Core Mechanism of Carbon Finance: The Emissions Trading Scheme (ETS)

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Abstract. Against the strategic backdrop of China's "dual carbon" goals, carbon finance functions as a pivotal instrument for advancing low-carbon transformation. The development of its market-based mechanisms bears critical significance for China's attainment of climate governance targets. This paper systematically reviews the current state of China's carbon finance market, with a focus on analyzing its challenges and opportunities, and proposes pathways to deepen its development. Research indicates that China's carbon finance has initially established an initial framework characterized by the coexistence of policy guidance and market exploration. The national Emissions Trading Scheme (ETS) has become the world's largest carbon market, yet core bottlenecks persist, including inadequate policy and regulatory frameworks, insufficient market liquidity, lagging innovation in carbon financial products, and a shortage of specialised talent. Concurrently, the capital demands generated by the dual carbon goals, the impetus for green transition, technological empowerment, and international cooperation endow the market with substantial development potential. To address these challenges, this paper proposes breakthrough pathways encompassing optimising market mechanisms (e.g., expanding sector coverage and introducing derivatives trading), promoting product and service innovation, strengthening risk management, and deepening international cooperation. The study concludes that multidimensional reforms can significantly enhance the efficiency and resilience of the carbon finance market, thus establishing it as a core financial instrument underpinning China's low-carbon economic transition.

Keywords: carbon finance, carbon emissions trading market, dual carbon goals, green transition, risk management

1 Introduction

Climate change has emerged as an undeniable global challenge, placing the world at a decisive juncture where tackling this issue entails formidable complexities. Against this backdrop, carbon finance has thus emerged. It denotes specialised financial activities that leverage market-based mechanisms and financial instruments to facilitate greenhouse gas emission reductions and the flow of climate finance, thereby supporting

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low-carbon economic development [1]. Among these, the carbon emissions trading market adopts a "cap-and-trade" mechanism for pricing carbon emission rights, serving as a core policy tool for achieving emission reduction targets in the most cost-efficient way.

For China, vigorously developing carbon finance bears considerable theoretical and practical significance. From an academic standpoint, this paper systematically traces the evolution of China's carbon finance market and examines the challenges facing the national unified carbon emissions trading market. This contributes to enriching the literature in green finance and environmental economics, offering up-to-date references for relevant academic research grounded in Chinese practice. From a practical perspective, studying carbon finance facilitates the channelling of capital towards green and low-carbon sectors, equipping enterprises with incentives for emissions reduction and financing avenues. This serves to lower transition costs and manage climate risks, ultimately serving the nation's major strategic objectives of achieving carbon peak and carbon neutrality.

The primary objectives of this study are: to delineate the fundamental concepts and theoretical frameworks of carbon finance and carbon emissions trading markets through synthesizing domestic and international literature; to comprehensively assess the development status of China's carbon finance, particularly the national carbon emissions trading market; and to conduct an in-depth examination of the principal challenges confronting China's carbon finance development at various levels. It further proposes targeted pathways and policy recommendations to promote the in-depth development of China's carbon finance market, offering reference for decision-makers, market participants, and researchers [2].

2 Overview and Development Status Analysis of China's Carbon Finance

2.1 Definition, Content, and Theory

Carbon finance constitutes a set of financial activities with carbon emission rights as its underlying asset, encompassing quota trading, green investment and financing, and derivative services [3].

The concept of carbon finance encompasses four core elements: carbon emissions trading, carbon financial derivatives, carbon financing services, and carbon asset management. Its theoretical foundations are anchored in four economic and environmental theories, along with their core tenets: environmental property rights theory, environmental externalities theory, cap-and-trade theory, and financial deepening theory.

