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Combined evaluation of corporate ecological and environmental responsibility: Evidence for forest preservation from Chinese forestry companies

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The ecological benefit of forest has an important influence on the sustainable development of society, thus, forest management has become a critical strategic action. Forest preservation is an inclusive process which depends on collaboration among a wide range of stakeholders. Forestry companies, who own and manage forest resources, are responsible for forest preservation and ecological construction, which is called corporate ecological environmental responsibility (CEER). Most existing analyses, however, were limited to corporate environmental responsibility (CER) and ignored the ecological responsibility of forestry enterprises. Therefore, in order to better play the role of forestry companies in forest preservation, it is urgent to define the content and the measurement of CEER. This paper established a CEER index system based on the characteristics of forestry enterprises. Furthermore, evaluated the CEER level of forestry enterprises using the combined evaluation method based on the GINI criterion, which is more effective and reasonable. It is found that forestry ecological environmental responsibility emphasizes ecological improvement and has shifted from traditional environmental protection to ecological construction. Qingshan Paper, Sun Paper, and Yong'an Forestry perform the best in CEER among all forestry companies. In addition, the results showed a low level but an obvious upward trend in forestry CEER and a noticeable heterogeneity in the performance of CEER in different forestry industries. Our findings can be useful for further promoting the ecological benefits of forest companies and developing relevant policies.

KEYWORDS

forest preservation, corporate ecological environmental responsibility, combined evaluation, forestry companies, carbon neutrality

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1. Introduction

With the deepening of green development, people pay more attention to ecological environmental protection. China has actively promoted green development and pledged to achieve carbon neutrality by 2060 to address climate change. Forests are the earth's lungs, the largest carbon storage and oxygen generator on land. Forest carbon sequestration is one of the most cost-effective ways to address climate change. China's total forest carbon storage has reached 9.2 billion tons and is still increasing yearly. In the context of carbon neutrality, the role of forestry becomes even more prominent (Wang et al., 2022). Forest is crucial for maintaining climate and ecological security and has been promoted to a strategic height concerning human survival and development, future, and destiny. Benefiting from the right to manage forest resources, forestry enterprises are a particular organization that can obtain economic, social, and ecological benefits from their management activities (Sui and Zhang, 2012). Thus, due to the ownership and management of forest resources, enterprises in the forestry industry should combine their advantages in green resources, give full play to its role in forest preservation, and actively fulfill ecological environmental responsibilities.

Achieving carbon neutrality requires joint efforts, of which "emission reduction" and "carbon sequestration" are the two main approaches. "Emission reduction" refers to the industrial sector's efforts to improve resource efficiency and energy consumption to reduce carbon dioxide emissions. "Carbon sequestration" is to increase the absorption of carbon dioxide by protecting forests, grasslands, and wetlands (Chen et al., 2022). Common enterprises mainly manage climate change through "emission reduction." In contrast, forestry enterprises can do it through "carbon sequestration" in addition to "emission reduction." Therefore, forestry enterprises also bear the responsibility of forestry ecological construction other than environmental protection for common enterprises. It should be noted that environmental protection and forestry ecological construction are two different measures. The former is to reduce the negative externality of business activities by reducing pollution and environmental damage. However, the latter requires further improvement in the ecological environment to increase the positive externality of forestry management (Zhang, 2021). Thus, forestry enterprises shoulder a special mission in ecological construction. The responsibilities of forestry enterprises for environmental and forest preservation should include green procurement policies, sustainable forest activities, ecological efficiency improvement, and renewable materials, emphasizing the impact on forest and ecosystem services (D'Amato et al., 2015).

It is normal to refer to the responsibility of environmental protection when discussing corporate environmental responsibility. However, its content is mainly limited to energy conservation, emission reduction, and clean production, ignoring the ecological responsibility of forest resources protection and ecological restoration of forestry enterprises. To be precise, forestry enterprises' environmental responsibility should be called "corporate ecological environmental responsibility (CEER)" rather than a simple "corporate environmental responsibility (CER)." In order to better play the role of forestry enterprises in forest preservation and ecological environment protection, questions such as the content of forestry CEER and how to measure and evaluate it deserves urgent discussion.

The research analyzed the content of CEER based on the particularity of forestry enterprises, constructed the CEER evaluation index system based on the natural resource-based view, and then evaluated the forestry CEER using a more robust combined evaluation method. Possible contributions of this paper are: (1) The research focused on a particular environmental responsibility of forestry enterprises, namely ecological environmental responsibility. Based on the characteristics of the forestry industry, a CEER index system was constructed, which enriched the existing research results. (2) A new evaluation method, the combined evaluation method based on the GINI criterion, was adopted to evaluate the ecological environmental responsibility of forestry enterprises, which avoided the data fluctuation caused by a single evaluation method, and made the evaluation more effective and reasonable.

The remainder of this study is arranged as follows. Section 2 is devoted to the literature review. Section 3 elaborates on the research method. Section 4 describes the empirical research design, including data source and index construction. Section 5 outlines the empirical results. Section 6 shows the further discussion of the empirical results, while Section 7 presents the conclusions and limitations.

