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Research Article

An Examination of Impact of the Board of Directors' Capital on Enterprises' Low-Carbon Sustainable Development

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Given the increasingly serious ecological and environmental problems in China, research on enterprises' low-carbon sustainable development behavior (LCSDB) has become a heated discussion. This is also because enterprises are a primary source of carbon emissions and environmental pollution. From the perspective of the board of directors' capital (BODC), this study considers empirical evidence from 286 enterprises listed on the Shanghai and Shenzhen stock exchanges in China from 2008 to 2016 to examine the BODC's impact on enterprises' LCSDB and its mechanisms. A group test is conducted using the enterprise's property, nature of rights, and region, among other factors, to investigate the heterogeneity of the impact of board capital on enterprises' LCSDB and its regulatory role. The research indicates (1) an increase in BODC promotes enterprises' LCSDB. (2) An awareness of social responsibility (AOSR) plays an intermediary role in the relationship between BODC and corporate LCSDB. (3) Media attention enhances the BODC's role in promoting enterprises' LCSDB. (4) Government regulatory factors promote the BODC's positive impact on LCSDB. These findings significantly impact the effectiveness of decision-makers within the company, the governance mechanism to address climate change risks, and the possible connection between corporate governance reform and carbon-related policies.

1. Introduction

With the rapid development of China's economy and urbanization, ecological and environmental problems have become increasingly severe. The report of Chinese government in 2022 proposed that "the battle of pollution prevention and control should be carried out in depth throughout the country. The emission of major pollutants continued to decline, and the average concentration of fine particulate matter (PM2.5) in cities decreased by 9.1%." As a constituent cell of the social economy, enterprises are an important source of carbon emissions and environmental damage. Although the Chinese government has paid more and more attention to environmental issues in recent years, the awareness of enterprises in this regard needs to be improved [1]. Reducing high-carbon energy consumption can resolve the most important issues of today and in the future, such as climate change, the environment, and sustainable development [2]. Currently, one critical problem of close focus worldwide involves enterprises' energy consumption and the alarm toward climate change. Low-carbon technologies can be sustainable because they reduce energy consumption and environmental pollution [3]. Additionally, governments must discuss energy emission regulations and the improvement of enterprises' energy efficiency [4]. To some extent, urging enterprises to implement low-carbon sustainable development behaviors (LCSDB) is an effective way to solve current ecological and environmental problems [5]. An enterprise's LCSDB is an economic behavior that reduces external negative externalities in the environment. It also entails a process in which enterprises: integrate low-carbon concepts into different links in their operations and management through low-carbon technological innovations and institutional arrangements and reduce high-carbon energy consumption, carbon emissions, environmental pollution, and resource recycling in such aspects of the product life cycle as product

research and development, material procurement, manufacturing, marketing, logistics, and after-sales service. Enterprises' LCSDB will permeate different aspects of the business, such as its decision-making, supply chain management, production, technology, and capital utilization.

Research on corporate environmental behavior can be traced back to Pigou's (1920) suggestion that government regulations should guide enterprises' green development [6]. However, some research indicates that although government regulations promote enterprises' low-carbon operations, their influence has gradually weakened [7]. Scholars have increasingly studied the influencing factors of enterprises' LCSDB from an internal governance perspective. As the core of the corporate governance mechanism, the board of directors undertakes various tasks—such as allocating resources to align with the corporate strategy, providing creative thinking, and establishing contact with the outside world—that impact the realization of enterprises' financial and nonfinancial objectives [8]. Many scholars have interpreted the relationship between the board of directors and enterprises' sustainable development behaviors based on institutional agency theory. For example, the board of directors is important within the corporate governance structure in addressing environmental risks and ensuring the environmental supervision of raw materials [9]. The board's structure can potentially impact the formulation and implementation of corporate social and environmental responsibility policies [10]. The characteristics of the board of directors, such as its size, proportion of independent directors, and gender diversity, can positively impact enterprises' environmental and sustainable development behaviors [11].

This study explores whether the board of directors' capital (BODC) as a resource endowment positively impacts enterprises' LCSDB, which provides a more evolved perspective than the agency and resource-dependence theories [12–14]. Integrating human capital and social capital of the enterprise's board of directors provides the foundational resources for green transformation, reduces transformation risks, and promotes sustainable development. For example, directors with embedded environmental protection experience can help enterprises develop low-carbon technologies and design low-carbon management strategies; directors with a government background can help enterprises best utilize government subsidies for low-carbon operations. Therefore, this paper describes the characteristics of the BODC and examines its key and mediating role in enterprises' LCSDB, which has important theoretical and practical significance in studying the microlevel factors of enterprises' LCSDB. The BODC concept has not yet been universally defined, but roughly includes directors' own experience; ability; and social resources, or the ability to provide resources for enterprises [15]; heterogeneity of directors' age; educational background; and work experience, among others [16].

The BODC is divided into two levels: human and social capital [16]. This paper describes the BODC through five dimensions to examine its impact on enterprises' LCSDB: the educational background, environmental protection experience, gender diversity, government relationships, and director connections. Additionally, the awareness of social responsibility (AOSR) is an intermediary variable that may promote the BODC's impact on the LCSDB. Meanwhile, this study analyzes the moderating effects of environmental rules and media attention on the relationship between board capital and enterprises' LCSDB. It also tests the heterogeneity of the BODC's impact on enterprises' LCSDB by grouping given the nature of property rights and the enterprise's location. As academic literature on the influencing factors of enterprises' LCSDB scarcely involves research from the BODC perspective, this paper provides highly significant research implications.