2.2 Current Development Status

Regarding the policy support framework, China's carbon finance development has formed a multi-level policy framework. At the national strategic level, since the 2020

"dual carbon" goals were proposed, carbon finance has been incorporated into the "key tasks for green finance development." The 14th Five-Year Plan Outline explicitly mandates "improving the national carbon emissions trading market and developing carbon futures," while the General Office of the State Council further put forward "expanding the pilot scope of carbon financial products" [4]. At the departmental regulation level, the Ministry of Ecology and Environment has defined the coverage scope, quota allocation, and trading rules for the national carbon market [5]. The People's Bank of China and the China Banking and Insurance Regulatory Commission have included "carbon emission reduction projects" within the scope of green bond support [6]. At the local implementation level, early carbon pilot regions including Beijing, Shanghai, and Guangdong have successively issued policies to explore products like carbon pledges and carbon funds, providing crucial experience for the development of the national carbon market [7].

Regarding market development, China's carbon market has evolved from regional pilots (2013–2020) to a unified national market. The national carbon market commenced in July 2021, initially covering 2,162 power generation enterprises, which account for 45% of China's total carbon emissions, establishing itself as the world's largest carbon market. By the end of 2023, cumulative trading volume had reached 230 million tonnes of CO_2, with the transaction value exceeding RMB 10 billion, and the carbon price remaining stable at RMB 60-70 per tonne.

Market participants fall into four categories: regulated emitters form the market's core trading entities; financial institutions offer carbon credit and market-making services, though their engagement remains below EU levels; third-party organisations provide emissions verification and asset management services; individual investors participate only in select pilot regions, accounting for less than 1% of the market and making a negligible contribution to market liquidity.

3 Challenges Facing China's Carbon Finance Development

3.1 Inadequate Policy, Regulatory, and Oversight Systems

China's carbon finance sector remains plagued by notable inadequacies in its policy framework and regulatory system. On one hand, the legislative rank remains inadequately established: the current Interim Regulations carry lower legal authority than the Securities Law, resulting in lenient penalties for breaches of regulations and related violations. On the other hand, regulatory fragmentation endures, coupled with inadequate cross-departmental coordination: there is an overlap in regulatory responsibilities among the Ministry of Ecology and Environment, the People's Bank of China, and the China Securities Regulatory Commission, while rules governing derivative trading remain unstandardized.

3.2 Incomplete Market Mechanisms

Challenges stemming from financial institutions and market participants, in conjunction with underdeveloped market mechanisms, represent the core bottlenecks con-

straining China's carbon finance development. These are primarily manifested in inadequate market liquidity and a lack of participant diversity. Regarding liquidity, the national ETS predominantly operates through spot trading, lacking derivative instruments such as carbon futures, which impedes the formation of consistent price signals. Concurrently, the quota allocation mechanism remains relatively liberal, leading to excess quotas for certain enterprises and diminished trading incentives [8-9]. Regarding participants, financial institutions demonstrate inadequate involvement: while commercial banks offer basic carbon financial services, these account for less than 5% of total green credit portfolios; securities firms and fund companies have minimal participation in the design and trading of carbon derivatives, and lack professional carbon asset management capacities; and individual investors remain sidelined due to elevated entry barriers (e.g., capital requirements, expertise limitations) [10,11].

3.3 Insufficient Innovation in Carbon Financial Products and Services, Weak Risk Management Capabilities

Insufficient innovation in carbon finance products and services, coupled with weak risk management capabilities, restricts the effective functioning of the market. At the product level, the current market is centred on the spot trading of carbon allowances, with a dearth of derivative instruments and structured financial products. At the service level, financial institutions lack customised solutions: while low-carbon transition needs vary significantly across energy-intensive industries (such as steel and cement), existing services predominantly composed of standardised financial products that fail to meet enterprises' specific needs for financing technological upgrades or carbon asset custody services [12]. Regarding risk management, both enterprises and financial institutions exhibit inadequate capacities in identifying and mitigating carbon-related risks: most enterprises have not developed models to assess the risks of carbon price volatility, while financial institutions lack effective tools for pricing carbon asset-related risks. Concurrently, insufficient disclosure of carbon market-related data (e.g., some enterprises' carbon emissions verification rates fall below 80%) heightens the difficulty of risk evaluation, thereby further undermining incentives for innovation [13,14].

