{p} a^2(j) = 1 \tag{7}$$

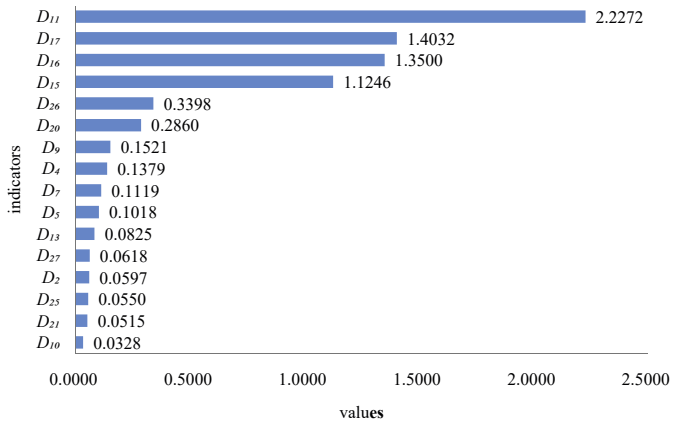

Fig. 2. Difference between an indicator's standard value and mean value.

Step 4: Order the results. Using the projection indicator function *Q(a)* in the PP model as the objective function and the projection *a(j)* of each indicator as the optimization variable, and running the eight steps of the RAGA, the optimal projection direction *a*(j)* can be obtained. After entering the data into formula (2), the projection value *z(i)* of each sample can be obtained. Sorting *z(i)* from large to small sorts the samples from good to bad, respectively.

4. Results

This section takes the thermal power generation industry as a case sample; uses the content analysis method based on the above indicator system; and sorts, extracts and scores the information disclosed by collected enterprises. The content analysis method is a specialized method for the objective and systematic quantitative analysis of the content of a document. Its basic method is to convert the text from media and valuable nonquantitative information in communication into quantitative data, and establish a meaningful category to decompose the communication content and analyze it. Patten (1992) and Darrell and Schwartz (1997) stated that this method is also the mainstream method in the research of social responsibility and environmental information disclosure. To ensure the reliability of the results, while analyzing the content, this study invited two experts in related fields to monitor the evaluation process and continuously correct the analysis results.

At the subcriterion level, the enterprise environmental performance information and enterprise financial information are related to the level of detail in a disclosure; therefore, they are graded according to the three aspects of significance (the disclosure of

Table 10
Projection results.

Enterprise Name Abbreviation	Stock Code	*z (i)*	Enterprise Name Abbreviation	Stock Code	*z (i)*
Shenzhen Energy	000027	2.2771	Zhangze Power	000767	1.1528
Guodian Power	600795	2.1457	Construction Investment Energy	000600	1.1135
Shanghai Electric Power	600021	2.0299	Eastern Energy	000958	1.1134
Yuneng Holdings	001896	1.9388	Binhai Energy	000695	1.0391
Ningbo Thermal Power	600982	1.9386	Hubei Energy	000883	1.0390
Tongbao Energy	600780	1.7405	Kingsoft	600396	1.0377
Huaneng International	600011	1.7390	Shaoneng Shares	000601	1.0350
Jingneng Power	600578	1.7388	SDIC Power	600886	1.0350
Funeng shares	600483	1.7310	Huadian Energy	600726	1.0304
Wanneng Power	000543	1.7227	Ganneng shares	000899	0.9416
Baoxin Energy	000690	1.5637	Jidian	000875	0.8570
Datang Power Generation	601991	1.5279	Changyuan Power	000966	0.8568
Chuantou Energy	600674	1.4769	Huitian Thermal Power	000692	0.8567
Tianfu Energy	600509	1.4596	Huadian International	600027	0.6491
Sui Hengyun A	000531	1.3622	Guangzhou Development	600098	0.5583
Huayin Power	600744	1.2367	Hongyang Energy	600758	0.5577
Inner Mongolia Huadian	600863	1.2367	Shenneng shares	600642	0.1919

indicators in the annual report, social responsibility report and investment prospectus is scored 3 points, disclosure in two of the reports is scored 2 points, disclosure in only one report is scored 1 point, and 0 points are scored if no disclosure occurs), quantitative (3 points for qualitative and quantitative disclosure, 2 points for qualitative disclosure, 1 point for quantitative disclosure, and 0 points if there is no disclosure) and timeliness (3 points are scored if past, present, and future information is disclosed; 2 points are scored if past and present information is disclosed; 1 point is scored if current information is disclosed; and 0 points are scored if there is no disclosure). Finally, the other indicators are all scored quantitatively (that is, if information is provided on the indicator, it is scored as 1; otherwise, it is 0).

