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Research on Carbon Audit Evaluation Indicator System of Chemical Enterprises Based on PSR Modeling

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Abstract: With the rapid development of China's economy, the problem of environmental pollution has become more and more prominent. Among them, chemical enterprises, as the main emitters of fossil energy, urgently need to accelerate their green transformation process. In this context, carbon audit, as an effective means of external supervision, plays a pivotal role in promoting the green transformation of enterprises and realizing the goal of "dual carbon" strategy. Based on the PSR model, this paper organically combines carbon auditing and environmental supervision, and then constructs a carbon audit evaluation index system, which is used as a monitoring and constraining mechanism to optimize the path of chemical enterprises to develop a green economy, and enhance the effect of carbon auditing and help the realization of the national strategy at the same time.

Keywords: PSR model, carbon audit, carbon audit evaluation system, chemical enterprise.

1. Introduction

At present, China has become the world's largest greenhouse gas emitter, with carbon dioxide emissions in mainland China alone reaching 10,550.2 million tons in 2022, accounting for 30.7% of the world's carbon emissions, and environmental issues require urgent attention. With the in-depth implementation of the national ecological environment construction strategy in recent years, the "dual-carbon" goal is constantly clear, the social awareness of environmental protection has been strengthened, the development and current situation of carbon auditing in China has also received extensive attention from the community, the research on combining carbon auditing and ecological modeling is increasing day by day, and the carbon audit evaluation system for different industries has been constructed. The carbon audit evaluation system for different industries has been constructed. In addition, the PSR model proposed by Canadian statisticians David J. Rapport and Tony Friend in 1979, which consists of three logical elements: pressure, states and response, has been widely used in the field of ecology and environment.

This paper combines PSR model and carbon audit, which has wide and profound research significance. At the level of the auditing body, under the analysis of the status quo and carbon footprint of chemical enterprises, constructing a carbon audit evaluation index system based on the PSR model can improve the existing evaluation indexes, refine the audit objectives, clarify the audit indexes, enhance the pertinence and rationality of the audit, and then issue a carbon audit report with a higher degree of trustworthiness. On the enterprise level, perfecting the carbon audit evaluation index system can prompt them to improve their awareness of emission reduction, enhance the effectiveness of relevant internal controls, clarify the relevant indicators involved in carbon emission information, and thus improve the authenticity and reliability of carbon emission information, and help enterprises to develop sustainably; on the national level, constructing the carbon audit evaluation index system can strengthen the effectiveness of carbon audit supervision and prompt enterprises to pay attention to controlling carbon emissions, optimize the energy structure, promote the energy transition, and promote the "carbon audit" on the basis of the implementation of the strategy of sustainable development. On the national level, the establishment of a carbon audit evaluation index system can strengthen the effectiveness of carbon audit supervision, prompt enterprises to focus on controlling carbon emissions, optimizing energy structure, promoting energy transformation, and facilitating the timely realization of the goals of "carbon peak" and "carbon neutrality" based on the implementation of sustainable development strategies.

Since General Secretary Xi Jinping proposed "dual carbon" in 2020, China has accelerated the formation of the "1+N" policy system and continuously strengthened the top-level design. In this context, the implementation of carbon audits in China has become a major trend, and the "Guidelines for Verification of Enterprise Greenhouse Gas Emission Reports (Trial)" issued in 2021 also provides new guidelines for carbon audits. As one of the high-carbon industries, improving the carbon audit evaluation index system of chemical enterprises will have a significant impact on realizing the sustainable development of enterprises and achieving the goal of "dual carbon". Therefore, it is valuable to apply the PSR model, which is used to evaluate the impact of human activities on the ecological environment, to the carbon audit and construct the carbon audit evaluation index system of chemical enterprises.

2. Literature Review

2.1. Carbon audits

Currently, scholars at home and abroad have carried out extensive research on carbon auditing, mainly focusing on the construction of concepts and frameworks and the challenges faced.

