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The Effects of Supply Chain Innovation on Corporate Carbon Emission Intensity

-- A Study based on the "Supply Chain Innovation and Application Pilot" Policy

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Abstract

In the context of the "dual-carbon" era, enterprises face a deep-seated contradiction between fulfilling environmental responsibility and improving economic efficiency. How to promote environmental protection practices while ensuring economic benefits has become a crucial issue that urgently needs to be addressed in China. This paper uses Chinese A-share listed companies from 2014 to 2023 as a research reference and the pilot policy of supply chain innovation and application as a research starting point. It conducts theoretical and empirical research on the impact of supply chain innovation on corporate carbon emission intensity, clarifying the direct effects and indirect transmission mechanisms of supply chain innovation on corporate carbon emission intensity, and verifying the positive value of supply chain innovation in corporate carbon reduction. The research results show that the pilot policy of supply chain innovation and application can significantly reduce corporate carbon emission intensity, and green innovation and industrial structure transformation and upgrading are important paths for the policy to exert its carbon reduction effect. The research findings of this paper are of great significance for promoting enterprises to achieve "dual-carbon" goals and improving macro-level green development risk prevention strategies, and can provide theoretical reference and practical guidance for the green and sustainable development of enterprises nationwide.

Keywords

Supply Chain Innovation; Carbon Emission Intensity; Corporate Green Transformation; Green Innovation; Industrial Structure.

1. Introduction

Over the past 40 years, extreme weather events caused by global climate change have shown a significant upward trend in both frequency and intensity. Emission reduction and carbon reduction have become a common consensus in the international community. Countries have carried out a series of negotiations on institutional arrangements and action plans for addressing climate change under the framework of the United Nations [6] . From the conclusion of the United Nations Framework Convention on Climate Change in 1992 to the signing of the Kyoto Protocol in 1997, and then to the formal entry into force of the Paris Agreement in 2016, the international community has gradually built up the political and legal foundation for addressing climate change. In 2020, China formally proposed the dual carbon target of " peaking carbon before 2030 and achieving carbon neutrality before 2060 " , taking the initiative to assume the responsibility of a major country in addressing global climate change. Compared with other major developed economies, China faces greater pressure and challenges in

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achieving its dual carbon target. Developed countries have passed the peak of carbon emissions and only need to continue the existing pace of emission reduction to achieve the goal of net zero emissions by 2050. However, China's total carbon emissions are still in the growth stage. It needs to achieve carbon peak before 2030 against the backdrop of a low per capita GDP level and complete carbon neutrality within just 30 years. The emission reduction time is more urgent and the emission reduction intensity is higher. The annual emission reduction rate needs to reach 8 % -10%. As the core subject of carbon emissions and the key action subject of the dual carbon target, the production and operation activities of enterprises directly affect the path to the realization of the dual carbon target [8] . Under the current development background, how to promote enterprises to achieve green transformation and effectively reduce carbon emissions has become the core research topic under the " 30·60 " dual carbon target.

Since 2018, my country has been conducting pilot demonstration programs for supply chain innovation and application in batches. The first batch identified 55 pilot cities and 266 pilot enterprises, followed by the selection of demonstration cities and enterprises in 2021 and 2022. This policy layout reflects my country's proactive attempt to explore green, efficient, and sustainable development paths for enterprises under the dual pressures of addressing global climate change and promoting carbon emission reduction. Based on this, this paper incorporates the supply chain innovation and application pilot policy with enterprise carbon emission intensity into the same research framework, analyzing the impact and underlying mechanisms of supply chain innovation on enterprise carbon emission intensity, providing a new theoretical perspective and approach for research on enterprise green transformation and sustainable development.

2. Literature Review

In the field of corporate carbon emission intensity research, existing studies have conducted a comprehensive and in-depth discussion on the definition and influencing factors of corporate carbon emissions [4] . Some studies focus on core issues such as the determinants of per capita carbon dioxide emission levels and the correlation between peak carbon emissions and GDP [3] . Scholars have analyzed various factors affecting corporate carbon emission intensity from the perspectives of external environment and internal characteristics. From the perspective of external environment, environmental regulation policies and the level of financial development are the focus of research. Among them, environmental regulation measures such as carbon emission trading, pollution rights trading, and clean production standards [7] , as well as financial policies such as green credit and carbon neutral bonds [10] , have been proven to effectively promote corporate carbon emission reduction. In addition, factors such as tax structure adjustment [15] , export tax rebate policy, social credit system construction, and ESG rating [2] also have a positive promoting effect on corporate carbon emission reduction [12] .