(1) The evaluation indicator values are normalized. To eliminate the dimension of each indicator value and unify the variation range of each indicator value, formula (1) is used to normalize the extreme values.
(2) The projection indicator function $Q(a)$ is constructed and optimized. MATLAB is used to process the data, and a mathematical model of accounting information quality evaluation standards is established for the data. The selected initial population is $n = 100$, the mutation probability is $P = 0.1$, the default crossover probability is 0.8, the number of iterations is 1000, and the other parameters are as follows:

a*=(0.0000,0.1846,0.0000,0.3125,0.1117,0.0000,0.1119,0.0000,0.2350,0.0558,0.4454,0.0000,0.0132,0.0000,0.1992,0.1545,0.2139,0.0000,0.0000,0.2946,0.0584,0.0000,0.0000,0.0000,0.3741,0.4814,0.1236,0.0000)

The component values of the best projection direction represent the weights of the corresponding indicators. In this part, the two indicators that have a greater impact on the quality of enterprise environmental information disclosure are D_{11} and D_{26}, which are indicated in the selected data (see Table 8). The two indicators of "three waste emissions" and "major environmental accidents" have the greatest impacts on the evaluation results. In contrast, indicators D_1, D_3, D_6, D_8, D_{12}, D_{14}, D_{18}, D_{19}, D_{22}, D_{23}, D_{24}, and D_{28} all have weights of zero, reflecting the fact that the disclosure of the case samples in these indicators is consistent. This kind of consistency has little effect on the evaluation results. (Note: The evaluation weights of the evaluation indicators are different for different case samples.)

Next, the above indicators with weights of zero will be specifically analyzed in combination with the original data (see Fig. 1). D_{24} has a good disclosure status. 94.12% of the enterprises disclosed this information in their annual reports. An example is "this year's report has issued a standard unqualified audit report issued by XXX certified public accountants". Only "Shanghai Power" and "Shenneng Shares" did not disclose this information. The disclosure percentage of D_3 is only 52.94%. This is the worst disclosure status, and all sample enterprises have not disclosed this relevant information. The disclosure levels of D_{12}, D_{19} and D_{28} are very poor, and the percentages are less than 10%. Regarding D_{28}, only "Huayin Power" disclosed relevant content on this topic in a certain year, and the rest of the enterprises did not disclose any relevant content. The quality of the disclosure of D_{12} and D_{19} is not high. For instance, the high-scoring "Huihengyun A" disclosed "three simultaneous implementations" of various types of pollution in its independent environmental report in that year and disclosed quantitative data in the form of a table, but it lacked a qualitative explanation with respect to time. The others have only brief qualitative descriptions of the content. The remaining D_1, D_6, D_8, D_{14}, D_{18}, and D_{22} also have poor disclosure levels with disclosure percentages ranging from 10% to 50%. Some enterprises disclose the indicators prospectively. According to the results, although the weights of the above indicators are zero, the total score of the enterprises that disclose this information is relatively high, indicating that the enterprises with higher scores are generally more aware of environmental information disclosure.

Excluding indicators with a weight of zero (see Table 9), a histogram of the differences between the full score and the mean of each indicator is drawn as follows.

