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The Impact and Mechanism of Internal Informal Institutions on Green Innovation: Empirical Evidence from Chinese Listed Companies

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Abstract: Green innovation is a key driving force in promoting the development of a low-carbon economy and society. However, previous studies have not paid enough attention to the influence of internal informal institutions on green innovation. To address this issue, this study conducts empirical tests by using a sample of A-share listed firms in China from 2013 to 2020. This study investigates whether and how carbon management strategies, as an important part of the internal informal institutions, promote corporate green innovation. The results show that carbon management strategies have a significant and positive impact on both the quantity and quality of green innovation. In addition, emphasizing meeting the needs of stakeholders and focusing on research and development (R&D) investment can significantly enhance the positive impact of carbon management strategies on green innovation. Furthermore, at the market level, carbon management strategies significantly boost green innovation in firms with larger market shares, which is enhanced by meeting stakeholder demands. At the firm level, state-owned enterprises pay attention to the mechanisms of both stakeholders' demands and R&D investment in driving green innovation. At the executive level, executive shareholding firms emphasize driving green innovation through R&D investment. Overall, these findings provide new evidence for the determinants of green innovation that have not been fully explored before through the perspective of internal informal institutions.

Keywords: internal informal institutions; carbon management strategy; green innovation; stakeholder demands; R&D investment; textual analysis

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1. Introduction

Achieving the greening and decarbonization of economic and social development is impossible without green innovation. Green innovation is characterized by a double externality, as it brings not only economic benefits but also environmental benefits. In addition, green innovation can bring social benefits, such as corresponding employment effects, etc. [1]. Firm green innovation is influenced by various factors, which have been extensively studied in the literature, mainly from three perspectives: formal systems, informal systems, and stakeholder pressure. Unlike formal institutions, which are typically created and enforced by the state through laws and regulations, informal institutions emerge organically from within society. They are often self-enforcing, relying on reputation and social sanctions rather than legal or coercive mechanisms [2,3]. While formal rules and structures are crucial for corporate governance, the role of informal institutions, especially internal informal institutions, cannot be ignored. Internal informal institutions refer to the unwritten rules, norms, and practices that guide behaviors and interactions within an organization. They shape the organization's environment and the behavior of its members, ultimately affecting the quality of corporate governance [4]. However, little empirical evidence is available about the implications of internal informal institutions on green innovation. Internal informal institutions exert a more direct influence on firms' internal management practices and can positively influence business decisions to pursue green innovation [5]. Given the growing attention paid to green innovation by both executives and academics, it is important to understand whether and how internal informal institutions affect firm green innovation.

Carbon management strategies, hereby defined, reflect firms' long-term strategic objectives and specific practices for implementing low-carbon management. This paper focuses on carbon management strategies, an important part of the internal informal institutions, and examines how they affect firm green innovation. It serves as a crucial component of a business's internal informal institutions and plays a guiding role in promoting green innovation.

At the United Nations General Assembly in 2020, General Secretary Jinping Xi proposed that carbon dioxide emissions should peak by 2030 and work towards achieving carbon neutrality by 2060. The report of the 20th Party Congress also emphasized the need to actively and steadily promote carbon peaking and carbon neutrality. Consequently, firms have been articulating carbon management strategies in their corporate social responsibility (CSR) reports. Several companies have been selected for inclusion in the FTSE4good index due to their excellent CSR performance, e.g., Pigeon, Zhongxing Telecom Equipment, Fosun International Limited, etc.

However, given the cost–benefit and negative externalities of innovation activities, firms lack sufficient incentives to innovate [6]. To meet legitimacy requirements, firms may adopt carbon management strategies [7,8], without actually taking concrete measures. The practice of greenwashing, characterized by excessive rhetoric and insufficient action by firms [9], will exacerbate the bubble of green innovation. Therefore, this paper examines whether the verbal commitments of firms can be effectively translated into tangible measures, namely whether carbon management strategies can effectively promote green innovation. This is a crucial issue that requires analysis and resolution to facilitate the implementation of green innovation.

Strategic management theory suggests that corporate strategies can affect both the external supervision and management and internal operational integration processes of a firm [10,11]. As an important part of corporate strategy, carbon management strategy is supposed to have a significant impact on external supervision and internal operational integration. Therefore, this paper examines the effect of carbon management strategies on green innovation from both external and internal perspectives. On the external side, the development of carbon management strategies can meet the low-carbon needs of stakeholders [12], thereby facilitating their access to stakeholder resources. This, in turn, increases firms' tolerance for short-term innovation failures and their ability to innovate [13], which promotes green innovation. On the internal side, firm strategies guide the behavior of firms based on the performance prism. Firms can take substantial measures in low-carbon management in their initiative. By developing carbon management strategies to promote investment in R&D, firms can optimize the allocation of resources and thus promote green innovation. Therefore, stakeholder resource support and R&D investment can influence the effect of firms' carbon management strategies on green innovation. Will there be a trade-off between stakeholder demand and the cost of R&D? It is a topic worth exploring. While some scholars have examined the various mechanisms by which internal informal institutions influence firm green innovation, there is scant literature on the mechanisms of balancing demand and cost from an integrated perspective.

This paper focuses on exploring the mechanism of carbon management strategies on firm green innovation. It further investigates the moderating effect of stakeholder resource support and R&D investment on the relationship between the two. Additionally, this study examines potential heterogeneity at the market level, firm level, and executive level resulting from the effects of carbon management strategies on green innovation and the moderating influence of stakeholder resource support and R&D investment. We conduct robustness tests by replacing the dependent variable, lagging the independent variable by one period, split-sample regression, and the instrumental variables method, and ultimately find that our results are robust and reliable.

Evidence from China provides an ideal research environment for this paper: First, China became the second-largest economy in the world in 2010, but has also emerged as a significant contributor of greenhouse gas emissions and a prominent environmental polluter. Second, the 20th National Congress of the communist party of China has emphasized that "promoting green and low-carbon economic and social development is a vital component of achieving high-quality development". China's low-carbon national strategy is a boost for global green development [14]. Third, a socialist market economy with Chinese characteristics will help this paper explore the effects of carbon management strategies on firm green innovation from a multi-level perspective. Last but not least, to protect China's ecosystem, various stakeholders collaborate to ensure effective innovative governance. For example, partnerships between government agencies and the private sector help drive the transition to low-carbon steel production by promoting advanced technologies and sustainable practices [15]. These collaborations foster knowledge sharing, technology transfer, and resource mobilization to develop and implement innovative solutions.

In-depth discussions on the internal informal institutions' ability to lead to a green transformation are of both theoretical and practical significance in achieving low-carbon economic and social development. The marginal contributions of this paper include the following: Firstly, a study on the influence of internal informal institutions on firm green innovation and a deeper analysis of the mechanism of firm carbon management strategies on green innovation deepen the theoretical exploration of the factors that influence firm green innovation. Secondly, from the perspective of demand and cost trade-offs, we analyze the mechanisms of stakeholder resource support and R&D investment in the process of carbon management strategies' influence on firm green innovation, respectively. This broadens the theoretical extension of the influence of carbon management strategies on firm green innovation, providing new theoretical guidance and decision-making reference for firms to carry out green innovation. Lastly, the utilization of machine learning methods to measure firm carbon management strategies is more scientific and objective.

The rest of this paper is structured as follows. Section 2 presents a literature review. Section 3 provides a theoretical framework and proposes the hypothesis. In Section 4, the research design including data sources, variable selection, and measurements is presented. Section 5 presents the analysis of empirical results. Section 6 summarizes the research conclusions and discussion.

2. Literature Review

This section firstly explores the different influencing factors affecting green innovation, secondly discusses the influence mechanisms of internal informal institutions on green innovation, and finally reviews the literature review and presents the research questions of this paper.

Firm green innovation is influenced by various factors, which have been extensively studied in the literature, mainly from three perspectives: formal institutions, informal institutions, and stakeholder pressure.

Formal institutions are divided into two levels: government regulation and market system. Both levels complement each other and can strongly promote green innovation. The government regulation level includes environmental protection subsidies [16], environmental regulations [17], a national energy-saving and emission reduction fiscal policy including a comprehensive demonstration of a pilot city [18], carbon emission trading policy [19,20], low-carbon pilot city policy [21], green financial reform and innovation pilot zone establishment [22], anti-corruption campaigns [23], and so on. The market system level includes smart city construction [24], fintech development [25], digital transformation [26], digital finance [27], green credit policy [28], green FDI [29], industrial agglomeration [30], industrial technology complexity [31], etc. However, some literature has different research findings. Wang et al. (2022) took Chinese A-share listed enterprises from 2010 to 2019 as samples and further differentiated government regulations, finding that environmental regulations based on command and market can promote green innovation, while voluntary environmental regulations can inhibit green innovation [32]. Xu et al. (2023) selected A-share listed industrial enterprises from 2009 to 2019 as the research object, finding that specific formal institutions, while positively promoting the quantity of green innovation, may have no impact on the quality of innovation [33]. Fu et al. (2023) conducted a study with panel data of green patents in 30 Chinese provinces from 2010 to 2019, finding that formal institutions have a negative impact on green innovation [34,35]. Additionally, some studies indicate that digital trade restrictions will negatively affect green innovation [36]. Studies on formal institutions have mixed findings, possibly because some studies do not further subdivide formal institutions or dimensions of green innovation, ignoring that firms will respond differently to different types of formal institutions.

Informal institutions have been studied mainly from the internal and external perspectives of firms. For external informal institutions, environmental legitimacy [37,38], market green demand [39], and firm reputation [40] can promote green innovation. In terms of internal informal institutions, firm risk appetite [41], firm risk taking [42], green entrepreneurial orientation [43], information technology capability [44], corporate social responsibility [45], and green knowledge acquisition [46] have significant promotion effects on firm green innovation. Additionally, Nie et al. (2022) used a green innovation data set of 30 Chinese provinces from 2010 to 2019, discovering the varied effects of university knowledge spillover on business green innovation [47]. R&D collaboration has a significant impact on the quality, rather than the quantity, of green innovation. Conversely, there is no evidence to suggest that patent citation or technology transfer improves the quality of green innovation, and both factors exhibit unequal effects on the quantity of green innovation. The possible reason why informal institutions have been under-studied may be the difficulty of measuring the informal institutions and mining the internal logic of informal institutions to influence firm behavior.

Stakeholder pressure, media attention [48,49], executive heterogeneity [50], consumer preference [51], and stakeholder environmental orientation [52] all significantly contribute to firm green innovation.

The current literature on the influence mechanisms of internal informal institutions on firm green innovation mainly focuses on financial aspects and stakeholders. With regard to the financial aspect, Guo and Ma (2023) explored the top management team's (TMT's) inherent characteristics that have different effects on firm green innovation, finding that financial constraints play a significant moderating role [50]. Qu et al. (2023) took Chinese A-share listed companies from 2007 to 2020 as the research sample, discovering the moderating effect of financial mismatches between risk taking and firm green innovation [42]. In terms of stakeholders, Guo and Ma (2023) found the mechanistic roles of executive compensation incentives between TMT's and firm green innovation [50]. CEO-specific personality traits, employee creativity, and customer engagement [43] have also been proven to play a mechanism role. The current literature predominantly focuses on the impact of internal informal institutions on green innovation from individual perspectives, without integrating these two aspects into a comprehensive framework that captures how trade-offs between them influence the effect of internal informal institutions on green innovation.

