A Review of Research on Enterprise Environmental Performance Evaluation

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Abstract. The long-term extensive economic growth model has led to increasingly serious environmental problems in China, and enterprise environmental performance evaluation is one of the effective ways to solve environmental problems. This article systematically reviews and sorts out the research achievements on enterprise environmental performance evaluation both domestically and internationally, and analyzes them from three aspects: the definition of enterprise environmental performance, the construction of environmental performance indicators, and the methods of enterprise environmental performance evaluation. It summarizes the current research status of environmental performance evaluation in China, prospects its future research trend, and provides reference for further development.

Keywords: Environmental performance evaluation; environmental performance implications; indicator construction; evaluation methodology.

1. Introduction

The long-standing extensive development model of humanity has dealt a heavy blow to the ecological environment. Issues such as global climate change, resource waste, and environmental pollution are becoming increasingly prominent, and environmental climate issues have become the biggest survival crisis faced by humanity in the 21st century. In 2003, China proposed the Scientific Outlook on Development, therefore the development of a low-carbon economy has become an objective requirement in this new situation. Enterprises are the basic units of the national economy and should become the main force in promoting low-carbon economic development. Environmental performance evaluation of enterprises is a basic means of supervising and assessing the effective performance of their environmental responsibilities. It can effectively encourage enterprises to internalize external environmental costs, consciously transform production methods from the institutional perspective, engage in green production, actively participate in low-carbon transformation, and help the whole society achieve sustainable development. Therefore, it is necessary to summarize the current research on enterprise environmental performance evaluation, understand its connotation, master the specific construction and application methods of indicators, and propose further research directions, in order to benefit the development of enterprise environmental performance evaluation research.

2. The Meaning of Enterprise Environmental Performance

Environmental performance is a concrete manifestation of the achievements of enterprise environmental management work. Tyteca (1997) [1] believes that corporate environmental performance is the efficiency and effectiveness achieved by enterprises in managing pollution prevention and resource utilization, and is the standard for measuring and comparing different enterprises. Charles. J. Corbet (2002) [2] believes that environmental performance is the effectiveness achieved by a company in environmental management, which is the results achieved by a company in reducing or minimizing external environmental impacts.

When defining environmental performance, the Organization for Economic Cooperation and Development (2006) specifically defines it as a positive achievement in both monetary and non-monetary aspects by constraining or adjusting the behavior of enterprises, controlling the adverse effects of their production activities on the ecological environment, in order to continuously improve

their comprehensive efficiency and cumulative effects in pollution control, resource conservation, and ecological protection. In the same year, Tang Jianrong and Zhang Chengxuan [3] also adopted this viewpoint and divided the positive results into the improvement of environmental quality and the value added brought by changes in environmental quality.

Zhang Shixing (2009) [4] believes that the environmental performance of a company reflects three aspects of impact, which are the impact of production activities on the natural environment, the impact of environmental protection actions taken by the company on finance, and the impact of environmental factors on management capabilities.

In summary, there is currently no consensus on the definition of environmental performance at home and abroad. Although the focus of different definitions varies, they are essentially used to reflect the degree and effectiveness of enterprises in achieving energy conservation, emission reduction, and clean production by formulating environmental protection plans and implementing environmental protection measures.

3. Construction of Environmental Performance Evaluation Indicators

3.1. Construction Standards for Environmental Performance Evaluation Indicators

3.1.1. Authoritative reports from international organizations

The organizations with significant influence in designing environmental performance evaluation indicators internationally include the Canadian Institute of Chartered Accountants (CICA), the International Organization for Standardization (ISO), the World Business Council for Sustainable Development (WBCSD), the Global Reporting Initiative (GRI), the Intergovernmental Working Group of Experts on International Standards of Accounting and Reporting (ISAR), and the European Financial Reporting Advisory Group (EFRAG).