2. Literature review

2.1. Definition of environmental responsibility

Our environment largely depends on the exploitation of natural resources by companies. Their operation often leads to air pollution, water pollution, soil loss, and other environmental issues. As a result, companies must undertake social responsibilities because the environment is a public resource. To improve environmental sustainability, companies must be responsible for environmental problems and completely disclose environmental information in financial statements in an accurate, timely manner (Long et al., 2022). The rollout of the concept of CER has emphasized the environmental responsibilities undertaken by all companies (Cohen et al., 2013). However, researchers seem to be more concerned about the environmental responsibility of polluting companies. CER is defined as any precautions and policies corporations apply to reduce environmental damage (Sarmento et al., 2005). Carroll (1979) believes that environmental responsibility is a part of social responsibility. Corporate social responsibility (CSR) can be divided into economic, legal, ethical, and conscious responsibility, while environmental protection, charitable donation, and employment support are involved in conscious responsibility. Enderle and Tavis (1998) proposed a corporation concept that is based on the responsibility to balance economic, social, and environmental responsibilities. Some scholars define CER as the environmentally friendly behavior of enterprises beyond the requirements of laws and regulations (Lyon and Maxwell, 2008). The broader definition of CER refers to the companies' behavior in managing the relationship between business activities and the natural environment (Aragón-Correa and Sharma, 2003).

As for forestry enterprises, most existing literature focuses on their social responsibility, and only a handful of research directly focuses on environmental responsibility. For example, Li and Gao (2019) found that forestry CSR is closely related to company scale, industry, ownership, and forest resources. Lu et al. (2017) found that the CSR of forestry enterprises was positively correlated with firm size and equity concentration but had no significant relation with profitability and financial leverage. However, from the forestry CSR priority, the main content of forestry CSR emphasizes environmental responsibility rather than social responsibility due to its direct and high impact on the natural environment (Nowak, 2006). Even though forestry enterprises fulfilled their social responsibilities, their social influences are often overlooked due to their environmental impacts (Kärnä et al., 2003). The focus of forestry CSR lies not only on contributing to social resource redistribution but also on balancing the relationship between profit gains and the sustainable development of the ecological environment (Toppinen and Korhonen-Kurki, 2013). Li and Toppinen (2011) believe that forestry enterprises would be selective in social responsibility content to report, with more environmental indicators than economic or social ones. Vidal and Kozak (2008) analyzed the social responsibility content of forestry companies and found that the most frequently mentioned responsibility was sustainable forest management, followed by accounting, employment, recycling, and forest. Although many scholars are aware of the importance of the environmental responsibility of forestry enterprises, few directly study it.

2.2. Evaluation of environmental responsibility

The existing evaluation methods of CER or CSR are divided into two categories. The first is the content analysis method, which assigns values according to the information disclosed to evaluate the enterprise's environmental (social) responsibility level. Li and Gao (2019) applied this method to evaluate the social responsibility of forestry enterprises. To evaluate environmental responsibility, he designed 10 contents, including pollution control, environmental restoration, recycling, and environmental products (Vidal and Kozak, 2008). Content analysis can transform qualitative information into quantitative data for analysis. However, it could be limited by the information disclosure, as the responsibility might be fulfilled but not yet disclosed.

Another evaluation is index analysis, constructing indexes for quantitative analysis. To meet two policy objectives of environmental health and ecosystem vitality, Pinar (2022) set up 32 environmental performance indicators, including climate change, pollution emission, and waste management. Li et al. (2021) proposed a time-based entropy method that can evaluate long-term changes in CSR and consider a company's static and dynamic aspects. Regarding the environmental responsibility of CSR, "urban maintenance and construction tax" was chosen as the measurement index for analysis (Li et al., 2021). Wang Y. L. et al. (2020) selected energy saving and intelligent operation management, water resource management, waste management, and air pollution prevention to measure the environmental responsibility of forestry enterprises. Index analysis requires objective comprehensiveness of indicators and data availability.

Index analysis has a major problem, the balance of index weight. Two main methods for assigning index weight are the subjective and the objective weighting methods. The typical subjective methods include the analytic hierarchy process, comprehensive scoring, and fuzzy evaluation method. Li et al. (2020) proposed an improved analytic hierarchy process-back propagation (AHP-BP) neural network algorithm to evaluate companies' CSR performance, and results showed that this improved AHP-BP neural network model could effectively estimate CSR performance. Ni et al. (2019) established a green index system and quantitatively evaluated the environmental quality of Guizhou geological parks based on the fuzzy comprehensive evaluation system. The subjective method can determine the importance of the evaluation index according to expert experience. However, human factors greatly influence the weight and cannot objectively reflect the index data information.

The objective weighting methods determine the weight of indexes by comparing the data information of different evaluation objects, which is not affected by human factors. The evaluation results are more objectively compared with subjective methods. Therefore, it has been extensively used at present. Common objective weighting methods include the entropy weight method, the technique for order preference by similarity to an ideal solution (TOPSIS) method, the coefficient of variation (CV) method, the criteria importance through intercriteria correlation (CRITIC) method, and the structural equation model. Considering the heterogeneity of stakeholders in the fuzzy environment, Yi et al. (2022) established a TOPSIS evaluation framework based on an internal type-2 trapezoidal fuzzy numbers (IT2TrFN) analytical hierarchy process. The author later evaluated the CSR performance of listed companies in 2017–2018. Aiming to investigate the employees' recognition level of CSR in companies, Stojanović et al. (2021) set CSR criteria indicators through five dimensions and determined the criteria weights using the entropy method. Yalcin and Ünlü (2018) evaluated the performance of initial public offering (IPO) firms using multiple measures and then used the CRITIC method to evaluate and rank IPOs' performances.

However, different evaluation methods are based on different principles and require different information, which may lead to different evaluation results. Some scholars put forward the idea of a combined evaluation. Wang W. et al. (2020) insisted that single method evaluation will lead to inconsistent results and proposed a combined evaluation method based on seven individual methods to assess the risk of comprehensive urban disasters. When evaluating the benefit of transnational power networking projects, Zhao et al. (2019) combined the order relation method and the GINI coefficient method to synthesize subjective and objective information. Fang and Song (2019) proposed an objective combined evaluation method based on the GINI criterion, combining five single evaluation methods, such as the entropy weight method and TOPSIS, using their results to evaluate the technological innovation ability of enterprises.