As evident from the foregoing, there is a dearth of research on the impact of informal institutions, particularly internal informal institutions, on firm green innovation as compared to formal institutions. However, internal informal institutions exert a more direct influence on the behavior of firms, thereby impacting green innovation behavior, which, in turn, affects high-quality development. As an important part of the internal informal institutions, whether firm carbon management strategies can effectively promote green innovation has still not received much attention from the academic community. Considering the significant impact of carbon management strategies on business behavior, this paper attempts to measure carbon management strategies through a machine learning method and unpack the "black box" of carbon management strategies using strategic management theory [53]. Moreover, while some scholars have examined the various mechanisms by which internal informal institutions influence firm green innovation, this paper attempts to explore the influence mechanism of balancing stakeholder demand and financial aspects (R&D cost) from an integrated perspective.

Do carbon management strategies affect corporate green innovation? Do stakeholder resource support and R&D investment have an impact on the transition from words to deeds? At this critical period when China is promoting low-carbon economic and social development, a systematic analysis and research on this issue can strengthen the theoretical foundation of the factors influencing green innovation. It is also of great practical significance for guiding firms to effectively carry out green innovation behavior.

3. Theoretical Analysis and Research Hypotheses

3.1. Carbon Management Strategies and Green Innovation

Green innovation involves a series of R&D capital and personnel investment measures aimed at achieving green, low-carbon, and circular development based on a strategic goal [49]. From a system theory perspective, green innovation is a global and systemic issue that requires long-term strategic planning and systematic design.

Carbon management strategy is a comprehensive term referring to firms' long-term goals and specific action plans for implementing low-carbon management [54]. It is an essential decision support system for achieving green innovation. Short-term carbon management behavior is highly likely to create a dissonance between economic and social performance, leading firms to only fulfill their minimum green and low-carbon responsibilities as required by laws and regulations. In some cases, firms may prioritize economic benefits over green and low-carbon considerations. Only through the long-term implementation of carbon management strategies can we systematically achieve an improvement in green innovation.

According to strategic management theory, carbon management strategies affect both the external supervision and management and internal operational integration processes of a firm. Therefore, this paper examines the effect of carbon management strategies on green innovation from both external and internal perspectives.

From the perspective of external supervision and management, the disclosure of firms' carbon management strategies will inevitably draw the attention of stakeholders. This reduces information asymmetry and firm moral hazard, alleviates financing constraints, and thus promotes firm green innovation. Disclosure of carbon management strategies reduces stakeholders' information asymmetry and increases their awareness of carbon management practices, strengthening their trust in the firm and promoting green innovation [55]. Moreover, the disclosure of the firms' carbon management strategies allows investors to monitor and restrain management's resource allocation behavior through firm governance mechanisms, reducing principal-agent costs and moral risks and promoting firm green innovation [56]. Additionally, firms' financial constraints can be reduced by disclosing their carbon management strategies, which encourages the development of green technologies. [57].

From the perspective of internal operational integration, it is imperative for a firm to formulate a series of global, long-term strategies that are rooted in a comprehensive understanding of its internal operations as well as the external business landscape. Firm carbon management strategies influence the integration of resources, management processes, and executive perceptions, serving as a guide and motivation for green innovation.

In terms of resource integration, carbon management strategies facilitate the restructuring of the firms' industrial structure, which influences the allocation of resources to ensure the realization of green innovation.

Regarding process management, according to the performance triple prism theory, firms must establish effective processes to achieve their strategies [58]. Carbon management strategies guide the practice of carbon management. Firm managers can design scientific carbon management processes to implement firm carbon management strategies. Based on the firms' vision of low-carbon strategy development, the firm will take a series of actions and measures to control carbon-based energy consumption and improve resource utilization, energy conservation, and energy structure optimization, which are conducive to achieving low carbon [59]. These measures cannot be achieved without the promotion and application of green innovative technologies.

In terms of executive cognition, executive cognition is the process by which managers focus on, interpret, and utilize strategic issues. Executive perceptions influence all aspects of the implementation of strategic change, linking internal and external contexts to strategic change. Green innovation, as an important way to promote green transformation, is highly dependent on the perceptions of executives and their investment decisions. Changes in the external environment brought about by the setting of dual-carbon targets and related policies will cause changes in executives' perceptions, and executives' perceptions and interpretations of environmental protection will in turn determine the use of organizational resources for green innovation. By recognizing the impact of external factors, embracing change, and proactively investing in green innovation, corporate executives can position their organizations at the forefront of environmental transformation while reaping the benefits of enhanced competitiveness and resilience [60]. Table 1 lists some key papers on carbon management strategy and green innovation.

Table 1. Key papers on carbon management strategy and green innovation.

Topic	Paper	Key Contribution
Media attention, environmental information disclosure, and green innovation	[49]	This work found that both positive and negative media attention and the quality of environmental information disclosure significantly contribute to corporate green technology innovation, with negative media attention having a more substantial impact than positive media attention.
Carbon management	[54]	This work defined carbon management as an approach based on the setting up of a project for the evaluation and reduction of gas emissions consisting of six main stages: awareness of greenhouse gas emissions; definition of the area to be studied; data acquisition; exploitation of findings; establishment of reduction action plan; execution of reduction action plan.
Retail investor attention and green innovation	[55]	This work investigated whether retail investor attention promotes or inhibits corporate green innovation. We further verify that retail investor attention increases corporate green innovation by increasing information transparency, alleviating financing constraints, and deterring agency costs.
Central environmental inspection and green innovation	[56]	This work found that CEI is conducive to corporate green innovation. This positive effect is strengthened in politically connected firms or firms in highly monopolized industries with lower bargaining intentions.
Financial constraints and carbon strategies	[57]	This work found that greenwashing by listed companies in China is widespread. Companies choose to greenwash environmental performance mainly due to future demand for investment and financing, and companies with higher debt levels are found more likely to engage in greenwashing.
Behavioral factors and carbon strategies	[59]	This work found that human factors influence low-carbon product management practices the most, followed by process practices and finally logistics practices.

In summary, this paper formulates the following hypothesis:

Hypothesis 1 (H1): *Firm carbon management strategies have a positive effect on green innovation.*

3.2. Moderating Effect of Stakeholder Resource Support

The formulation of carbon management strategies is conducive to gaining the support of stakeholders' resources. Based on stakeholder theory, a firm is a symbiotic system of multiple capital concluded by stakeholders [61]. As in the performance prism proposed by Neely et al. (2002) [58], the paramount objective of any firm is to satisfy the needs of its stakeholders. Firms must develop strategies that align with the expectations of their stakeholders. Against the backdrop of the dual-carbon target, firms will proactively adjust their operations to cater to the low-carbon demands of their stakeholders. Consequently, low-carbon management practices, such as low-carbon investment and financing management, low-carbon marketing, and low-carbon value chain management, are orchestrated scientifically and systematically [48]. Signaling theory suggests that firm carbon management strategies can signal legitimacy to stakeholders [62] and cater to their low-carbon needs [63]. Furthermore, expectation theory posits that stakeholders hold expectations of the firm, and the extent to which a firm meets these expectations determines the level of stakeholder support for its management. The implementation of carbon management strategies is thus instrumental in meeting stakeholder expectations for carbon management practices, thereby promoting resource investment in the firm [64].

Access to stakeholder resources plays a crucial role in promoting the positive effect of carbon management strategies on green innovation. Firms must collaborate with stakeholders to share resources and establish capacity systems to achieve collective innovation, as green innovation cannot be achieved by any single firm alone.

From a knowledge-based perspective, knowledge is a prerequisite for firm innovation. Firms can innovate not only by acquiring knowledge from within but also by acquiring knowledge from external sources. Active low-carbon management assists firms in building extensive and profound relationships with both internal and external stakeholders. Within a stakeholder network, firms can improve communication, share and exchange information, broaden their information collection, and acquire more complementary knowledge and resources [65]. Stakeholders, including employees, suppliers, and research institutions, contribute to knowledge exchange related to carbon management and green innovation. This exchange helps identify best practices, technological advancements, and innovative solutions that can further enhance sustainability efforts. [66] Therefore, access to stakeholders' resources is instrumental in promoting knowledge exchange and enhancing the implementation of carbon management strategies and firm green innovation.

From a resource-based theory perspective, enterprises have different tangible and intangible resources, which can be transformed into unique capabilities and are the source of lasting competitive advantage. These resources include monetary capital, human capital, and social capital [58]. However, the resources necessary for firms' activities are not self-sufficient, and require sustained stakeholder input. For example, financial support from shareholders and creditors can enhance the financial status of the firm; knowledge and skills from employees can improve the production and operation of the firm; quality supplies from suppliers can boost the competitiveness of the firms' products; resources from customers and consumers can enhance the sales ability of the firm and help the firm capture the market; resources from public relations such as society and media can enhance the reputation of the firm; and resources from the government can provide a conducive market environment for the firm and facilitate the establishment of a social network for the firm. Therefore, firms can increase their tolerance for short-term innovation failures and hence achieve green innovation. In addition, stakeholder resources play a crucial role in mitigating risks associated with carbon management strategies and green innovation, helping the firm navigate challenges and overcome barriers to implementation.

In summary, this paper posits the following hypothesis:

Hypothesis 2 (H2): *Stakeholder resource support positively moderates the positive effect of firm carbon management strategies on green innovation.*

3.3. Moderating Effect of R&D Investment

The development of carbon management strategies is likely to augment their investment in R&D. Drawing on materialistic dialectics, human agency is the primary motivating force behind development. However, human consciousness influences objective things by guiding practical actions. To transform the objective world, we must comprehend what needs to be done and how to do it. The formulation of carbon management strategies by firms demonstrates their subjective initiative. To achieve low-carbon strategic objectives, such as carbon offsetting, carbon reduction, and carbon independence [12], firms must engage in a series of low-carbon practical behaviors. Based on the concept of performance prism, firm strategies shape processes. The carbon management strategies guide carbon management practices. Firm managers can devise and implement scientific carbon management processes to execute firm carbon management strategies, such as low-carbon design, life cycle assessment, low-carbon management in procurement, production and sales, etc. Investment in R&D is a critical guarantee for implementing carbon management practices and executing carbon management processes [67], which implies that firms with carbon management strategies are likely to increase their investment in R&D. As shown in Table 2, there is an upward trend in R&D investment of Chinese companies, which is in line with our theoretical analyses.

Table 2. Trends of R&D investment.

Year	R&D Investment (Unit: RMB)
2013	306,593,765,971
2014	355,192,920,183
2015	423,580,600,817
2016	505,661,402,793
2017	643,722,983,007
2018	816,321,372,440
2019	957,801,068,724
2020	1,102,241,003,533

Increased investment in R&D plays a significant role in moderating the positive effect of carbon management strategies on green innovation. It provides the necessary technical and creative resources to convert carbon management efforts into tangible, innovative outcomes. From a strategic resource allocation perspective, the type of strategies adopted by a firm influences the areas of R&D investment. The formulation of carbon management strategies is likely to boost R&D investment in green technology, thus promoting green innovation. From a resource allocation theory perspective, rational resource allocation is a critical means of achieving firm green innovation. In reality, R&D investment is a form of resource allocation [68]. In the short term, R&D investment may lead to increased costs. However, in the long run, scientific and rational resource allocation can optimize the business management process and enhance the low-carbon supply chain management capability of firms. This reduces the cost of carbon emission reduction for firms, enhances their competitive advantage, and promotes green innovation.