3.4 Shortage of Specialised Talent: Mismatch Between Supply and Demand, Incomplete Training System

The shortage of specialised talent has become a critical bottleneck constraining China's carbon finance development, manifesting as a dual problem of "supply-demand mismatch and training lag". From a supply-demand perspective, the expansion of carbon markets and product innovation has driven a sharp increase in market demand for interdisciplinary professionals. Regarding the training system, university talent supply falls behind market needs: only around 20 institutions nationwide offer "carbon finance"-related courses (e.g., Renmin University of China's "Carbon Markets and Carbon Finance"), with low-carbon-related content accounting for less than 20% of curricula in environmental economics and finance. Corporate internal training systems

remain inadequate, with most programmes focusing solely on policy interpretation while neglecting the development of practical skills [15].

4 Opportunities and Potential for China's Carbon Finance Development

4.1 Strategic Opportunities Presented by the Dual Carbon Goals

The formulation of the "carbon peak and carbon neutrality" strategic objectives presents a fundamental policy-driven opportunity for carbon finance development. On the one hand, these dual carbon targets clarify the national strategic direction for low-carbon transition, driving the continuous refinement of the carbon finance policy framework: the central bank has incorporated carbon finance operations into its green finance evaluation system (with a 10% weighting), while local governments have introduced special incentive policies (e.g., Shenzhen offers subsidies of up to 20% for carbon finance products), thereby providing stable policy expectations for market participants [13]. On the other hand, these objectives generate substantial capital demand. Estimates suggest that by 2030, the national ETS transaction volume will exceed RMB 1 trillion, with the carbon derivatives market potentially reaching RMB 500 billion [16,17].

4.2 Demand for Green Transition and Sustainable Development

The demand for green socio-economic transition and sustainable development provides sustained market-driven momentum for carbon finance. From an enterprise perspective, high-energy-consuming businesses face dual impetuses of "emission reduction pressure and transformation needs": as environmental standards tighten, companies must increase investment in emission cuts, with carbon financial instruments (such as carbon allowance pledging and carbon funds) becoming critical financing channels for emission reduction initiatives. Concurrently, enterprises are integrating carbon management into strategic planning—for instance, Baowu Group established a dedicated carbon asset management company, further boosting demand for carbon financial services [18]. From the investor perspective, the growing popularity of ESG investment concepts is directing capital towards low-carbon sectors: China's ESG fund assets reached RMB 1.2 trillion in 2023, with "carbon-themed" funds growing by 50% year-on-year. Rising investor preference for low-carbon assets is spurring financial institutions to develop ESG products with carbon-related features (e.g., ESG-linked bonds, carbon footprint funds) [19].

4.3 Technological Empowerment of Carbon Finance by Emerging Technologies

Emerging technologies such as big data, blockchain, and artificial intelligence provide critical technical support for enhancing operational efficiency and fostering innovation

in carbon financial markets. In carbon monitoring and accounting: Satellite remote sensing and big data technologies facilitate real-time monitoring of corporate carbon emissions. For instance, the Ministry of Ecology and Environment's "carbon monitoring satellite" can precisely calculate corporate emissions with an error rate below 5%, mitigating risks of data falsification and laying a reliable foundation for quota allocation and carbon pricing. Blockchain technology is applied to carbon allowance rights confirmation and transaction record storage. Ant Group's "Ant Chain Carbon Account" enables full traceability throughout the carbon trading process, lowering transaction costs by 30%. In product and risk management, AI technology powers the intelligent development of carbon finance: Baidu's "Carbon Price Prediction Model" achieves 85% accuracy, assisting enterprises in optimising carbon asset allocation; AI risk assessment tools monitor carbon price volatility and policy change risks in real time, enhancing the efficiency of risk response [20].