2.3. Literature summary

It can be seen that the current research on environmental responsibility has made some progress, but there are still limitations:

From the perspective of environmental responsibility content, almost all existing studies implicitly regard enterprises as "the source of pollution" (Liu et al., 2021; Jiang et al., 2022). Thus the CER content is tied up with "pollution mitigation" (Yang, 2012), and the study object focuses on heavy pollution industries with negative externalities, such as steel, food processing, and mineral industries(Kovalevsky et al., 2018; Chen et al., 2020). Forestry is a particular industry that integrates economic, ecological and social benefits. As Senko pointed out, day-to-day forestry operations may have significant implications for the sustainable development of forests (Senko and Pykäläinen, 2020), so their environmental responsibility must be different from ordinary enterprises (Sharma and Henriques, 2005). Unfortunately, the existing research failed to pay attention to the positive environmental externalities of forestry enterprises, making the definition of CER less comprehensive.

In terms of environmental responsibility evaluation methods, on the one hand, the content analysis method was frequently used, while the index analysis was less used. However, the content analysis method does not apply to CER because the level of CER disclosure is generally low in China (Lu and Abeysekera, 2014). In addition, there is a discrepancy between the disclosure statements and the environmental performance of enterprises. Thus, the environmental responsibility level cannot be measured by the content of corporate disclosure alone (Acar and Temiz, 2020). On the other hand, the objective weighting method is widely used when adopting the index analysis method. However, previous literature used a single method to distribute each index's weight. Different evaluation mechanisms make the evaluation results of different methods on the same problem biased (Xu et al., 2019). The combined evaluation method can fully use more information and has stronger stability because the data fluctuation caused by a single method is smoothed (Zhang et al., 2016). It is verified that the combination idea can obtain high convergence and credibility evaluation results and solve the problem of inconsistent evaluation results of different methods (Li et al., 2018). Regrettably, the combined method has not been applied to CER.

In order to solve the above problems, this paper focused on the particularity of forestry enterprises, analyzed the content of CEER and constructed the CEER evaluation index system based on the natural resource-based view. By using a more robust combined evaluation method, this paper evaluated the CEER level of forestry enterprises and found an upward trend in forestry CEER and a noticeable heterogeneity in the performance of CEER in different forestry industries.

3. Research method

Given the different importance of each indicator, different weights should be given to these specific indicators when constructing the index system to evaluate the forestry CEER. Considering that the subjective weighting method is highly arbitrary as it depends on personal experiences, the objective weighting method was chosen according to the conventional practice. In this paper, the combined evaluation method was adopted to avoid the deviating results caused by the abnormal weight of individual indicators with a single method. The basic idea of the combined evaluation is to combine the results of single methods with appropriate ways to obtain the integrated value. Fang and Song (2019) proposed an objective combined evaluation method based on the GINI criterion, and it is more effective than other combined evaluation methods, including the average value, Borda, and Copeland. In this paper, the method was applied to evaluate CEER. Specifically, single evaluation methods such as entropy weight, CRITIC, and CV were first used to evaluate forestry enterprises' CEER. These single evaluation results were combined to obtain a completed evaluation result of CEER by applying the combined evaluation method based on the GINI criterion.

3.1. Single evaluation methods

Suppose there are m sample enterprises and n evaluation indexes, X_{ij} is the value of index j of enterprise i, and the original matrix is $A = (x_{ij})_{m \times n}$. In order to eliminate the influence of different measurements on evaluation results, it is necessary to standardize each index and get a standardized matrix $A = (y_{ij})_{m \times n}$, the maximum value of the standardized index is 1, and the minimum value is 0.

Standardization formula of positive index

$$y_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (1)$$

Standardization formula of negative index

$$y_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}} \quad (2)$$

Where, x_{ij} represents the index j's value of enterprise i, represents the maximum value of index j, and represents the minimum value of index j.

3.1.1. Entropy weight method

The concept of entropy originated from thermodynamics and was later introduced into information theory. Information entropy can reflect the degree of indicators' variation, thereby making a comprehensive evaluation. The greater the gap between the indicators, the greater the information provided by the indicator, and the greater the role it plays in the comprehensive evaluation, so does the weight. Otherwise, the smaller the weight. The calculation of entropy weight is usually divided into the following steps:

(1) Calculate the relative proportion, denoted as p_{ij} ;

$$p_{ij} = y_{ij} \div \sum_{i=1}^{m} y_{ij} \quad (3)$$

Where, y_{ij} is the standardized value of index j of enterprise i, and m is the number of sample enterprises.

(2) Calculate the entropy value of index j, denoted as E_j ;

$$E_j = -\frac{1}{\ln m} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \quad (4)$$

Where, p_{ij} is the relative proportion of the enterprise i in index j.

(3) Calculate the entropy weight of each index, denoted as w_j ;

$$w_j = \frac{1 - E_j}{n - \sum_{j=1}^{n} E_j} \quad (5)$$

Where, E_j is the entropy value of index j, and n is the total number of evaluation indexes.

3.1.2. CRITIC method

CRITIC (criteria importance through intercriteria correlation) method is an objective weighting method proposed by Diakoulaki et al. (1995). The core idea of CRITIC lies in two indicators, volatility (contrast intensity) and conflict (correlation). The volatility is represented by standard deviation; the larger the standard deviation of the data, the greater the fluctuation and the higher the weight. The conflict is represented by the correlation coefficient; the larger the correlation value between indicators, the smaller the conflict, and the lower the weight. The calculation steps of CRITIC weight are as follows:

(1) Calculate the volatility of index j, denoted as S_j ;

$$S_j = \sqrt{\frac{\sum_{i=1}^{m} \left(y_{ij} - \bar{y}_j\right)^2}{m - 1}} \quad (6)$$

Where, $\bar{y}_j$ is the mean of index j of all enterprises.