Moreover, the investment in R&D can enhance the effectiveness of carbon management strategies by generating new knowledge, techniques, and tools that make carbon management processes more efficient and less resource intensive. The R&D processes involve activities such as idea generation, testing, and the improvement of new technologies or processes related to carbon management, during which green innovations are likely to emerge. Therefore, the more a company invests in R&D, the greater the potential of carbon management strategies to drive green innovation.

In summary, this paper posits the following hypothesis:

Hypothesis 3 (H3): *R&D investment positively moderates the positive effect of firm carbon management strategies on green innovation.*

The research framework is constructed given the above research hypotheses, as shown in Figure 1.

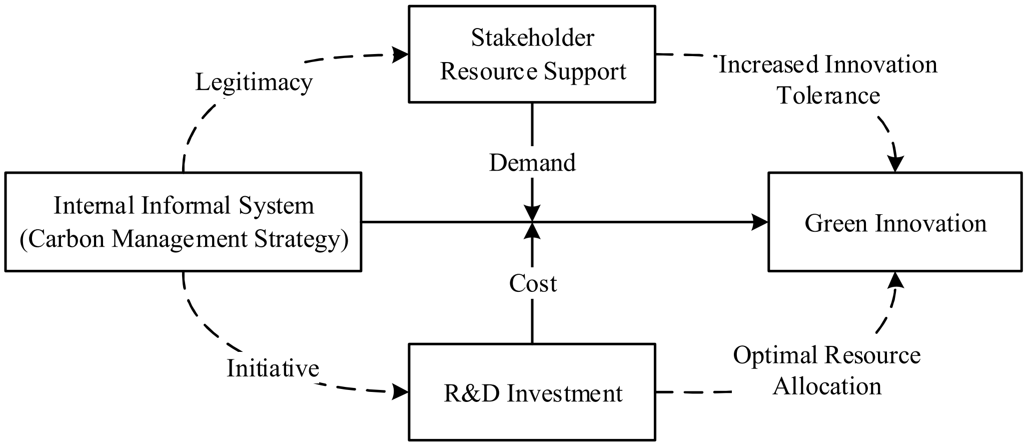

Figure 1. Research framework.

4. Research Design

4.1. Data Sources and Sample Selection

Given that the 18th National Congress of the Communist Party of China, which was held in November 2012, emphasized the vigorous promotion of ecological civilization, firms paid more attention to green innovation and carbon management after 2012. Therefore, this paper selects A-share firms listed on the Shanghai and Shenzhen stock exchanges in China from 2013 to 2020 as the research sample. The A-share market is the largest, most liquid, and most traded stock market in China. Therefore, the data of Shanghai and Shenzhen A-share markets can reflect the overall situation of China's domestic economy and the operation of the capital market. The primary sources of data include the following: (1) data related to carbon management strategies obtained from the CSR reports, environment, society, and governance (ESG) reports, and sustainability reports of the sample firms, which are crawled on the Juchao Website using Python; (2) data related to firm green patents obtained from the innovation patent research database in the Chinese Research Data Services Platform (CNRDS), which is developed in co-operation with well-known experts and scholars in the academic and practical fields at home and abroad [69]; (3) relevant financial data collected from the China Stock Market and Accounting Research Database (CSMAR), which is developed from the academic research needs, drawing on the professional standards of CRSP of the University of Chicago, Standard & Poor's Compustat, and other international databases [70].

In this paper, the data underwent prescreening based on the following steps: (1) In China's stock market, the "ST" designation is used to signify that the company is facing financial challenges, such as a significant decline in profitability, inability to meet debt obligations, or other issues that raise concerns about the company's financial health. Therefore, this paper excludes ST firms to avoid the adverse effect of ST firms' data on the empirical results. (2) Financial firms are excluded due to their special financial report structure. (3) Firms with formatting issues in CSR reports, ESG reports, and sustainability reports that hinder text mining are excluded. (4) Firms with incomplete or missing data are excluded. Following these four screening steps, 2711 observations were finally obtained. To mitigate the impact of extreme values, all continuous variables were winsorized at the 1% and 99% levels.

4.2. Definition of Variables

4.2.1. Dependent Variable

Existing methods of measuring enterprises' green technology innovation are mainly from the perspectives of patent quantity [71] and textual analyses [56]. This paper opts to use the quantity of green patents to assess the level of green innovation due to its objectivity. Due to the time lag in patent granting and the requirement to undertake audits and pay annual fees, the number of patent applications is more consistent, timely, and trustworthy than the number of patents awarded and is a truer indication of the current degree of innovation of a firm [72]. To determine the level of green innovation technology of the firms, this study adds one to the total number of independently submitted green invention patents and green utility model patent applications applied by group firms in the year, and then takes the logarithm [73].

4.2.2. Independent Variable

The literature on carbon management strategies remains relatively limited, and the measurement methods are singular. Existing literature mainly measures carbon management strategy variables through questionnaire surveys [74,75]. Firms that prioritize environmental protection have a greater incentive to disclose more environmental information to enhance their firm reputation and long-term business value. Therefore, this paper quantifies carbon management strategies indicators by text mining CSR reports, ESG reports, and sustainability reports, leveraging the information content of these reports. The variable measurement process comprises three specific steps:

(1) Construction of a thesaurus of firm carbon management strategies: Firstly, seed keywords related to carbon management strategies are hand-selected from relevant policy reports (such as the Proposal of the Central Committee of the Communist Party of China on Formulating the 14th Five-Year Plan for National Economic and Social Development and the Visionary Targets for 2035, Circular of the State Council on Issuing the Action Plan for Carbon Peaking by 2030, Recent Government Work Reports, etc.) and academic literature [12]. Secondly, natural language processing techniques are utilized to expand the seed keywords twice to compensate for any possible omissions in the manual selection method. This paper employs the Tencent AI Lab open-source corpus and listed firms' CSR reports, ESG reports, and sustainability reports as a corpus and leverages the Tencent word vector model and word2vec bag-of-words model for synonym extraction of seed keywords. Word2vec is an unsupervised model used to learn the text corpus [76]. It can quickly and efficiently express a word into vector form based on a given corpus with an optimized training model, providing a new tool for applied research in the field of natural language processing. Bag of words is an algorithm in word2vec used to train the corpus. Then, manual screening and de-weighting are conducted to obtain a final set of 672 keywords.

(2) Determining the corpus content: CSR reports, ESG reports, and sustainability reports disclosed by listed firms possess distinct attributes in structure and content, rendering them difficult to study. Conversely, unstructured data hold significant informative worth and merit extensive investigation. Hence, this paper elects to choose the CSR, ESG, and sustainability reports disclosed by the sample firms and employs natural language processing techniques, coupled with optical character recognition (OCR), to transform the reports into text format, ultimately constituting the corpus [77].

(3) Quantifying the degree of firm carbon management strategies: This paper utilizes keyword frequencies for gauging the level of firm carbon management strategies. Firstly, a lexicon of firm carbon management strategies is integrated into the jieba thesaurus, which is then leveraged to syllabify the corpus [76]. Secondly, natural language processing techniques are employed to sort the text by word frequency statistics of keywords and total text words. Due to the considerable variation in the length of CSR reports, ESG reports, and sustainability reports of different listed firms, this paper quantifies the level of firm carbon management strategies as follows: the initial step involves summing up the frequency of all keywords in the sample firms annually; the second step entails calculating the ratio of the total frequency of keywords to the total number of reported words for each year in the sample firms; the third step requires computing the proportion of the sample firms' keyword proportion to the total keyword proportion of the sample firm in the same industry and in the same year, which is utilized to measure the carbon management strategy level. In the case that no keywords are evident in the annual report of the sample

firm, the carbon management strategy level of the aforementioned firm in that year is assigned a value of 0.

4.2.3. Moderating Variables

(1) Stakeholder resource support

There is scant literature on the direct definition of stakeholder resource support. Satisfying stakeholder demands enables access to stakeholder resource support, and the stronger the stakeholder demand drive, the more formidable the resource support a firm receives upon meeting the demand. Current research mainly employs stakeholder pressure to portray the role of stakeholder demand in driving firm behavior, but it is predominantly gauged through questionnaire surveys [75,78], which is more subjective. This paper selects the amount of industrial pollution control investment accomplished per unit of GDP in each province, the proportion of shares held by pressure-resistant institutional investors, the proportion of bank loans, the concentration of suppliers, and the concentration of customers to signify the resource support from the government, shareholders, creditors, suppliers, and customers, respectively, which provides data availability and objectivity.

The following is the rationale for the selection of indicators of stakeholder resource support.

Firstly, government environmental regulation is a crucial driver of firm green innovation. The amount of industrial pollution control investment completed per unit of GDP in each province is a form of environmental regulation. The higher the government investment in industrial pollution control, the higher the government's demand for green innovation, and the more formidable the resource support a firm receives upon meeting the government's demand. Thus, the amount of industrial pollution control investment completed per unit of GDP in each province is selected to indicate the government resource support.

Secondly, institutional investors, as an important part of shareholders, can mitigate the opportunism of firm management and have a positive governance effect on firm management [79]. In particular, pressure-resistant institutional investors, which mainly comprise social security funds, securities investment funds, qualified foreign institutional investors, etc., possess a long-term profit-making demand for firms and intervene more actively in firm management. The higher the shareholders' demand for profit, the more formidable the resource support a firm receives upon meeting the shareholders' demand. Consequently, the shareholding ratio of pressure-resistant institutional investors is chosen to represent shareholder resource support.

Moreover, banks impose more stringent requirements for the soundness of the lending firms' business conditions, which has a significant impact on business decisions [80]. The higher the bank's pressure for positive business conditions, the more formidable the resource support a firm receives upon meeting the banks' demand. Therefore, the bank loan ratio, i.e., the sum of short- and long-term bank borrowings divided by total liabilities, is selected to represent the creditor's resource support.

Additionally, supplier concentration signifies the bargaining power of suppliers. The higher the concentration of suppliers, the greater the likelihood of supplier encroachment on the firms' interests, which has a more significant impact on the firms' production operations [81]. The more a firm meets supplier demand, the more resource support it receives from suppliers. Hence, the supplier concentration indicator is chosen to denotate supplier resource support.

Lastly, customer concentration implies the degree of dependence on customers. The higher the degree of dependence, the greater the drive from customers [82]. The more a firm meets customer demand, the more resource support it receives from customers. Therefore, the customer concentration indicator is chosen to represent supplier resource support.

The final stakeholder resource support in this paper is the sum of government, shareholder, creditor, supplier, and customer resource support, which are normalized before summing to eliminate the influence of magnitude.

(2) R&D investment

Prior research primarily employs indicators such as the ratio of R&D investment to operating revenue [83], the ratio of R&D investment to total assets [84], and the investment in R&D personnel to quantify the R&D investment of firms. However, due to the limited availability of information on R&D personnel, this paper selects the ratio of firm R&D investment to operating revenue to measure the R&D investment of firms.