From the perspective of internal corporate characteristics, corporate governance mechanisms and corporate digital transformation are key factors affecting carbon emission intensity. Institutional investors, as important governance entities, not only pursue long-term financial returns but also promote the improvement of corporate environmental governance systems. Relevant research data from multinational corporations and American companies show that the increase in the shareholding ratio of institutional investors helps reduce corporate carbon emissions [1] . The characteristics of the board of directors also affect corporate carbon emission behavior. The increase in gender diversity of the board of directors and the increase in the number of female directors can effectively reduce corporate carbon emission intensity [5] . In addition, the carbon emission reduction effects of factors such as CEO individual characteristics and digital transformation of industrial enterprises have also become important directions of existing research [9] .

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Existing research shows that the integration of digital technology and supply chain management can promote the green transformation of enterprises from both internal and external perspectives [16] : internally, supply chain digitalization can enhance the internal integration capabilities of enterprises, narrow the information gap between management and stakeholders, improve the transparency of enterprise operations, reduce supervision costs, and force management to promote the green transformation of enterprises [13] ; externally, supply chain digitalization can enhance the external integration capabilities of enterprises, promote information exchange between enterprises, improve the efficiency of supply chain resource allocation, and thus drive the green development of enterprises [14] .

Overall, existing research has confirmed the positive role of supply chain innovation in corporate green development. However, research on the direct impact and underlying mechanisms of supply chain innovation and application pilot policies on corporate carbon emission intensity is still lacking, and systematic research results have not yet been formed. Therefore, conducting research on supply chain innovation and application pilot policies to analyze their impact and pathways on corporate carbon emission intensity has important theoretical supplementary significance.

3. Theoretical Analysis and Research Hypotheses

3.1. The Direct Impact of Supply Chain Innovation and Application Pilot Policies on Corporate Carbon Emissions

The implementation of pilot policies for supply chain innovation and application can directly promote enterprises to reduce carbon emissions from two dimensions: industrial division of labor and policy empowerment. On the one hand, the implementation of pilot policies can promote the improvement of the level of specialization within enterprises, prompting them to focus on high-value-added and core-competitive business segments and optimize and integrate non-core businesses. This optimization of the division of labor model can promote the in-depth development of green technology research and application, achieve a qualitative leap in the level of green technology, and thus reduce the carbon emissions of enterprises from the perspective of production technology.

On the other hand, the supply chain innovation and application pilot program is a national-level industrial development policy. Policy support provides important resources and institutional guarantees for the development of enterprises in the supply chain, enabling them to achieve structural and digital empowerment. Under the pilot policy, enterprises can leverage next-generation information technologies such as big data, the Internet of Things, and blockchain to optimize key elements of the supply chain, including structure, policies, and channels, breaking down structural barriers to information and resource access between enterprises and reducing carbon emissions from the supply chain operation level.

Based on this, this paper proposes research hypothesis 1: Supply chain innovation and application pilot policies can effectively reduce corporate carbon emission intensity.

3.2. Indirect Impact Path of Supply Chain Innovation and Application Pilot Policies

The impact of supply chain innovation and application pilot policies on corporate carbon emission intensity not only has a direct effect, but also has an indirect effect by influencing corporate green innovation behavior. Green innovation may play a mediating role between the two.

The pilot policy for supply chain innovation and application provides a favorable policy environment and resource support for enterprises' green innovation. Pilot enterprises can leverage this policy support to obtain more R&D resources, technological support, and market

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opportunities, promoting the deep integration of supply chain innovation and green innovation. Guided by the pilot policy, enterprises will place greater emphasis on the R&D and application of green production technologies, green products, and green management models. Through the digital and green upgrading of the supply chain, they can integrate upstream and downstream innovation resources, forming a synergistic effect of green innovation and enhancing their overall green innovation capabilities. The improvement in enterprises' green innovation capabilities can directly drive the green transformation of production methods, reducing energy consumption and carbon emissions in the production process through the application of green production technologies. Existing research confirms that enterprise green innovation is the core driving force for reducing carbon intensity, and there is a significant negative correlation between the improvement of green innovation capabilities and the reduction of enterprise carbon intensity.