As seen from the results (see Fig. 2), there is a certain gap between the disclosure of each indicator and the optimal result. The difference between the mean value and the standard value of D_{11} is the largest. Twenty-four enterprises have disclosed this indicator. The quantitative performance of the enterprises in this item is better. All enterprises scored 3, indicating that the enterprises actively responded to the call in terms of pollutant emissions and proactively disclosed qualitative descriptions and quantitative substantive content; however, they disclosed significantly poor performance over time, resulting in poor overall disclosure. The three major environmental financial information disclosures of D_{17}, D_{16} and D_{15} are also not ideal. D_{17} best reflects the level of an enterprise's environmental protection practice. 19 enterprises disclosed this indicator. Most of the disclosures were government subsidies and a small part of the income obtained through an environmental protection project. D_{16} is disclosed by only two enterprises, "Huitian Thermal Power" and "Ganneng Shares", and in both instances it is related to environmental protection departments' fines for noncompliance with enterprise emissions. The disclosure of D_{15} is the best of the five "enterprise environmental financial information" indicators. Even so, the quality of its disclosure is not high. In terms of "reliability", indicators D_{26} and D_{20} are generally disclosed. Only 10 companies disclosed negative information related to D_{26}. Only one enterprise, "Shanghai Electric Power", disclosed their "internal environmental control situation". The disclosure levels of the remaining indicators also differ from the standard values as a whole, but most of the disclosures are qualitative description indicators; therefore, I will not go into too much detail here. In practice, we can analyze the original data individually as needed.

(3) Bring a^* into (4) to get the corresponding projection value $z(i)$.

The projection values can be used to sort and compare the EAID quality of the sample enterprises (see Table 10). The top three are "Shenzhen Energy", "Guodian Power" and "Shanghai Electric Power", and the projection values are 2.2771, 2.1457, and 2.0299, respectively. From the original data, the three enterprises with the highest scores not only released independent social responsibility reports but also disclosed relevant environmental accounting information in their annual reports, social responsibility reports and investment prospectuses. "Shenzhen Energy" also released an independent environmental report note, which disclosed the discharge methods, quantity, and concentration of the major pollutants it released in detail. Furthermore, it explained the types and quantities of its enterprise environmental assets one by one. The company has a strong awareness of environmental information disclosure and has adopted a more positive attitude towards the disclosure of key environmental information, but it still lacks a description of the "three simultaneous implementations" and "recycling situation" indicators. "Guodian Power" has disclosed the four indicators of D_{11}-D_{14} in "environmental performance information", with scores of 7, 4, 6, and 5, respectively, which are more comprehensive and significant than other enterprises. Compared with others, the disclosure is more comprehensive, significant and quantitative, but the company only discloses the information in the year of its annual report, and the information lacks vertical comparability. "Shanghai Electric Power" disclosed all indicators

except D_6 and D_7 in "enterprise environmental policies and responsibilities", and disclosed three items D_{11}, D_{13}, and D_{15} in quantifiable information. However, it has a low level of disclosure in terms of reliability and only disclosed two items.

The worst disclosure quality is "Shenneng Shares" with a projection value of 0.1919. Although it issued an independent social responsibility report, it lacked effective information disclosure. Among all indicators, only three indicators D_2, D_{13} and D_{14} were disclosed. The key quantitative indicator D_{13} score is also only 5, and the disclosure significance and time score are 1 point each.

Regarding the overall situation of the projection values, the average evaluation value is 1.2921 and the perfect score is 3.3700, indicating that the overall EAID quality of the thermal power listed enterprises in China is poor. The extreme difference of the evaluation is 2.0852, which indicates that the information disclosure quality of various enterprises is uneven.

5. Discussion

Based on the above analysis of the EAID of China's thermal power listed enterprises, we can see that there are still many problems. The following will discuss the causes of the low EAID quality of thermal power enterprises from the aspects of the enterprise itself and the government's supervision, and then make suggestions for improvement.

First, I find that regardless of whether the weight is zero or not, most of the indicators with extremely poor evaluation statuses disclose content that is more voluntarily, and the disclosure of such information requires enterprises to indeed take positive actions and achieve results in environmental protection. Examples include D_{19} "environmental income", D_{17} "environmental rights", D_{16} "environmental liabilities", D_{15} "environmental assets", D_{26} "major environmental accidents", and D_{20} "internal control of environmental work". If the enterprise does produce positive information related to these contents in the production process, the enterprise will generally disclose it actively for social responsibility reasons and to establish its own enterprise image. If the information is negative, the enterprise may consciously conceal it without relevant laws and regulations to force its disclosure. Therefore, the voluntariness of information disclosure will greatly affect the quality of enterprise information disclosure.