This work also presents the following marginal contributions: (1) this study is the first to examine enterprises' LCSDB from a board capital perspective. Currently, most academic research has studied the driving factors and mechanisms of enterprises' LCSDB from the perspective of external and internal stakeholder pressures, but the research focusing on BODC is currently in its infancy. (2) In analyzing enterprises' LCSDB, this study adopts the back-propagation (BP) neural network mathematical model to construct a low-carbon behavioral index for enterprises. Neural network has the advantages of nonlinear mapping ability, self-learning, and self-adaptive ability, which can be widely used in pattern recognition and analysis [17], thus can solve problems better. As academic circles have yet to reach a unified understanding of the concept and indicators of enterprises' low-carbon behavior, this paper's results provide a high-value reference for further academic research.

The remainder of this paper is structured as follows: Section 2 reveals the theoretical analysis and hypothesis and constructs a conceptual framework between the BODC and enterprises' LCSDB. Section 3 presents the research design and methodology and describes the samples used in this study. Section 4 empirically tests the data and discusses the results. Section 5 presents the relationship between the BODC and LCSDB to facilitate sustainable development. Finally, Section 6 discusses the limitations and future research direction.

2. Theoretical Analysis and Hypothesis Development

2.1. Relationship between BODC and Enterprises' LCSDB. Studies of BODC reveal two important elements: human and social capital. The former is the result of specific human investment and ultimately accumulates the professional background, relevant experience, skills, and knowledge for enterprise decision-making [18–20]. The latter refers to individuals' or social units' ability to obtain the sum of the actual and potential resources they, or the enterprises, need in their relationship network [15]. In practical research, it is difficult to distinguish between these two concepts. To examine the BODC's mechanism of influence on LCSDB, this paper analyzes the board of directors given five aspects: the educational background, environmental protection experience, gender diversity, political connections, and director connections.

First, a close relationship exists between the board of directors' human capital and enterprises' sustainable development behavior, with a positive connection between board members' educational background and the board's responsibility for social and environmental issues [21, 22]. This is because the higher the senior executives' educational background, the more they understand and focus on sustainable development in society. Board members with embedded environmental protection work experience have accumulated rich relevant knowledge; further, companies with board members with such work experience have lower greenhouse gas emissions [23]. This may be because such board members are more inclined to make decisions conducive to the sustainable development of society. As a strategic human resource, board members are crucial to the future development of the company [24].

Previous studies have observed that gender diversity in the board of directors adds value to governance because it can bring various advantages [25]. For example, female directors are more inclined to assume social responsibilities, delay risks, and focus on social and environmental issues to improve enterprises' sustainable development behaviors [26]. Several studies have also empirically verified that female directors positively influence enterprises' sustainable development behaviors [27–29]. Second, members of the board of directors can use their political connections to help enterprises obtain government-controlled resources, such as subsidies for environmental protections; expand financing channels; and reduce financing costs. Simultaneously, directors who hold political positions have a sharp attention to industry information and better understand consumers' green preferences and competitors' LCSDB to promote their own enterprise's sustainable development and LCSDB. Moreover, when a board connection occurs—or specifically, a phenomenon in which organizations are connected through overlapping board members and executives [30]—the board connection may diffuse the LCSDB among different enterprises. Subsequently, the affiliated enterprises can reference each other's LCSDB activities, gain experience in low-carbon technology innovation, pool their resources, and accelerate green transformation. This leads to the following Hypothesis 1.

Hypothesis 1. The BODC can promote enterprises' LCSDB.

2.2. Media Attention and Environmental Regulations Mediate the Relationship between BODC and LCSDB. In the theory of institutional economics, public opinion is regarded as an informal environmental system [31], while social schools posit that public opinion is a social normative mechanism. The media is an independent social supervisory force that reveals enterprises' moral and immoral behaviors, bringing public pressure and compelling them to fulfill their social responsibilities [32]. With the enhancement of the public's awareness of environmental protections, the public will focus more on which enterprises' behaviors are harmful to the environment. The news media will typically prioritize stories that can attract public attention based on the driving force of interest [33], and thus, are more inclined to report negative information, such as enterprises' environmental pollution and high carbon emissions. Media attention provides a way for enterprises to obtain legitimacy, but also acts as a source of crisis regarding such legitimacy [34]. According to legitimacy theory, whether an enterprise's behavior is legal depends on its evaluation by the public [35]. As society closely observes environmental problems, environmental protections and the low-carbon transformation of enterprises have become important aspects of legitimacy; for example, high-carbon-emitting enterprises must improve their levels of carbon emissions to win the public's trust and establish a positive corporate image.

Additionally, environmental regulations have become an important way to effectively solve environmental problems in China's current legal society. First, the government restrains enterprises' carbon emissions behaviors by establishing carbon emissions standards, punishing highly polluting enterprises, implementing environmental assessments, and setting production technical standards. These administrative measures influence the firm to not only weigh its need to produce and emit against the costs of possible violations but also improve environmental performance [36]. Second, the government corrects enterprises' high carbon ranking by strengthening its supervision, such as through the collection of fossil fuel taxes, sewage charges, and emissions-trading plans [37]. These measures aim to increase enterprises' environmental control costs through the market mechanism to curb the demand for petrochemical energy. Enterprises will adopt clean technologies, such as desulfurization and denitrification methods, to achieve emissions reduction targets [38].

