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Research on the Relationship Between Carbon Emission Trading and Corporate Green Innovation

Yanxi Yang

School of Finance, Capital University of Economics and Business, Beijing, China
2022332008@email.cufe.edu.cn

Abstract: Against the backdrop of accelerated global climate governance and the deepening of the "dual carbon" goals, the carbon emissions trading system (ETS) has become a core policy tool for coordinating the contradiction between economic growth and carbon emission reduction. However, there is no systematic consensus on the driving path of ETS on corporate green innovation and its heterogeneous impact. Especially under the dual challenges of the institutional environment of emerging economies and the reconstruction of the global value chain, theoretical deepening and policy innovation are urgently needed. This paper uses a mixed research method to systematically explore the mechanism and boundary conditions of ETS on corporate green innovation, covering the development process of carbon emissions trading policies and the trend of corporate green technology innovation. It deeply analyzes the impact, mechanism, and heterogeneous impact of carbon emissions trading on corporate green innovation, aiming to optimize the operating mechanism of the carbon emissions trading market, thereby promoting the green transformation and sustainable development of enterprises, and providing a policy framework that is both efficient and fair for the construction of carbon markets in emerging economies. At the same time, it fills the gap in the existing literature on the dynamic interaction mechanism of "institution-market-enterprise".

Keywords: Corporate green technology innovation, carbon emissions trading system, corporate carbon emission reduction.

1. Introduction

In recent years, with the acceleration of economic globalization, ecological damage and resource depletion have become major transnational challenges. The United Nations Intergovernmental Panel on Climate Change (IPCC) pointed out that if the global temperature rise exceeds 1.5°C, the risk of extreme weather, sea level rise and ecosystem collapse will increase sharply (IPCC, 2021). Against this backdrop, the Emission Trading Scheme (ETS) has become the world's mainstream carbon pricing tool. As of 2023, 28 carbon trading markets have been established around the world, covering 17% of greenhouse gas emissions [1]. Among them, the EU ETS, as the world's first cross-border carbon market, covers 45% of carbon emissions from the power, industrial and aviation industries; since the launch of China's national carbon market in 2021, the annual trading volume has exceeded 200 million tons of CO2, making it the largest emerging carbon market. These practices show that ETS can effectively coordinate the contradiction between economic development and carbon emission reduction through market mechanisms. As the main body of carbon emissions, the green

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innovation behavior of enterprises is the key breakthrough in achieving low-carbon transformation. Green innovation covers green technology innovation (such as renewable energy technology, carbon capture and storage technology) and green management innovation (such as carbon emission accounting system, and green supply chain management), which can not only directly reduce the carbon emission intensity of enterprises, but also promote the low-carbon transformation of the entire industry through technology spillover and market competition [2].

Clarifying the incentive path and boundary conditions of carbon emission trading on corporate green innovation can provide a scientific basis for optimizing carbon market design and promoting policy coordination. According to existing literature, the price signal mechanism [3], policy expectation mechanism [4], and market competition mechanism [5] have been confirmed to be the key paths for carbon emission trading to affect corporate green innovation. However, there is controversy in academia over the effectiveness of some mechanisms. For example, regarding the effectiveness of the policy expectation mechanism, some scholars have found that carbon price fluctuations will weaken the certainty of corporate innovation investment. In addition, the passive position of enterprises in developing countries in the global value chain may weaken the transmission efficiency of the carbon market on their green innovation. These disputes show that the mechanism of carbon emission trading is constrained by multiple factors such as institutional environment, market structure, and corporate characteristics, and systematic research is urgently needed to clarify its boundary conditions. In the context of global value chain reconstruction, whether the incentive path of carbon emission trading for green innovation of enterprises in developing countries has evolved and how to design policies to balance emission reduction costs and innovation incentives are important directions for the future.