Second, as for the government's mandatory enterprise disclosure indicators, the evaluation results show that they are more quantitative but lack significance and timeliness. For instance, most enterprises in D_{11} "three waste emissions" only make quantitative disclosures of data for the current year but are not willing to pay more to optimize the quality and practicality of these data. The D_{23} "government audits" disclosure indicator is 0.00%, reflecting that the government has not played its due role in the reliability of enterprise environmental accounting information. The final evaluation results show that the level of EAID quality of thermal power enterprises is uneven, and the overall performance is poor. Enterprises with higher scores do have stronger awareness of environmental protection and environmental protection measures, but they still lack significant and timeliness in the disclosure of some key quantitative indicators, and their disclosures are relatively random.

Third, enterprises tend to voluntarily disclose information that can help them avoid taking risks and legal liabilities. D_3 "environmental laws and regulations disclosure and implementation", D_{10} "environmental policy risks", D_{21} "statement on environmental information compliance", D_{24} "third party audit", D_{25} "internal audits", etc., are well disclosed. However, the purpose of enterprises tending to disclose this information is not to improve the quality of environmental accounting information. Therefore, in addition to the compulsory disclosure by the government, some laws and regulations have also played very important roles in the negative incentives of enterprises' environmental protection. Since this paper mainly studies the related content of environmental accounting information, the legal aspects of environmental protection incentives is no longer mentioned.

An enterprise's own awareness of environmental protection is weak, and it lacks a complete and systematic environmental protection system and EAID system. Most enterprises cannot invest too much of their limited resources in environmental protection. For example, the disclosure content of "enterprise environmental policies and responsibilities" is qualitative descriptions, which can be obtained without excessive investment, but there are still many enterprises that are not involved, indicating that the overall environmental awareness is weak. Only one enterprise discloses relevant information with an independent environmental report, and few enterprises issue social responsibility reports. In the analysis of the results, it was found that the disclosure of these indicators was only mentioned sporadically in some parts of the annual reports and social responsibility reports, and they did not form a systematic disclosure system. Obtaining information requires careful reading of large annual reports, which is extremely inefficient. Enterprises have the best quantitative performance in the "three wastes emissions" indicator. The main reason is that some laws and regulations promulgated in China currently recommend or force certain polluting enterprises to disclose this information while there are fewer hard requirements for other indicators since the content is informal. Similarly, basically all enterprises' disclosure lacks comparability over time, which is very unfavorable for information users to have a full understanding of the overall level or the overall process of the enterprises' environmental protection cause, which leads to mistakes in decision-making due to information being too one-sided.

From the perspective of the government, China's current disclosure of environmental accounting information lacks normative, compulsory and relevant departmental supervision. Normative and compulsory pressures have a positive role in promoting the disclosure of enterprise environmental accounting information. The results of this study show that when enterprises disclose environmental accounting information, the disclosures lack horizontal comparability among the enterprises. When some enterprises disclose certain indicators and some enterprises disclose other indicators, it is not possible to visually compare the quality of their disclosures. If the government regulatory authorities adopt a standardized information disclosure system and actively perform regulatory functions to restrict the relevant behaviors of enterprises, enterprises will be forced by the government to improve the quality of their environmental information disclosure.

In response to the above discussion, this paper proposes the following policy recommendations for both enterprises and the government.

Enterprises should carefully study the recently-released environmental protection-related legal documents and establish an independent EAID system based on this. First, they should determine the disclosure items; the methods of surveying, recording and accounting for key quantitative disclosure items; and the form and method of these information disclosures. Furthermore, a prediction model should be established to predict future data and information should be disclosed at the same time as the current year and last year. It is recommended that enterprises not only disclose environmental accounting information in annual reports, prospectuses and social responsibility reports but also issue independent environmental reports, and appropriately release news about environmental protection-related activities and progress on the enterprise's homepage or other channels. Simultaneously, it is

recommended that enterprises establish a reasonable internal control system for environmental protection to ensure the reliability of EAID in all aspects.