4.2.4. Control Variables

Existing studies have found that firms' ownership attributes, operating and financial status, equity composition, management characteristics, firm industry, year, and region may also influence firm green innovation [33,79]. This paper introduces the control variables from the following aspects:

(1) Firms' ownership attributes: ownership nature (*SOE*); (2) operating and financial status: leverage ratio (*LEV*), return on total asset (*ROA*), operating cash flow (*Cash*), total asset turnover ratio (*TAR*), quick ratio (*QR*), resource slackness (*Slack*); (3) equity composition: equity concentration (*SD*); (4) management characteristics: whether environmental management is certified (*ISO*) and management's education level (*EDU*).

To alleviate the impact of heteroskedasticity, robust standard-error-adjusted t statistics are utilized by default in all regression equations. Additionally, dummy variables for the region (*Province*), year (*YEAR*), and industry (*IND*) are controlled to absorb fixed effects as much as possible. In summary, the variable definitions are shown in Table 3.

Table 3. Variable definition.

Variable Type	Variable	Definition
Dependent variable	*GTI*	Green innovation: LN (number of green patent applications + 1)
Independent variable	*CMS*	Carbon management strategy: computed using text mining method
Moderating variables	*SRS*	Stakeholder resource support: the sum of government, shareholder, creditor, supplier, and customer resource support
	RD	R&D investment: the ratio of firm R&D investment to operating revenue
Control variables	*SOE*	Nature of ownership: assign a value of 1 if the actual controller of the firm is state-owned, otherwise assign a value of 0
	LEV	Leverage ratio: the ratio of total liabilities' book value at the end of the period to total assets' book value
	ROA	Return on total asset: net profit divided by the average total asset balance
	Cash	Operating cash flow: net cash flows from operating activities divided by total assets at the end of the period
	SD	Equity concentration: the proportion of shareholding by the largest shareholder
	TAR	Total asset turnover ratio: revenue divided by the total asset balance at the end of the period
	QR	Quick ratio: the ratio of quick assets to current liabilities
	ISO	Assign a value of 1 if the firm has obtained ISO14001 certification, otherwise assign a value of 0
	EDU	Management's education level: assign a value of 1 to 6 based on the average education level of the management—below junior college, junior college, undergraduate, master's degree, doctorate, and other (such as honorary doctorate)
	Slack	Resource slackness: cash and cash equivalent balance at the end of the period divided by the total outstanding shares at the end of the period
	YEAR	Annual dummy variable: a value of 1 for the current year and 0 for all other years
	IND	Industry dummy variable: a value of 1 for the current industry and 0 for all other industries
	Province	Region dummy variable: a value of 1 for the current region and 0 for all other regions

4.2.5. Model Construction

Drawing upon the preceding theoretical framework and research hypotheses, this paper formulates the three ensuing regression models. Model (1) is employed to examine whether firm carbon management strategies exert a significant and positive impact on green innovation. Models (2) and (3) assess whether stakeholder resource support and R&D investment, respectively, act as moderating variables between carbon management strategies and green innovation.

To mitigate the effects of heteroscedasticity, robust standard-error-adjusted t statistics are used by default in all regression equations. In addition, dummy variables for the region (*Province*), YEAR (*YEAR*), and industry (*IND*) are also controlled to absorb the fixed effects as much as possible.

$$\begin{aligned} GTI &= \alpha_0 + \alpha_1 CSM + \alpha_2 SOE + \alpha_3 LEV + \alpha_4 ROA + \alpha_5 Cash + \alpha_6 SD + \alpha_7 TAR + \alpha_8 QR + \alpha_9 ISO \\ &+ \alpha_{10} EDU + \alpha_{11} Slack + \sum \alpha_i YEAR_i + \sum \alpha_j IND_j + \sum \alpha_k Province_k + \varepsilon \end{aligned} \tag{1}$$

$$\begin{aligned} GTI &= \beta_0 + \beta_1 CSM + \beta_2 SRS + \beta_3 CSM \times SRS + \beta_4 SOE + \beta_5 LEV + \beta_6 ROA + \beta_7 Cash + \beta_8 SD + \beta_9 TAR \\ &+ \beta_{10} QR + \beta_{11} ISO + \beta_{12} EDU + \beta_{13} Slack + \sum \beta_i YEAR_i + \sum \beta_j IND_j + \sum \beta_k Province_k + \varepsilon \end{aligned} \tag{2}$$

$$\begin{aligned} GTI &= \gamma_0 + \gamma_1 CSM + \gamma_2 RD + \gamma_3 CSM \times RD + \gamma_4 SOE + \gamma_5 LEV + \gamma_6 ROA + \gamma_7 Cash + \gamma_8 SD + \gamma_9 TAR \\ &+ \gamma_{10} QR + \gamma_{11} ISO + \gamma_{12} EDU + \gamma_{13} Slack + \sum \gamma_i YEAR_i + \sum \gamma_j IND_j + \sum \beta_k Province_k + \varepsilon \end{aligned} \tag{3}$$

5. Results

5.1. Descriptive Statistics

Table 4 displays the descriptive statistics and correlation analysis for each variable. From the table, it can be seen that the mean value of green innovation (*GTI*) is 1.777. The minimum value is 0, and the maximum value is 5.903, with a standard deviation of 1.506, signifying a wide variation in the level of green innovation among firms. The mean value of the carbon management strategy (*CMS*) is 0.101, the minimum value is 0.002, and the maximum value is 0.8, indicating that the overall carbon management strategy of the sample firms is at a moderate to low level. The mean value of stakeholder resource support (*SRS*) is 1.563, the minimum value is 0.328, and the maximum value is 3.182, indicating that the overall stakeholder resource support of the sample firms is at a moderate to lower level. The mean value of R&D investment (*RD*) is 3.347, the minimum value is 0, the maximum value is 19.3, and the standard deviation is 3.358, revealing significant differences in R&D investment between firms. The mean value of *SOE* is 0.592, indicating that 59.2% of the sample firms are state-owned firms. A total of 40.6% of the sample firms are ISO14001-certified firms. Except for *EDU* and *Slack*, the standard deviations of the control variables are all below 1, indicating that the control variables are relatively stable. The highest VIF value among the variables is 3.43, which is considerably lower than the critical value of 10, implying that there is no severe issue of multicollinearity among the variables.

Table 4. Descriptive statistics of variables.

Variable	N	Mean	Std. Dev.	Min	Max
GTI	2711	1.777	1.506	0.000	5.903
CMS	2711	0.101	0.147	0.002	0.800
SRS	2711	1.563	0.454	0.328	3.182
RD	2711	3.347	3.358	0.000	19.300
SOE	2711	0.592	0.492	0.000	1.000
LEV	2711	0.510	0.174	0.121	0.867
ROA	2711	0.040	0.052	−0.151	0.209
Cash	2711	0.056	0.059	−0.107	0.230
SD	2711	3.163	0.902	−0.284	4.297
TAR	2711	0.663	0.398	0.105	2.135
QR	2711	1.139	0.831	0.197	5.213
ISO	2711	0.406	0.491	0.000	1.000
EDU	2711	2.360	1.422	0.000	4.176
Slack	2711	1.790	1.870	0.089	10.220

5.2. Regression Analysis

This section examines whether firm carbon management strategies (*CMS*) have an impact on green innovation (*GTI*) and investigates whether stakeholder resource support (*SRS*) and R&D investment (*RD*) play a moderating role in the impact of firm carbon management strategies on green innovation. The statistical findings are presented in Table 5.

Table 5. Regression results.

Variable	GTI (1)	(2)	(3)
CMS	1.607 ***	1.299 ***	1.822 ***
	(6.921)	(5.821)	(6.808)
CMS × *SRS*		0.728 *	
		(1.910)	
SRS		0.560 ***	
		(7.547)	
CMS × *RD*			0.208 **
			(2.277)
RD			0.065 ***
			(5.590)
SOE	0.085	0.053	0.118 *
	(1.379)	(0.862)	(1.919)
LEV	1.318 ***	1.037 ***	1.455 ***
	(5.644)	(4.483)	(6.200)
ROA	1.872 ***	1.331 **	2.050 ***
	(3.282)	(2.305)	(3.598)
Cash	0.108	−0.078	0.095
	(0.223)	(−0.163)	(0.199)
SD	0.046	0.005	0.045
	(1.618)	(0.154)	(1.598)
TAR	−0.043	−0.091	0.057
	(−0.577)	(−1.217)	(0.745)
QR	−0.039	−0.052	−0.052
	(−0.998)	(−1.369)	(−1.361)
ISO	−0.185 ***	−0.169 ***	−0.201 ***
	(−3.561)	(−3.288)	(−3.890)
EDU	0.049 ***	0.018	0.047 ***
	(2.738)	(1.040)	(2.650)
Slack	0.075 ***	0.053 ***	0.073 ***
	(4.386)	(3.144)	(4.306)
Year Fixed Effect	YES	YES	YES
Industry Fixed Effect	YES	YES	YES
Province Fixed Effect	YES	YES	YES
Constant	−2.087 ***	−1.347 **	−1.524 ***
	(−4.108)	(−2.367)	(−3.005)
N	2.711	2.711	2.711
Adjusted *R*-Square	0.415	0.430	0.423

Notes: ***, **, and * represent statistically significant at the level of 1%, 5%, and 10%, respectively; t statistics are in parentheses.

The outcomes reveal that the coefficient of *CMS* and *GTI* exhibits a significantly positive relationship at the 1% level with a coefficient of 1.607 when no moderating variables are integrated in column (1). The regression results demonstrate that carbon management strategies contribute significantly and positively to green innovation. Hypothesis H1 is confirmed. When stakeholder resource support is introduced as a moderating variable in column (2), the cross product of firm carbon management strategy and stakeholder resource support (*CMS* × *SRS*) also displays a significant and positive correlation with green innovation at the 10% level with a coefficient of 0.728. In column (3), when R&D investment is incorporated as a moderating variable, the cross product of firm carbon management strategy and R&D investment (*CMS* × *RD*) exhibits a significant and positive correlation with green innovation at the 5% level with a coefficient of 0.208. These empirical results illustrate that stakeholder resource support and R&D investment can enhance the favorable impact of firm carbon management strategies on green innovation. Hypothesis 2 is validated.

5.3. Robustness Tests

5.3.1. Alternative Measurement Dependent Variable

In this paper, the dependent variable is substituted with the count of green innovations awarded, evaluated by adding the count of green invention patents, green utility model patents, and design patents granted by the company in the following year, and then transformed using the logarithmic function. According to column (1) of Table 6, it is evident that *CMS* displays a significant and positive correlation with *GTI* at the 1% level with a coefficient of 1.531, which indicates that carbon management strategies can affect not only the quantity but also the quality of green technology innovation. The regression results are in line with the primary regression outcomes. Thus, the findings in this study are robust and trustworthy.

Table 6. Robustness tests.

