# The Digital Transformation of China's Carbon Finance Market

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**Abstract.** As the world races toward carbon neutrality and the Kyoto Protocol keeps guiding national pledges, carbon finance has moved to the centre of the climate arena, praised for its promise to curb emissions while steering capital toward greener growth. In parallel, waves of fintech breakthroughs keep rewriting the rules of traditional finance and trading, opening fresh doors for carbon markets and raising puzzles that regulators and participants still need to solve. This paper focuses on China's carbon finance market, systematically sorts out the theoretical basis, technology application, policy mechanism and practical path of digital integration of carbon finance, and focuses on the contribution of key technologies such as blockchain, big data, and artificial intelligence to improving the transparency and efficiency of the carbon market. It is found that there are four mechanisms for the digital transformation of the carbon finance market: first, digitalization realizes the upgrading and reshaping of the MRV system; second, digitalization to build an efficient and credible market environment; third, digitalization promotes the innovation and application of financial instruments; Fourth, digitalization is driving "RegTech" to a new stage. However, although digital technology has significantly promoted the system efficiency of carbon finance, there are still problems such as technical security risks, imperfect regulatory systems, and market fragmentation.

**Keywords:** Carbon finance, Digital transformation, Blockchain, Green finance

## 1. Introduction

Climate change poses a serious global challenge, and the strategic value of carbon finance, as a key response tool, is becoming increasingly prominent at the international level. Carbon finance, derived from the United Nations Framework Convention on Climate Change and established by the Kyoto Protocol, is a green investment and financing system with carbon trading as the core, which has both environmental benefits and significant commercial value and market potential. However, there are structural problems in traditional carbon finance: first, the problem of data fraud is prominent; The second is the high cost of regulation, as transactions need to be certified and cleared by multiple intermediaries, which is inefficient [1]. These pain points not only weaken the effectiveness of the market, but also expose the trust crisis of the centralized trading model.

However, with blockchain, artificial intelligence, big data and other technologies providing a new path for the rapid development of carbon finance: blockchain technology can effectively solve the problem of carbon emission data fraud by building a trusted data traceability mechanism through distributed ledgers and encryption algorithms [2]; Artificial intelligence and big data can drive accurate pricing and risk assessment of carbon assets to improve market efficiency [3]; Digital platforms such as SWIFT Go can significantly reduce cross-border transaction costs through real-time payment tracking [4].

Despite the initial verification of technological potential, the deep integration of fintech and carbon finance still faces many challenges: technical security risks (system failures may induce financial risks) [2]; differences in regulatory rules hinder cross-border transactions [3]; Research limitations are prominent: existing studies on the mechanism effect of multi-measure digital finance on environmental governance have not been deeply explored, and the measurement methods have flaws [5]. Fixing this mix calls for a research scaffold where finance, ecology and code sit at the same table and borrow each other’s lenses.

This paper systematically analyzes the application of financial technology in the field of carbon finance and deeply explores the mechanism of technological innovation on market ecology. It is found that technology empowerment is mainly achieved through three paths: first, the immutability of

blockchain can improve data transparency and solve the core problem of information asymmetry [6]; second, smart contracts, which can simplify intermediate links and transaction procedures and reduce transaction costs with almost zero fees and instantaneous speed [1]; third, big data analysis can strengthen risk management and provide a scientific basis for regulatory decision-making [7]. The marginal contribution of this paper is that it systematically integrates the interdisciplinary research framework of financial technology and carbon finance, puts forward the realization path and policy suggestions of technology empowerment, lays a theoretical foundation for subsequent research, and provides practical reference for regulatory authorities to improve market construction.

## 2. The current state of the carbon finance market

### 2.1. What is carbon finance?

As an important market-oriented tool to combat climate change, carbon finance has developed rapidly around the world in recent years. Carbon finance refers to financial activities and services carried out in the financial market around carbon emission rights or emission reduction projects, mainly including carbon emission trading, carbon derivatives trading, carbon asset management, and carbon credit [3]. The essence of carbon finance is the "commercialization" of carbon emission rights and their derivatives, aiming to maximize capital under sustainable development [8]. In the carbon finance arena, the key players range from banks and investment houses to individual firms, state bodies and multilateral agencies, while the tradable items cover emission allowances, offset credits and a string of carbon-tied derivatives [9]. Day-to-day operations revolve around spot trades in permits, exchange-listed futures, over-the-counter options, active portfolio management of carbon holdings, labelled bonds and preferential green loans [2, 3].