The government should work with experts in related fields to determine a complete and effective EAID system, define the various contents that enterprises should disclose, clarify the specific meanings of these contents and the specific requirements for disclosure and regularly audit the information disclosed by the enterprise. In the implementation process, the system can be adjusted according to different regions, different industries, and even different times. The details should be clarified to the public. In addition to acting as the commander, the government should also play propaganda and incentive roles. First, it is necessary to publicize the importance and necessity of enterprise EAID by promulgating related documents or holding related activities. Second, it is indispensable to establish a reasonable EAID quality evaluation system. The government should regularly evaluate the quality of the information disclosed by various enterprises. By ranking and publicizing the evaluation results, enterprises with better performance can be encouraged or rewarded to encourage other enterprises to continuously improve their information disclosure quality. Meanwhile, enterprises with poor rankings will also pay more attention to environmental protection due to the protection of their enterprise image.

The results of the empirical application of the evaluation system show that the evaluation system is simple and universally applicable. For the same sample, only certain evaluation results can be obtained. These overcome human factors and have sufficient accuracy. The evaluation index comprehensively and in-depth covers the content of environmental accounting information, and, combined with the projection pursuit model, it can evaluate the comprehensive quality level of the sample and the quality level of each index. The system can not only get the evaluation result, but it can also assess the original data to analyze the cause of the result to inspire you to find a solution to the problem.

6. Conclusion

This paper evaluates and analyzes the EAID quality of the listed thermal power enterprises in China by constructing an EAID quality evaluation indicator system and projection pursuit model, and draws the following conclusions.

(1) This research enriches, completes and refines the content of the environmental accounting information evaluation system based on previous studies. To a certain extent, it improves the objectivity of the evaluation, enriches the existing literature in China, and provides a reference for enterprises and governments to evaluate EAID quality.

(2) This paper innovatively introduces a projection pursuit model based on accelerated genetic algorithms. This model can not only overcome the artificially weighted interference and restrictions on the data structure of traditional evaluation methods but also show better robustness in processing high-dimensional nonlinear data. The method has a simple structure; a clear mathematical meaning; is intuitive and easy to understand; and its subsequent application is convenient, simple and effective. In practice, it provides a reference for each discipline to solve high-dimensional problems with one-dimensional statistical methods. It is confirmed by this study that the method is suitable for evaluating EAID quality. The evaluation results are combined with the original data analysis to verify that the method's evaluation results have certain reliability.

(3) Through this research, it is found that the overall EAID quality of China's listed thermal power enterprises is poor. The main manifestation is that the enterprise's overall awareness of environmental protection is weak; there is a lack of a complete and systematic environmental protection system and EAID system; and the disclosure of key quantitative indicators lacks significance, quantitativeness and timeliness. The government lacks regulation, compulsory and relevant departmental supervision of EAID. The randomness of the information disclosure by enterprises is not conducive to information users' quick and effective access to information. In view of the above problems, this paper proposes specific suggestions from the perspectives of enterprises and the government with the goal to provide new ideas for China's environmental accounting research.

This research has enriched the literature in the field of enterprise environmental accounting and has certain referential value for evaluating enterprise EAID quality. The introduced projection pursuit model has largely overcome the subjective factors generated by the evaluation method, but it still cannot completely overcome the subjectivity brought by the content analysis method. Although this paper establishes a more complete and comprehensive evaluation index as much as possible, deeper research in this field in the future can make the evaluation index more comprehensive and the definition increasingly clearer, and the evaluation results will become increasingly more objective.

CRediT authorship contribution statement

Zhibin Liu: Conceptualization, Resources, Writing - original draft, Supervision, Funding acquisition. **Ming Liu:** Methodology, Formal analysis, Writing - original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Aerts, W., Cormier, D., Magnan, M., 2007. Corporate environmental disclosure, financial markets and the media: an international perspective. Ecol. Econ. 64, 643–659. https://doi.org/10.1016/j.ecolecon.2007.04.012, 03.

Bian, Y.W., 2009. Research status and development direction of dnvironmental performance evaluation based on DEA. Commer. Today 64–65. https://doi.org/10.3969/j.issn.1002-5863.2009.06.033, 06.

Cai, F.J., 2017. Research on Quality Evaluation of Environmental Accounting Information Disclosure of Iron and Steel. Jiangsu Univ. https://xuewen.cnki.net/CMFD-1017718112.nh.html.

Chaklader, B., Gulati, P.A., 2015. A study of corporate environmental disclosure practice of companies doing business in India. Global Bus. Rev. 16, 321–335. https://doi.org/10.1177/0972150914564430, 02.