Variable	*GTI*			
	(1)	**(2)**	**(3)**	**(4)**
CMS	1.531 ***	1.761 ***	1.473 ***	4.998 **
	(8.252)	(5.784)	(5.462)	(2.395)
SOE	0.050	0.095	0.087	0.115 *
	(0.915)	(1.143)	(1.254)	(1.821)
LEV	1.309 ***	1.402 ***	1.375 ***	1.121 ***
	(6.452)	(4.585)	(5.378)	(4.292)
ROA	1.156 **	1.498 *	2.066 ***	1.792 ***
	(2.382)	(1.921)	(3.342)	(2.785)
Cash	0.607	−0.322	0.286	−0.115
	(1.419)	(−0.511)	(0.547)	(−0.220)
SD	0.040	0.015	0.052	0.040
	(1.551)	(0.332)	(1.640)	(1.364)
TAR	−0.112 *	−0.074	−0.074	−0.036
	(−1.691)	(−0.724)	(−0.911)	(−0.456)
QR	0.012	−0.023	−0.038	−0.035
	(0.354)	(−0.403)	(−0.894)	(−0.756)
ISO	−0.135 ***	−0.211 ***	−0.165 ***	−0.229 ***
	(−2.945)	(−3.103)	(−3.002)	(−4.238)
EDU	0.046 ***	0.054 **	0.085 ***	0.051 **
	(2.876)	(2.339)	(4.433)	(2.237)
Slack	0.047 ***	0.099 ***	0.079 ***	0.053 ***
	(3.144)	(4.268)	(3.934)	(2.945)
Year Fixed Effect	YES	YES	YES	YES
Industry Fixed Effect	YES	YES	YES	YES
Province Fixed Effect	YES	YES	YES	YES
Constant	−1.309 ***	−3.030 ***	−0.677 **	−4.488 ***
	(−3.436)	(−4.610)	(−2.398)	(−2.686)
N	2.711	1.631	2.124	2711
Adjusted *R*-Square	0.420	0.430	0.428	0.324

Notes: ***, **, and * represent statistically significant at the level of 1%, 5%, and 10%, respectively; t statistics are in parentheses.

5.3.2. Independent Variable Lagged by One Period

Innovation is a lengthy process, and the influence of corporate carbon management strategy on green innovation may have a delayed effect. Therefore, this study incorporates a one-period lag of the carbon management strategy variable in the regression model to examine the robustness of the outcomes. The regression results are presented in column (2) of Table 6, which demonstrates that *CMS* exhibits a significant and positive correlation with *GTI* at the 1% level with a coefficient of 1.761. This finding is consistent with the primary regression outcomes, indicating that carbon management strategies facilitate a virtuous circle of business development and have a long-term impact on green technology innovation. Thus, the regression results of this study are robust and trustworthy.

5.3.3. Sub-Sample Regression

Industrial enterprises are the main source of carbon emissions and have a stronger incentive to adopt carbon management strategies and engage in green innovation. Therefore, this paper selects industrial enterprises as a separate research sample for robustness testing. The results from column (3) of Table 6 indicate that *CMS* and *GTI* exhibit a significant and positive correlation at the 1% level with a coefficient of 1.473, which shows that firms with relatively high carbon emissions have the incentive to both develop and focus on the implementation of carbon management strategies, which in turn promotes green innovation. The results are consistent with the primary regression outcomes. Therefore, the regression findings presented in this study are robust and trustworthy.

5.3.4. Endogeneity Test

As there may exist a reverse causal relationship between carbon management strategies and green innovation, this study adopts an instrumental variable to handle the endogeneity issue. The carbon management strategies of other companies in the same region will not directly impact the green innovation of this firm. However, firms in the same region operate in a similar policy and business environment. Therefore, according to the cohort effect, the carbon management strategy of this firm will be influenced by other firms in the same region. Hence, the mean value of carbon management strategies in the same region in the same year was selected as the instrumental variable, and the two-stage least squares method was employed to handle the endogeneity problem. The exogeneity test and the weak instrumental variable test were conducted, and the Hausman test chi-squared value of 2.757 rejects the exogeneity hypothesis at the 10% level. Additionally, the weak instrumental variable test has a minimum eigenroot of 35.211, which is greater than the Stock–Yogo test critical value of 16.38, rejecting the weak instrumental variable hypothesis. Therefore, the instrumental variable was appropriately chosen. The results of the second-stage regression are presented in column (4) of Table 6, which reveals that *CMS* and *GTI* exhibit a significantly positive correlation at the 1% level with a coefficient of 4.998, consistent with the primary regression results. Thus, the regression findings in this study are robust and trustworthy.

5.4. Heterogeneity Test

The preceding empirical findings reveal that carbon management strategies exert a significant positive influence on green innovation, with stakeholder resource support and R&D investment playing a positive moderating role in the process. It is noteworthy that, firstly, firms with a high market share can attract top talent, possess more innovative resources, and are less risky in transitioning to carbon management practices. Therefore, the level of market share may also impact the effect of firm carbon management strategies on green innovation and the moderating effect of stakeholder resource support and R&D investment. Secondly, carbon neutrality and carbon peaking, as crucial national strategic objectives, are highly esteemed and supported by the government [85]. The policy effects are more prominent among state-owned firms, which may result in heterogeneity in the effects of firm carbon management strategies on green innovation and the moderating effects of stakeholder resource support and R&D investment among state-owned and non-state-owned firms. Additionally, providing equity incentives to executives may motivate them to engage in green innovation. Thus, the effect of carbon management strategies on green innovation may be greater in executive-owned firms compared to firms that do not adopt executive equity incentives, and the moderating effects of stakeholder resource support and R&D investment may also exhibit heterogeneity. Based on this, this section further divides the sample into groups based on the market share, nature of ownership, and whether or not the executives hold shares, to provide more comprehensive empirical evidence for the theoretical analysis presented in this study.

5.4.1. Heterogeneity Test Based on Market Share

In this paper, the participating firms have been categorized into two groups based on the median industry sales share. Table 7 presents the regression outcomes. The findings reveal that in the group with a greater market share, *CMS* is significantly and positively associated with *GTI* at the 1% level with a coefficient of 0.751; *CMS* × *SRS* is significantly and positively linked to green innovation at the 5% level; and *CMS* × *RD* is not significantly associated with green innovation. It demonstrates that stakeholder resource support can bolster the affirmative influence of firm carbon management strategies on green innovation. In the group with a lower market share, *CMS*, *CMS* × *SRS*, and *CMS* × *RD* are not significantly related to *GTI*, indicating that there is no significant impact of firm carbon management strategies on green innovation. For the Fisher portfolio test, the empirical *p*-value corresponding to *CMS* × *SRS* in model (2) is 0.009, which is significant at the 1% level. It indicates that the moderating effect of stakeholder resource support is significantly different between state-owned and non-state-owned firms.

Table 7. Heterogeneity test based on market share.

Variable	GTI					
	(1)		(2)		(3)	
	High Market Share	Low Market Share	High Market Share	Low Market Share	High Market Share	Low Market Share
CMS	0.751 ***	0.725	0.591 **	0.488	0.820 ***	0.605
	(2.952)	(1.379)	(2.327)	(0.857)	(2.763)	(1.186)
CMS × *SRS*			0.915 **	−1.111		
			(2.143)	(−0.835)		
SRS			0.299 ***	−0.023		
			(2.958)	(−0.183)		
CMS × *RD*					0.054	0.289
					(0.495)	(1.576)
RD					0.083 ***	0.074 ***
					(4.209)	(4.855)
SOE	−0.001	0.146 *	−0.014	0.140 *	0.099	0.154 **
	(−0.010)	(1.959)	(−0.139)	(1.849)	(0.968)	(2.067)
LEV	−0.072	0.699 **	−0.222	0.678 **	0.213	0.808 ***
	(−0.188)	(2.432)	(−0.571)	(2.337)	(0.536)	(2.785)
ROA	0.318	1.871 ***	−0.172	1.851 ***	0.425	2.127 ***
	(0.324)	(2.720)	(−0.171)	(2.675)	(0.430)	(3.114)
Cash	0.002	−0.337	−0.033	−0.358	−0.051	−0.325
	(0.003)	(−0.574)	(−0.048)	(−0.609)	(−0.073)	(−0.563)
SD	−0.044	0.059	−0.067	0.056	−0.044	0.058 *
	(−1.041)	(1.636)	(−1.544)	(1.494)	(−1.042)	(1.646)
TAR	−0.585 ***	−0.134	−0.584 ***	−0.137	−0.421 ***	−0.049
	(−5.142)	(−1.086)	(−5.153)	(−1.114)	(−3.378)	(−0.395)
QR	−0.116	−0.072 *	−0.115	−0.074 *	−0.099	−0.091 **
	(−1.601)	(−1.653)	(−1.585)	(−1.691)	(−1.381)	(−2.136)
ISO	−0.035	−0.090	−0.039	−0.088	−0.060	−0.097
	(−0.491)	(−1.359)	(−0.550)	(−1.329)	(−0.853)	(−1.477)
EDU	0.068 ***	−0.006	0.044 *	−0.006	0.065 ***	−0.012
	(2.648)	(−0.214)	(1.740)	(−0.247)	(2.581)	(−0.453)
Slack	0.025	0.037	0.019	0.035	0.025	0.032
	(1.040)	(1.623)	(0.786)	(1.533)	(1.047)	(1.393)
Year Fixed Effect	YES	YES	YES	YES	YES	YES
Industry Fixed Effect	YES	YES	YES	YES	YES	YES
Province Fixed Effect	YES	YES	YES	YES	YES	YES
Constant	0.080	−0.021	0.374	0.069	0.064	0.157
	(0.108)	(−0.059)	(0.475)	(0.186)	(0.089)	(0.438)
N	1.355	1.356	1.355	1.356	1.355	1.356
Adjusted *R*-Square	0.562	0.331	0.567	0.330	0.568	0.344
$P_{\text{Fisher-test}}$	0.485		0.009		0.123	

Notes: ***, **, and * represent statistically significant at the level of 1%, 5%, and 10%, respectively; t statistics are in parentheses.

The above analysis shows that the effect of firm carbon management strategies on green innovation and the moderating effect of stakeholder resource support is more pronounced for firms with a higher market share. This may be because firms with a greater market share are more likely to attract the attention of stakeholders. They also have more sophisticated business management models and stronger relationships with stakeholders. As a result, firms with a higher market share are more motivated to implement carbon management strategies and thus promote green innovation practices.

5.4.2. Heterogeneity Test Based on Nature of Ownership

Table 8 presents the regression outcomes for the grouping of the nature of ownership. The results reveal that in the state-owned group, *CMS* displays a significant and positive correlation with *GTI* at the 1% level with a coefficient of 1.595; *CMS* × *SRS* is significantly and positively correlated with green innovation at the 10% level; and *CMS* × *RD* is significantly and positively correlated with green innovation at the 1% level. This illustrates that stakeholder resource support and R&D investment can enhance the favorable impact of firm carbon management strategies on green innovation. *CMS* and *GTI* exhibit a significant and positive correlation at the 1% level in the non-state-owned group, but neither *CMS* × *SRS* nor *CMS* × *RD* show any significant correlation with *GTI*. The outcomes indicate that there is no significant moderating effect of stakeholder resource support and R&D investment on the positive influence of firm carbon management strategies on green innovation in the non-state-owned group. For the Fisher portfolio test, the empirical *p*-value corresponding to *CMS* × *RD* in model (3) is 0.008, which is significant at the 1% level. This indicates that the moderating effect of R&D investment differs significantly between state-owned and non-state-owned firms.

Table 8. Heterogeneity test based on the nature of ownership.