The Canadian Institute of Chartered Accountants (CICA) has made outstanding contributions in the field of environmental accounting research, and its Environmental Performance Report [5] lists environmental performance indicators for different industries. The report lists 15 environmental performance indicators for 7 industries including resources, utilities, large manufacturing, small manufacturing, retail, transportation, and other service industries. However, this indicator system mainly considers the information needs of external stakeholders of the enterprise, and may not be fully applicable to the internal needs of enterprise environmental management. Therefore, enterprises also need to make choices based on actual situations.

The International Organization for Standardization (ISO) has successively developed some international standards related to environmental performance evaluation since 1994, and officially announced ISO14031 (Environmental Performance Evaluation Standard) [6] in November 1999. This standard provides guidance for the internal design and implementation of environmental performance audits. It divides environmental performance evaluation indicators (EPIs) into environmental status indicators around the organization and internal environmental performance evaluation indicators within the organization, the latter can be further divided into management performance indicators and operational performance indicators. Among them, Environmental Status Indicators (ECIs) provide the environmental conditions around the organization, reflecting the impact of the organization on local, regional, national, and global environmental conditions. Management Performance Indicators (MPIs) provide information on the decisions and actions taken by the organization's management to improve environmental performance, as well as the efforts made in environmental management. Operational Performance Indicators (OPIs) refer to the environmental performance of an organization at the operational level, including the entire operational process of enterprise operation, from resource and energy input, internal production process transfer and change, to the final discharge of waste and pollutants. This indicator system provides a comprehensive framework for enterprises to conduct environmental performance evaluation, which is conducive to establishing an environmental performance evaluation system based on their own actual situation. However, it does not consider the

connection between the enterprise and external stakeholders, as well as the connection between environmental management and sustainable business goals. At the same time, this indicator system cannot directly reflect the economic benefits of the enterprise, and therefore cannot effectively mobilize the enthusiasm of enterprises to carry out environmental management.

The World Business Council for Sustainable Development (WBCSD) proposed the world's first set of ecological efficiency evaluation standards [7] in August 2000. Ecological efficiency indicators are mainly used for environmental performance evaluation of enterprises, for managers to set goals and propose improvement plans. They are also an important tool for enterprises to communicate with their internal and external stakeholders. Under the entire WBCSD indicator framework, the basic formula for ecological benefit indicators is:

Ecological benefits=value of products or services/environmental impact

The value of a product or service can be expressed in terms of production capacity, output, total revenue, profit margin, etc. The environmental impact can be expressed as total energy consumption, total raw material consumption, total water consumption, total greenhouse gas emissions, etc. The ecological efficiency indicator combines environmental indicators with financial indicators, requiring enterprises to achieve greater value with less environmental impact and ultimately achieve sustainable development.

In 1997, the United States Environmental Responsibility Economic Consortium (CERES) and the United Nations Environment Programme (UNEP) jointly initiated the establishment of the Global Reporting Initiative (GRI). The main task of GRI is to develop, promote, and disseminate the globally applied 'Sustainable Development Reporting Guidelines' (referred to as the' Guidelines'), providing a common framework for sustainable development reporting worldwide. In 2000, GRI released the first version of the 'Guidelines', with the second and third generation (G3) guidelines being released in 2002 and 2006, respectively. In 2013, GRI released the fourth generation reporting guidelines (G4). Overall, the G4 guidelines reflect to a greater extent the level of corporate social responsibility management. On October 19, 2016, the organization released the "GRI Standard" [8], which includes global and special standards and replaces the previously issued "Sustainable Development Reporting Guidelines" 4th edition (G4 Guidelines), where GRI300 is a standard specifically designed to regulate environmental reporting. It mainly includes 8 dimensional indicators: materials (GRI301), energy (GRI302), water (GRI303), biodiversity (GRI304), exhaust emissions (GRI305), sewage and waste (GRI306), environmental compliance (GRI307), and supplier environmental assessment (GRI308).

