Research on Green Governance Evaluation of Mining Industry Based on Entropy Weight TOPSIS Method

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Abstract. With the rapid development of society, Chinese enterprises have achieved great success, but there are still many deficiencies in green governance. In this study, some listed mining companies were taken as the research object, and the evaluation index of green governance was constructed, and the entropy weight TOPSIS method was used to analyze the green governance ability. The results of the study show that there are great differences in the green governance of different companies.

Keywords: Mining industry; Green governance; Entropy weight TOPSIS method

1 INTRODUCTION

The 19th Party Congress report puts forward the basic strategy of "insisting on the harmonious coexistence of human beings and nature", to achieve the development of human beings and nature, it is necessary to form a new "unity of man and nature" view of green governance [1]. Green governance is to build an ecological civilization, to achieve green sustainable development as the goal, by the participation of the governance body, governance means of implementation and governance mechanism synergistic "public affairs activities" [2], is forward-looking, strategic and participatory integration of natural resources into an effective means of sustainable management [3], can promote the green enterprise and low-carbon development. As a heavily polluting industry, the development of the mining industry must face the enormous pressure of environmental protection and sustainable development. In this context, the mining industry needs to vigorously promote green governance and green sustainable development. To this end, this paper evaluates the green governance level of companies in the mining industry, identifies and solves problems, and incentivises companies to strengthen environmental protection and promote green development. Taking 2022 Chinese A-share listed companies in the mining industry as a research sample, this paper constructs a green governance evaluation index system applicable to companies in

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the mining industry, and evaluates and analyses the green governance level of mining companies using the entropy weight method combined with the TOPSIS method.

2 ESTABLISHMENT OF A GREEN GOVERNANCE EVALUATION INDEX SYSTEM FOR THE MINING INDUSTRY

The construction of evaluation index system is a key link in green governance evaluation research, and plays a crucial role in the comprehensive evaluation of the level of corporate green governance. Based on this, this paper draws on the research results of previous researchers [4,5], refers to authoritative standards and policy documents such as the ISO14031 standard developed by the International Organisation for Standardisation (ISO) and the Guidelines for Environmental Information Disclosure of Listed Companies issued by the Ministry of Environmental Protection (MEP) in 2010, and follows the principles of scientificity, comprehensiveness, and feasibility, etc., to establish a green governance evaluation index system (see Table 1), which can accurately reflect the level of green governance of an enterprise.

Table 1. Green governance evaluation index system

Objective indicator	Primary indicators	Secondary indicators	polarity	weight
X Green governance level	X1 Green governance system	X11 Green ideology	+	2.36%
		X12 Green governance organizational	+	6.92%
		X13 Environmental protection man-	+	2.99%
		X14 Employee environmental educa-	+	7.37%
		X15 Green publicity	+	6.94%
	X2 Green production and operation	X21 Clean production	+	2.75%
		X22 Green procurement	+	11.97%
		X23 Green innovation	+	6.28%
		X24 Green performance assessment	+	9.35%
	X3 Green environmental performance	X31 Magnitude of environmental	+	0.61%
		X32 Penalty amount for corporate en-	-	0.98%
		X33 Measures and impacts pertaining	+	1.47%
		X34 Measures and impacts related to	+	2.04%
		X35 Compliance with pollutant emis-	+	1.70%
		X36 Discharge permits and environ-	+	1.84%
		X37 Treatment of pollutants and haz-	+	1.73%
		X38 Waste recycling	+	2.77%
		X39 Natural resource use and conser-	+	4.37%
		X41 Disclosure of environmental vio-	+	0.36%

X4 Green information disclosure	X42 Disclosure of pollutant emissions	+	1.37%
	X43 Disclosure of energy efficiency	+	5.33%
	X44 Stakeholder communication	+	5.60%
X5 Green regulatory mechanism	X51 Emergency preparedness plan	+	1.46%
	X52 Environmental self-monitoring	+	1.59%
	X53 Establishment and operation of environmental protection equipment	+	4.94%
	X54 Environmental monitoring and accountability mechanisms	+	4.94%

3 RESEARCH METHODS

In this paper, entropy weight TOPSIS method is used as the research method and the evaluation steps are as follows:

With m evaluation companies and n evaluation indicators, X_{ij} represents the raw data of the jth indicator in the ith evaluation company (i=1, 2,..., m; j=1, 2,..., n).