This paper aims to use quantitative analysis and case study methods to focus on the differences in the effectiveness of the three major mechanisms of carbon emission trading under different institutional environments. The research conclusions can provide a theoretical basis for the differentiated design of carbon markets in emerging economies, and make up for the lack of research on the dynamic interaction mechanism of "market-institution-enterprise" in existing literature while providing empirical support for policy optimization that balances emission reduction costs and innovation incentives.

2. Carbon emissions trading and corporate green innovation

2.1. The development process of carbon emissions trading policy

The carbon emission trading policy aims to control greenhouse gas emissions through market mechanisms and promote the green transformation of enterprises. In 1997, the Kyoto Protocol proposed to solve the problem of greenhouse gas emission reduction through market mechanisms, which gave birth to the carbon emission trading mechanism. In 2002, the London Stock Exchange in the UK took the lead in carbon emission trading. The outbreak of the financial crisis in 2008 prompted the EU to adjust the quota allocation method, gradually shifting from free allocation to an auction system. The EU officially launched the carbon emission trading system. Since then, the United States, Japan, New Zealand and South Korea have also established their carbon emission trading markets.

To prepare for carbon emission trading policies at the end of the 11th Five-Year Plan. In 2011, the National Development and Reform Commission issued the "Notice on Carrying out Pilot Work on Carbon Emission Trading", approving seven provinces and cities, including Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong and Shenzhen, to carry out pilot work, opening up the practical exploration of carbon emission trading in China. The differentiated exploration of the pilot areas has provided important experience for the construction of a unified national market, especially the quota auction mechanism in Guangdong and the CCER trading innovation in Hubei. The pilot

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areas have actively improved relevant systems, covering carbon quota allocation methods, initial carbon prices, pricing mechanisms, reward and punishment mechanisms, cross-regional trading mechanisms, etc., and launched financial products such as carbon mortgages, carbon funds, and carbon bonds to enhance the liquidity of carbon quotas. In July 2021, the national carbon emission trading market officially started trading, with a turnover of more than 200 million yuan on the first day. In the initial stage, it only covers the power industry, and will gradually radiate to multiple industries such as electrolytic aluminum, cement, steel, petrochemicals, chemicals, papermaking, aviation, etc. in the future. It is expected to become the world's largest carbon emission trading market, marking that China's carbon emission trading policy has entered a new stage of development.

2.2. Development trends of enterprise green technology innovation

Green technology innovation refers to technological innovation aimed at minimizing the total cost of a product's life cycle. It is the entire process from the formation of green technology ideas to its introduction to the market, covering a wide range of technologies such as pollution control, source reduction, and waste minimization. Since sustainable development and environmental issues have a certain degree of public nature, and their impact is universal, scholars from different disciplinary backgrounds conduct green innovation research based on different perspectives [6].

2.2.1. Macroeconomic policy environment: synergistic drive between international rules and domestic goals

The deepening of the global climate governance framework and the iteration of low-carbon policies in various countries have provided rigid constraints and strategic guidance for green technology innovation. The EU Carbon Border Adjustment Mechanism (CBAM) will be put into trial operation in 2023, requiring imported goods to calculate implicit carbon emissions and pay corresponding fees, forcing export-oriented enterprises to accelerate low-carbon technology upgrades; China's "dual carbon" goal requires that non-fossil energy consumption account for 25% in 2030, and covers high-energy-consuming industries such as electricity and steel through the national carbon emission rights trading market, forming a "policy pressure-market incentive" dual-wheel drive model. Such policies not only reshape industry technical standards but also guide the reconstruction of the global industrial chain through tools such as carbon tariffs and green finance.

2.2.2. Meso-industry trends: integration of digital empowerment and low-carbon technologies

Green technology innovation presents "Efficiency improvement + model reconstruction" With dual-track features, industrial enterprises are optimizing production processes through digital twin technology to achieve real-time monitoring of carbon emissions and improve energy efficiency. For example, Baosteel has reduced carbon emissions per ton of steel by 12% through a digital twin system. Renewable energy, carbon capture and storage (CCUS), hydrogen energy, and other technologies are developing in parallel. The number of CCUS projects worldwide will increase to 135 in 2023, with an annual storage capacity of more than 400 million tons of CO_2.