The Intergovernmental Working Group of Experts on International Standards of Accounting and Reporting (ISAR) issued a series of guidelines on environmental accounting reporting in the early 21st century. Among them, the "Handbook for the Use of Ecological Efficiency Indicators" proposed the Ecological Efficiency Indicator (EPI) [9], which considers the ecological efficiency indicator to be the ratio of environmental performance variables to financial performance variables, combining the added value in environmental performance and financial indicators to reflect ecological efficiency. Environmental performance indicators specifically include: primary energy consumption/added value, water consumption/added value, global warming gas emissions/added value, ozone depleting gas emissions/added value, and solid and liquid waste/added value. Financial indicators specifically include energy cost/added value, water cost/added value, solid and liquid waste cost/added value.

On November 28, 2022, the European Council officially approved the Corporate Sustainability Reporting Directive (CSRD), laying a solid legal foundation for the development and implementation of the European Sustainability Reporting Standards (ESRS) [10]. On November 22, 2022, the European Financial Reporting Advisory Group (EFRAG) submitted the first batch of 12 ESRSs to the European Commission for approval, including General Requirements, General Disclosures, Climate Change, Pollution, Water and Marine Resources, Biodiversity and Ecosystems, Resource Use and Circular Economy, Own Workforce, Workers in the Value Chain, Affected Communities, Consumers and End Users, and Business Conduct. There are as many as 5 guidelines related to environmental issues, highlighting the priority and urgency of environmental issues in ESG. This

approval is expected to be approved as a formal guideline in the first half of 2023, which may herald the end of the ESG reporting era and the arrival of the sustainable development reporting era.

3.1.2. Authoritative guidelines from domestic organizations

The evaluation standards for corporate environmental performance in China are mainly reflected in the corresponding guidelines and measures issued by the Ministry of Environmental Protection, the Development and Reform Commission, the People's Bank of China, the China Banking Regulatory Commission, and others.

The "Guidelines for the Preparation of Enterprise Environmental Reports (HJ 617-2011)" issued by the Ministry of Environmental Protection of the People's Republic of China proposes four first level indicators including environmental management status, environmental goals, measures and performance to reduce environmental loads, and relationships with society and stakeholders, as well as 83 second level evaluation indicators. [11]

The "Measures for Enterprise Environmental Credit Evaluation (Trial)" issued by four ministries in 2013 covers the content of enterprise environmental credit evaluation, including pollution prevention and control, ecological protection, environmental management, and social supervision, as well as 21 secondary evaluation indicators. [12]

In 2010, the Hangzhou Municipal Government released the first urban corporate social responsibility evaluation system, which is divided into five aspects: market responsibility, environmental responsibility, employment responsibility, public welfare responsibility, and social evaluation. There are 50 secondary indicators. Among them, environmental responsibility indicators include two secondary indicators, namely environmental protection and emission reduction, low-carbon energy conservation, and 13 tertiary indicators, including environmental management system, environmental action, and pollutant emissions. [13]

In 2011, the Ministry of Environmental Protection of China formulated the "Guidelines for Environmental Information Disclosure of Listed Companies", which includes environmental management, resource consumption, pollutant emissions, and greenhouse gas emissions. However, its scope of adaptation is relatively narrow, limited to the 16 categories of heavily polluting enterprises classified by the China Securities Regulatory Commission, and there are few evaluation indicators. [14]

3.2. Specific Construction of Environmental Performance Evaluation Indicators

Foreign scholars have started early in the specific construction of environmental performance evaluation indicators and have achieved many research results. Ramos (2009) [15] established environmental performance policy indicators for the public sector based on existing research on environmental performance and the Enterprise Environmental Performance Evaluation Standard (ISO14031), developed a SEPI indicator framework for defense sector policies, and validated its effectiveness in the Portuguese defense sector. JR FH (2014) [16] designed environmental performance evaluation indicators for industrial enterprises based on the environmental performance evaluation indicators (EPI) proposed by the GRI (Global Reporting Initiative) guidelines, analyzed the use of environmental performance indicators by industrial enterprises, and found that the nature and scale of production vary, and the use of environmental performance indicators also varies. Lorne (2015) [17] established an environmental performance measurement EPM model from the perspective of stakeholders, based on four dimensions: stakeholder relationships, organizational systems, environmental tracking, and operational strategies. This model can effectively measure the differences between enterprises in different industries or regions. Federica (2017) [18] proposed a multi standard decision analysis (MCDA) method, which comprehensively considered multiple environmental indicators, such as government environmental protection expenditure, greenhouse gas emissions, waste reuse, etc., and assessed the current environmental performance and energy performance of European countries from the perspective of sustainable development using the analytic hierarchy process. Elias (2019) [19] used the life cycle method to analyze and study the