Based on this analysis, this paper proposes the following hypotheses.

Hypothesis 2. Media attention positively regulates the relationship between BODC and enterprises' LCSDB.

Hypothesis 3. Environmental regulations have a positive regulatory effect on the relationship between BODC and enterprises' LCSDB.

Figure 1 illustrates the assumptions presented in this section and the conceptual framework for the BODC's mechanism of influence on LCSDB.

3. Research Design and Empirical Analysis

3.1. Variable Definition and Construction

3.1.1. Dependent Variable: The Low-Carbon Behavioral Index. The dependent variable in this study is the enterprise's low-carbon behavioral index (LCBI), which refers to the enterprise's degree of behavior related to low energy consumption, low pollution, and low emissions, which will lead to the enterprise's economic benefits and the sustainable development of society and the environment. This paper considers prior research to posit that LCSDB is guided by the concept of sustainable development [39–45]. Specifically, this concept shapes the enterprise's low-carbon culture and

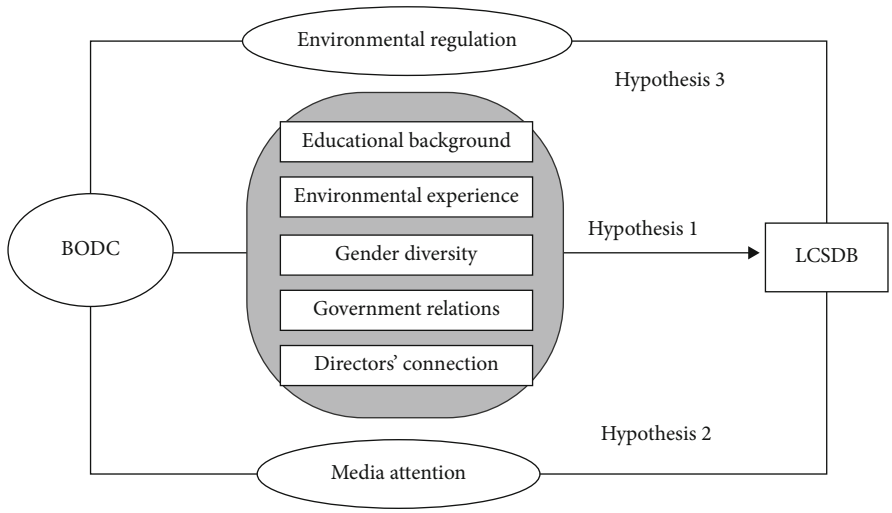

Figure 1: The mechanism of the BODC's influence on LCSDB and this paper's conceptual framework.

involves formulating low-carbon-development strategies with low-carbon technological innovations as a driving force. It includes the realization of low-carbon management in product manufacturing, logistics, marketing, and other cycles; and the selecting of low-carbon materials, low-carbon energy, and green human resource management. Carbon emissions should be reduced to achieve a mutually beneficial situation that promotes both environmental and economic benefits. Therefore, this study constructs an enterprise LCSDB evaluation system to measure the enterprise's LCBI given the six dimensions of low-carbon culture: the low-carbon strategy, innovations, investments, operations, and emissions. Table 1 shows the enterprise's LCSDB evaluation system.

Simultaneously, Liu (2021) used a BP neural network method to determine the weight of each index in the evaluation index system and address the complex relationships within this system to obtain a more objective weight [46]. The specific steps are as follows.

First, the BP neural network structure is built. The input layer is marked as vi, $(i = 1, 2, .., m)$, $I = (v1, v2, v3, \cdots vm)\ T$, the hidden layer is represented by hi, $(i = 1, 2, .., n)$, $H = (h1, h2, h3, \cdots hn)\ T$, the actual output from the output layer is expressed as $didj$, and the predicted output is expressed as Oi, $(i = 1, 2, .., n)$.

Second, the standardized treatment index is calculated; the forward and reverse indicators are standardized using the following two equations.

$$\vartheta_i = \frac{\vartheta_i{}' - \min\left(\vartheta_i{}'\right)}{\max\left(\vartheta_i{}'\right) - \min\left(\vartheta_i{}'\right)}, \tag{1}$$

$$\vartheta_{\mathrm{i}} = \frac{\vartheta_{\mathrm{i}}' - \min\left(\vartheta_{\mathrm{i}}'\right)}{\max\left(\vartheta_{\mathrm{i}}\right) - \min\left(\vartheta_{\mathrm{i}}'\right)} \mathrm{i} = 1, 2, \cdots \mathrm{m}. \tag{2}$$

Third, a forward transmission is performed; the transfer from the input layer to the metaphor layer and from the metaphor layer to the output layer is displayed in Equations (3) and (4), respectively.

$$H_j = f\left(\sum_{i=1}^{m} \alpha_{ij}\vartheta_i + v_j\right), \tag{3}$$

$$O_j = f\left(\sum_{i=1}^{k} b_i h_i + v_j\right), \tag{4}$$

where f is the activation function, and the sigmoid function is used, with v_j as the threshold.