Based on this, this paper proposes research hypothesis 2: the pilot policy for supply chain innovation and application indirectly reduces the carbon emission intensity of enterprises by promoting green innovation, and green innovation plays an intermediary role.

3.3. The Transmission Effect of Industrial Structure: Another Indirect Impact Path of Supply Chain Innovation and Application Pilot Policies

There is an inherent link between industrial structure and regional and corporate carbon emission levels. The transformation and upgrading of industrial structure can effectively promote the reduction of carbon emission intensity, while supply chain innovation and application pilot policies can inhibit corporate carbon emission intensity by promoting industrial structure transformation. Industrial structure has become an important transmission channel between the two.

The macro-environment for my country's economic and social development is undergoing profound changes, with a new round of industrial transfer accelerating. The implementation of pilot policies for supply chain innovation and application provides significant impetus for industrial restructuring and upgrading. Under these pilot policies, enterprises can leverage information technologies such as mobile payment platforms and big data to accurately acquire user information and consumer data, enabling in-depth analysis of market demand preferences and gaps. Simultaneously, these policies guide enterprises to invest more resources in product research and development and technological innovation, reducing reliance on traditional labor-intensive industries and resource-based processing industries. This creates space for the development of strategic emerging industries and modern service industries, promoting the optimization and upgrading of regional industrial structures. Furthermore, the transformation and upgrading of industrial structures will drive the production and operation models of upstream and downstream enterprises in the supply chain towards greener and more efficient models, achieving an overall reduction in corporate carbon emission intensity at the industrial level.

Based on this, this paper proposes research hypothesis 3: the pilot policy for supply chain innovation and application indirectly inhibits corporate carbon emissions by promoting industrial structure transformation and upgrading, and the industrial structure plays a transmission role.

4. Research Design

4.1. Sample Selection and Data Sources

This paper selects Chinese A-share listed companies as research samples, and sets the research time window as 2014-2023 . In order to ensure the scientificity and effectiveness of the research samples, this paper strictly screens the samples in accordance with the research

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norms: First, financial listed companies are excluded because the business model and carbon emission characteristics of financial companies are fundamentally different from those of non-financial companies, and including them in the sample will affect the accuracy of the research results [11] ; Second, ST and *ST listed companies are excluded because the operating conditions of such companies are abnormal and their carbon emission data and operating data are not representative; Third, listed companies with missing carbon emission intensity, financial data and corporate governance data are excluded to ensure the integrity of the sample data; Fourth, companies that have been identified as supply chain innovation and application pilots multiple times during the research period are excluded to avoid the interference of repeated statistics on the research results; Fifth, newly listed and delisted companies during the research period are excluded to ensure the continuity of the sample.

The research data in this paper comes from authoritative databases and public reports from multiple channels. The acquisition paths for various data are as follows: Data related to corporate carbon emission intensity were mainly extracted from listed companies' annual reports and social responsibility reports (ESG reports). Some missing data were supplemented through professional financial databases. For companies that did not directly disclose carbon emission data, existing research findings were referenced, and scientific estimations were made using industry carbon emission coefficients combined with corporate energy consumption data. Data on pilot enterprises for supply chain innovation and application came from the list of pilot enterprises jointly released by eight departments including the Ministry of Commerce, the Ministry of Finance, and the Ministry of Ecology and Environment. The identities of pilot enterprises and specific pilot years were determined manually . Furthermore, to avoid the interference of extreme values on the research results, all continuous variables were shortened.

4.2. Variable Definition

4.2.1. Dependent Variable: Corporate Carbon Intensity (CEI)

This paper uses the carbon emissions per unit of corporate revenue as a measure of corporate carbon emission intensity. This indicator can intuitively reflect the carbon emission efficiency of enterprises [4] . The larger the value of the indicator, the more carbon emissions generated per unit of corporate revenue and the lower the carbon emission efficiency; the smaller the value of the indicator, the higher the carbon emission efficiency of enterprises.