socio-economic benefits and environmental performance of biogas implementation based on the estimation of emissions at each stage of biogas production.

The construction of environmental performance evaluation indicators in China is mainly based on the evaluation indicator standards at home and abroad, combined with China's national conditions, and considering multiple perspectives such as material flow cost, value chain theory, balanced scorecard, PSR model, PDCA model and three performance theories.

Material flow cost accounting is an environmental management accounting method intended to reduce the cost of enterprises and environmental pollution. It decreases costs by reducing the generation of waste, so as to improve the productivity of enterprises. Zhao Liping et al. (2016)[20] believe that incorporating MFCA into environmental performance evaluation indicators can comprehensively and truly reflect the information on waste costs in enterprise environmental performance , in line with the relevant requirements of sustainable development for environmental information disclosure. Based on this, four secondary indicators, namely environmental management level, waste discharge, environmental finance, and resource recycling, have been designed. Following with 5 qualitative tertiary indicators such as establish a basic system for environmental governance, formulate environmental governance emergency plans, and 14 quantitative tertiary indicators such as unit product wastewater discharge and unit product exhaust emissions.

The value chain theory was first proposed by Michael Bolton in 1985. It refers to the value-added process of products formed by different but closely related production and operation activities in the entire process of designing, producing, selling, and transporting products. It can be divided into external and internal value chains. Chang Yuan et al. (2016) [21] conducted environmental performance evaluations of each link in the internal and external value chains of enterprises based on a new perspective of value chain theory, and constructed a new environmental performance evaluation system from three dimensions: value chain environmental performance evaluation indicators, value chain environmental performance evaluation methods, and value chain environmental performance information disclosure.

The Balanced Scorecard comprehensively evaluates the company's performance from four dimensions: finance, customers, internal processes, innovation and learning. It compensates for the shortcomings of traditional performance evaluation methods that are single and have a short assessment period, and has gradually become an indispensable assessment tool for enterprise management. Zhang Benyue et al. (2017) [22] applied the Balanced Scorecard to the evaluation of environmental performance and embedded environmental factors into the assessment index system. They added assessment of environmental factors to the original four dimensions, adopting the "BSC+E model" to expand the application of the Balanced Scorecard, in order to encourage business management to pay more attention to their own environmental behavior and provide comprehensive enterprise environmental information. Zhang Yonghong et al. (2018)[23] used the balanced scorecard as the basic framework, combined with the ISO14031 standard and the characteristics of the coalbed methane industry, and from a new perspective of carbon emissions, focused on the movement footprint of carbon emission elements on the value chain, innovatively established a carbon emission value chain for coalbed methane enterprises and introduced new green EVA (GEVA) indicators based on this, filling the shortcomings of traditional green EVA in coalbed methane enterprises. Finally, an environmental performance evaluation index system for coalbed methane enterprises based on BSC and GEVA was established.

The PSR model was first proposed by Canadian statisticians Tony Friend and David Rapport in the 1970s, which includes three indicator dimensions: stress, state, and response. Peng Manru et al. (2017) [24] constructed a corporate environmental performance indicator system based on the pressure state response (PSR) model in the context of haze control. Pressure indicators mainly describe the demand for resources and pollution caused to the environment by industrial enterprises in production and operation; The status indicators mainly reflect three aspects: social benefits, economic benefits, and environmental benefits; Response indicators refer to the measures taken by

enterprises to address environmental issues such as smog, including environmental management, environmental governance, and environmental evaluation.