(2) Calculate the conflict of index j, denoted as A_j ;

$$A_j = \sum_{k=1}^{n} \left(1 - r_{kj}\right) \quad (7)$$

Where r_{kj} represents the correlation coefficient between index k and index j.

(3) Calculate the information content of index j, denoted as C_j ;

$$C_j = S_j \times A_j \quad (8)$$

Where, S_j is the volatility of index j, and A_j is the conflict of index j.

(4) Calculate the weight of index j, denoted as w_j ;

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \quad (9)$$

Where, C_j is the information content of index j.

3.1.3. CV method

The CV method assigns weight to each index according to the degree of variation of each index. A significant index CV indicates that the index has rich discriminative information and can clearly distinguish the evaluated objects, so the index should be assigned a greater weight. Otherwise, the index obtains a smaller weight. The CV is calculated by the mean and standard deviation of the index, and the calculation of weight is as follows:

(1) Calculate the CV of the evaluation index j, denoted as v_j ;

$$v_j = \frac{S_j}{\bar{\bar{y}}_j} \quad (10)$$

Where, S_j is the standard deviation of the index j, $\bar{y}_j$ is the mean of index j.

(2) Calculate the weight of each indicator, denoted as w_j;

$$w_j = \frac{v_j}{\sum_{j=1}^{n} v_j} \tag{11}$$

Where, v_j is the CV of index j.

After obtaining the index weight of a single evaluation method, the evaluation result of the ith enterprise can be calculated as follows:

$$Y_i = \sum_{j=1}^{n} w_j y_{ij} \tag{12}$$

Where, w_j is the weight of index j, and y_{ij} is the standardized value of index j of enterprise i.

3.2. Combined evaluation based on GINI criterion

Fang and Song (2019) proposed an objective combined evaluation method based on the GINI criterion, which measures the information purity of different evaluation methods through the GINI coefficient. Then it assigns weights to different evaluation methods according to the degree of information purity. The greater the information purity of a certain evaluation method, the greater the certainty of the evaluation result of it, and the greater the weight is given to it. On the contrary, a smaller weight would be given. The specific calculation steps are as follows:

(1) Select K single evaluation methods to form a single method set;
(2) Use Kendall test to check whether the single method set is consistent. If not, re-select single methods to replace;
(3) Calculate the information purity of a single method k, denoted as d_k;

$$d_k = \sum_{i=1}^{m} p_{ik}^2 \tag{13}$$

Where, p_{ik} is the relative proportion, and the calculation formula is:

$$p_{ik} = Y_{ik} / \sum_{i=1}^{m} Y_{ik} \tag{14}$$

Where Y_{ik} is the evaluation result of the ith enterprise in the kth evaluation method, m is the total number of enterprises;

(4) Determine the weight of each single method, denoted as w_k;

$$w_k = d_k / \sum_{k=1}^{K} d_k \tag{15}$$

Where, d_k is the information purity of the evaluation method k;

(5) Calculate the combined evaluation value;

$$Z_i = \sum_{k=1}^{K} w_k Y_{ik} \tag{16}$$

Where, w_k is the weight of the evaluation method and Y_{ik} is the evaluation value of enterprise i of evaluation method k.

4. Empirical research

4.1. Sample selection and data sources

According to the Classification of Forestry and Related Industries (Trial), companies that do not have forest resources but carry out the follow-up processing of forest products also belong to forestry enterprises. Although these companies statistically belong to forestry enterprises, they have no forest resources and have the same environmental responsibility as general manufacturing companies. Therefore, this paper does not take them as research objects. The samples in this paper are A-share listed forestry companies with forest resources, including forest enterprises, forest-board integration enterprises, and forest-paper integration enterprises. Considering that the Implementation Rules of China's Forest Certification were promulgated in 2009, this paper chose 2009–2021 as the research period. This paper removed enterprises under Special Treatment in accordance with practice. For enterprises with industry changes during the study period, this paper only kept the data when the companies were in the forestry industry and deleted the rest data. As a result, 215 imbalanced panel data from 18 sample enterprises were obtained. Data for environmental investment, environmental penalties and biological assets come from the CSMAR database, data for environmental statement, non-commercial forest and forest land come from enterprises' annual reports and official websites, and data for environmental certification, environmental label product certification and forest certification come from the State Administration of Market Regulation website.

4.2. Construction of index system

CER is the strategic responsibility of CSR (Orazalin and Baydauletov, 2020). Based on the competitive advantage theory of the relationship between enterprises and the natural environment,

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Hart et al. put forward the natural resource-based view with three strategies: pollution prevention, product management, and sustainable development (Hart and Dowell, 2011). This paper constructed the forestry CEER index under the theoretical basis of the natural resource-based view.

Pollution prevention requires enterprises to minimize environmental pollution through source prevention, process control, and end treatment of clean production. This paper measured the responsibility of forestry enterprises in pollution prevention through two dimensions, environmental input and social relations.

The product management strategy requires enterprises to minimize exploiting non-renewable resources from the natural environment. According to the utilization of renewable resources, enterprises can modify existing products to reduce environmental pollution. Environmental management and green production were two dimensions chosen in this paper to measure the forestry enterprises' responsibility in product management.

The sustainable development strategy requires a long-term vision and avoid to pursue short-term profits that are harmful to the environment. Forest protection and ecological improvement were two dimensions chosen in this paper to measure the responsibility of forestry enterprises in sustainable development.

With the characteristics of forestry enterprises and data availability, nine indicators were designed under the six dimensions (as shown in Table 1). Among them, the index marked (+) represents a positive index, and the index marked (−) represents a negative index.