In terms of the conceptual framework of carbon auditing, Jessie Francois first proposed the concept of "carbon auditing" in 2003, which means that carbon auditing, as a branch of environmental auditing, is a key step in reducing carbon dioxide emissions. Specifically, for the object of carbon audit, Li Boying and Wang Panjing take the ecological impact of carbon emissions generated in the process of inspection, supervision and forensics as the object of carbon

audit, while Zheng Shiqiao believes that the object of carbon audit is the fulfillment of carbon emission management responsibility undertaken by the agent based on the principal-agent theory. With regard to the subject of carbon audit, Miao Lei comprehends the views and insights of scholars at home and abroad on the subject, scope, standard and report of carbon audit, and puts forward the corresponding development direction on the basis of the problems and controversies among them. In terms of the challenges faced by carbon auditing, Hongyuan Fang takes the low carbon economy as the background, selects chemical enterprises represented by Sinopec, and analyzes the existing problems of carbon auditing and related countermeasures; Xiaoyu Wang analyzes the relationship between low carbon governance and auditing of state-owned enterprises, and clarifies the dilemmas and countermeasures faced by carbon auditing of state-owned enterprises in the realization of carbon neutrality.

2.2. Carbon audit evaluation indicator system

At present, there are fewer studies on carbon audit evaluation index system based on PSR model in China, and the construction of carbon audit evaluation index system mainly focuses on performance auditing and economic responsibility auditing, and there is a lack of research on carbon audit evaluation index system. Zhang Huanjing analyzed the current situation of geocarbon audit in Henan Province, and used the analytic hierarchy process to construct a low-carbon audit evaluation index system in Henan Province from the aspects of low-carbon environment, low-carbon economy, low-carbon policy, low-carbon consumption and carbon dioxide benefits; Shi Ran and Li Changchu analyzed the application of PSR model in carbon audit, and finally combined with the content of carbon audit of electric power enterprises, constructed a carbon audit index evaluation system. In addition, foreign scholars have also conducted some research on the evaluation index system of carbon audit; Panayis used the content analysis method to evaluate the audit results of carbon trading and the quality of carbon disclosure of 50 companies listed on the Johannesburg Stock Exchange; the U.S. has already formed an audit model focusing on carbon dioxide as the main source of emissions, automobiles, real estate and lifestyles; and the Danish government has adopted a combined approach of carbon accounting and carbon audit; and the Danish government has adopted an integrated approach of carbon audit. The Danish government has also adopted a combination of carbon accounting and carbon auditing to regularly monitor carbon emissions and emphasize follow-up.

2.3. Literature review

Although the existing literature has carried out certain research on the basic framework of carbon audit and the subject and method of carbon audit evaluation index system, in terms of research method, most of the existing literature adopts the hierarchical analysis method, and only some of the literature introduces the PSR model. At the same time, for the research body, the research on carbon audit evaluation system based on PSR model mostly takes electric power and iron and steel enterprises as examples, and analyzes chemical enterprises less. However, as one of the heavy pollution emitting enterprises, it is of great significance to analyze the carbon audit evaluation index system of chemical enterprises.

3. Overview and Application Analysis of the PSR Model

3.1. Overview of the PSR model

The PSR (Pressure-State-Response) model was first designed and proposed by Canadian scientists David J. Report and Tony Friend in 1979, and was later advocated by the Organization for Economic Cooperation and Development (OECD) and the United Nations Environment Programme (UNEP) in the 1980s and 1990s for the study of environmental issues. The model consists of three logical elements: pressure (P), state (S) and response (R), and is now mainly used as a framework system for studying economic and environmental issues, and has become a commonly used evaluation model in the discipline of environmental quality assessment. Specifically, the PSR model is organized around three core logical elements, forming three levels: Pressure (P) refers to the pressure and impact of human activities on the environment, such as the use and consumption of energy resources in the process of production and business; State (S) refers to the changes in environmental conditions or states caused by pressure in a given time period, such as the increase in carbon dioxide emissions resulting in air pollution and global warming problems are becoming more serious; Response (R) refers to the protective and remedial response of human beings to environmental

damage and energy consumption. Such as the introduction of carbon emissions trading market policy, the establishment of low-carbon city pilot and other environmental regulatory policies. The use of the PSR model to establish an evaluation index system for carbon auditing can help guide and assess the work of carbon auditing more effectively.