Variable	*GTI*					
	(1)		(2)		(3)	
	State Firm	**Non-State Firm**	**State Firm**	**Non-State Firm**	**State Firm**	**Non-State Firm**
CMS	1.595 ***	1.858 ***	0.874 ***	1.853 ***	2.279 ***	1.718 ***
	(4.796)	(5.348)	(2.686)	(5.245)	(5.075)	(4.822)
CMS × *SRS*			1.099 *	0.809		
			(1.670)	(1.412)		
SRS			0.739 ***	0.360 ***		
			(7.957)	(2.745)		
CMS × *RD*					0.495 ***	0.014
					(3.027)	(0.118)
RD					0.058 ***	0.090 ***
					(3.068)	(5.584)
LEV	1.272 ***	1.399 ***	0.955 ***	1.216 ***	1.290 ***	1.699 ***
	(4.211)	(3.450)	(3.233)	(2.982)	(4.262)	(4.156)
ROA	1.236	2.495 ***	0.543	2.153 ***	1.153	2.740 ***
	(1.484)	(3.142)	(0.648)	(2.691)	(1.393)	(3.410)
Cash	1.097	−1.433 **	0.711	−1.356 **	1.079	−1.316 **
	(1.624)	(−2.093)	(1.093)	(−1.969)	(1.608)	(−1.963)
SD	0.098 **	−0.005	0.051	−0.035	0.105 **	−0.013
	(2.192)	(−0.140)	(1.145)	(−0.832)	(2.322)	(−0.373)
TAR	0.007	−0.177	−0.012	−0.258 **	0.082	−0.019
	(0.070)	(−1.409)	(−0.119)	(−1.971)	(0.780)	(−0.148)
QR	0.121 **	−0.156 ***	0.098 *	−0.164 ***	0.102 *	−0.150 ***
	(2.302)	(−2.682)	(1.906)	(−2.862)	(1.960)	(−2.594)
ISO	−0.170 **	−0.227 ***	−0.141 **	−0.225 ***	−0.172 **	−0.267 ***
	(−2.501)	(−2.722)	(−2.139)	(−2.720)	(−2.558)	(−3.233)
EDU	0.056 ***	0.075 **	0.014	0.066 *	0.055 ***	0.063 *
	(2.765)	(2.052)	(0.667)	(1.801)	(2.734)	(1.731)
Slack	0.070 ***	0.069 **	0.043 **	0.054	0.071 ***	0.067 **

Table 8. *Cont.*

Variable	GTI (1)		(2)		(3)	
	State Firm	Non-State Firm	State Firm	Non-State Firm	State Firm	Non-State Firm
	(3.409)	(2.048)	(2.089)	(1.571)	(3.481)	(1.978)
Year Fixed Effect	YES	YES	YES	YES	YES	YES
Industry Fixed Effect	YES	YES	YES	YES	YES	YES
Province Fixed Effect	YES	YES	YES	YES	YES	YES
Constant	−2.225 ***	−1.614 ***	−1.086	−0.826	−1.271 *	−1.197 **
	(−3.478)	(−2.716)	(−1.522)	(−1.601)	(−1.906)	(−2.118)
N	1.605	1.106	1.605	1.106	1.605	1.106
Adjusted *R*-Square	0.479	0.402	0.501	0.407	0.484	0.420
$P_{Fisher\text{-}test}$	0.349		0.337		0.008	

Notes: ***, **, and * represent statistically significant at the level of 1%, 5%, and 10%, respectively; t statistics are in parentheses.

The above analysis demonstrates that there is a positive effect of the firm carbon management strategies on green innovation in both the state-owned and non-state-owned groups. However, the moderating effect of stakeholder resource support and R&D investment is stronger in the state-owned group. The reason for this could be that for the state-owned group, the government is one of the key stakeholders and has a stronger driving force on them. Therefore, the formulation of strategies in state-owned firms is closely linked to the state's dual-carbon target, which leads to a greater emphasis on the construction of carbon management systems, active implementation of carbon management strategies, and increased R&D investment, thus promoting green innovation.

5.4.3. Heterogeneity Test Based on Executive Shareholding

Table 9 displays the regression outcomes based on the categorization of whether the executives hold shares or not. The findings reveal that in the group of firms with executive shareholding, *CMS* is significantly positively associated with *GTI* at the 1% level with a coefficient of 1.361; *CMS* × *SRS* is not significantly associated with green innovation; and *CMS* × *RD* is significantly positively linked to green innovation at the 5% level, demonstrating that R&D investment can bolster the affirmative influence of firm carbon management strategies on green innovation. In the non-executive shareholding group, *CMS* is significantly positively associated with *GTI* at the 1% level with a coefficient of 1.552; *CMS* × *SRS* and *CMS* × *RD* are not significantly associated with *GTI*, indicating that there is a significant positive impact of firm carbon management strategies on green innovation. However, there is no significant moderating effect of stakeholder resource support and R&D investment in the positive influence of firm carbon management strategies on green innovation. For the Fisher portfolio test, the empirical *p*-value corresponding to the *CMS* in model (1) is 0.43. This indicates that the influence of firm carbon management strategies on green innovation is not significantly different between the executive shareholding group and the non-executive shareholding group.

The above analysis shows that carbon management strategies have a significant positive impact on green innovation in both executive and non-executive shareholding firms. However, the moderating effect of R&D investment is stronger in the executive shareholding group than in the non-executive shareholding group. This may be because executives in firms with carbon management strategies have a greater incentive to invest in R&D, which in turn increases the level of green innovation.

Table 9. Heterogeneity test based on executive shareholding.

Variable	GTI (1) Executive Shareholding	(1) Non-Executive Shareholding	(2) Executive Shareholding	(2) Non-Executive Shareholding	(3) Executive Shareholding	(3) Non-Executive Shareholding
CMS	1.361 ***	1.552 ***	1.067 ***	0.835 **	1.538 ***	1.836 ***
	(4.876)	(3.304)	(3.919)	(1.966)	(4.886)	(2.818)
CMS × *SRS*			0.262	1.045		
			(0.560)	(1.551)		
SRS			0.713 ***	0.673 ***		
			(7.335)	(5.662)		
CMS × *RD*					0.208 **	0.147
					(1.981)	(0.641)
RD					0.068 ***	0.053 **
					(4.823)	(2.191)
SOE	0.157 **	0.331 ***	0.121	0.407 ***	0.207 ***	0.319 ***
	(1.998)	(2.753)	(1.560)	(3.334)	(2.624)	(2.639)
LEV	1.472 ***	0.732 *	1.083 ***	0.496	1.660 ***	0.767 **
	(4.780)	(1.953)	(3.561)	(1.387)	(5.333)	(2.029)
ROA	2.274 ***	−0.885	1.449 **	−1.114	2.576 ***	−0.930
	(3.293)	(−0.823)	(2.055)	(−1.046)	(3.725)	(−0.860)
Cash	0.227	0.970	−0.117	0.897	0.267	0.947
	(0.357)	(1.231)	(−0.187)	(1.164)	(0.423)	(1.205)
SD	0.010	0.106 **	−0.062	0.086 *	0.006	0.108 **
	(0.282)	(2.388)	(−1.577)	(1.954)	(0.156)	(2.465)
TAR	−0.075	0.185	−0.151	0.183	0.042	0.246
	(−0.784)	(1.253)	(−1.599)	(1.229)	(0.423)	(1.631)
QR	−0.070	0.013	−0.096 *	−0.004	−0.081	0.003
	(−1.371)	(0.200)	(−1.905)	(−0.057)	(−1.634)	(0.049)
ISO	−0.198 ***	−0.266 ***	−0.184 ***	−0.239 **	−0.210 ***	−0.271 ***
	(−3.062)	(−2.817)	(−2.899)	(−2.564)	(−3.290)	(−2.893)
EDU	0.093 ***	−0.032	0.057 **	−0.057 *	0.090 ***	−0.032
	(3.932)	(−1.113)	(2.427)	(−1.955)	(3.775)	(−1.104)
Slack	0.054 **	0.098 ***	0.029	0.060 **	0.051 **	0.099 ***
	(2.486)	(3.643)	(1.376)	(2.208)	(2.366)	(3.686)
Year Fixed Effect	YES	YES	YES	YES	YES	YES
Industry Fixed Effect	YES	YES	YES	YES	YES	YES
Province Fixed Effect	YES	YES	YES	YES	YES	YES
Constant	−1.342 **	−2.048 ***	−0.569	−0.607	−0.789	−1.568 **
	(−2.134)	(−3.284)	(−0.931)	(−1.128)	(−1.306)	(−2.556)
N	1.785	926	1.785	926	1.785	926
Adjusted *R*-Square	0.426	0.498	0.445	0.519	0.434	0.499
$P_{\text{Fisher-test}}$	0.43		0.197		0.358	

Notes: ***, **, and * represent statistically significant at the level of 1%, 5%, and 10%, respectively; t statistics are in parentheses.

6. Discussion and Conclusions

6.1. Conclusions

Green innovation is crucial for the establishment of an economic system with low-carbon-cycle development. This paper elucidates the theoretical mechanism of the influence of carbon management strategies on green innovation based on strategic management theory. It employs the OLS regression model and moderating effect model to conduct an empirical study based on sample data from 2013 to 2020. The findings indicate the following:

(1) Carbon management strategies have a significant positive impact on green innovation. Robustness tests including replacing the dependent variable, lagging the independent

variable by one period, split-sample regression, and the instrumental variables method ultimately find that our results are robust and reliable.

(2) Stakeholder resource support and R&D investment can augment the affirmative influence of firm carbon management strategies on green innovation.

(3) Further analysis reveals that carbon management strategies positively impact the development of green technology in both state-owned and non-state-owned firm groups. However, the moderating effect of stakeholder resource support and R&D investment is stronger in the state-owned group. Additionally, for firms with a higher market share, the moderating effect of stakeholder resource support and the influence of firm carbon management strategies on green innovation is more significant. Furthermore, for both executive and non-executive shareholding firms, carbon management strategies significantly favor green innovation. Nonetheless, the moderating effect of R&D investment is more robust in the group of firms with executive ownership.

6.2. Theoretical Implications

First, compared to formal institutions, the literature on the impact of informal institutions on green innovation is still relatively limited. In this paper, we chose one dimension of the internal informal institutions, carbon management strategy, to study its impact on green innovation, enriching the relevant research on the factors influencing green innovation.

Second, the possible reason why informal institutions have been understudied may be the difficulty of measuring the informal institutions. This paper attempts to measure carbon management strategies through machine learning methods, which are more scientific and objective.

Third, the current literature predominantly focuses on the impact of internal informal institutions on green innovation from individual perspectives. This paper investigates the impact mechanism of carbon management strategy on green innovation from the perspective of balancing stakeholders' demands and R&D costs, mining the internal logic of informal institutions to influence firm green innovation.

6.3. Policy Implications

The results of this paper have important policy implications for promoting green innovation and achieving dual-carbon targets.

First, the government should establish a collaborative stakeholder governance system and focus on internal and external operational integration. The advancement of green innovation is a long-term, systemic endeavor. The government can collaborate with other stakeholders to influence the internal and external operational integration process of firms [13], such as facilitating collaboration between academia, industry, and research institutions. Additionally, the government can establish an effective policy system that ensures stakeholder resource support and promotes the sharing and complementarity of innovation resources. This can effectively facilitate the steps of knowledge production, transfer, absorption, utilization, testing, and debugging and the dissemination of results to build a comprehensive and viable innovation system [46].

Second, the government should allocate resources rationally while increasing resource support to non-state firms and small- and medium-sized firms, to enhance their internal drive for green innovation. The government should rationally allocate resources to enhance innovation support for non-state and small- and medium-sized firms, including providing tax incentives, grants, subsidies, and research funding. Environmental regulation should consider the differences in the financial situation, human capital, and green innovation of various types of firms [86]. Appropriate environmental regulation policies should be formulated to avoid imposing excessive operating costs on firms due to overly stringent environmental regulation standards. Additionally, a favorable institutional and business environment should be created to encourage the concentration of capital and talent in firms that implement green innovation, thus strengthening the internal impetus for firms to take the initiative in green innovation.