① Data standardisation:

To ensure the accuracy of green governance evaluation, the indicators are divided into positive and negative categories: the larger the value of positive indicators, the higher the level of green governance, and vice versa. The evaluation process needs to standardise these indicators to eliminate the problem of non-uniformity of scale and unit [6-7], see equation (1) and (2).

Positive indicators:

$$y_{ij} = \frac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} \tag{1}$$

Negative indicators:

$$y_{ij} = \frac{x_{j\max} - x_{ij}}{x_{j\max} - x_{j\min}} \tag{2}$$

where y_{ij} represents the standardized value of the *j*th evaluation indicator for the *i*th evaluation company; $x_{j\max}$ and $x_{j\min}$ denote the maximum and minimum values of the raw data for evaluation indicator *j*.

② Calculation of information entropy:

$$e_j = -k \sum_{i=1}^{m} (p_{ij} \ln p_{ij}) \tag{3}$$

where $p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{m} Y_{ij}}$, represents the weight of the value of the *i*th evaluation company indicator at the *j*th indicator; $k = \frac{1}{\ln m}$.

③ Calculation of the indicator's entropy weight:

$$w_j = \frac{1-e_j}{\sum_{j=1}^{n}(1-e_j)} \tag{4}$$

where $1-e_j$ represents the information utility value; $w_j \in [0,1]$, $\Sigma_{j=1}^{n} w_j = 1$.

④ Construction of weighted decision matrix:

$$Z = (z_{ij})_{m\times n}, \ (z_{ij}) = w_j y_{ij} \tag{5}$$

⑤ Calculating the positive ideal solution and negative ideal solution for each indicator:

$$Z_j^+ = \max\left(z_{1j}, z_{2j}, \ldots, z_{nj}\right) \tag{6}$$

$$Z_j^- = \min\left(z_{1j}, z_{2j}, \ldots, z_{nj}\right) \tag{7}$$

⑥ Calculating the Euclidean distance between each evaluation company and the positive ideal solution and negative ideal solution:

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(z_{ij} - z_j^+\right)^2} \tag{8}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}\left(z_{ij} - z_j^-\right)^2} \tag{9}$$

⑦ Calculating the relative proximity of each evaluation company:

$$C_i = \frac{d_i^-}{d_i^- + d_i^+}, \ C_i \in [0,1] \tag{10}$$

The higher the relative proximity C_i the higher the level of green governance of the evaluation company, and vice versa.

4 EMPIRICAL RESEARCH

4.1 Samples and Data

This paper selects Chinese A-share listed companies in the mining industry in 2022 as the research sample, excludes ST, *ST companies and sample companies with missing data values, and finally obtains 61 companies with 1586 valid observations. Data sources include annual reports, social responsibility reports, and social and governance (ESG) reports disclosed by listed companies in the mining industry.

4.2 Assignment of Secondary Indicators

The secondary indicators in the green governance evaluation index system are divided into two categories of qualitative and quantitative by nature. Referring to the study of Huang Lianqin et al. [4], the qualitative indicators are scored by content analysis method and scale scoring method, and four levels of scoring are carried out according

to the exhaustiveness of green governance information disclosed by the company. For example, the scoring criteria for the "green design and clean production" indicator are as follows: 0 points for no disclosure, 1 point for non-specific disclosure of measures, 2 points for specific disclosure of measures or effects, and 3 points for quantitative data proving significant effects. For quantitative indicators, the natural logarithm of the raw data is taken to reduce data discrepancies.

4.3 Valuation Results

Firstly, the raw data of the green governance evaluation index system of each evaluation company is obtained by scoring and assigning values to each secondary index; secondly, the weights of each secondary index are calculated using entropy weighting method according to formula (1) to formula (4) (see Table 1); lastly, the relative closeness of each evaluation company is calculated and ranked in descending order using TOPSIS method according to formula (5) to formula (10) to obtain the mining Ranking of green governance level of listed companies in the industry (see Table 2).