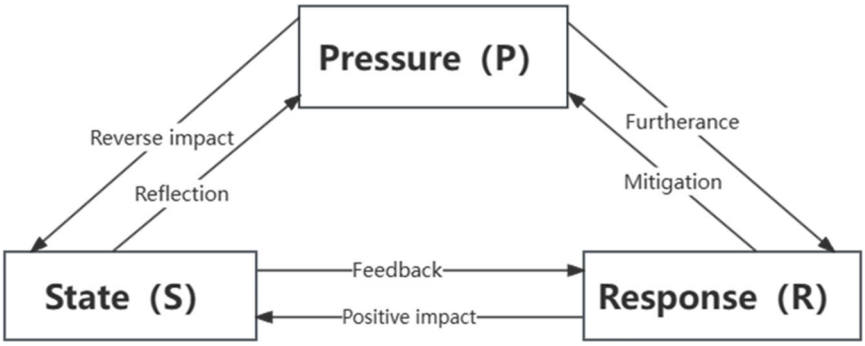

Figure 1. Schematic diagram of PSR model

3.2. Application of the PSR model to carbon audits

The evaluation index of carbon audit should objectively describe the development level of carbon emission of an enterprise in a certain period, and effectively reflect the trend of the interaction between the enterprise and the society, economy and environment in a certain period. The specific principle of the PSR model for carbon audit is that: the content of carbon audit includes carbon emission reduction policy, carbon emission reduction management system, carbon emission reduction fund, carbon accounting and carbon social responsibility, etc., which involves monitoring and evaluating the whole process of the carbon emission level, carbon emission reduction initiative and carbon information disclosure of an enterprise, and this whole process corresponds to the three levels of the PSR model. It involves the supervision and evaluation of the whole process of corporate carbon emission level, carbon emission reduction initiatives and carbon information disclosure, and this whole process echoes the three levels of PSR model. Therefore, it is of great significance to construct a carbon audit evaluation index system based on the PSR model to improve the carbon audit process and enhance the effect of carbon audit.

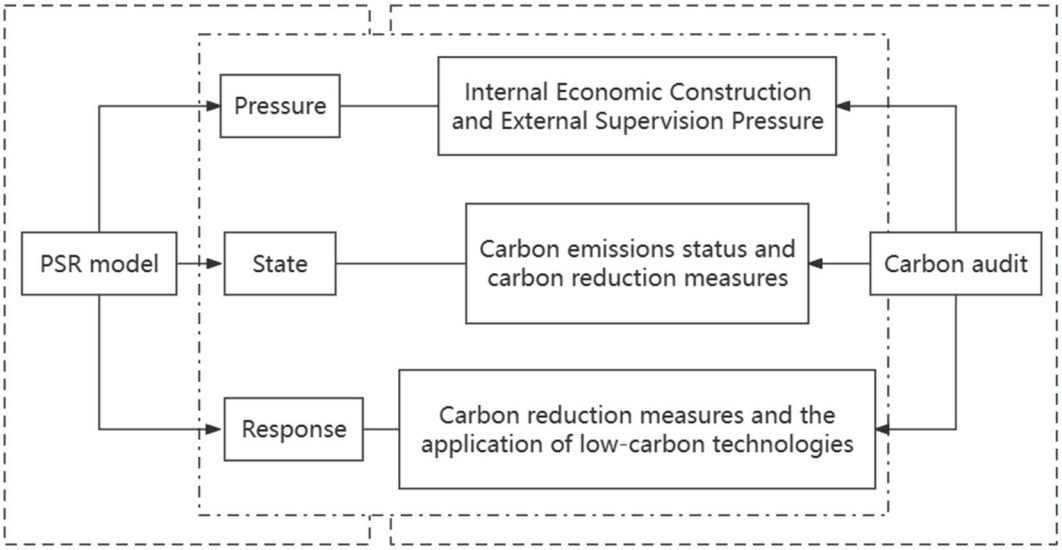

Figure 2. Application diagram of PSR model in carbon auditing

4. Building a Carbon Audit Evaluation Indicator System for Chemical Enterprises Based on PSR Modeling

4.1. Constructive principles

4.1.1. Principles of science and feasibility

To build the carbon audit evaluation index system of chemical enterprises, it is necessary to select specific evaluation indicators scientifically and reasonably, and the indicators should comprehensively reflect the fulfillment of environmental responsibility of the audited units while meeting the requirements related to the carbon audit process of chemical enterprises. In addition, in order to ensure the operability of the carbon audit evaluation index system, it is necessary to choose indicators that are easy to measure, observe and obtain, so as to improve the feasibility of the selection of indicators, and to avoid lowering the efficiency and quality of the audit due to the difficulty of detecting the indicators and the complexity of the calculation.