Table 2 shows the descriptive statistical results of each index. In pollution prevention strategy, significant differences between environmental investment and penalties, and about half of the enterprises have disclosed environmental responsibility reports. In product management strategy, 74% of the enterprises have obtained environmental certification, 30.2% have obtained environmental label product certification, and 41.9% have passed forest certification. In the sustainable development strategy, the forest land area owned by the sample enterprises was not much. In addition, the forest land area and biological assets value were significantly different, and the enterprises holding non-commercial forests account for only 17.2%.

5. Result and analysis

5.1. Forestry CEER results of single method

The mean score of forestry CEER using the entropy weight method, CRITIC method, and CV method is displayed in Table 3. By using these three methods, CEER obtained an average value of 0.286, 0.403, and 0.266, respectively. The data show great differences in the evaluation values of these three methods, resulting in different rankings, especially for Kangxin New Materials, Huatai Paper, Jilin Forest, and Fujian Jinsen Forestry. The Wilcoxon paired signed rank test was further used to compare the three methods. All hypotheses were rejected at the 1% level according to Table 4, which indicates the different results of the three single methods: median value of CRITIC (0.412) > median value of entropy weight (0.265) > median value of CV (0.250). Clearly, different single methods evaluate from different angles, and their results reflect the characteristics of a certain aspect, which is bound to lead to inconsistent conclusions. Therefore, it is necessary to combine different evaluation methods to smooth the volatility of a single method.

5.2. Forestry CEER results of combined evaluation

It is necessary to test whether the set of single methods is consistent before the combined evaluation. If it is consistent, the single methods can be combined; otherwise, new single methods need to be selected for combination. Kendall's W test was used to test the concordance of the three methods. According to Table 5, the Kendall coordination coefficient of the three evaluation methods is 0.964, and the null hypothesis is rejected at the 1% level, that is, the three single evaluation methods set is considered consistent and can be evaluated in combination.

TABLE 1 Index of forestry CEER.

Key strategy	Dimension	Index	Explanation
Pollution prevention	Environmental input	Environmental investment (+)	Amount of investment related to environmental protection
	Social relations	Environmental penalties (−)	Pollution discharge fees
		Environmental statement (+)	If the enterprise disclosed environmental statement, the value is 1; otherwise, the value is 0.
Product management	Environmental management	Environmental certification (+)	If the enterprise passed the ISO environment certification, the value is 1; otherwise, the value is 0.
	Green production	Environmental label product certification (+)	If the enterprise passed the environmental label product certification, the value is 1; otherwise, the value is 0.
		Forest certification (+)	If the enterprise passed the forest certification, the value is 1; otherwise, the value is 0.
Sustainable development	Forest protection	Forest land (+)	The area of forestland owned or controlled by the enterprise
	Ecological improvement	Biological assets (+)	Ending balance of biological assets
		Non-commercial forest (+)	If the enterprise owns non-commercial forest, the value is 1; otherwise, the value is 0.

TABLE 2 Data description of each index.

Key strategy	Dimension	Index	Min	Max	Avg	Std
Pollution prevention	Environmental input	Environmental investment	0.000	157730.755	3226.153	13300.38
	Social relations	Environmental penalties	0.000	14289.923	898.329	2484.173
		Environmental statement	0.000	1.000	0.433	0.497
Product management	Environmental management	Environmental certification	0.000	1.000	0.740	0.440
	Green production	Environmental label product certification	0.000	1.000	0.302	0.460
		Forest certification	0.000	1.000	0.419	0.494
Sustainable	Forest protection	Forest land	0.060	1800.000	168.257	357.554
development	Ecological improvement	Biological assets	0.000	899738.498	60584.437	106557.031
		Non-commercial forest	0.000	1.000	0.172	0.378

TABLE 3 Score of forestry CEER.

	Single method						Combined method	
	Entropy weight method		CRITIC method		CV method			
	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Qingshan paper	0.486	1	0.578	2	0.431	1	0.498	1
Sun paper	0.419	3	0.604	1	0.371	3	0.462	2
Yong'an forestry	0.453	2	0.492	5	0.412	2	0.452	3
Kangxin new materials	0.403	4	0.41	9	0.363	4	0.383	4
Meili cloud	0.336	6	0.513	3	0.304	7	0.382	5
Huatai paper	0.317	9	0.511	4	0.298	9	0.373	6
Pingtan development	0.319	8	0.48	6	0.29	10	0.361	7
Jilin forest	0.326	7	0.394	11	0.363	4	0.360	8
Fujian Jinsen forestry	0.349	5	0.375	12	0.312	6	0.345	9
Yueyang paper	0.308	10	0.426	7	0.303	8	0.344	10
Bohui paper	0.278	11	0.413	8	0.244	11	0.310	11
Fenglin Wood	0.264	12	0.399	10	0.238	12	0.298	12
MYS group	0.213	13	0.356	13	0.198	14	0.254	13
Chenming paper	0.194	14	0.327	14	0.199	13	0.238	14
WeiHua	0.188	15	0.293	15	0.173	15	0.216	15
Tubao	0.137	16	0.256	16	0.13	16	0.172	16
Dare power Dekor	0.105	17	0.193	17	0.101	18	0.132	17
Yihua wood	0.092	18	0.184	18	0.105	17	0.126	18
Max	0.612		0.778		0.548		0.625	
Min	0.015		0.060		0.017		0.030	
Avg	0.286		0.403		0.266		0.274	
Std	0.154		0.177		0.134		0.152	

Next, the combined evaluation of the above three single methods was carried out following the steps in section 3.2. Table 6 shows the combination of the three methods. The information purity of the entropy weight method is 0.06, and the weight is 34.52%, indicating that the evaluation value of this method fluctuates the most, with the highest information purity and the best evaluation effect. The information purity of the CRITIC value is 0.055, and the weight is 31.92%, indicating that the value of this method fluctuates the least, with low certainty and a relatively poor evaluation effect. The information purity of the CV method is 0.058, and the weight is 33.56%, which is located between the former two.