Darrell, W., Schwartz, B.N., 1997. Environmental disclosures and public policy pressure. J. Account. Publ. Pol. 16 (2), 125–154. https://doi.org/10.1016/S0278-4254(96)00015-4.

Fu, Q., Fu, H., Wang, L.K., 2003. Study on the PPE model based on Raga to evaluating the water quality. Sci. Geogr. Sin. 23, 236–239. https://doi.org/10.3969/j.issn.1000-0690.2003.02.018, 02.

Gallego-Alvarez, I., Lozano, M.B., Rodriguez-Rosa, M., 2018. An analysis of the environmental information in international companies according to the new GRI standards. J. Clean. Prod. 182, 57–66. https://doi.org/10.1016/j.jclepro.2018.01.240.

Guo, H.J., Long, W., Zhang, D.L., 2019. Evaluation of rural revitalization based on projection pursuit model. World Agric. 12, 44–52. https://doi.org/10.13856/j.cn11-1097/s.2019.12.006.

Kong, H.G., Tang, W., 2016. Factors affecting the quality of environmental information disclosure from the perspective of stakeholders. Manag. Rev. 28, 182–193. https://doi.org/10.14120/j.cnki.cn11-5057/f.2016.09.016, 09.

Kosajan, V., Chang, M., Xiong, X.Y., Feng, Y., Wang, S.W., 2018. The design and application of a government environmental information disclosure indicator in China. J. Clean. Prod. 202, 1192–1201. https://doi.org/10.1016/j.jclepro.2018.08.056.

Kruskal, J.B., Shepard, R.N., 1974. A nonmetric variety of linear factor analysis. Psychometrika 39, 123–157. https://doi.org/10.1007/BF02291465, 02.

Li, G.P., 2016. Innovation, evaluation and enlightenment of the conceptual framework of international financial reporting. Financ. Account. Mon. (22), 90–95. https://doi.org/10.19641/j.cnki.42-1290/f.2016.22.025.

Li, Z.J., 2015. Research on evaluation method of accounting information quality. Contemp. Econ. (20), 122–123. https://doi.org/10.3969/j.issn.1007-9378.2015.20.054.

Lin, S., Li, X., Zhao, Q., 2006. Improvement of genetic algorithms in several fields of water science. Water Sci. Eng. Technol. 39–41. https://doi.org/10.19733/j.cnki.1672-9900.2006.04.017, 04.

Liu, D., Feng, J.P., Li, H., Fu, Q., Li, M., Faiz, M.A., Ali, S., Li, T.X., Khan, M.I., 2019. Spatiotemporal variation analysis of regional flood disaster resilience capability using an improved projection pursuit model based on the wind-driven optimization algorithm. J. Clean. Prod. 241, 1–16. https://doi.org/10.1016/j.jclepro.2019.118406.

Luo, W.B., Guo, X.X., Zhong, S.H., Wang, J.Z., 2019. Environmental information disclosure quality, media attention and debt financing costs: evidence from Chinese heavy polluting listed companies. J. Clean. Prod. 231, 268–277. https://doi.org/10.1016/j.jclepro.2019.05.237.

Newell, G.E., Kreuze, J.G., Newell, S.J., 1997. Hazardous waste accounting-Is your company facing possible environmental responsibility. World Environ. 26–28, 01. https://xuewen.cnki.net/CJFD-SJHJ199701010.html.

Ouyang, X.B., 2012. Research on Application of Projection Pursuit Model in Comprehensive Evaluation of “Four Modernizations”. Hunan Univ. https://xuewen.cnki.net/CMFD-1012481016.nh.html.

Patten, D.M., 1992. Intra-industry environmental disclosures in response to the alaskan oil spill: a note on legitimacy theory. Account. Org. Soc. 17, 471–475. https://doi.org/10.1016/0361-3682(92)90042-Q, 05.

Patten, D.M., Trompeter, G., 2003. Enterprise responses to political costs: an examination of the relation between environmental disclosure and earnings management. J. Account. Publ. Pol. 22 (1), 83–94. https://doi.org/10.1016/S0278-4254(02)00087-X.