### 2.2. The development status of the carbon finance market

Since its debut in 2005, the European Union Emissions Trading System has grown into the world's biggest and longest-running carbon market, and it now serves as a reference point for emission-cutting efforts everywhere [2]. From 2009 onward, the EU has collected €80.737 billion through allowance auctions, a sum that equals roughly 78 percent of all money ever raised by global carbon markets [10]. By capping the total amount of carbon that installations may release and letting them swap unused allowances, the EU ETS nudges firms toward cleaner technology at the lowest possible cost. California's cap-and-trade program offers another example of how inventive market rules can steer companies toward steady, measurable cuts in their greenhouse-gas output. China, one of the planet's largest emitters, has spent recent years piecing together a nationwide carbon market that relies on tradable permits to keep $CO_2$ in check and to hit the country's climate targets [3]. After the national market opened in 2020, carbon finance activity in China kept climbing, yet uneven regional uptake, thin trading volumes, opaque disclosure and shaky price discovery continue to hold the scheme back [9]. The shortfall is starkest in the central and western provinces, where carbon finance still lags far behind the more mature ecosystems found along the eastern seaboard [8]. Products and services also lack a common template, and when trades cross borders they run into mismatched rules and a tangle of separate regulatory regimes [4].

## 3. The drivers of the digital transformation of the carbon finance market

### 3.1. The internal drivers of the digital transformation of the carbon finance market

Long-standing carbon finance markets still carry a bundle of sore spots: buyers and sellers rarely see the same data, ledgers stay dim, fees nibble at every deal, trading books remain thin, and projects sometimes wear a thin coat of "greenpaint" [11, 12]. One open worry is the trustworthiness of emission figures; in 2022 alone, China's Ministry of Ecology and Environment called out four separate organisations for submitting carbon reports that mix the false with the genuine. In addition,

regulatory costs remain high, and carbon trading requires a large number of intermediaries from data certification to clearing, which is time-consuming and labor-intensive [1]. The high cost and low efficiency of carbon data measurement, reporting and verification (MRV) processes exacerbate data credibility issues [12]. Digital technology realizes traceability and tamper-proof records of carbon assets through blockchain, preventing double computation and forgery, and improving data authenticity and credibility [3, 6]. Leverage AI for real-time risk monitoring, market forecasting, and carbon emission management to enhance market stability and optimize emission reduction strategies [2]; Improve the efficiency of carbon asset pricing and resource allocation through big data analysis, and use smart contracts to automate the execution of transactions and emission reduction verification to reduce human operation risks [6, 12].

### 3.2. The external driver of the digital transformation of the carbon finance market

The external drive mainly stems from the rapid development of digital technology and the active promotion of the policy environment. The maturity of technologies such as artificial intelligence, big data, cloud computing, and blockchain lays the foundation for the digitalization of carbon finance [3]; For example, artificial intelligence can automate the processing of carbon trading processes and improve execution efficiency; Big data integrates multi-source data to achieve accurate assessment and prediction of carbon emissions [12]; Blockchain enhances transaction transparency and security through distributed ledgers and tokenized carbon assets, such as IBM and Energy Grid's solutions [6]. At the policy level, governments such as China have launched the "dual carbon" goal, the digital finance development plan, and the Fintech Development Plan 2022-2025, which clearly emphasize the integration of green and low-carbon and technology, providing institutional guarantees and market opportunities for the digitalization of carbon finance [8, 11, 12]. Digital platforms (such as the integrated green finance service platform in Huzhou, Zhejiang Province) can reduce service costs, expand inclusive financial coverage, and improve the efficiency and credibility of green financial services by integrating data and intelligent risk control [11].

## 4. The mechanism of digitalization in the carbon finance market

### 4.1. Realize the upgrade and reshaping of the MRV system

The effective creation of carbon assets relies on an accurate and transparent measurement, reporting, and verification (MRV) system. The traditional MRV process generally has problems such as low data quality, high verification cost, low transparency, and easy human tampering, which seriously restricts the credibility and efficient operation of the carbon market. Digital technology systematically reshapes the MRV process through convergence, big data, artificial intelligence and blockchain, injecting new capabilities in real-time, automation and tamper-proof to ensure the credible creation of carbon assets from the source.

By analyzing multi-dimensional data such as energy consumption and production processes, artificial intelligence technology can more accurately quantify carbon emissions, identify abnormal emission patterns, and provide a basis for scientific assessment and quota allocation of enterprise carbon emissions [9]. According to Cheng et al., the application of fintech tools, when leveraged alongside big data analytics, can lead to a significant reduction in the expenses for green identification and environmental benefit evaluation, concurrently enhancing the automation of MRV systems [11].