Fourth, a directional correction is performed, with the error function given in Equation (5). The value of the error function is set to 10-5 and minimized by repeatedly correcting the weight and threshold.

$$E = \frac{1}{2}\sum_{i=1}^{n}\left(d_i - o_j\right)^2. \tag{5}$$

Fifth, we confirm the weight, which is calculated using Equation (6).

$$w_i = \frac{\sum_{k=1}^{n}|\alpha_{ik}|}{\sum_{j=1}^{m}\sum_{k=1}^{n}|\alpha_{jk}|}. \tag{6}$$

Sixth, the LCBI is obtained by calculating the weighted average.

$$\mathrm{LCBI} = \mathrm{w_i}\vartheta_{\mathrm{i}}. \tag{7}$$

3.1.2. Independent Variable: The Board's Capital. This study selected five indicators—the directors' educational background, environmental protection experience, gender diversity, political connections, and directors' connections—to construct the board capital variable (BC). If the director has a master's degree or above, the educational background

Table 1: The enterprise's LCSDB evaluation system.

General index	Secondary indicators	General index	Secondary indicators
Low-carbon culture	Management layer	Low-carbon innovations	Low-carbon technology R&D
	Employee layer		Low-carbon equipment update
Low-carbon strategy	Regulations and rules of low-carbon management	Low-carbon operations	Low-carbon production
	Low-carbon financial strategy		Low-carbon marketing
	Low-carbon human resource management (HRM) strategy		Low-carbon logistics
Low-carbon input	Low-carbon materials		Low-carbon services
	Clean energy	Low-carbon emissions	Low-carbon gas
	Green HRM		Low-carbon solid waste

is scored as one, and zero otherwise. The average score of the director's educational background was used to measure the educational background of the board of directors. If the directors have embedded environmental protection experience, this is scored as one, and zero otherwise; the average score of this experience is used to measure the board's environmental protection experience. The board's gender diversity is measured by the ratio of the number of female directors in the board of directors. If the directors have experience in central, provincial, and municipal governments, their political connections are scored as three, two, and one, respectively, while the rest are noted as zero. The average score for the directors' political connections was used to measure the board's political connections. The ratio of directors with connections to total directors was used to measure director connections. Finally, the average score of the five indicators was calculated as the BODC.

3.1.3. Moderating Variables: MC, ER, SOE, and DISTRICT. The text of news reports from the CSMAR news database was analyzed using Python software, and irrelevant reports were filtered through a keyword analysis. Subsequently, 129,658 reports related to the listed companies were obtained. A sample of text for training was taken that included news related to pollution accidents from a public environmental research center to summarize the negative environmental keywords. The news reports were also searched to weigh the sample's media attention. Finally, a surrogate variable for the MC was established that assumes a value of one if the number of negative reports is greater than the sample's median, and zero otherwise.

The ER surrogate variables were primarily measured by the administrative supervisory status of enterprises' carbon emissions in the region where the enterprise is located. This was confirmed by the number of local laws and regulations issued by the local government in the China Environmental Yearbook 2008-2016. The cumulative value of each year since 2008 was ranked according to the sample's environmental regulatory status; enterprises with scores greater than the sample's median were given a value of one, while those with values less than the sample's median were ranked as zero.

This study also constructs the SOE and DISTRICT virtual variables and scale used for the heterogeneity test. The SOE indicates whether the enterprise is state-owned, with such enterprises scored as one, and zero otherwise. If the enterprises are located in China's eastern region, then, DISTRICT is given a value of one, and zero otherwise.

3.1.4. Intermediary Variable: The Awareness of Corporate Social Responsibility. A comprehensive integration of human and social capital has resulted in the BODC increasing the awareness of corporate social responsibility, thus promoting enterprises' low-carbon sustainable development activities. In this regard, a board's consciousness of its social responsibility may mediate the explanatory and interpreted variables. To further investigate the existence of this intermediary transmission channel—or specifically, the board's capital impacting CSR awareness, and subsequently, enterprises' low-carbon sustainable development behavior—this paper measures corporate social responsibility awareness (AOSR) according to whether enterprises publish social responsibility or sustainable development reports [47]. According to Parsa et al. (2021), if an enterprise publishes social responsibility, environmental, or sustainable development reports in its first year, the index variable is set as one, and zero otherwise [48].

3.1.5. Control Variables. We chose some control variables to avoid biased results and a study largely founded on previous empirical literature, we will choose some control variables. According to Alshirah et al. (2020) and Malm et al. (2020), the control variables in this study include the board's structure (EB), return on assets (ROA), cash flows (cash), enterprise size (in size), and asset-liability ratio (LEV) [49, 50].

The variable EB indicates the number of directors on the board [51]. As boards are responsible for making a corporation's significant decisions, a larger board is more desirable because it allows the directors a greater opportunity to use their skills, experiences, knowledge, and external networks [52] to maintain the enterprise's sustainable operations and encourage social responsibility behaviors.

The variable ROA is a key indicator of profitability and is calculated as the earnings before tax divided by total assets. Although some studies disagree that a positive relationship exists between profitability and the extent of their social responsibilities [53, 54], most researchers confirm a positive relationship [55, 56].

The variable cash represents the net cash flow of business operations, calculated by subtracting the cash outflow from operating activities from the cash inflow from operating activities. The level of cash affects enterprises' investment behaviors, such as purchasing materials, hiring employees, and paying logistics expenses. Therefore, the cash situation relates to other low-carbon operational behaviors.