Further, the weight of each index can be calculated. According to Table 7, among all dimensions, the most important one is ecological construction responsibility, accounting for 27.55%. That is because the forest resources owned by the forestry enterprises can fix a large amount of CO_2, protecting wetlands and woodland soil. In addition, forest carbon sequestration also benefits biodiversity protection and climate change. The second important is green production responsibility, accounting for 26.79%. As a fundamental market subject, forestry enterprises should perform adequately in green management during operation, such as recycling forest waste to improve the utilization

TABLE 4 Results of Wilcoxon analysis.

	Median (P25, P75)		Median difference	z-value	*p*
	Group 1	Group 2			
CRITIC *match* entropy weight	0.412(0.3,0.5)	0.265(0.2,0.4)	0.147	12.373	0.000***
CV *match* entropy weight	0.250(0.2,0.4)	0.265(0.2,0.4)	−0.014	8.878	0.000***
CRITIC *match* CV	0.412(0.3,0.5)	0.250(0.2,0.4)	0.162	12.587	0.000***

* $p<0.1$, ** $p<0.05$, *** $p<0.01$.

TABLE 5 Kendall W coordination coefficient analysis.

Evaluator	Evaluation object	Kendall coordination coefficient	χ^2	*p*
3	215	0.964	618.889	0.000***

* $p<0.1$, ** $p<0.05$, *** $p<0.01$.

TABLE 6 Combination of 3 single methods.

	Entropy weight method	CRITIC method	CV method
Information purity	0.06	0.055	0.058
Weight	34.52%	31.92%	33.56%

TABLE 7 Weight of each index.

Dimension	Weight	Index	Weight
Environmental input	10.94%	Environmental investment	10.94%
Social relations	14.86%	Environmental penalties	2.55%
		Environmental statement	12.31%
Environmental management	7.36%	Environmental certification	7.36%
Green production	26.79%	Environmental label product certification	14.76%
		Forest certification	12.03%
Forest protection	12.50%	Forest land	12.50%
Ecological improvement	27.55%	Biological assets	9.77%
		Non-commercial forest	17.78%

efficiency of forest resources, extensively use of other new environmental materials as raw materials to produce low carbon pollution-free products that meet the social demand for green products. In contrast, environmental management and environmental input were less weighted, accounting for 7.36 and 10.94%, respectively. The reason is that environmental pollution prevention has become a continuous routine work of each forestry enterprise, and there is little difference in these indicators. As for the specific index, non-commercial forest, environmental label product certification and forest land have the highest weight, accounting for 17.78, 14.76, and 12.50%, respectively. Environmental penalties and environmental certification have the lowest weight, accounting for 2.55, 7.36%, respectively. This shows that forestry enterprises' ecological environmental responsibility has shifted from traditional environmental protection to ecological construction.

Finally, the final combined value can be obtained in Table 3. Qingshan Paper, Sun Paper, and Yong'an Forestry perform best in CEER. Those three companies rank top 3 with scores of 0.498, 0.462, and 0.452, respectively. The result is consistent with the reality of the enterprise and the previous study (Yao and Yu, 2016; Du, 2020). Qingshan Paper, Sun Paper, and Yong'an Forestry have made many efforts in ecological environmental protection and won many honors. Various measures of forest protection and environmental innovation are shown in their annual reports, and they persist in carrying out forest certification and disclosing environmental reports. However, forestry enterprises performed poorly in CEER generally. Qingshan Paper, which ranks first in CEER, had an average score of less than 0.5 in the past 12 years. The mean CEER score of all samples was only 0.274, indicating that there is still much room for improvement in ecological environmental responsibility of forestry enterprises.

6. Discussion

6.1. Time trend analysis of forestry CEER

Figure 1 shows the vertical change in the CEER performance of forestry enterprises from 2009 to 2021. Although the average score of CEER was a bit low, it still shows an apparent upward trend of forestry CEER from 2009 to 2020, which increased from 0.19 in 2009 to 0.42 in 2020. The reason is the increase of forestry resources owned by forestry companies and the improvement of the forestry certification ratio of the listed companies. However, there is a slight decrease in 2021. The minor decrease was mainly due to the decline in environmental investment of some enterprises, which may be related to the COVID-19 pandemic, causing more cautious investment.

The results coincide with Cheng's study, which shows that the forestry environmental responsibility is dynamic; that is, with the change of ecological environment, the environmental responsibility of forestry enterprises will change accordingly (Cheng and Xu, 2018). Vidal and Kozak also found that the environmental concerns of forestry have been moving away from purely environmental issues such as pollution and recycling to the role forestry plays in the global climate (Vidal and Kozak, 2008). Generally speaking, forestry CEER shows an obvious upward trend yearly, which indicates that the forestry enterprises' awareness of forest and ecological environmental protection is

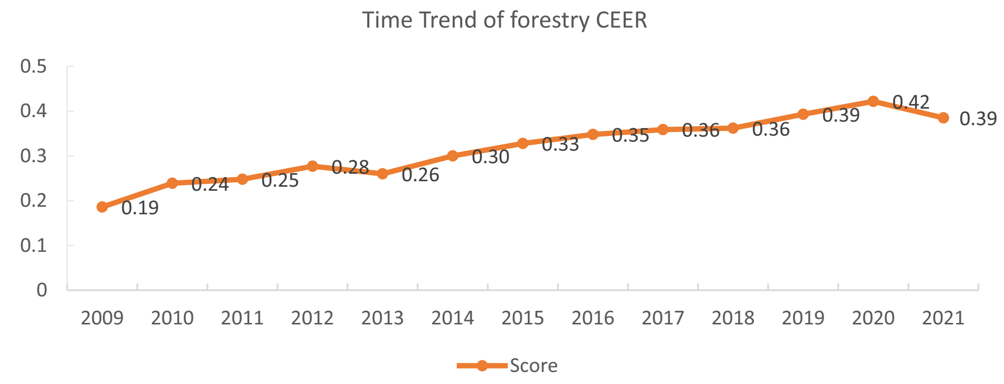

FIGURE 1
Time trend of forestry CEER.