Pei, W., Fu, Q., Li, T.X., Wang, P., Hou, R.J., 2019. Study of the spatiotemporal variability in agricultural drought vulnerability based on a dynamic classification projection pursuit model. Arab. J. Geosci. 12, 762. https://doi.org/10.1007/s12517-019-4949-0.

Peng, H.C., 2016. Summary and evaluation of the IASB's new financial report conceptual framework. Chin. Certif. Public Account. 48–55. https://doi.org/10.16292/j.cnki.issn1009-6345.2016.03.006, 03.

Qin, Z.Y., 2018. Research on Quality Evaluation of Environmental Accounting Information of Jiangxi Province's Heavy Polluting Listed Companies. East China Jiaotong Univ. https://xuewen.cnki.net/CMFD-1018818758.nh.html.

Ren, S.C., Feng, L.Y., 2016. Basic quality characteristics of accounting information: an interpretation based on information economics. Account. Res. (10), 9–17. https://doi.org/10.3969/j.issn.1003-2886.2016.10.002.

Ren, Y.F., 2019. Research on Evaluation of Environmental Accounting Information Disclosure Quality of Heavy Polluted Enterprises. Shandong Technol. Bus. Univ.. https://xuewen.cnki.net/CMFD-1019051484.nh.html

Shen, H.T., Huang, Z., Guo, F.R., 2014. Confess or defense? A study on the relationship between environmental performance and environmental disclosure. Nankai Bus. Rev. 17, 56–63+73. https://doi.org/10.3969/j.issn.1008-3448.2014.02.007, 02.

Shi, H.J., 2018. Application of comprehensive evaluation for college students' employment platform on user projection pursuit model. Mod. Inf. Technol. (10), 15–17+20. https://doi.org/10.3969/j.issn.2096-4706.2018.10.006, 02.

Su, Q., Yu, Y.Q., 2018. Research on evaluation of enterprise sustainable development capability based on accelerated genetic algorithm projection pursuit model. Oper. Res. Manag. Sci. 27, 130–139, 05. https://xuewen.cnki.net/CJFD-YCGL201805017.html.

Wang, J.L., Zhang, Z.Y., 2018. Research on improving the environmental accounting information disclosure of Chinese enterprises——thinking of the Zijin mining pollution gate incident. Rural Econ. Sci.Technol. 29, 55–57, 01. https://xuewen.cnki.net/CJFD-NCJI201801020.html.

Wang, J.M., 2008. Research on the correlation among environmental information disclosure, industry differences and supervisory system. Account. Res. 54–62. https://doi.org/10.3969/j.issn.1003-2886.2008.06.006, 06.

Wang, X.L., Liu, S.X., Yang, W.J., 2018. Soil quality evaluation based on particle swarm projection pursuit interpolation model. J. Univ. Jinan (Sci. Technol.). 32, 223–226. https://doi.org/10.13349/j.cnki.jdxbn.2018.03.009, 03.

Wen, L., Huang, L.L., 2019. Analysis of influencing factors of Chinese provincial carbon emissions based on projection pursuit model and markov transfer matrix. Int. J. Clim. Chang. Strateg. Manag. 11, 406–423. https://doi.org/10.1108/IJCCSM-05-2017-0116, 03.

Wu, M.T., Liu, Y., Shi, Y., 2012. Evaluation of enterprise accounting information quality based on projection pursuit model. J. Liaoning Tech. Univ. 14, 383–385, 04. https://xuewen.cnki.net/CJFD-NLGC201204013.html.

Xie, B.S., 2013. Research on Accounting Information Disclosure and Quality of Listed Companies' Forest Assets. Fujian Agric. For. Univ. https://xuewen.cnki.net/CMFD-2005125513.nh.html.

Yao, J.Q., 2019. Research on the Operating Performance of china's Retail Listed Companies. Xi'an Univ. Sci. Technol. https://xuewen.cnki.net/CMFD-1019618442.nh.html.

Zhao, Z.J., Wang, X.M., Wen, X.Y., 2017. Quality evaluation of isatidis radix from different ecotypes by projection pursuit model. Chin. J. Inf. Tradit. Chin. Med. 24, 91–94, 05. 10.3969/j.issn.1005-5304.2017.05.021.