The variable size is calculated as the logarithm of total assets [57]. Firm size is expected to significantly impact LCSDB because larger firms must disclose more social, economic, and environmental information than smaller firms to satisfy stakeholders' needs [58]. Moreover, low-carbon investments have costly implementation costs, and thus, larger companies may have more resources and expertise to enable them to undertake LCSDB, which will also improve their image and reputation [59].

The variable LEV is measured as the total debt over assets [60]. However, previous empirical evidence has been inconclusive. Many high-leverage firms are more prone to disclose voluntary information and behavior to reduce both agency and capital costs. Table 2 presents the definition or measurement of the variables.

3.2. Samples and Data Source. According to existing literature, Chinese industries are a primary source of heavy pollution in China, and enhancing their positive environmental behaviors is key to promoting LCSDB [61–66]. Therefore, this study samples large-share companies listed on the Shanghai and Shenzhen stock exchanges from 9 heavy-pollution industries: thermal power generation, iron and steel, cement, electrolytic aluminum, coal, metallurgy, chemical, petrochemical, and papermaking industries. This study's primary research sample includes 286 listed companies selected from these industries, with data spanning 2008 to 2016; sample companies with "ST" and "∗ ST" prefixes and companies with missing financial data were then omitted. Enterprises with "ST" before the stock abbreviation will perform special treatments for the stock transactions of listed companies with abnormal financial or other conditions. Further, stock abbreviations preceded by "∗ ST" indicate risk, in that their shares may be delisted and differ from the shares of other companies. The sample data has been selected since 2008 because in reality, China's environmental pollution is more serious after 2008.

3.3. Building Models. This study examines the impacts of board capital on LCSDB by constructing the panel regression benchmark model in the following form:

$$\begin{aligned}\mathrm{LCBI}_{it} = {} & \beta_0 + \beta_1 * \mathrm{BC}_{it} + \beta_2 * \mathrm{EB}_{it} + \beta_3 * \mathrm{ROA}_{it} \\ & + \beta_4 * \mathrm{CASH}_{it} + \beta_5 * \mathrm{LnSIZE}_{it} + \beta_6 * \mathrm{LEV}_{it} + \varepsilon_{it}.\end{aligned} \tag{8}$$

Among them, the intercept term is β_0, β_1 to β_6 are coefficients, and ε_{it} is residual. If β_1 is greater than zero, the BODC can promote the LCSDB. To further investigate the mediating role of AOSR, this study constructs an extended model:

$$\begin{aligned}\mathrm{LCBI}_{it} = {} & \beta_0 + \beta_1 * \mathrm{BC}_{it} + \beta_2 * \mathrm{EB}_{it} + \beta_3 * \mathrm{ROA}_{it} \\ & + \beta_4 * \mathrm{CASH}_{it} + \beta_5 * \mathrm{LnSIZE}_{it} + \beta_6 * \mathrm{LEV}_{it} + \varepsilon_{it},\end{aligned} \tag{9}$$

$$\begin{aligned}\mathrm{AOSR}_{it} = {} & \alpha_0 + \alpha_1 * \mathrm{BC}_{it} + \alpha_2 * \mathrm{EB}_{it} + \alpha_3 * \mathrm{ROA}_{it} + \alpha_4 \\ & * \mathrm{CASH}_{it} + \alpha_5 * \mathrm{LnSIZE}_{it} + \alpha_6 * \mathrm{LEV}_{it} + \varepsilon_{it},\end{aligned} \tag{10}$$

$$\begin{aligned}\mathrm{LCBI}_{it} = {} & \gamma_0 + \gamma_1 * \mathrm{BC}_{it} + \gamma_2 * \mathrm{AOSR}_{it} + \gamma_3 * \mathrm{EB}_{it} \\ & + \gamma_4 * \mathrm{ROA}_{it} + \gamma_5 * \mathrm{CASH}_{it} + \gamma_6 * \mathrm{LnSIZE}_{it} \\ & + \gamma_7 * \mathrm{LEV}_{it} + \varepsilon_{it}.\end{aligned} \tag{11}$$

In these three equations, we focus on (β_1, α_1) and (γ_1, γ_2). On the one hand, if α_1 is significant, then, the BODC will affect the corporate AOSR. On the other hand, if γ_1 and γ_2 are simultaneously significant and the absolute value of γ_3 is less than that of $\beta 1$, we can consider AOSR as mediating corporate LCSDB. If γ_2 is significant, but γ_1 is not, then, the corporate AOSR fully mediates the BODC regarding the impact of corporate LCSDB.

This study further investigates the moderating effects of MC and ER on the BODC's impact on LCSDB by constructing the following extended models:

$$\begin{aligned}\mathrm{LCBI}_{it} = {} & \beta_0 + \beta_1 \mathrm{BC}_{it} + \beta_2 \mathrm{MC}_{it} + \beta_3 \mathrm{MC}_{it} * \mathrm{BC}_{it} \\ & + \beta_4 \mathrm{EB}_{it} + \beta_5 \mathrm{ROA}_{it} + \beta_6 \mathrm{CASH}_{it} + \beta_7 \mathrm{LnSIZE}_{it} \\ & + \beta_8 \mathrm{LEV}_{it} + \varepsilon_{it},\end{aligned} \tag{12}$$

$$\begin{aligned}\mathrm{LCBI}_{it} = {} & \beta_0 + \beta_1 \mathrm{BC}_{it} + \beta_2 \mathrm{ER}_{it} + \beta_3 \mathrm{ER}_{it} * \mathrm{BC}_{it} \\ & + \beta_4 \mathrm{EB}_{it} + \beta_5 \mathrm{ROA}_{it} + \beta_6 \mathrm{CASH}_{it} + \beta_7 \mathrm{LnSIZE}_{it} \\ & + \beta_8 \mathrm{LEV}_{it} + \varepsilon_{it}.\end{aligned} \tag{13}$$

In Equations (12) and (13), if β_3 is greater than zero, then, MC and ER have positive regulatory effects on the BODC's impact on LCSDB; otherwise, these have negative regulatory effects.