For the calculation of corporate carbon emissions, referencing the mainstream methods of existing research, the direct carbon emissions and indirect carbon emissions of enterprises are comprehensively considered. Direct carbon emissions are greenhouse gas emissions generated by the direct consumption of energy during the production process of enterprises, while indirect carbon emissions are mainly greenhouse gas emissions generated by the consumption of electricity and heat by enterprises. After comprehensive calculation, the annual carbon emissions of enterprises are obtained, and then divided by the annual operating income of enterprises to obtain the carbon emission intensity index of enterprises [4] .

4.2.2. Key Explanatory Variable: Supply Chain Innovation (SCIN)

This paper uses whether a company is recognized as a pilot enterprise for supply chain innovation and application as a proxy variable for supply chain innovation, and employs a dummy variable for measurement. Simultaneously, a dummy variable for the policy implementation year (Post) is introduced. Combining the pilot enterprise's status with the policy implementation time, a core explanatory variable SCIN×Post is constructed to measure the net impact of the supply chain innovation and application pilot policy on the company's carbon emission intensity.

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If the coefficient of this variable shows a significant negative correlation, it indicates that the supply chain innovation and application pilot policy can effectively reduce corporate carbon emission intensity. For enterprises identified as pilot enterprises in batches, the value of the policy implementation dummy variable is adjusted according to the actual pilot year to ensure accurate identification of the policy effect.

4.2.3. Mediator Variables

This paper selects internal integration capability (INTE) and external resource allocation efficiency (EXTE) as mediating variables to analyze the intrinsic mechanism by which supply chain innovation affects corporate carbon emission intensity.

Internal integration capability is measured by the company's total asset turnover ratio. This indicator reflects the efficiency of the company's internal resource utilization and operational management level. The higher the value of the indicator, the stronger the company's internal resource integration capability, which can effectively reduce resource waste and carbon emissions in the production process. External resource allocation efficiency is measured by the company's supply chain concentration. This indicator reflects the degree of collaboration between the company and the core companies in the upstream and downstream of the supply chain. The higher the value of the indicator, the higher the efficiency of the company's external supply chain resource allocation, which can achieve carbon emission reduction through supply chain collaboration.

4.2.4. Control Variables

To eliminate the interference of other factors on corporate carbon emission intensity and ensure the accuracy of the research results, this paper refers to the results of existing related studies and selects a series of representative variables as control variables, covering multiple dimensions such as corporate characteristics, corporate governance, industry, and time: Firm size (Size) is measured by the natural logarithm of total assets, reflecting the firm's resource and technological advantages; the debt-to-equity ratio (Lev) is measured by the ratio of total liabilities to total assets, reflecting the firm's financial risk; profitability (ROE) is measured by the return on equity, reflecting the firm's profitability and carbon emission reduction investment capacity; firm age (Age) is measured by the difference between the current year and the year of establishment, reflecting the degree of solidification of the firm's production model; institutional investor shareholding ratio (Inst) is measured by the ratio of the number of shares held by institutional investors to the total number of shares, reflecting the driving role of institutional investors in corporate environmental governance; and board size (Board) is measured by the natural logarithm of the number of board members, reflecting the scientific nature of corporate environmental governance decisions. Simultaneously, industry and year dummy variables are set to control for industry-level carbon emission differences and the impact of time-level factors such as macroeconomic environment and policy changes.

5. Research Results

5.1. The Direct Carbon Emission Reduction Effect of Supply Chain Innovation and Application Pilot Policies

The core findings indicate that the supply chain innovation and application pilot policy has a significant negative impact on corporate carbon emission intensity, validating the validity of research hypothesis 1. This means that becoming a pilot enterprise for supply chain innovation and application significantly reduces a company's carbon emission intensity, demonstrating that supply chain innovation can effectively play a positive role in corporate carbon reduction.

The implementation of the supply chain innovation and application pilot policy has brought enterprises support in terms of policy, technology, and resources, promoting optimization and

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upgrading from multiple dimensions such as production processes, resource allocation, and operation management. Pilot enterprises have leveraged policy dividends to accelerate their digital and green transformation, improving internal specialization and focusing on green technology research and development in their core businesses, thereby reducing resource consumption and carbon emissions in non-core operations .