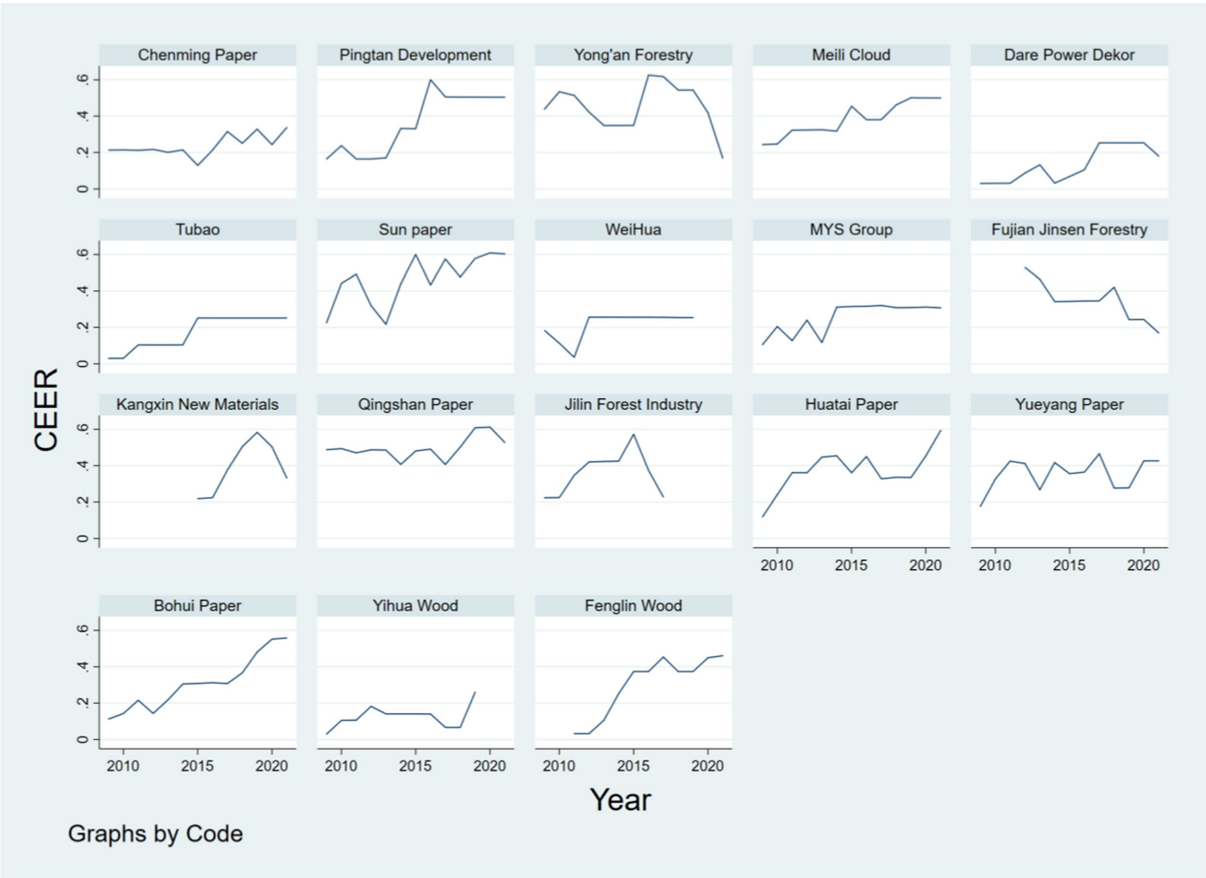

FIGURE 2
Forestry CEER time trend of each company.

constantly improving and also indicates a constantly increasing attention in the country and society toward the ecological environment.

Figure 2 shows the time trend of each company. Most enterprises show an apparent upward trend, while Fujian Jinsen forestry shows a downward trend; Chenming Paper, Qingshan Paper, and MYS Group show a relatively stable trend, while Yong'an Forestry and Sun Paper show relatively intense volatility. It can be seen that forestry CEER performance varies among enterprises.

The reason for the difference is that CEER depends on company characteristic, corporate governance, ownership, forest resources, and other factors. Assisted by green subsidies, firms show better environmental performance than those without (Lin et al., 2015). Jiang et al. (2022) found a positive relationship between environmental protection subsidies and enterprise green innovation. Regulatory policies pressure firms to comply with environmental protection requirements and have a higher quality of environmental performance (Liu et al., 2021). Xie et al. (2020) found that women on boards contribute to environmental and sustainable development strategies. Wang's empirical results showed that stakeholder pressures could significantly affect corporate environmental strategy in developed countries (Wang L. et al., 2020). All those factors may vary considerably among different forestry enterprises, which causes the varied performance of forestry CEER.