4. Results and Discussion

4.1. Descriptive Statistics. Table 3 presents the sample's descriptive statistics. The following can be observed: (1) *t*he enterprises' average and median LCBI are 0.382 and 0.238, respectively, which indicates that overall, enterprises in heavy-pollution industries do not exhibit particularly remarkable low-carbon behaviors. The standard deviation of 0.493 suggests a certain difference in low-carbon behaviors among the sample enterprises. (2) The sample's maximum BC was 1.905, while the minimum BC was 0.130. This substantial range reveals that a difference exists between the samples' BODC. Further, there is a large gap

Table 2: The definition or measurement of the variables.

Variable type	Variables	Variable description or measurement method
Dependent variable	LCBI	Calculated using a BP neural network method and LCSDB evaluation system
Independent variable	BC	Average score of five indicators regarding the board of directors
Intermediary variable	AOSR	Scored as one if social responsibility, environmental, or sustainable development reports are disclosed, and zero otherwise
Control variable	EB	The number of directors on the board
	ROA	The earnings before taxes divided by total assets
	CASH	The cash outflow from operating activities subtracted from the cash inflow from operating activities
	In size	The logarithm of total assets
	LEV	Liabilities divided by total assets
Moderating variable	MC	Scored as one if the number of negative reports is greater than the sample's median, and zero otherwise
	ER	Scored as one if larger than the sample's median, and zero otherwise
	SOE	Scored as one if enterprise is state-owned, and zero otherwise
	DISTRICT	Scored as one if enterprise in located in China's eastern region, and zero otherwise

Table 3: The variables' descriptive statistics.

Variables	Mean	Median	Std. dev.	Minimum	Maximum
LCBI	0.382	0.258	0.493	0.000	2.310
BC	4.697	4.235	41.30	0.130	1.905
AOSR	0.459	1.000	0.486	0.000	1.000
EB	8.480	9.000	2.552	5.000	17.00
ROA	0.051	0.045	0.478	-0.412	0.062
CASH	0.070	0.062	0.070	-0120	0.279
In SIZE	10.20	10.12	0.587	8.982	11.55
LEV	1.924	1.316	1.502	-1.203	15.88
MC	0.556	0	0.489	0	1.000
ER	0.768	0	0.186	0	1.000

between the best- and poorest-performing samples. (3) The mean value of AOSR is 0.459; therefore, the investigated heavy-pollution enterprises do not actively disclose social responsibility or sustainable development reports. (4) The control variables' standard deviations are less than one, except for that of the enterprise's asset-liability ratio (Lev), which is greater. This indicates a relatively stable range of fluctuations.

4.2. The Relationship between BODC and LCSDB and Its Regulatory Role. Table 4 displays the test results regarding the relationship between the enterprises' BODC and LCSDB and its moderating effects. The regression results in column 1 reveal that a positive correlation exists between enterprises' BODC and LCSDB; hence, BODC promotes LCSDB, in that board members' human and social capital improve the enterprises' levels of LCSDB. The higher the BODC, the more inclined the enterprises are to implement LCSDB. Thus, Hypothesis 1 is verified.

To further investigate the regulatory effects of MC and ER on the relationship between BODC and lcsdb, columns 1 and 3 introduce the interaction terms of MC × BODC and ER × BODC, respectively. It can be noted that MC and ER have a positive moderating effect on the relationship between BODC and LCSDB; thus, Hypotheses 2 and 3 are verified.

4.3. The Mediating Role of AOSR. Table 5 illustrates the results from testing the mediating role of AOSR. The coefficient of BODC in the second column is significantly positive, indicating that BODC significantly improved AOSR among the sample enterprises. The AOSR coefficient in the third column is significantly positive, the BODC coefficient is significantly positive, and the absolute value is less than the absolute value of the BODC coefficient in the first column; therefore, AOSR plays an intermediary role between BODC and LCSDB.

4.4. Heterogeneity Test. This study further investigates the heterogeneity of the BODC's impact on enterprises' LCSDB by selecting two indicators of heterogeneity: the nature of enterprises' property rights and the enterprise's home region. Given the nature of property rights, the sample enterprises were divided into state-owned and nonstate-owned enterprises. According to their respective regions, the sample enterprises were divided into the central and western regions and eastern regions of China. After the samples were classified according to these criteria, the characteristics of heterogeneity were revealed through grouping tests. Table 6 lists the test results.

In the first column, the coefficient of BODC is significantly positive, although this coefficient in the second column was not statistically significant. In the third column, the coefficients of SOE and SOE × BODC are significant; hence, the BODC's promotional effect on enterprises' LCSDB differs due to the enterprises' different ownership. Specifically, the BODC of state-owned enterprises has a more obvious promotional effect on LCSDB. This may occur because state-owned enterprises with rich board capital are more likely to respond to the government's low-carbon

Table 4: The results from testing the relationship between BODC and LCSDB and its regulatory role.