4.1.2. Principle of combining quantitative and qualitative indicators

Carbon audit evaluation indicators need to combine quantitative and qualitative indicators, qualitative indicators are influenced by subjective consciousness, but are conducive to judging the purpose and substance of the enterprise's environmental behavior; quantitative indicators use mathematical and theoretical methods to produce more scientific results, but they are unable to respond to the connotations of specific behavior. Therefore, it is necessary to select a combination of qualitative and quantitative indicators for different needs, so as to analyze the carbon emissions of the audited unit more comprehensively.

4.1.3. Principle of harmonization of dynamics and stability

Carbon audit is an auditing behavior of a third-party auditing institution to supervise and evaluate the carbon emission management activities of the government and enterprises and their results. Therefore, the evaluation indicators selected for carbon audit should follow the principle of dynamism, which can not only reflect the past business behavior of the enterprise, but also show the carbon emission activities of the audited unit at present, and from which the future development tendency of the enterprise can be obtained. At the same time, the indicators should be stable to ensure that they can be continuously observed and their changes are within a reasonable range, which is conducive to the comprehensive evaluation of the carbon emission control ability of the audited unit.

4.1.4. Principle of separation of common and specific indicators

The selection of carbon audit evaluation indicators should incorporate both common and characteristic indicators. Firstly, according to the connotation and characteristics of carbon audit, the common evaluation indexes should be constructed in line with the characteristics of multiple

industries, so as to provide reference for them to carry out carbon audit evaluation according to local conditions. On this basis, combining the specific situation of different enterprises and the nature of the industry, special indicators should be included in the evaluation system to finally meet the principle of separating the common indicators from the characteristic indicators.

4.1.5. Principle of comparability

Comparability usually includes horizontal comparability and vertical comparability, in which horizontal comparability requires that the evaluation indexes selected should be applicable to different chemical enterprises in order to make a comparative analysis of their carbon emissions; vertical comparability requires that the indexes can reflect the carbon emission behavior of chemical enterprises at different points in time in order to make a dynamic analysis of the effect of the fulfillment of their environmental responsibility.

4.2. Carbon Footprint of Chemical Companies and Carbon Audit Process Analysis

4.2.1. Carbon Footprint Analysis of Chemical Enterprises

Carbon footprint is the total amount of carbon released during the production of an activity. By analyzing the energy and substances consumed by a chemical enterprise in a certain period of time, the carbon emissions generated in the process of producing and operating products or providing services of the unit can be derived. Currently, the tracking measurement of carbon footprint is an effective way to measure carbon emissions, and the carbon footprint system boundary analysis is currently an important part of the auditors' understanding of carbon sources. Since chemical companies account for a large proportion of non-clean energy, the consumption of fossil fuels has been at a high level for a long time, and the production process is cumbersome, it is necessary to measure the carbon footprint and clarify the carbon trajectory, in order to facilitate the process of separating the energy consumption of chemical companies.