2.2.3. Micro-enterprise behavior: differentiation strategy and dynamic capability building

Leading enterprises integrate technology research and development with ecological management through "green dynamic capabilities " and take the lead in formulating industry standards [7]. For example, CATL launched "zero-carbon battery" technology and built a full-chain carbon management system from lithium mining to battery recycling ; Haier relied on the industrial Internet

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platform to achieve transparency of the carbon footprint of the supply chain and form a green brand premium.

Limited by funding and technological barriers, small and medium-sized enterprises rely more on government subsidies and carbon market revenue to drive short-term innovation. Among China's carbon market pilot enterprises in 2022, the proportion of green patents of small and medium-sized enterprises increased by 15%, but they were concentrated in end-of-pipe treatment technologies, with few original breakthroughs.

Have embedded low-carbon technologies into the global value chain through the strategy of “institutional entrepreneurship” [8]. For example, Apple requires its suppliers to achieve 100% clean energy production by 2030, which has led to a 40% increase in photovoltaic installed capacity among Chinese supply chain companies.

2.3. How does carbon emissions trading affect corporate green innovation

2.3.1. Impact of carbon emissions trading on corporate green innovation

Most studies have shown that carbon emissions trading can significantly promote green innovation in enterprises. The "Porter hypothesis" states that reasonable environmental regulations can encourage enterprises to carry out green innovation and achieve a win-win situation for the economy and the environment. Under the carbon emissions trading policy, enterprises will actively invest resources in green innovation to reduce costs and gain profits, such as developing more efficient emission reduction technologies and optimizing production processes. This not only contributes to the sustainable development of the enterprise itself but also promotes the green upgrade of the entire industry.

A few studies, such as Chen et al., believe that the carbon emission trading pilot policy may be detrimental to corporate green innovation and reduce the proportion of green patents [9]. The reason may be that carbon prices crowd out R&D investment, causing companies to choose to reduce production rather than conduct green technology innovation to meet emission reduction requirements. However, from the overall research, this inhibitory effect is not a mainstream view and may be affected by specific research samples and environmental factors.

This paper believes that the positive impact of carbon emission trading policy on corporate green innovation is the main one, but some issues still need to be paid attention to during the implementation process. The government should further optimize the policy design, such as improving the carbon quota allocation mechanism, establishing a carbon price range regulation mechanism, and starting the quota repurchase when the carbon price is lower than the innovation incentive threshold, to improve the scientificity and fairness of the allocation and give full play to the incentive effect of the policy on green innovation of various enterprises. At the enterprise level, strengthen the guidance and support for enterprises, provide technical and financial assistance, reduce the cost and risk of green innovation of enterprises, and key energy-consuming enterprises should establish a carbon asset management system and incorporate carbon costs into innovation decisions, to better promote corporate green innovation and achieve the "dual carbon" goal and sustainable economic development. At the market level, develop carbon financial derivatives to help enterprises hedge innovation risks.

2.3.2. The mechanism of carbon emissions trading on the green innovation path of enterprises

Carbon emissions trading forms a dynamic cycle of "external pressure-internal motivation-market feedback" through the synergy of price signals, policy expectations, and market competition, driving corporate green innovation.