Blockchain technology serves as the foundational pillar of the digital MRV system, particularly for trusted certificate storage and anti-counterfeiting. Leveraging its distributed, tamper-proof, and traceable ledger, it guarantees that all emission data is tracked on-chain, with any modifications being permanently recorded and publicly visible. This fundamentally eliminates data fraud and double-counting [2], thereby not only curbing greenpaint and fraudulent offset projects but also establishing a bedrock of trust for the carbon finance market [1, 6].

Big data tools can now trace the hidden carbon patterns behind every corporate invoice, shipment and kilowatt-hour, turning those patterns into verifiable evidence that regulators and traders can use

when they set a price for each tonne of carbon [7]. The shift goes beyond a simple software update; it builds a fresh layer of institutional scaffolding whose ledgers are harder to tamper with, a change that makes the data surrounding carbon assets more believable, precise and open, and in doing so gives owners, auditors and exchanges the confidence they need to define, value and swap those assets.

### 4.2. Builds an efficient and credible market environment

The core of the carbon trading market lies in price discovery and liquidity enhancement. The digital platform significantly enhances transaction efficiency and transparency by integrating blockchain, smart contracts, and real-time clearing systems. The practice of SWIFT in global payment systems shows that the introduction of message formats and API interfaces based on the ISO 20022 standard has achieved efficient data exchange and transaction processing across systems and regions [4]. Similarly, in carbon trading, the platform-based architecture can support the coexistence of multiple message formats, adapt to the technology iteration rhythm of different institutions, and avoid friction caused by inconsistent system upgrades.

Blockchain technology enables automatic clearing and settlement of carbon allowances through distributed ledgers and smart contracts, reducing intermediaries and transaction costs further emphasized that blockchain-supported carbon credit trading platforms such as Climate Trade and Veridium can also automatically execute transactions and verification through smart contracts, further improving efficiency [3, 6]. Additionally, AI algorithms can predict market conditions and analyze risks, helping investors formulate more scientific trading strategies [2]. Digital trading platforms not only enhance market liquidity but also provide a technical foundation for the diversification of carbon financial products (such as carbon futures and carbon options).

### 4.3. Drives innovation and application of financial instruments

Carbon finance includes not only transactions but also various financing instruments such as carbon credits, green bonds, and carbon funds. The application of digital technology in this link is mainly reflected in product innovation, risk pricing and capital matching. Cheng et al. found that fintech accurately identifies the green financing needs of enterprises through big data and cloud computing, and promotes the personalized design of green credit and green insurance products [11]. Blockchain technology splits carbon credits into smaller units through asset tokenization, lowering the investment threshold and attracting more small and medium-sized investors to participate [6]. In addition, artificial intelligence plays an important role in assessing the carbon emission reduction potential and financing risks of enterprises, such as building credit models through corporate environmental behavior data and optimizing the green credit approval process [11]. These innovations not only broaden financing channels, but also improve the efficiency of capital allocation.

### 4.4. Driving "RegTech" to a new stage

The global carbon finance market is very complex. Traditional rules struggle to manage cross-border trades, data fraud, and manipulation. Digital regulation tools help by collecting data in real time and using smart contracts. This creates a more efficient and transparent system, which is key to supporting a healthy market.

The A consortium-built carbon market system gives regulators much better tools. Imagine all deal information is instantly written into a shared notebook that all permissioned parties can see. This creates transparent, end-to-end oversight and makes the market much clearer. Additionally, smart contracts can have the rules built right into them. They can then automatically carry out actions like freezing an account or pausing trading if needed. This reduces the need for human decisions, which lowers mistakes and risks [1]. Furthermore, because the record-keeping system is distributed, every trade is checked by several parties. This stops people from cheating or selling the same carbon credit twice [6]. Cheng and his team also added that fintech can help create a digital system that gathers green data from many sources. This allows for constant monitoring and smart analysis of carbon finance activities [11].

Digital supervision helps to enforce policies better and makes the market easier to forecast. It also gives us the tools and systems to create a single set of rules that all countries can follow [7]. To sum up, regulatory technology is very important. It not only makes regulating the carbon market much more efficient and accurate but also ensures the market is stable and can connect globally. Imagine it as the indispensable rulebook and foundation for the entire world's effort to reach carbon neutrality.