Table 2. Green governance level ranking

Stock sym-	C_i	Rank	Stock	C_i	Rank	Stock	C_i	Rank
601857	0.8712	1	601958	0.40	22	600968	0.28	43
600028	0.8229	2	601168	0.39	23	600339	0.27	44
601088	0.7881	3	600971	0.39	24	000603	0.25	45
600497	0.7870	4	603993	0.38	25	600871	0.24	46
600547	0.7134	5	000655	0.38	26	000426	0.23	47
600256	0.7129	6	002683	0.38	27	600777	0.23	48
600489	0.6883	7	002554	0.37	28	603619	0.23	49
002128	0.5991	8	000923	0.36	29	603727	0.23	50
600259	0.5907	9	605086	0.36	30	601899	0.23	51
601898	0.5899	10	001203	0.36	31	000688	0.22	52
000762	0.5815	11	600123	0.35	32	601001	0.22	53
601666	0.5575	12	601969	0.35	33	600988	0.22	54
600188	0.5501	13	600338	0.35	34	600395	0.19	55
000758	0.5342	14	600508	0.35	35	600121	0.16	56
601225	0.5265	15	603505	0.34	36	000975	0.16	57
601699	0.5116	16	002155	0.32	37	000983	0.14	58
601101	0.5068	17	600397	0.32	38	000968	0.14	59
601918	0.4840	18	600583	0.31	39	000506	0.10	60
000552	0.4786	19	601808	0.29	40	300483	0.08	61
600348	0.4518	20	600711	0.28	41			
600985	0.4122	21	601069	0.28	42			

4.4 Results Analysis

General Analysis of Green Governance in the Mining Industry. The comprehensive analysis results of the green governance level in the mining industry can be found in Table 3. The mean value of the relative proximity of green governance level among publicly listed mining companies is 0.3950, with a median of 0.3617. Consequently, it is evident that the overall green governance level in the mining industry is relatively low, with a majority of companies exhibiting green governance levels below the average, signifying significant potential for improvement. Furthermore, the range is 0.7819, and the standard deviation is 0.1862, indicating substantial variations in the performance of mining companies in terms of green governance.

Table 3. Descriptive statistics for each dimension of green governance level

Indicators	Mean value	Maximum value	Minimum value	Standard deviation	Range	Median
X	0.3950	0.8712	0.0893	0.1862	0.7819	0.3617
X1	0.3999	0.9270	0.0583	0.2548	0.8687	0.3333
X2	0.3194	1.0000	0.0525	0.2160	0.9475	0.2720
X3	0.5876	0.9781	0.1521	0.2033	0.8260	0.6030
X4	0.4462	1.0000	0.0299	0.2489	0.9701	0.5036
X5	0.4588	1.000	0.0630	0.2155	0.9370	0.5131

Analysis of Green Governance Dimensions in the Mining Industry. Based on the data presented in Table 3, it is evident that listed companies within the mining industry exhibit commendable performance in the dimension of green environmental practices. The average proximity value for this dimension is remarkably high, standing at 0.5876, surpassing other dimensions significantly. This underscores the substantial investments made by mining companies in environmental protection governance, along with the effective measures implemented to address pollutants and promote energy conservation and emission reduction. As for the dimensions of green regulatory mechanism and information disclosure, their mean proximity values are moderately rated at 0.4588 and 0.4462, respectively, indicating a satisfactory overall performance. However, the dimensions of green governance system and production and operation display relatively lower proximity values, measuring 0.3999 and 0.3194, respectively. This indicates an insufficiency in the establishment of a comprehensive green governance system and the failure to integrate the concept of green governance across all aspects of production and operation. Therefore, it is imperative to intensify efforts regarding the construction of these two dimensions to foster the green and sustainable development of the mining industry.

Analysis of the Nature of Property Rights for Green Governance in the Mining Industry. The outcomes of the analysis regarding the nature of property rights pertaining to green governance in the mining industry are illustrated in Table 4. On the whole, among the listed companies operating within the mining industry, central enterprises exhibit the most elevated degree of green governance, as evidenced by an average relative proximity of 0.4613, surpassing other enterprises. Local state-owned enterprises and private enterprises, demonstrate comparable levels of green governance, with respective average relative proximity values of 0.3751 and 0.3591.