Third, the government should cultivate and promote entrepreneurial sentiment and environmental awareness. Entrepreneurs are the leaders and decision makers of green innovation in firms. The government can create a favorable institutional environment to promote the establishment of a modern firm system, which can guide firms in their low-carbon transformation. Additionally, the government can foster a sense of social responsibility among entrepreneurs, who should not only seek to maximize profits but also contribute to the development of society.

Last but not least, the government should establish mechanisms to protect and incentivize intellectual property related to green technologies. This can include streamlined patent processes, patent fee reductions, or legal frameworks that encourage technology sharing while safeguarding the rights of innovators. Such support can foster innovation and attract investment in green technologies.

6.4. Limitations and Future Research

This study explores the relationship between carbon management strategies on green innovation, but there are still some limitations.

First of all, the focus of this paper is solely on Chinese firms, which could limit the generalizability of the findings. Given that different countries and regions have varying cultures, laws, and institutions that can influence the adoption and implementation of firm carbon management strategies, future research can expand the sample scope, covering more regions and countries, and comparative studies could also be conducted. Moreover, case studies can be conducted in future research to test whether and how internal informal institutions affect green innovation.

Secondly, not all listed companies have published CSR reports, ESG reports, or sustainability reports, and there have also been formatting issues in some reports that hinder text mining, so this study has limitations in the completeness of dependent variable data. Considering that incomplete data could affect the generalizability of the study, future research can utilize additional methods, such as deep learning, to accurately capture large amounts of data on carbon management strategies.

Thirdly, the paper uses text-mining methods to measure carbon management strategies. Text-mining algorithms are typically designed to provide an objective analysis of the text data, minimizing human bias and subjectivity. However, textual data often contain ambiguous terms, abbreviations, or acronyms that can be challenging for automatic processing. Therefore, it is beneficial to combine text mining with manual review and validation by human experts who can provide contextual understanding, domain knowledge, and subjective judgment. Moreover, future research can explore the incorporation of diverse data sources, such as financial reports, interviews, or surveys, to enhance the credibility and soundness of scholarly investigations. Furthermore, future research can explore in depth which aspects of a carbon management strategy are most influential in green innovation.

Lastly, this paper examines the moderating effects of stakeholder resource support and R&D investment, and it would be worthwhile to investigate in future research whether and how the interaction between the two could influence green innovation.

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References

1. Rennings, K. Redefining innovation—Eco-innovation research and the contribution from ecological economics. *Ecol. Econ.* **2000**, *32*, 319–332. [CrossRef]
2. Estrin, S.; Prevezer, M. The role of informal institutions in corporate governance: Brazil, Russia, India, and China compared. *Asia Pac. J. Manag.* **2011**, *28*, 41–67. [CrossRef]
3. Helmke, G.; Levitsky, S. Informal institutions and comparative politics: A research agenda. *Perspect. Politics* **2004**, *2*, 725–740. [CrossRef]
4. Sauerwald, S.; Peng, M.W. Informal institutions, shareholder coalitions, and principal–principal conflicts. *Asia Pac. J. Manag.* **2013**, *30*, 853–870. [CrossRef]
5. Allen, F.; Jun, Q.; Qian, M. Law, finance, and economic growth in China. *J. Financ. Econ.* **2005**, *77*, 57–116. [CrossRef]
6. Caravella, S.; Crespi, F. Unfolding heterogeneity: The different policy drivers of different eco-innovation modes. *Environ. Sci. Policy* **2020**, *114*, 182–193. [CrossRef]
7. Shu, C.; Zhou, K.; Xiao, Y.; Gao, S. How green management influences product innovation in China: The role of institutional benefits. *J. Bus. Ethics* **2016**, *133*, 471–485. [CrossRef]
8. Yunus, S.; Elijido-Ten, E.; Abhayawansa, S. Determinants of carbon management strategy adoption. *Manag. Audit. J.* **2016**, *31*, 156–179. [CrossRef]
9. Wang, W.; Sun, Z.; Zhu, W.; Ma, L.; Dong, Y.; Sun, X.; Wu, F. How does multi-agent govern corporate greenwashing? A stakeholder engagement perspective from "common" to "collaborative" governance. *Corp. Soc. Responsib. Environ. Manag.* **2023**, *30*, 291–307. [CrossRef]
10. Johnson, R.A.; Hoskisson, R.E.; Hitt, M.A. Board of director involvement in restructuring: The effects of board versus managerial controls and characteristics. *Strateg. Manag. J.* **1993**, *14*, 33–50. [CrossRef]
11. Boyne, G.A.; Walker, R.M. Strategic management and public service performance: The way ahead. *Public Adm. Rev.* **2010**, *70*, s185–s192. [CrossRef]
12. Weinhofer, G.; Hoffmann, V.H. Mitigating climate change—How do corporate strategies differ? *Bus. Strateg. Environ.* **2010**, *19*, 77–89. [CrossRef]
13. Watson, R.; Wilson, H.N.; Smart, P.; Macdonald, E.K. Harnessing difference: A capability-based framework for stakeholder engagement in environmental innovation. *J. Prod. Innovat. Manag.* **2018**, *35*, 254–279. [CrossRef]
14. Cui, K.; Li, X.; Li, G. What kind of fiscal policies and natural resources efficiency promotes green economic growth? Evidence from regression analysis. *Res. Policy* **2023**, *85*, 103941. [CrossRef]
15. Zhu, T.; Liu, X.; Wang, X.; He, H. Technical Development and Prospect for Collaborative Reduction of Pollution and Carbon Emissions from Iron and Steel Industry in China. *Engineering* **2023**. [CrossRef]
16. Du, C.; Zhang, Q.; Huang, D. Environmental protection subsidies, green technology innovation and environmental performance: Evidence from China's heavy-polluting listed firms. *PLoS ONE* **2023**, *17*, e0278629. [CrossRef]
17. Yu, W.; Ramanathan, R.; Nath, P. Environmental pressures and performance: An analysis of the roles of environmental innovation strategy and marketing capability. *Technol. Forecast. Soc.* **2016**, *117*, 160–169. [CrossRef]
18. Jin, H.; Yang, J.; Chen, Y. Energy saving and emission reduction fiscal policy and corporate green technology innovation. *Front. Psychol.* **2022**, *13*, 1056038. [CrossRef] [PubMed]
19. Luo, S.; He, G. Research on the influence of emission trading system on enterprises' green technology innovation. *Discret. Dyn. Nat. Soc.* **2022**, 1–9. [CrossRef]
20. Liu, W.; Qiu, Y.; Jia, L.; Zhou, H. Carbon emissions trading and green technology innovation-a quasi-natural experiment based on a carbon trading market pilot. *Int. J. Environ. Res. Public Health* **2022**, *19*, 16700. [CrossRef]
21. Ma, J.; Hu, Q.; Shen, W.; Wei, X. Does the low-carbon city pilot policy promote green technology Innovation? Based on green patent data of Chinese A-share listed companies. *Int. J. Environ. Res. Public Health* **2021**, *18*, 3695. [CrossRef] [PubMed]
22. Sun, X.; Zhang, A.; Zhu, M. Impact of pilot zones for green finance reform and innovations on green technology innovations: Evidence from Chinese manufacturing corporates. *Environ. Sci. Pollut. Res.* **2023**, *30*, 43901–43913. [CrossRef] [PubMed]
23. Nie, C.; Zhou, Y.; Feng, Y. Can anti-corruption induce green technology innovation? Evidence from a quasi-natural experiment of China. *Environ. Sci. Pollut. Res. Int.* **2023**, *30*, 34932–34951. [CrossRef] [PubMed]
24. Guo, C.; Wang, Y.; Hu, Y.; Wu, Y.; Lai, X. Does smart city policy improve corporate green technology innovation? Evidence from Chinese listed companies. *J. Environ. Plan. Manag.* **2022**, 1–30. [CrossRef]
25. Xue, Q.; Bai, C.; Xiao, W. Fintech and corporate green technology innovation: Impacts and mechanisms. *Manag. Decis. Econ.* **2022**, *43*, 3898–3914. [CrossRef]
26. Chen, X.; Zhou, P.; Hu, D. How does digital economy affect green technology innovation? Evidence from energy conservation and environmental protection in China. *Sci. Total Environ.* **2023**, 162708. [CrossRef]