First, the price signal mechanism directly transmits external cost pressure through carbon price fluctuations. Wei Lili et al. pointed out that carbon price is the cost of carbon emissions for enterprises

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and the benefit of carbon emission reduction. Its level directly affects the green innovation decisions of enterprises [10]. When carbon price rises, the cost of enterprises to purchase carbon quotas increases significantly. After carbon emission reduction is achieved through green innovation, the profit from selling remaining carbon quotas will also increase accordingly. This change in price signal makes enterprises more inclined to choose green innovation in the process of weighing costs and benefits. Zhu Yanli et al. further elaborated that to maximize profits, enterprises will compare the cost of green innovation input with the cost of purchasing carbon quotas. A reasonable carbon emission rights trading mechanism can ensure that the "innovation compensation" brought by green innovation is greater than its cost, thereby encouraging enterprises to actively carry out green innovation activities [11]. However, a single price signal is easily affected by market fluctuations. For example, the EU carbon price plummeted by 40% in 2022 due to the energy crisis, causing steel companies to suspend carbon capture projects. Therefore, the effectiveness of price signals is highly dependent on the supplement of policy expectation mechanisms.

Policy expectations are transformed into the internal driving force of corporate strategic adjustment through mandatory constraints and positive incentives. The mandatory requirements of the policy on corporate carbon emissions and the corresponding penalty measures have strengthened the willingness of enterprises to reduce carbon emissions through green technology innovation to balance emission reduction and economic goals. If an enterprise fails to fulfill its contractual obligations, it will face penalties such as cancellation of energy-saving advanced evaluation and inclusion in credit files. This forces enterprises to carry out green technology innovation to meet policy requirements and reduce operating costs and potential risks. Wang Dandan et al.'s research detailed the role of this forced mechanism in promoting corporate green technology innovation [12]. In addition, Mei Linhai et al. found that the carbon emission rights trading system can promote corporate green innovation by increasing the amount of government subsidies and the number of news reports received by enterprises [13]. Government support provides enterprises with funds and resources, reducing the financial pressure of innovation; media attention prompts enterprises to pay more attention to environmental protection issues, increase environmental protection investment, and improve green innovation performance.

Finally, the market competition mechanism forms an innovation-closed loop through revenue feedback and competitive pressure. Under the constraints of the carbon emission trading policy, enterprises will actively carry out green technology innovation to obtain more economic benefits and enhance market competitiveness. Li Chuang et al. pointed out that enterprises can obtain economic benefits by reducing carbon emissions and having more carbon quotas for market transactions based on ensuring that they do not exceed emissions, or they can obtain additional benefits by carrying out green projects to obtain national certified voluntary emission reductions for carbon neutrality or market transactions, and all of these are inseparable from the support of green technology [14]. Mei Linhai et al. believe that fierce market competition has led enterprises to compete to carry out green technology innovation to be the first to complete the green and low-carbon transformation and become the leader in the industry, and even trigger innovation competition [13]. In this competitive atmosphere, enterprises continue to increase their investment in innovation and promote the advancement and application of green technology.

2.3.3. Heterogeneous impact of carbon emissions trading on corporate green innovation

First, the scale of enterprises. The study found that the carbon emission trading policy has a stronger incentive effect on the exploratory green innovation of large-scale enterprises. However, due to the relatively high cost of technological innovation and the relatively weak resource acquisition and risk tolerance of small-scale enterprises, the feedback of green innovation is not significant. Policies for small and medium-sized enterprises need to reduce their innovation risks and provide financial

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support. Possible measures include setting up special funds or subsidies to help small and medium-sized enterprises conduct green technology research and development.

Second, the nature of enterprise property rights. State-owned enterprises usually have advantages in terms of resource acquisition and policy support, are more responsive to policies, and are relatively cautious in their decision-making process; non-state-owned enterprises are more flexible in decision-making and have a stronger ability to adapt to market changes. However, from the existing literature, research based on the different nature of enterprise property rights has not yet formed a consensus. For example, Zhu Yanli et al. found that the carbon emission trading policy has a stronger incentive effect on exploratory green innovation in non-state-owned enterprises [11]. Wang Dandan et al.'s research shows that the carbon emission trading system has a more significant driving effect on green technology innovation in state-owned emission-controlled enterprises [12]. For state-owned enterprises, the assessment mechanism can be strengthened and green innovation can be included in the performance evaluation of management; for non-state-owned enterprises, market incentives such as credit concessions or tax exemptions can be used to encourage them to carry out green innovation.