Table 4. Descriptive statistics on the nature of green governance property rights in the mining industry

Property ownership	proportions	Mean value	Maximum value	Minimum value	Standard deviation	Range	Median
Central enterprises	26.23%	0.4613	0.8712	0.2438	0.1647	0.6273	0.3957
Local state-owned enterprises	44.26%	0.3751	0.7134	0.1427	0.1468	0.5708	0.3588
private enterprises	29.51%	0.3591	0.7129	0.0893	0.1470	0.6236	0.3548

Regional Analysis of Green Governance of Listed Companies in the Mining Industry. The outcomes of the regional analysis pertaining to the green governance of mining industry listed companies are elaborated upon in Table 5. The registered locations of the assessed companies are categorized into the eastern, central, and western regions based on their respective regions, aiming to delve into the regional disparities in the level of green governance among the aforementioned industry's listed companies. On the whole, the eastern region boasts the highest number of listed companies within the mining industry as well as the most elevated level of green governance, reflected by an average relative proximity of 0.3950. Following closely behind is the western region, showcasing a comparable proximity of 0.3912 to that of the eastern region. In contrast, the central region exhibits the lowest level of green governance, evidenced by a mere average proximity of 0.3365, thereby necessitating amplified investment in green governance.

Table 5. Regional descriptive statistics of green governance for listed companies in the mining industry

Region	proportions	Mean value	Maximum value	Minimum value	Standard deviation	Range	Median
Eastern region	49.18%	0.3950	0.8712	0.0893	0.1847	0.7819	0.3617
Central Region	26.23%	0.3365	0.5575	0.1427	0.1099	0.4148	0.3494
Western Region	24.59%	0.3912	0.7870	0.1661	0.1498	0.1307	0.3633

5 CONCLUSIONS AND RESPONSES

5.1 Conclusion

This paper takes 2022 Chinese A-share listed companies in the mining industry as the research sample, and uses entropy weight TOPSIS method to construct green governance evaluation index system to comprehensively evaluate the level of green governance of China's mining industry companies, and the research conclusions are as follows:

(1) The overall level of listed companies in the mining industry in terms of green governance is not high, and there exists a large space for improvement and inter-firm differences. Specifically, the median of the relative closeness of green governance level is only 0.3617, which is lower than the average value of 0.3950, reflecting that the green governance performance of most companies is not up to standard. In addition, the extreme difference in the relative proximity of green governance levels is as high as 0.7819, highlighting the significant differences in green governance performance between different companies.

(2) The study reveals that mining companies perform differently in different aspects of green governance, especially in terms of relatively better environmental performance and weaker in terms of governance system and production operations. Some companies neglected the construction of environmental protection equipment and environmental monitoring, and had insufficient information disclosure and stakeholder communication, while not investing enough in employees' environmental education and green awareness campaigns, and lacked green purchasing and performance appraisal systems.

(3) Mining companies perform well on mandatory requirements for green governance, but not on non-mandatory requirements. This paper finds that mining companies perform well in mandatory requirements stipulated by policies and regulations, such as clean production, disclosure of emissions information, and disclosure of corporate environmental violations and penalties, while they perform poorly in non-mandatory requirements, such as green procurement, employee environmental education and training, and stakeholder communication.

(4) The level of green governance in mining companies is heterogeneous according to the nature of ownership. Specifically, central enterprises have the best performance in green governance, and their green governance level is relatively high. Local SOEs and private enterprises are relatively close to each other in terms of green governance level, but there is a large gap compared to central enterprises.

(5) There is heterogeneity in the green governance level of mining companies according to the region they belong to. Mining companies in the eastern region have the largest number of listed companies in the mining industry and have the best green governance level, followed by those in the western region, while mining companies in the central region perform relatively poorly in terms of green governance.

5.2 Recommendations

Based on the above findings, the following recommendations are proposed to improve the green governance level of the mining industry:

(1) Enhance the awareness of green governance and system construction: Mining companies need to enhance the awareness of green governance, establish clear green governance objectives and sustainable development strategies, improve the organisational structure, and strengthen employee training and green publicity.

(2) Incorporate green governance concepts into the whole process of production and operation: In view of the poor performance of production and operation, mining companies should increase the introduction and application of green technology, improve green performance assessment, and promote clean production and efficient use of resources.

(3) Strengthen green governance supervision and accountability: establish a comprehensive internal audit and monitoring system, regularly assess the implementation of green governance, and encourage third-party assessment, and implement accountability measures for companies that fail to meet the standards.

(4) Promote intra-industry cooperation and exchanges: Given the differences in green governance levels, intra-industry cooperation and experience sharing should be strengthened.

(5) Implementing differentiated management: Considering the nature of property rights and regional differences, differentiated management should be carried out to improve the green governance policies of central enterprises, strengthen the supervision and support of local enterprises, and formulate green governance strategies based on regional characteristics.

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