## 5. International experience and reference

The EU Emissions Trading System (EU ETS) is a pioneer in carbon markets. It was launched back in 2005, making it the first of its kind globally. Over the years, it has grown into a very mature market. This means it now has a comprehensive and well-developed set of rules for trading and for regulating the market. It effectively promotes corporate emissions reductions through the "cap control and trading" mechanism, and raises a large amount of funds for climate action through the quota auction mechanism. According to statistics, the global carbon market auction revenue exceeded US$103 billion between 2009 and 2020, of which the European Union contributed 78% [10]. The California carbon market in the United States is also known for its flexible mechanisms, emphasis on regional synergy and technological innovation [2]. In contrast, China's carbon market started late but is developing rapidly. Since the pilot program in seven provinces and cities in 2013 and the official operation of the national carbon market in 2021, China has built the world's largest carbon market covering emissions. However, China's carbon market still faces problems such as low carbon prices, insufficient data authenticity, imperfect verification systems, and limited market liquidity [1, 2].

In terms of financial product innovation, developed markets such as the European Union have established high market activity, including carbon futures, options, and credit lines [3]. Instruments such as green bonds and carbon bonds also provide important financing channels for low-carbon projects [2]. China's carbon financial products are still dominated by spot trading, and the development of derivatives such as carbon futures and carbon funds is relatively lagging behind [7]. Although green credit and green bonds have formed certain policy synergies in the development process, the banking industry's lack of professional capabilities and weak risk management limit the depth of services [9, 11].

The application of science and technology is another important dimension of difference. The EU and North American markets have introduced technologies such as big data, blockchain, and artificial intelligence to improve the efficiency and transparency of carbon emission monitoring, transaction verification, and risk management [3, 12]; China has shown latecomers in the field of green digital finance, such as Ant Forest promoting public low-carbon consumption through behavioral incentives, and Sesame Credit guiding green investment through credit mechanisms [5]. Additionally, China is promoting fintech applications such as the "SUPER-CARBON" consortium chain platform to enhance transparency and credibility in the carbon market [1]. However, it isn't perfect and still deals with some key challenges. It needs to get better at communicating with different systems (cross-chain interoperability), it needs to ensure system safety (technical security), and it has to work well within existing government rules (compatibility with regulatory systems) [7].

For China's carbon finance market to develop well in the future, we need to focus on two main actions. First, we must invest more in basic and applied research to find new and creative tech solutions. Second, because fintech and carbon finance bring together many sectors, we have to build a special system for cross-industry collaboration. This means creating ways for everyone to communicate and break down silos between different sectors.

## 6. Conclusion

This paper studies digital innovation in the carbon finance market. Carbon finance is a important market tool to combat climate change. Its healthy development is crucial for reaching the world's emission reduction targets. The paper analyzes how financial technology is used in carbon finance.

Technologies like blockchain, artificial intelligence, and big data are fundamentally changing the carbon market. They improve data credibility, reduce transaction costs, optimize resource allocation, and strengthen risk supervision. Here is how each technology helps: Blockchain makes carbon emission data authentic and transparent from the source because it cannot be altered and is traceable. Smart contracts make the clearing and settlement of carbon transactions automatic. This greatly reduces intermediary links and operational risks. Big data and artificial intelligence enable accurate pricing of carbon assets, improve risk assessment, and help optimize emission reduction strategies. This significantly increases market efficiency.

At the international level, mature carbon markets such as the European Union and California have accumulated rich experience in mechanism design, product innovation and technology application, while China, as a latecomer, has expanded its market size rapidly, but it still faces challenges such as imperfect carbon price mechanisms, uneven regional development, insufficient derivatives innovation, and cross-border rule compatibility. To further promote the digitalization of carbon finance, we need to continue to strengthen technology integration and institutional coordination, and build a cross-chain interoperable, safe, reliable, and standardized infrastructure system.

Based on the above findings, it is recommended to improve the construction of the carbon financial market from the following aspects: first, establish and improve the blockchain-based MRV standard and data sharing mechanism, and strengthen the trusted management of the whole chain of carbon data; The second is to promote the application of smart contracts and digital trading platforms, encourage the innovation of derivatives such as carbon futures and carbon funds, and improve market liquidity and pricing efficiency. third, strengthen international regulatory cooperation, jointly formulate rules and agreements for digital carbon finance, and promote cross-border market connectivity; Fourth, guide financial institutions to deepen cooperation with technology enterprises and build a comprehensive service platform covering carbon accounting, green credit, and environmental risk early warning.

Future research can further explore the integration and application of blockchain with new technologies such as the Internet of Things and generative artificial intelligence, and build an automatic carbon asset management and certification system. In addition, it is necessary to deepen the measurement of economic benefits and environmental impact of digital carbon finance, develop more scientific evaluation models and tool systems, and provide more operational theoretical support and practical reference for the global carbon neutrality process.

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