Variables	LCBI (1)	(2)	(3)
BC	4.483∗ (1.897)	-21.354∗∗∗ (-2.329)	-12.368∗∗∗ (-2.527)
MC		125.600∗∗∗ (12.975)	
MC × BC		2.311∗∗∗ (2.862)	
ER			-2.566∗∗∗ (-1.109)
ER × BC			1.638∗∗∗ (2.354)
Control variables	Control	Control	Control
R^2	0.318	0.362	0.275
Model	Fixed-effects	Fixed-effects	Fixed-effects

Note: ∗∗∗, ∗∗, and ∗ are significant at the level of 1%, 5%, and 10%, respectively; the value of t-test is in parentheses.

environmental protection policies and more actively participate in low-carbon operations and production methods. Additionally, board members of state-owned enterprises are more likely to obtain financing for low-carbon transformations than private enterprises due to their strong political background. Simultaneously, such firms have fewer risks during the low-carbon transition because they can receive more support for policies and financial subsidies. In other situations, state-owned enterprises present more obvious low-carbon behaviors than nonstate-owned enterprises.

The coefficient of BODC in the fifth column regression was not statistically significant, while this coefficient in the fourth column regression was significantly positive. In the sixth column, the coefficient of the interaction between DISTRICT and BODC is significant, which indicates that regional heterogeneity exists in the BODC's promotional effect on enterprises' LCSDB. Specifically, this effect on enterprises in the eastern region is more obvious, possibly due to the far-reaching impact of China's reform and opening-up policy. Given the superior economic foundation and sustainable development vision in China's eastern region, such enterprises are more inclined to engage in low-carbon environmental protections under the same board capital conditions, with a stronger sense of social responsibility and organizational legitimacy.

4.5. Robustness Test. We performed several robustness tests. First, we changed the explanatory variables' measurement method. Referring to existing literature (Haynes and Hillman, 2010) [16], board capital is specifically divided into its breadth and depth, and such indicators as heterogeneity in the educational level, gender, environmental protection work experience, chain director, and political association are used as proxy indicators of the board capital's breadth. Literature measures the degree of heterogeneity using more Herfindahl-Hirschman coefficients, where Pm denotes the percentage of M members on the board of directors, and Q is the category, with its value range set as $Q \in [0, 1]$.

After standardizing the five indicators' scores, the average value is the score of the board capital's breadth, which ranges from zero to one; the higher the score, the greater the breadth. Additionally, the ratio of the number of concurrent positions of board members in the same industry to the number of concurrent positions of all chain directors is used as a measure of the board of directors' capital depth, with values ranging between one and zero. The higher the score, the higher the board's capital depth. Finally, the breadth and depth of the board's capital are added to provide a comprehensive measurement of board capital, as follows:

$$H = 1 - \widehat{\alpha}_{m\ddot{l}\mu Q} P_m^2. \tag{14}$$

Second, we controlled for the influence of endogeneity. In this study, the propensity score-matching method (PSM) was used to test Hypothesis 1; and EB, ROA, CASH, LnSIZE, and LEV were selected to carry out a repeatable one-to-one nearest-neighbor matching of the sample enterprises. The sample with the highest tendency score and the sample with the lowest score of a certain board of directors' capital sample will form a paired sample. After obtaining the pseudovalues, we determined if they met the equilibrium hypothesis. If so, the paired sample was placed into the model to regress. The experimental results demonstrate that enterprises with higher board capital achieve better LCSDB. Therefore, this study's research conclusions remain unchanged.

Finally, we control for the influence of endogeneity by regressing board capital against the lag of other control variables. We also attempted to eliminate the loss samples and add other control variables, such as the enterprise's year of establishment. After the previously noted robustness test, this study's conclusion is still valid.

5. Conclusions

This paper considered data from Chinese-listed companies in heavily polluting industries spanning 2008 to 2016 to examine how BODC affects enterprises' LCSDB and its influencing mechanism from the enterprise perspective. The results reveal that the BODC can significantly promote enterprises' LCSDB. Further, media reports and environmental regulations promote the relationship between board capital and such behavior. Simultaneously, corporations' awareness of social responsibility mediates the relationship between BODC and LCSDB. This conclusion is still valid after changing the explanatory variables, using a PSM test, combining lags, adding other control variables, and performing other robustness tests. Further research indicates that the board capital's effect on enterprises' low-carbon sustainable development behavior is influenced by the nature of property rights and the enterprise's location. Compared with private enterprises, the capital of board of directors in state-owned enterprises is more significant than that of private

Table 5: The results from testing the mediating role of enterprises' AOSR.

Variables	LCBI (1)	AOSR (2)	LCBI (3)
BC	1.256∗(1.817)	0.025∗(1.523)	1.128∗(1.648)
AOSR			22.148∗∗∗(5.287)
Control variables	Control	Control	Control
R^2	0.439	0.487	0.391
Model	Fixed-effects	Fixed-effects	Fixed-effects

Note: ∗∗∗, ∗∗, and ∗ are significant at the level of 1%, 5%, and 10%, respectively; the value of ***t***-test is in parentheses.

Table 6: Heterogeneity test results regarding the relationship between BODC and LCSDB.