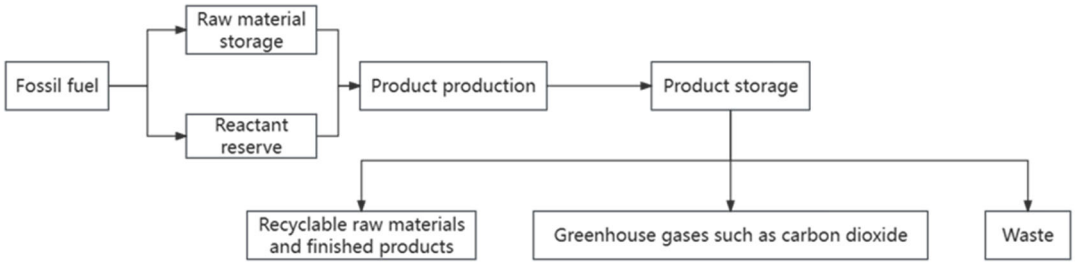

Figure 3: Boundary map of carbon footprint for chemical enterprises

4.3. Design of carbon audit evaluation indicators and construction of the system

4.3.1. Framework structure for the construction of the indicator system

Based on the PSR model, this paper, starting from the connotation of carbon audit and combining with the production and operation characteristics of chemical enterprises, designs and screens the indicators that can reflect the current status of their carbon emissions and carbon reduction potential. In constructing the evaluation index system of carbon audit for chemical enterprises, this paper considers three levels, namely, the target level, the guideline level and the index level, in accordance with the hierarchical analysis method. Among them, the target layer is the general goal of the indicator system, reflecting the actual effect of enterprise carbon audit. The criterion layer consists of the influencing factors needed to realize the target layer, mainly focusing on the three aspects of pressure, state and response. The indicator layer refers to the indicators that constitute the evaluation index system of chemical enterprise carbon audit, and the main data are obtained by querying relevant information.

Based on the PSR model to build the carbon audit evaluation index system can enhance its logic and scientific, and then standardize the carbon emission reduction behavior of enterprises, promote enterprises to achieve green transformation, and ultimately help China's "dual carbon" goal.

4.3.2. Construction of evaluation index system of chemical enterprise carbon audit

(1) Stress indicators

Influenced by the internal and external environment, the pressure faced by chemical enterprises to realize green transformation mainly comes from both economic pressure and environmental pressure.

Economic pressure mainly reflects whether enterprises have sufficient financial support for the application of green and low-carbon technologies, and whether they enhance their performance by strengthening the regulation of carbon emissions, specifically including indicators such as business income and investment return rate; environmental pressure mainly reflects whether enterprises have sufficient motivation to improve energy utilization efficiency and accelerate the process of green transformation under the supervision of the external environment, specifically including the comprehensive energy consumption intensity, Carbon productivity, total accumulated carbon trading, whether there are any environmental violations, environmental letters and visits, and whether there are any sudden environmental accidents.

(2) Status indicators

The state-based indicators of chemical enterprises refer to the current state of carbon emissions presented by enterprises under the influence of internal and external pressures. Specifically, it includes indicators such as the intensity of total carbon emissions, the intensity of carbon emissions per unit of tax revenue, whether the pollutant emissions meet the standards, whether it is a key pollution monitoring unit,

whether it has an environmental protection concept, whether it has set up environmental protection targets, and whether it applies clean production technology.

(3) Responsiveness indicators

Responsiveness indicators are used to describe the response of chemical enterprises to the pressure of the ecological environment and the existing state, and are used to characterize the ability of chemical enterprises to save energy and reduce carbon emissions, not only to enhance the financial performance and value of the enterprise within the carrying capacity of the natural environment, but also to reduce the impact on the natural environment and reduce the emission of carbon dioxide and other greenhouse gases. Specifically, it covers such indicators as the growth rate of total carbon emissions, environmental protection investment costs, green technology innovation, investment in low-carbon emission reduction projects, whether to establish an environmental protection management system, whether to conduct environmental protection education and training, whether to carry out special environmental protection actions, whether to set up an emergency response mechanism for environmental incidents, and whether to set up a "three-simultaneity" system.