5.2. Results of the Test on the Mediating Effect of Green Innovation

The research results confirm that green innovation plays a significant mediating role in the impact of supply chain innovation and application pilot policies on corporate carbon emission intensity, thus verifying research hypothesis 2. Pilot policies create a favorable policy environment for corporate green innovation, enabling pilot enterprises to obtain more R&D funding, technological support, and market incentives, thereby increasing investment in green production technologies, green product development, and green management models. Simultaneously, supply chain innovation promotes the integration of innovation resources among upstream and downstream enterprises, forming a synergistic effect of green innovation and comprehensively enhancing enterprises' green innovation capabilities. This enhanced green innovation capability directly drives the transformation of production methods towards low-carbon and green practices, reducing energy consumption through efficient green production technologies and meeting market demands for green consumption through green product development, ultimately reducing carbon emission intensity. This highlights the important value of green innovation as a mediating pathway for the carbon emission reduction effect of supply chain innovation.

5.3. Test Results of the Transmission Effect of Industrial Structure

The transformation and upgrading of industrial structure has played an effective role in transmitting the carbon emission reduction effect of the pilot policy on supply chain innovation and application, thus confirming research hypothesis 3. Under the pilot policy, enterprises use digital means to accurately grasp market demand, gradually adjust their production layout and product structure, reduce their reliance on traditional labor-intensive and resource-intensive industries, and invest more resources in technology-intensive and green low-carbon business areas. This enterprise-level industrial restructuring further drives the transformation and upgrading of the regional industrial structure, releasing space for the development of strategic emerging industries and modern service industries, and promoting the transformation of the regional industrial system towards greening and high-end development. The optimization and upgrading of the industrial structure, in turn, drives the green transformation of upstream and downstream enterprises in the supply chain, forming a synergy for carbon emission reduction at the industrial level, resulting in a systematic reduction in the carbon emission intensity of enterprises within the scope of the pilot policy.

5.4. Results of Heterogeneity Analysis

From the perspective of heterogeneity analysis based on enterprise attributes and industry characteristics, the carbon emission reduction effects of supply chain innovation and application pilot policies exhibit certain differences. Regarding enterprise attributes, the carbon emission reduction effect is more significant for state-owned enterprises (SOEs) than for non-state-owned enterprises. This is because SOEs have greater initiative in implementing national dual-carbon policies and assuming environmental responsibility, and possess richer resources and technological advantages, enabling them to better leverage supply chain innovation policies to achieve carbon emission reduction .

In terms of industry characteristics, the carbon emission reduction effect of enterprises in heavily polluting industries is significantly higher than that of non-heavily polluting industries. As a key area for carbon emission reduction, heavily polluting industries are subject to higher

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policy regulations and market attention. The implementation of supply chain innovation and application pilot policies has provided them with an opportunity and support for transformation. Through the optimization and upgrading of the supply chain, high-energy-consuming and high-emission production links have been effectively reduced. The carbon emission reduction effect of supply chain innovation in technology-intensive industries is also quite prominent. These industries have strong technological research and development capabilities and can deeply integrate supply chain innovation with green technologies to achieve efficient reduction of carbon emission intensity.

6. Research Conclusion

(1) Supply chain innovation and application pilot policies can significantly reduce corporate carbon emission intensity and are an effective policy tool for promoting corporate green transformation and achieving carbon emission reduction. The policy support, technological empowerment, and resource integration brought about by the pilot policies can help companies optimize their internal production division of labor and improve external supply chain collaboration, thereby reducing carbon emissions throughout the entire production and operation process, achieving synergistic development of corporate economic and environmental benefits, and resolving the contradiction between corporate environmental responsibility and economic growth in the dual-carbon era.