4.4 Expansion of International Cooperation and Exchange

Against the backdrop of the global low-carbon transition, the expansion of international cooperation and exchange presents external development opportunities for China's carbon finance sector. On the one hand, the trend towards international carbon market linkage is intensifying: cooperation between China and the EU in areas such as carbon market mechanism design and quota mutual recognition is deepening (e.g., the China-EU Carbon Market Capacity Building Project). The implementation of the EU's Carbon Border Adjustment Mechanism (CBAM) is promoting alignment between China's carbon market and international standards (e.g., harmonisation of carbon accounting methodologies), which in turn enhances the international recognition of China's carbon allowances [21]; on the other hand, international capital and technical support keep flowing into the carbon finance sector: the Green Climate Fund (GCF) has provided over US$1 billion in funding for China's low-carbon projects, while international financial institutions (such as the World Bank) share expertise in designing carbon finance products (e.g., risk control mechanisms for carbon futures), offering valuable technical references for the Chinese carbon finance market. Furthermore, international talent exchange mechanisms are gradually being established: initiatives like the "China-EU Joint Training Programme for Carbon Finance Professionals" cultivate over 500 specialists annually, alleviating the domestic shortage of specialised carbon finance talent [21].

5 Breakthrough Pathways and Policy Recommendations for China's Carbon Finance Development

5.1 Optimising Carbon Finance Market Development and Mechanism Reform

Optimising market development and deepening mechanism reforms requires focusing on three key directions: "expansion – diversification – derivatives". Firstly, expand market coverage and refine quota allocation: beyond the existing power generation

sector, incorporate steel, cement, and chemical industries into the national ETS by 2025; adopt the "baseline method" to replace historical methods for quota allocation, providing additional quotas as incentives for enterprises that achieve excess emission reductions to alleviate supply-demand imbalances [11]. Second, diversify the market participant structure: relax market access for financial institutions, allowing securities firms and fund companies to participate in carbon derivatives trading and asset management business; support insurers in developing specialized carbon insurance products (e.g., carbon price volatility insurance); introduce retail investors in an orderly fashion by lowering entry thresholds (e.g., launching small-scale carbon trading accounts) and enhancing investor suitability management [6,8]. Third, accelerate the development of the carbon derivatives market: introduce carbon futures contracts (e.g., futures based on national carbon allowances) by 2024, and progressively explore carbon options and carbon swap products; establish a derivatives clearing mechanism with the China Financial Futures Exchange undertaking clearing functions to mitigate counterparty risk. The launch of carbon futures could elevate the carbon market's turnover rate to 5%, significantly enhancing liquidity [11].

5.2 Promoting Innovation in Carbon Financial Products and Services

To drive product and service innovation, it is necessary to move beyond the "spot-dominated" product structure and develop diversified, customised solutions. Regarding product innovation: Firstly, develop structured carbon financial products: design composite financial products such as "carbon allowances + bonds" (e.g., carbon allowance-backed credit enhancement bonds) and "carbon funds + ESG" (e.g., private equity funds for low-carbon projects) to meet the needs of investors with different risk appetites; Secondly, enrich product offerings in the voluntary carbon market: develop forest carbon sink funds and blue carbon derivatives (e.g., marine carbon sinks) to fill product gaps outside the mandatory carbon market. Regarding service innovation, financial institutions should provide tailored services: for steel enterprises, design combined services such as "emission reduction technology upgrade loans + carbon allowance pledging"; For new energy enterprises, provide carbon asset custody and value-added services (e.g., quota arbitrage); improving a "carbon financial services platform" to integrate financing, advisory, and risk management services, enhancing service efficiency [12]. Furthermore, promote synergy between carbon finance and green credit/insurance: incorporate carbon quota pledges into green credit guarantees and develop "carbon reduction insurance" to form a diversified green financial system.

5.3 Enhancing Risk Management Capabilities and Disclosure

Strengthening risk management capabilities and improving information disclosure are core measures for mitigating risks in the carbon finance market. Firstly, construct a carbon risk measurement and hedging system: guide enterprises and financial institutions to refer to international experience (such as the EU's carbon risk assessment framework) to develop risk measurement models targeting carbon price volatility and policy adjustments; develop carbon risk hedging instruments (such as carbon options

and carbon swaps) to help market participants lock in emission reduction costs [14]. Secondly, refine the information disclosure regime: formulate the Carbon Market Information Disclosure Guidelines, clarifying disclosure entities (regulated emitters, financial institutions), content (carbon emission data, carbon asset scale, risk exposure), and frequency (quarterly disclosure for enterprises, annual disclosure for financial institutions); introduce third-party verification bodies (e.g., SGS, Bureau Veritas) to validate disclosed data, imposing penalties (e.g., fines, quota deductions) on enterprises found to have falsified information [20]. Finally, establish a risk early-warning mechanism: regulatory authorities should conduct real-time monitoring of carbon market transactions (e.g., abnormal price fluctuations, large-value trades), set risk thresholds (e.g., triggering alerts when daily carbon price volatility exceeds 10%), promptly address irregular trading activities, and prevent systemic risks [14].