6.2. Industry analysis of forestry CEER

Table 8 shows the CEER scores of the three industries in different dimensions. Forest enterprises scored the highest of the total score of CEER, with an average score of 0.350. In terms of specific responsibilities, forest enterprises perform better in ecological construction and green production than other industries. That is because forest enterprises directly take forests as their business objects and carry out abundant forest cultivation work daily. The total score of CEER was followed by forest-board integrated enterprises, with an average score of 0.325, whose responsibility for forest protection is more important than that of other industries, which is related to its high dependence on timber resources. Forest-paper integrated enterprises scored at the bottom of the CEER score, with an average score of 0.301. The CEER of forest-paper integrated enterprises has obvious duality. On the one hand, it is the positive environmental externality brought by forest protection and cultivation. On the other hand, it is the negative environmental externality brought by heavily polluting industries. Therefore, the forest-paper integrated companies put more energy into environmental governance and more effort to establish a green image of the enterprise. Compared with other industries, forest-paper integrated companies focus more on the dimension of environmental input and environmental management.

The Kruskal-Wallis test was further adopted to examine differences between the three groups. It was found that there were no significant differences among different industries in the total score of CEER. However, through the comparison of specific responsibilities, it is found that the dimensions of environmental input, social relations, environmental management, forest protection, and ecological construction were all significant at a 1% level, indicating there is a significant industry heterogeneity in the implementation of forestry ecological environmental responsibilities.

The industry heterogeneity of forestry has been tested by previous studies. Many insights into CSR behavior emerge from this industry-specific analysis. Godfrey pointed out that CSR vary by industry. Manufacturing firms, service firms and banks engaged in different responsibilities; thus, sectors will exhibit different patterns of CSR (Godfrey et al., 2010). In Li's research, the overall CSR of forestry shows no significant difference among industries. However, the regression analysis confirmed a meaningful relationship between the industry and environmental responsibility, which shows that forestry environmental responsibility highly depends on the industry (Li and Gao, 2019). The research of this paper supported and extended the existing results. Different forestry industries attach importance to certain aspects of CEER, and the specific responsibilities of CEER are statistically different.

7. Conclusion

7.1. Conclusion and suggestions

This paper analyzed the content of forestry ecological environmental responsibilities and then evaluated the level of forestry CEER by using a combined evaluation method. Our conclusions can be drawn as follows:

Firstly, when evaluating forestry CEER, results of different single methods are obviously different due to the various data used. The combined evaluation method can obtain more reasonable results because it comprehensively uses all aspects of information and the advantages of every single method.

TABLE 8 Industry comparison of forestry CEER.

Dimension	Forest ($n=23$)	Forest -broad ($n=66$)	Forest-paper ($n=126$)	H value of Kruskal-Wallis	p
Environmental input	0.015	0.034	0.044	10.005	0.007***
Social relations	0.106	0.072	0.075	15.938	0.000***
Environmental management	0.038	0.049	0.06	11.402	0.003***
Green production	0.122	0.094	0.091	1.081	0.582
Forest protection	0.015	0.031	0.012	19.109	0.000***
Ecological improvement	0.054	0.046	0.018	10.361	0.006***
Total score	0.350	0.325	0.301	3.550	0.169

* $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Second, the particularity of ecological environmental responsibility of forestry enterprises originates from the duality of its impact on the environment: The negative externalities caused by operating and the positive externalities brought by forest resources. Therefore, forestry enterprises bear the dual responsibility of pollution prevention and ecological construction, which should be called "corporate ecological environmental responsibility (CEER)." Regarding specific responsibilities, the most important are ecological construction and green production, and the less important are environmental management and environmental input. The result enriches the definition of corporate environmental responsibility based on the perspective of green resource-based enterprises.

Third, the best CEER companies are Qingshan Paper, Sun Paper, and Yong'an Forestry, while the relatively poor CEER companies are Tubao, Dare Power Dekor, and Yihua Wood. The CEER of forestry enterprises remains poor but shows an apparent upward trend, which indicates an increased awareness of forest and ecological environmental protection of forestry, and the attention of the country and society to the ecological environment.

At last, there is obvious industry heterogeneity in ecological environmental responsibility. Forest enterprises prioritize forest cultivation and pay more attention to ecological construction and green production. Forest-board integrated enterprises depend more on wood so as to focus on sustainable forest development. Forest-paper integrated enterprises pay attention to environmental input and environmental management due to their features of heavy pollution industry. The result brings more attention to the industry characteristic of corporate environmental responsibility.

The above conclusions can be useful for further promoting the ecological benefits of forest companies and developing relevant policies:

First, the government must set up a clear procedure for the identification and evaluation of CEER, which can measure the forestry CEER scientifically and objectively. A unified evaluation procedure makes the CEER of different forestry enterprises comparable, so as to better help society understand the CEER level of various enterprises.

Second, develop a supervisory mechanism for forestry CEER involving the participation of all stakeholders. If the voluntary principle is always adopted, the CEER of forestry enterprises will remain low. The government should give full play to the power of all sectors, such as the media and the public, and formulate corresponding supervision and incentive measures to promote improving the CEER level of forestry enterprises.

Finally, forestry companies should enhance their awareness of CEER and undertake their responsibilities based on their industry characteristics. Forestry enterprises should incorporate CEER into their daily management and strategic objectives and actively participate in China's ecological environment construction.

7.2. Limitations

In this research, there are two limitations. First, CEER covers a wide range of contents. However, due to data availability, the indicators selected in this paper may not cover the entire content of CEER. Typical CEER activities, including forest disaster control, wildlife protection, environmental protection training, and public service activities such as "Earth Hour" were not included in the study, which may result in biased research results. In-depth research is needed to obtain primary data to make the research results more objective. Second, in addition to listed companies, many non-listed forestry enterprises in China also have relatively rich forest resources and can produce ecological benefits. However, these companies were excluded from this study, and future research should involve more samples.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

FL: writing, data collection, and review. WS: data analysis, improve, concept, and English corrections. XL: review, methods, and data analysis. RU: review, editing, discussion, and implications. QC: writing draft, conclusion, revision, and discussion. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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