Table 1. Carbon audit evaluation index system

target level	standardized layer	indicator layer	Nature of the indicator
Carbon audit evaluation indicator system	P (Pressure)	Business operating income C1	Quantitative indicators (positive)
		Enterprise return on investment C2	Quantitative indicators (positive)
		Comprehensive energy intensity of enterprises C3	Quantitative indicators (negative)
		Carbon productivity C4	Quantitative indicators (positive)
		Total cumulative corporate carbon transactions C5	Quantitative indicators (positive)
		Whether there is an environmental violation C6	Qualitative indicators (negative)
		Whether there is an environmental petition incident C7	Qualitative indicators (positive)
		Whether there is an environmental emergency C8	Qualitative indicators (negative)
	S (Status)	Total carbon intensity C9	Quantitative indicators (negative)
		Compliance with pollutant emission standards C10	Qualitative indicators (positive)
		Whether it is a key pollution monitoring unit C11	Qualitative indicators (negative)
		Carbon emission intensity per unit of tax revenue C12	Quantitative indicators (negative)
		Whether there are environmental protection concepts C13	Qualitative indicators (positive)
		Whether to establish environmental objectives C14	Qualitative indicators (positive)
		Whether cleaner production technologies are applied C15	Qualitative indicators (positive)
	R (Response)	Growth rate of total carbon emissions C16	Quantitative indicators (negative)
		Environmental investment costs C17	Quantitative indicators (positive)
		Enterprise green technology innovation level C18	Quantitative indicators (positive)
		Whether to establish an environmental management system system C19	Qualitative indicators (positive)
		Whether to conduct environmental education and training C20	Qualitative indicators (positive)
		Whether to carry out special environmental protection actions C21	Qualitative indicators (positive)
		Whether an emergency response mechanism for environmental incidents is in place C22	Qualitative indicators (positive)
		Whether to establish a "three simultaneous" system C23	Qualitative indicators (positive)
		Investment in low-carbon emission reduction projects C24	Quantitative indicators (positive)

5. Conclusions and outlook of the study

5.1. Conclusions of the study

With the continuous development of the economy, the use of fossil energy for human production and operation to provide convenience at the same time, but also caused great pressure on the ecological environment, and its emission of greenhouse gases has become one of the main causes of global warming. In this context, the greening of enterprises has gradually developed into the mainstream trend of transformation, and carbon emission reduction has also become one of the social responsibilities that enterprises must undertake. Carbon audit, as an effective means of external supervision, can actively promote the implementation of corporate environmental responsibility, improve energy efficiency, and ultimately realize the balanced development of economic development and environmental protection.

In recent years, the 20th Party Congress put forward the strategic significance of the "dual carbon" goal, scholars at home and abroad actively carry out research on the content of carbon audit, but at present has not yet formed a more complete set of carbon audit evaluation index system for chemical enterprises. This paper summarizes and analyzes the relevant research results, and based on the PSR theoretical model, it exploratively constructs a carbon audit evaluation index system for chemical enterprises, and specifically draws the following conclusions:

First, this paper combed the status quo of the carbon emission situation of chemical enterprises in China, and found that China currently lacks a more standardized carbon audit index system. But for chemical enterprises, as an important cornerstone of national economic development, the industry's carbon dioxide emissions accounted for xx, the degree of impact on environmental pollution is heavy.

Secondly, this paper applies the PSR model to study the evaluation index system of carbon audit in chemical enterprises. Combined with the production and operation characteristics of chemical enterprises, this paper selects indicators at different levels and categorizes them into the pressure, state and response guideline layers.

Third, after calculating the weights of the indicators, this paper combines the evaluation results with the current situation of the enterprises and puts forward three points of improvement, including increasing the proportion of clean energy use, introducing advanced low-carbon green technologies, and optimizing the carbon information disclosure system.

5.2. Research outlook

This paper constructs a carbon audit evaluation index system for chemical enterprises based on the PSR model, but there are still deficiencies due to the small amount of relevant literature and insufficient disclosure of carbon emission information. First, in the selection of carbon audit evaluation indexes, the accuracy of the indexes still needs to be further verified. Second, this paper only utilizes the PSR model to construct the evaluation system, without comparing it with other models to analyze its advantages and disadvantages, so the universality of the conclusion still needs to be further debated. Third, the methodology. Therefore, the study should further complete the design scheme of carbon audit evaluation indexes to improve the objectivity and applicability of the results. In the future, it will be refined from the following two points:

First, use other models such as DSR model and 3E model to construct the evaluation index system of chemical enterprise carbon audit in the future. By comparing the evaluation index system constructed by different models, it proves whether the system constructed based on PSR model is advanced or not.

Secondly, the comprehensive use of a variety of weight assignment methods, such as the combination of hierarchical analysis and entropy value method, principal component analysis, etc., to ensure the objectivity and accuracy of the indicator weights.

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