(2) Green innovation is a crucial intermediary pathway for supply chain innovation and application pilot policies to leverage their carbon reduction effects. These pilot policies provide a favorable policy environment and resource support for enterprise green innovation, encouraging companies to increase investment in green innovation, integrate supply chain innovation resources, and enhance their green innovation capabilities. This enhanced green innovation capability, in turn, directly drives the low-carbon transformation of enterprise production methods, reducing carbon emission intensity and forming a transmission mechanism of " supply chain innovation - green innovation - carbon reduction . "

(3) Industrial restructuring and upgrading is a crucial channel for transmitting the carbon emission reduction effects of supply chain innovation and application pilot policies. These policies guide enterprises to adjust their production structures and optimize their product portfolios, promoting their transformation from traditional resource-based industries to green technology-based industries, thereby driving the optimization and upgrading of regional industrial structures. In turn, industrial restructuring and upgrading create a synergy for carbon emission reduction at the industry level, which in turn promotes the green development of upstream and downstream enterprises in the supply chain, achieving a systematic suppression of corporate carbon emission intensity. This constructs a pathway of " supply chain innovation - industrial restructuring and upgrading - carbon emission reduction . "

(4) The carbon reduction effects of supply chain innovation and application pilot policies exhibit significant heterogeneity. From the perspective of enterprise attributes, state-owned enterprises and large enterprises show more significant carbon reduction effects; from the perspective of industry characteristics, heavily polluting industries and technology-intensive industries are better able to leverage the carbon reduction role of supply chain innovation. This heterogeneity reflects that enterprise resource endowment, policy implementation capabilities, and industry foundation are important factors influencing the carbon reduction effect of supply chain innovation.

Overall, supply chain innovation is a crucial pathway for enterprises to achieve carbon reduction and green sustainable development. The implementation of supply chain innovation and application pilot policies, through both direct and indirect transmission effects, has effectively promoted the reduction of corporate carbon intensity, providing micro-level

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practical support for achieving my country's dual-carbon goals. Furthermore, this study clarifies the intrinsic mechanism by which supply chain innovation affects corporate carbon intensity, filling gaps in existing research on the correlation between supply chain innovation and corporate carbon reduction, and providing new theoretical perspectives and research ideas for subsequent related studies.

7. Policy Recommendations

7.1. Government level

(1) We will continue to advance pilot programs for supply chain innovation and application, and expand the coverage of pilot policies. Building on existing pilot enterprises and cities, we will gradually extend pilot policies to SMEs, non-state-owned enterprises, and the central and western regions. We will develop differentiated pilot identification standards and support policies for enterprises of different sizes and with different characteristics, so that more enterprises can participate in supply chain innovation pilots, share policy dividends, and achieve universal carbon emission reduction benefits.

(2) Increase policy support for pilot enterprises and build a multi-dimensional policy support system. In terms of finance, establish a special fund for supply chain innovation and green carbon emission reduction, providing financial subsidies and tax breaks for pilot enterprises' green innovation R&D and digital supply chain construction. In terms of finance, guide financial institutions to launch financial products such as supply chain green loans and green bonds, providing low-cost financing support for pilot enterprises' supply chain transformation and carbon emission reduction projects. In terms of technology, build a public service platform for supply chain innovation and green technology R&D, integrating the technological resources of universities and research institutes to provide pilot enterprises with technical guidance and services.

(3) Establish and improve the assessment and evaluation system for supply chain innovation and carbon emission reduction. Incorporate indicators such as carbon emission intensity reduction, green innovation investment, and industrial restructuring into the assessment and evaluation scope of pilot enterprises. Establish a dynamic assessment and exit mechanism, recognizing and rewarding pilot enterprises with significant carbon emission reduction achievements, while requiring enterprises that fail to meet the assessment standards to rectify within a specified period or canceling their pilot qualifications. This will compel pilot enterprises to effectively fulfill their carbon emission reduction responsibilities and improve the carbon emission reduction effect of supply chain innovation.

(4) Strengthen cross-regional and cross-departmental policy coordination. The Ministry of Commerce, the Ministry of Ecology and Environment, the Ministry of Finance, and other relevant departments should establish a joint working mechanism to coordinate and promote supply chain innovation and carbon emission reduction, break down policy barriers between regions, and promote the nationwide implementation of pilot policies. At the same time, they should strengthen the coordination between environmental regulatory policies and supply chain innovation policies, integrate carbon emission reduction requirements into all aspects of supply chain innovation, and achieve the superposition of policy effects.

7.2. Enterprise Level

(1) Enterprises should proactively seize the opportunities presented by pilot policies and accelerate the integration of digitalization and greening in the supply chain. They should actively apply for supply chain innovation and application pilot programs, leveraging policy support to increase investment in information technologies such as big data, the Internet of Things, and blockchain. This will enable them to build digital supply chain management

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platforms, achieving information sharing, resource collaboration, and process optimization among upstream and downstream enterprises. Simultaneously, they should integrate green and low-carbon concepts into the entire supply chain construction process, from raw material procurement, production and processing, product sales to logistics and distribution, building a green supply chain system and reducing carbon emissions at each stage.