The PDCA cycle is a commonly used quality management model that can drive continuous quality improvement. Li Dongwei et al. (2018) [25] used the PDCA to control and manage enterprise environmental performance evaluation by following the process of "Plan-Do-Check-Improve", and constructed an enterprise environmental performance evaluation index system using the Analytic Hierarchy Process.

Selecting environmental indicators using Life Cycle Assessment (LCA) is a new perspective to characterize the environmental performance of products or systems, which can involve product production, waste recycling and treatment, or the entire life cycle process. Zhao Di et al. (2020) [26] established environmental performance evaluation indicators and methods for electronic waste recycling and treatment systems based on life cycle tools from two aspects: material metabolism efficiency and ecological environmental benefits. They also analyzed the current environmental performance level and improvement potential of China's recycling and treatment system, taking discarded mobile phones as the research object.

The triple bottom line theory refers to the fundamental economic, environmental, and social responsibilities that enterprises must fulfill. Yuan Jingjing et al. (2021)[27] combined the triple performance theory with the establishment of an industry environmental evaluation system proposed by the Ministry of Environmental Protection, conducted a quantitative analysis and overall evaluation of the environmental performance of CNPC and CNOOC from four dimensions: environmental compliance, resource consumption, environmental pollution, and environmental governance effectiveness.

The evaluation system of ecological civilization began in the mid-20th century, including various aspects such as economy, environment, culture, health, education, etc. Wu Sijia et al. (2021) [28], from the perspective of ecological civilization, constructed 16 specific indicators in four dimensions of ecological environment protection, ecological investment, ecological culture and ecological system, and used entropy method to comprehensively evaluate the environmental performance of middling coal Group in recent five years.

4. Evaluation Methods for Corporate Environmental Performance

Scholars at home and abroad have used a variety of methods to evaluate environmental performance. Common methods include Data envelopment analysis, fuzzy comprehensive evaluation, analytic hierarchy process, principal component analysis, entropy weight method, etc.

Data envelopment analysis (DEA) is a method of applying mathematical programming to evaluate the relative effectiveness of the same type of departments or units with multiple inputs and outputs. Toshiyuki (2013) [29] used the Data envelopment analysis method to evaluate and analyze the environmental performance of American thermal power enterprises. Joseph Sarkis and Srinivas Talluri (2014) [30] established a data envelopment model to address the shortage of ecological efficiency indices and used this method to evaluate environmental performance. Lin Ye (2021) [31], based on the revised Environmental Impact Assessment Law and Circular Economy Promotion Law, in combination with the characteristics of marine transportation enterprises, organically combines environmental performance related input cost indicators (input volume) with the related output benefit indicators (output volume) through Data envelopment analysis, and measures the value of observation to produce quantifiable assessment results, so as to build a set of standardized, quantifiable and targeted environmental performance evaluation method.

The fuzzy comprehensive evaluation method is often combined with the Analytic Hierarchy Process to determine indicator weights and implement evaluation plans. Jiao Rui (2020) [32] used the fuzzy comprehensive evaluation method to study the environmental management performance in the green supply chain, and analyzed it using IKEA as a case study; Cao Yangmin (2019) [33] focused on indicator selection, hierarchical structure analysis, weight determination, and evaluation standard

setting, taking a pharmaceutical enterprise as an example, using the AHP fuzzy comprehensive evaluation method to evaluate its environmental management performance. Chen Minmin (2020) [34] used the Analytic Hierarchy Process and the fuzzy comprehensive evaluation method to establish an indicator system from four aspects: sewage treatment plant operation, pollutant reduction, energy consumption, and resource utilization, evaluating the environmental performance of 8550 urban sewage treatment plants in China based on the results of the second national pollution source census.