27. Feng, S.; Zhang, R.; Li, G. Environmental decentralization, digital finance and green technology innovation. *Struct. Chang. Econ. D* **2022**, *61*, 70–83. [CrossRef]
28. Wang, H.; Wang, S.; Zheng, Y. China green credit policy and corporate green technology innovation: From the perspective of performance gap. *Environ. Sci. Pollut. Res. Int.* **2023**, *30*, 24179–24191. [CrossRef]
29. Amendolagine, V.; Lema, R.; Rabellotti, R. Green foreign direct investments and the deepening of capabilities for sustainable innovation in multinationals: Insights from renewable energy. *J. Clean. Prod.* **2021**, *310*, 127381. [CrossRef]
30. Peng, H.; Shen, N.; Ying, H.; Wang, Q. Can environmental regulation directly promote green innovation behavior?—Based on situation of industrial agglomeration. *J. Clean. Prod.* **2021**, *314*, 128044. [CrossRef]
31. Hobday, M. Product complexity, innovation and industrial organization. *Res. Policy* **1998**, *26*, 689. [CrossRef]
32. Wang, L.; Long, Y.; Li, C. Research on the impact mechanism of heterogeneous environmental regulation on enterprise green technology innovation. *J. Environ. Manag.* **2022**, *322*, 116127. [CrossRef] [PubMed]
33. Xu, A.; Zhu, Y.; Wang, W. Micro green technology innovation effects of green finance pilot policy—From the perspectives of action points and green value. *J. Bus. Res.* **2023**, *159*, 113724. [CrossRef]
34. Fu, L.; Yi, Y.; Wu, T.; Cheng, R.; Zhang, Z. Do carbon emission trading scheme policies induce green technology innovation? New evidence from provincial green patents in China. *Environ. Sci. Pollut. Res.* **2023**, *30*, 13342–13358. [CrossRef]
35. Li, S.; Chen, L.; Xu, P. Quantity or quality? The impact of financial geo-density on firms' green innovation. *Environ. Sci. Pollut. Res.* **2023**, *30*, 54073–54094. [CrossRef] [PubMed]
36. Wang, S.; Wen, J.; Yang, X.; Deng, P.; Wang, N. Impacts of digital trade restrictiveness on green technology innovation: An empirical analysis. *Emerg. Mark. Financ. Trade* **2023**, 1–23. [CrossRef]
37. Su, Y.; Zhu, X.; Deng, Y.; Chen, M.; Piao, Z. Does the greening of the tax system promote the green transformation of China's heavily polluting enterprises? *Environ. Sci. Pollut. Res. Int.* **2023**, *30*, 54927–54944. [CrossRef]
38. Li, D.; Huang, M.; Ren, S.; Chen, X.; Ning, L. Environmental legitimacy, green innovation, and corporate carbon disclosure: Evidence from CDP China 100. *J. Bus. Ethics* **2018**, *150*, 1089–1104. [CrossRef]
39. Lin, R.-J.; Tan, K.H.; Geng, Y. Market demand, green product innovation, and firm performance: Evidence from Vietnam motorcycle industry. *J. Clean. Prod.* **2013**, *40*, 101–107. [CrossRef]
40. Li, B.; Song, P. Driving force mechanism of the core green technology innovation of equipment manufacturing enterprises towards industry 5.0 in China. *Math. Probl. Eng.* **2022**, 2022, 1404378. [CrossRef]
41. Wu, G.; Deng, L.; Niu, X. Evolutionary game analysis of green technology innovation behaviour for enterprises from the perspective of prospect theory. *Discret. Dyn. Nat. Soc.* **2022**, 2022, 5892384. [CrossRef]
42. Qu, S.; Wang, J.; Li, Y.; Wang, K. How does risk-taking affect the green technology innovation of high-tech enterprises in China: The moderating role of financial mismatch. *Environ. Sci. Pollut. Res. Int.* **2023**, *30*, 23747–23763. [CrossRef]
43. Luu, T.T. Fostering green service innovation perceptions through green entrepreneurial orientation: The roles of employee green creativity and customer involvement. *Int. J. Contemp. Hosp. Manag.* **2022**, *34*, 2640–2663. [CrossRef]
44. Rasool, S.F.; Samma, M.; Mohelska, H.; Rehman, F.U. Investigating the nexus between information technology capabilities, knowledge management, and green product innovation: Evidence from SME industry. *Environ. Sci. Pollut. Res. Int.* **2023**, *30*, 56174–56187. [CrossRef] [PubMed]
45. Yang, H.; Shi, X.; Wang, S. Moderating effect of chief executive officer narcissism in the relationship between corporate social responsibility and green technology innovation. *Front. Psychol.* **2021**, *12*, 717491. [CrossRef] [PubMed]
46. Sahoo, S.; Kumar, A.; Upadhyay, A. How do green knowledge management and green technology innovation impact corporate environmental performance? Understanding the role of green knowledge acquisition. *Bus. Strateg. Environ.* **2023**, *32*, 551–569. [CrossRef]
47. Nie, L.; Gong, H.; Zhao, D.; Lai, X.; Chang, M. Heterogeneous knowledge spillover channels in universities and green technology innovation in local firms: Stimulating quantity or quality? *Front. Psychol.* **2022**, *13*, 943655. [CrossRef]
48. He, Z.; Cao, C.; Feng, C. Media attention, environmental information disclosure and corporate green technology innovations in China's heavily polluting industries. *Emerg. Mark. Financ. Trade* **2022**, *58*, 3939–3952. [CrossRef]
49. Hu, S.; Wu, H. The mechanism of media pressure on corporate green technology innovation: The moderating effect of corporate internal governance. *Technol. Anal. Strateg.* **2022**, 1–17. [CrossRef]
50. Guo, S.; Ma, H. Will companies take the initiative in green technology innovation? Empirical evidence from listed manufacturing companies in China. *Appl. Econ.* **2023**, *55*, 636–652. [CrossRef]
51. Li, Y.; Huang, L.; Tong, Y. Cooperation with competitor or not? The strategic choice of a focal firm's green innovation strategy. *Comput. Ind. Eng.* **2021**, *157*, 107301. [CrossRef]
52. Berry, M.A.; Rondinelli, D.A. Proactive corporate environmental management: A new industrial revolution. *Acad. Manag. Perspect.* **1998**, *12*, 38–50. [CrossRef]
53. Minbaeva, D.B.; Ledeneva, A.; Muratbekova-Touron, M.; Horak, S. Explaining the persistence of informal institutions: The role of informal networks. *Acad. Manag. Rev.* **2023**, *48*, 556–574. [CrossRef]
54. Dossou, P.-E.; Mitchell, P. Modeling and performance improvement: The remedy to treat social and environment issues for enterprises in today's difficult economic climate. *LogForum* **2015**, *11*, 29–40. [CrossRef]
55. He, F.; Yan, Y.; Hao, J.; Wu, J. Retail investor attention and corporate green innovation: Evidence from China. *Energy Econ.* **2022**, *115*, 106308. [CrossRef]

56. Zhang, Z.; Peng, X.; Yang, L.; Lee, S. How does Chinese central environmental inspection affect corporate green innovation? The moderating effect of bargaining intentions. *Environ. Sci. Pollut. Res. Int.* **2022**, *29*, 42955–42972. [CrossRef]
57. Xia, F.; Chen, J.; Yang, X.; Li, X.; Zhang, B. Financial constraints and corporate greenwashing strategies in China. *Corp. Soc. Resp. Environ. Manag.* **2023**, *30*, 1770–1781. [CrossRef]
58. Neely, A.D.; Adams, C.; Kennerley, M. *The Performance Prism: The Scorecard for Measuring and Managing Business Success*; Prentice Hall Financial Times: London, UK, 2002.
59. Stefanelli, N.O.; Jabbour, C.J.C.; Amui, L.B.L.; de Oliveira, J.H.C.; Latan, H.; Paillé, P.; Hingley, M. Unleashing proactive low-carbon strategies through behavioral factors in biodiversity-intensive sustainable supply chains: Mixed methodology. *Bus. Strateg. Environ.* **2021**, *30*, 2535–2555. [CrossRef]
60. Wang, D.; Luo, Y.; Hu, S.; Yang, Q. Executives' ESG cognition and enterprise green innovation: Evidence based on executives' personal microblogs. *Front. Psychol.* **2022**, *13*, 1053105. [CrossRef]
61. Donaldson, T.; Preston, L.E. The stakeholder theory of the corporation: Concepts, evidence, and implications. *Acad. Manag. Rev.* **1995**, *20*, 65–91. [CrossRef]
62. Czinkota, M.; Kaufmann, H.R.; Basile, G. The relationship between legitimacy, reputation, sustainability and branding for companies and their supply chains. *Ind. Mark. Manag.* **2014**, *43*, 91–101. [CrossRef]
63. Zhong, X.; Chen, W.; Ren, G. The impact of corporate social irresponsibility on emerging-economy firms' long-term performance: An explanation based on signal theory. *J. Bus. Res.* **2022**, *144*, 345–357. [CrossRef]
64. Mahmoudian, F.; Lu, J.; Yu, D.; Nazari, J.A.; Herremans, I.M. Inter-and intra-organizational stakeholder arrangements in carbon management accounting. *Brit. Account. Rev.* **2021**, *53*, 100933. [CrossRef]
65. Pittaway, L.; Robertson, M.; Munir, K.; Denyer, D.; Neely, A. Networking and innovation: A systematic review of the evidence. *Int. J. Manag. Rev.* **2004**, *5/6*, 137–168. [CrossRef]
66. Luo, X.; Du, S. Exploring the relationship between corporate social responsibility and firm innovation. *Mark. Lett.* **2015**, *26*, 703–714. [CrossRef]
67. Bae, J.; Chun, D. How do country-specific R&D environments affect CCUS research performance and efficiency? From the perspective of knowledge diffusion and application. *Environ. Sci. Pollut. Res. Int.* **2023**, 1–10. [CrossRef]
68. Sinha, K.K.; Osiyevskyy, O.; Radnejad, A.B. Propositions for R&D governance regimes: A behavioral perspective. *Int. J. Innov. Technol.* **2022**, *19*, 1–30.
69. Allen, F.; Gu, X.; Li, C.W.; Qian, J.; Qian, Y. Implicit guarantees and the rise of shadow banking: The case of trust products. *J. Financ. Econ.* **2023**, *149*, 115–141. [CrossRef]
70. Wong, T.J.; Yu, G.; Zhang, S.; Zhang, T. Calling for transparency: Evidence from a field experiment. *J. Account. Econ.* **2023**, 101604. [CrossRef]
71. Liu, H.; Zhang, J.; Lei, H. Crowding in or crowding out? The effect of imported environmentally sound technologies on indigenous green innovation. *J. Environ. Manag.* **2023**, *345*, 118579. [CrossRef] [PubMed]
72. Zeng, Q.; Tong, Y.; Yang, Y. Can green finance promote green technology innovation in enterprises: Empirical evidence from China. *Environ. Sci. Pollut. Res.* **2023**, *30*, 87628–87644. [CrossRef]
73. Liao, Z. Is environmental innovation conducive to corporate financing? The moderating role of advertising expenditures. *Bus. Strateg. Environ.* **2020**, *29*, 954–961. [CrossRef]
74. Moussa, T.; Allam, A.; Elbanna, S.; Bani, M.A. Can board environmental orientation improve U.S. firms' carbon performance? The mediating role of carbon strategy. *Bus. Strateg. Environ.* **2020**, *29*, 72–86. [CrossRef]
75. Yunus, S.; Elijido-Ten, E.O.; Abhayawansa, S. Impact of stakeholder pressure on the adoption of carbon management strategies: Evidence from Australia. *Sustain. Account. Manag. Policy J.* **2020**, *11*, 1189–1212. [CrossRef]
76. Pan, X.; Chen, X.; Sinha, P. Navigating the haze: Environmental performance feedback and CSR report readability. *J. Bus. Res.* **2023**, *166*, 114116. [CrossRef]
77. Sun, Y.; Xu, C.; Li, H.; Cao, Y. What drives the innovation in corporate social responsibility (CSR) disclosures? An integrated reporting perspective from China. *J. Innov. Knowl.* **2022**, *7*, 100267. [CrossRef]
78. Lopes de Sousa Jabbour, A.B.; Chiappetta Jabbour, C.J.; Sarkis, J.; Latan, H.; Roubaud, D.; Godinho Filho, M.; Queiroz, M. Fostering low-carbon production and logistics systems: Framework and empirical evidence. *Int. J. Prod. Res.* **2021**, *59*, 7106–7125. [CrossRef]
79. Xu, J.; Zeng, S.; Qi, S.; Cui, J. Do institutional investors facilitate corporate environmental innovation? *Energy Econ.* **2023**, *117*, 106472. [CrossRef]
80. Liu, S.; Jin, J.; Nainar, K. Does ESG performance reduce banks' nonperforming loans? *Financ. Res. Lett.* **2023**, 103859. [CrossRef]
81. Zhang, X.; Zou, M.; Liu, W.; Zhang, Y. Does a firm's supplier concentration affect its cash holding? *Econ. Model.* **2020**, *90*, 527–535. [CrossRef]
82. Ni, J.; Cao, X.; Zhou, W.; Li, J. Customer concentration and financing constraints. *J. Corp. Financ.* **2023**, 102432. [CrossRef]
83. Lou, Z.; Chen, S.; Jia, Y.; Yu, X. Business group affiliation and R&D investment: Evidence from China. *Emerg. Mark. Financ. Trade* **2021**, *57*, 2307–2322.
84. Jindal, N. The impact of advertising and R&D on bankruptcy survival: A double-edged sword. *J. Mark.* **2020**, *84*, 22–40.

85. Chen, S.; Mao, H.; Sun, J. Low-carbon city construction and corporate carbon reduction performance: Evidence from a quasi-natural experiment in China. *J. Bus. Ethics* **2022**, *180*, 125–143. [CrossRef]
86. Wang, Q.J.; Wang, H.J.; Chang, C.P. Environmental performance, green finance and green innovation: What's the long-run relationships among variables? *Energy Econ.* **2022**, *110*, 106004. [CrossRef]