Third, industry differences. Different industries have differences in carbon emission characteristics, technological foundations, and market demand, which leads to different impacts of carbon emission trading policies. Scholars hold different views on this. Lan Guanxiufeng et al. found that the carbon emission trading system has different effects on the green technology innovation of heavy polluting enterprises and non-heavy polluting enterprises, and is more conducive to the green technology innovation of heavy polluting enterprises, because heavy polluting enterprises are more affected by environmental regulation policies, and the pressure of emission costs forces them to increase their R&D investment [15]. Li Chuang et al. found that the carbon emission trading policy has a positive effect on the green technology innovation of environmental protection industries and upstream enterprises, but a negative effect on the green technology innovation of non-environmental protection enterprises and downstream enterprises [14]. Formulating carbon quota innovation incentive coefficients for different industries and adjusting policy intensity according to industry characteristics may be an effective method.

Fourth, regional differences. Xiao Longjie et al.’s research shows that the carbon emission trading policy has a better effect on promoting green innovation of enterprises in the eastern region than in the central and western regions, because the eastern region has a high level of economic development, a more complete regulatory system and a more market-oriented level, and can better mobilize resources to transfer to green innovation [16]. The eastern region has a high degree of marketization and can gradually increase the quota auction ratio and strengthen market constraints; the central and western regions need more technical support and economic compensation to promote the transfer and application of green technologies. Establish special funds or technology transfer platforms to help the central and western regions introduce and promote green technologies.

3. Conclusion

This paper systematically combs the development context of carbon emission trading policy and the evolution trend of corporate green technology innovation, revealing the multi-level impact of carbon emission trading on corporate green innovation and its dynamic mechanism. The study found that: First, carbon emission trading policy forms a synergistic driving link of "external pressure -internal motivation feedback " through three mechanisms: price signals, policy expectations, and market competition, significantly improving the efficiency of corporate green innovation. Second, there is significant heterogeneity in the impact of carbon emission trading. Large-scale enterprises are more likely to achieve exploratory innovation due to their outstanding resource integration capabilities, while small and medium-sized enterprises need to rely on policy compensation due to financial and technological barriers; heavily polluting industries have stronger innovation responses under the

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pressure of emission costs, but environmental protection industries need to be wary of technology lock-in risks; the eastern region has become an innovation highland with its market-oriented advantages, while the central and western regions are in urgent need of technology transfer and institutional coordination. The study of carbon emission trading and corporate green innovation occupies an important position in the global response to climate change and the pursuit of sustainable development. Existing research has presented the development context of carbon emission trading policy, revealed its incentive mechanism and heterogeneous impact on corporate green innovation, and laid a solid foundation for subsequent exploration.

However, as the global economic structure undergoes profound adjustments and the global value chain undergoes accelerated reconstruction, enterprises in developing countries are facing new opportunities and challenges. This study also has certain limitations: first, the case study focuses on the manufacturing industry, and the universality of green innovation in the service industry remains to be verified; second, the policy simulation does not fully consider the impact of international carbon tariffs (such as the EU CBAM) on the global industrial chain. Future research can be further expanded to multi-industry comparisons, and indicators such as global value chain embeddedness can be introduced to quantify the transmission path of external policy shocks on corporate innovation. In addition, how to balance emission reduction costs and innovation incentives in policy design, and how to ensure corporate competitiveness while promoting corporate green innovation, is also a direction that future policymakers and researchers need to focus on.

In summary, carbon emissions trading is not only a tool for emission reduction but also a core engine driving the green technology revolution. Through mechanism optimization and policy coordination, it can be transformed into an "innovation accelerator" for corporate low-carbon transformation, providing an efficient and fair path for global climate governance and sustainable development goals.

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