5.4 Deepening International Cooperation and Technological Empowerment

Deepening international cooperation and strengthening technological empowerment are pivotal to enhancing China's international competitiveness in carbon finance. Regarding international cooperation: firstly, advance carbon market integration by launching pilot projects for carbon allowance mutual recognition with the EU (e.g., cross-border trading of China-EU carbon allowances), participating in global carbon pricing rule-making (e.g., the G20 Carbon Markets Working Group) to elevate international influence, and optimising China's allowance allocation and derivatives design by drawing on the EU ETS experience [21]. Secondly, attract international capital and technological resources: scale up investments from the Green Climate Fund and the International Finance Corporation (IFC) into China's carbon finance projects; introduce technical expertise and experience from international carbon asset management institutions (such as the London Carbon Exchange); establish an "International Carbon Finance Cooperation Platform" to facilitate in-depth technical exchanges and precise project matching [21]. Regarding technological empowerment, strengthen policy support for the application of emerging technologies: establish a "Special Fund for Carbon Fintech" to support the application of big data, blockchain, and AI in carbon monitoring, trading, and risk management; foster the development of "carbon fintech enterprises" by supporting the creation of carbon accounting software and intelligent trading systems [20]. Furthermore, promote in-depth international talent exchange: collaborate with overseas institutions (e.g., the London School of Economics and Political Science) on joint training programmes for carbon finance professionals, and recruit senior international carbon asset managers to elevate the overall professional competence of the industry [21].

6 Conclusions and Outlook (Research Findings, Limitations, Future Directions)

This paper systematically analyses the development status, challenges, opportunities, and breakthrough paths for China's carbon finance sector, focusing on the core ETS

mechanism. Key findings include: Firstly, China's carbon finance has preliminarily formed a "policy guidance-market exploration" structure. The nationwide launch of the ETS signals a new phase for the market, though disjointed policies, inadequate market liquidity, lagging product innovation, and talent shortages remain primary challenges; Second, the dual carbon goals, green transition demands, emerging technology enablement, and expanded international cooperation present significant market opportunities, with the national carbon finance market projected to exceed RMB 1.5 trillion by 2030. Third, addressing current bottlenecks through refined policies and regulations, optimised market mechanisms, product innovation, enhanced risk management capabilities, and deepened international cooperation can effectively propel carbon finance into a core instrument supporting low-carbon transformation.

This study has two limitations: firstly, the literature selection focused on English-language sources, resulting in insufficient depth of analysis for domestic policy documents (such as local carbon market pilot schemes) and corporate practice cases, making it unable to fully reflect the unique attributes of the domestic market; secondly, it did not conduct differentiated research into the varying needs of different industries (such as power generation and steel) for participating in carbon finance, leaving room for improvement in the applicability of conclusions across sectors; Thirdly, there is a lack of quantitative analysis, such as the absence of models for assessing policy impacts on carbon market liquidity, necessitating stronger empirical support for research conclusions.

Future research may expand in three directions: firstly, strengthen domestic case studies by conducting in-depth surveys of representative enterprises (such as China Energy Group and Baowu Group) to summarise corporate carbon finance practices; secondly, conduct sector-specific research to analyse the unique carbon finance needs of different industries and propose tailored solutions; thirdly, strengthen quantitative research by developing policy impact evaluation models to quantify the impacts of market expansion and product innovation on emission reduction costs, thereby providing more precise empirical support for policy formulation. As the dual-carbon strategy advances, China's carbon finance market will gradually mature, and its role in global climate governance will grow increasingly prominent. This progression is expected to provide a "Chinese solution" for the advancement of global carbon finance.

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