	Enterprises' ownership			Enterprises' region		
	State-owned	Nonstate-owned	All samples	Eastern District	Non-Eastern District	All samples
	(1)	(2)	(3)	(4)	(5)	(6)
BODC	5.438∗∗∗	1.897	1.620∗∗	2.609∗∗	1.102	4.586∗∗
	(2.360)	(1.254)	(1.961)	(1.153)	(1.892)	(2.923)
SOE			-18.238∗			
			(-1.059)			
SOE × BODC			4.026∗			
			(1.298)			
DISTRICT						9.264
						(1.256)
DISTRICT × BODC						2.358∗
						(-1.985)
Control variables	Control	Control	Control	Control	Control	Control
R^2	0.529	0.285	0.311	0.286	0.331	0.203
N	1224	1350	2574	855	1719	2574
Model	Fixed-effects	Fixed-effects	Fixed-effects	Fixed-effects	Fixed-effects	Fixed-effects

Note: ∗∗∗, ∗∗, and ∗ are significant at the level of 1%, 5%, and 10%, respectively; the value of t-test is in parentheses.

enterprises in promoting enterprises' low-carbon sustainable development behavior. Compared with enterprises in the central and western regions, the board capital of enterprises in eastern China has a more significant impact on enterprises' low-carbon sustainable development behavior. The research results help enterprises actively respond to realize national sustainable development strategies from a governance structural perspective.

Given these research conclusions, this paper proposes the following: (1) enterprises should augment their boards' levels of human and social capital. The selection of board members should focus on their environmental protections, work experience, and educational background, as such characteristics will enhance and guide the transmission of low-carbon sustainable development behavioral information through the board's human capital channel. On the one hand, we should focus on the board's gender diversity, improve the ratio of female directors on the board, and enhance the board's awareness of the social environment to compel them to assume more social responsibilities. (2) The government should improve enterprises' low-carbon transformation environment through financial support and knowledge-sharing to drive sustainable low-carbon transformations. This will involve strengthening and improving relevant laws and regulations, which will protect the ownership of inventions and patent rights in pursuing low-carbon innovation. The government must also attempt to transfer low-carbon technologies, knowledge, and operations to enterprises, as such resources have become a font of wisdom and a strong support for enterprises' low-carbon transformations. In addition, the government should not only focus on controlling the total carbon emissions of heavily polluting enterprises but also pay attention to the control of energy consumption and vigorously encourage enterprises to improve relevant technologies and processes. (3) The media should increase the publicity of low-carbon sustainable development of enterprises and make the concept of "low-carbon development" a new social value orientation. The media should play a greater role in guiding low-carbon awareness and low-carbon behavior and supervising the implementation of low-carbon behavior by enterprises and residents. At the same time, the media guide and encourage residents to disseminate and share low-carbon elements through a variety of social media, including self-media social

circles. (4) In considering regional heterogeneity, the government must enhance the low-carbon development environment and policy support for low-carbon transformations in the central and western regions and help the low-carbon transformation of western enterprises through production, learning, and research. Alternatively, and in considering that financing constraints may impact the low-carbon transformation of enterprises in the central and western regions, the government can promote low-interest environmental loans to mitigate environmental enterprises' funding limitations, thus promoting enterprises in the central and western regions to enhance their low-carbon behaviors.

6. Limitations and Future Research

The main limitations of this paper are mainly reflected in three aspects. First, the number of heavily polluting industries in China is about 16, and the types of industries involved are more complex. However, the sample of this paper only selects 9 representative industries instead of analyzing the whole sample. In order to deeply reveal the relationship between corporation's BODC and LCSDB, the wider the research industry, the more reliable the results may be. Moreover, when studying the mechanism of the impact of BODC on corporation's LCSDB, this study only considers the intermediary variable of AOSR. However, in fact, when the board of directors of an enterprise is rich in capital, it may have a strong ability to bear the risk of low carbon green innovation and a good profitability, which can provide relevant protection for low-carbon behavior. Therefore, the transmission mechanism of this paper is relatively limited and lacks a richer perspective. In addition, most of the data used in this study are public historical data, and there is a lack of field interviews with the research objects to obtain first-hand data. The advantage of field interview is that it can obtain more extensive information, such as how the capital of the board of directors affects the psychology of enterprise management and then affects LCSDB.

In future research, we look forward to further mining the mechanism of the impact of BODC on LCSDB. Selecting a wider range of data acquisition channels and increasing methods such as expert evaluation, enterprises' interview, and questionnaire to verify and test the multiple data. Furthermore, it is expected to establish a comprehensive framework affecting LCSDB in the future, rather than limited to the microlevel of enterprise board of directors. At the same time, considering the influencing factors such as external environmental regulation, market competition, and consumer preference, we will study how the above factors cooperate with the BODC to jointly affect the low-carbon behavior of enterprises and how the impact degree and contribution value for each factor. So as to better provide suggestions for the realization of low-carbon development of enterprises. Additionally, with the implementation of carbon inclusion and improvement of the carbon market trading system, we will consider exploring the multiple path to realize LCSDB from more dimensions, including corporate social responsibility, environmental regulation, carbon market, and carbon inclusion in the future research.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

Authors' Contributions

Lipeng Liu did the writing and editing, revisions, investigation, data curation, data analysis, validation, reviewing, and proofreading. Xiaoxue Liu did the conceptualization, supervision, funding acquisition, reviewing, and editing. Zihao Guo did the writing and editing, revisions, data curation, data analysis, validation, reviewing, and proofreading. Shuangshuang Fan did the data analysis, data curation, investigation, reviewing, and proofreading.

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