Principal component analysis (PCA) utilizes forms such as coordinate translation or orthogonal transformation to maximize the authenticity of data, reduce its information loss rate, and reassemble data from multiple dimensions into a new set of analytical data. Hao Chunxu et al. (2016) [35] used 2011 statistical data as the basis with principal component analysis to study the importance of four secondary indicators in the evaluation index system on the Environmental Performance Index (EPI): environmental health, ecological protection, sustainable resource utilization, and environmental governance. Feng Yu et al. (2019) [36] constructed an environmental performance evaluation index system from four dimensions: environmental health, ecological protection, resource utilization, and environmental governance, using principal component analysis to evaluate the environmental performance of 11 provinces and cities in the Yangtze River Economic Belt.

The entropy weight method is a method of determining objective weights based on the variability of indicators. Yu Yubing et al. (2019) [37] constructed a performance evaluation index system for water environment governance from four levels: environmental, social, economic, and management, based on the theme framework model of water environment. The performance index of water environment governance in Chengdu from 2007 to 2016 was calculated by the target progressive method, entropy weight method, radar chart method and other measurement methods. Zhang Ran et al. (2020) [38] combined the specific practice of ecological civilization construction, designed a performance audit evaluation index system for air pollution prevention and control step by step under the PSR framework, and further used the structural entropy weight method and fuzzy comprehensive evaluation method to evaluate the status of air pollution prevention and control performance audit. Wang Yu et al. (2021) [39] constructed a framework for air pollution prevention and control performance audit evaluation index system based on the PSR model, used the AHP- entropy weight method to determine the weights of each evaluation index, and used the environmental merit model to comprehensively evaluate and analyze the environmental pollution prevention and control effectiveness of Anhui Province in the past 5 years. Yang Jie et al. (2021)[40], in response to the current lack of a quantifiable carbon performance evaluation system for the coal industry in China, selected 15 indicators to construct a carbon performance evaluation system and built an entropy weighted TOPSIS model for evaluation. This system cannot only evaluate the advantages and disadvantages of enterprise carbon performance from the three basic dimensions of energy, environment, and economy, but also judge the coordinated development of enterprise carbon emission reduction between economy, energy, and environment.

5. Summary

After reviewing the literature on environmental performance evaluation, it can be found that although the definition of environmental performance is not yet unified, it essentially refers to the actual effectiveness or level of environmental management and improvement activities such as adjusting production processes, implementing environmental policies, and formulating environmental plans based on environmental responsibility and management objectives.

The environmental performance evaluation indicators released by international and domestic authoritative institutions serve as framework based evaluation standards, providing ideas for the selection of evaluation indicators, which have the characteristics of universality and versatility at the macro level. However, there is also a slight lack of targeted guidance at the micro level. Countries and industries should develop unified environmental performance evaluation guidelines with operability, industry universality, and regional characteristics based on authoritative domestic and

international environmental performance evaluation standards according to specific national conditions and industry characteristics, so that enterprises can conduct environmental performance evaluation more standardized and systematic.

In terms of the specific construction of environmental performance evaluation indicators, foreign research mainly focuses on the standards issued by non-profit organizations, and constructs an evaluation system with industry characteristics. Based on the value chain theory, PSR model and the principle of balanced scorecard, most domestic enterprises construct environmental performance evaluation index systems from the perspective of sustainable development, ecological civilization, product life cycle, circular economy and material flow cost. The theoretical basis and research perspectives are relatively diverse, but due to the different business and internal environments of different enterprises, and different reference guidelines, the comparability within the industry is poor, which is not conducive to comparative analysis among enterprises. Therefore, when constructing specific indicators, it is also necessary to fully integrate the overall characteristics of the industry while considering the enterprise's own situation, which can make the indicator system has universality and applicability, and the results comparable.

The research on environmental performance evaluation methods has achieved certain results in industries with high pollution and energy consumption, but it is still less involved in other industries, so expanding the research scope is imperative. Currently, there are many evaluation methods, but each has its own advantages and disadvantages. How to improve or integrate existing methods to make them more efficient and avoid their weaknesses is also another research direction.

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