(2) Increase investment in green innovation and strengthen the deep integration of supply chain innovation and green innovation. State-owned enterprises and large enterprises should play a leading role by establishing special funds for green innovation R&D and strengthening research and application in green production technologies, green products, and green management models. Small and medium-sized enterprises can rely on industry alliances and public technology platforms to carry out joint green innovation and reduce R&D costs. At the same time, enterprises should integrate innovation resources across the supply chain, establish a collaborative mechanism for green innovation, and achieve the sharing and transformation of green innovation achievements in all links of the supply chain to enhance overall green innovation capabilities.

(3) Develop differentiated carbon reduction strategies based on their own characteristics. State-owned enterprises should further strengthen their environmental responsibility, incorporate carbon reduction targets into their corporate development strategies, and accelerate supply chain transformation by leveraging their resource and technological advantages. Small and medium-sized enterprises should focus on their core businesses and integrate into the green supply chain system through supply chain cooperation with large pilot enterprises to achieve indirect carbon reduction. Enterprises in heavily polluting industries should combine supply chain innovation with industrial upgrading, gradually eliminate high-energy-consuming and high-emission production processes, and transform into green and low-carbon industries. Enterprises in technology-intensive industries should continue to deepen technological research and development, deeply integrate supply chain innovation with green technologies, and create a low-carbon and high-end supply chain system.

(4) Improve the company's internal environmental governance system and enhance the implementation of carbon emission reduction. Companies should establish and improve their carbon emission accounting and management systems, accurately monitor carbon emissions in each production stage, and formulate scientific carbon emission reduction targets and implementation plans. At the same time, carbon emission reduction results should be included in the performance evaluation of the company's management and various departments to strengthen the implementation of carbon emission reduction responsibilities within the company and create an atmosphere of carbon emission reduction with the participation of all employees.

7.3. Industry Level

(1) Establish an industrial supply chain innovation alliance to achieve resource integration and collaborative innovation at the industry level. With pilot enterprises as the core, integrate upstream and downstream enterprises, universities, research institutes, financial institutions, and other entities in the industrial chain to form an industrial supply chain innovation alliance. Build a cooperation platform for resource sharing, technological collaboration, and market linkage to promote supply chain innovation and green transformation in all links of the industrial chain, and form a joint force for carbon emission reduction at the industry level.

(2) Promote the optimization and upgrading of industrial structure and cultivate a green and low-carbon industrial system. Relying on the pilot policy of supply chain innovation and application, guide various industries to gradually reduce their dependence on traditional resource- based and labor-intensive industries, and increase the cultivation of strategic emerging industries, modern service industries, and green and low-carbon industries; at the

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same time, promote the combination of industrial transfer and industrial upgrading, eliminate outdated production capacity in the process of industrial transfer, realize the green and high-end transformation of industrial structure, and reduce carbon emission intensity at the industrial level.

(3) Strengthen supply chain collaboration among industries to achieve cross-industry carbon emission reduction linkages. Encourage supply chain cooperation among different industries such as manufacturing, logistics, and services to build a cross-industry green supply chain system. For example, manufacturing and logistics can cooperate to create a green logistics supply chain to reduce carbon emissions in the logistics process; the service industry can provide digital and green supply chain services to manufacturing to improve the carbon emission reduction efficiency of manufacturing. Through cross-industry collaborative development, the overall carbon emission reduction effect can be improved.

(4) Foster an industrial ecosystem for supply chain innovation and carbon emission reduction. Focusing on supply chain innovation and green carbon emission reduction, cultivate a group of professional supply chain service companies, green technology R&D companies, and carbon emission accounting and consulting institutions to provide professional service support for the green transformation of industrial supply chains. Simultaneously, strengthen talent cultivation in the industry; universities and enterprises should cooperate to offer majors and training courses related to supply chain innovation and green carbon emission reduction, cultivating compound talents with knowledge of both supply chain management and carbon emission reduction, providing talent support for the green development of industrial supply chains.

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