

Research on the Path of Carbon Market Risk Governance Empowered by Accounting Tools

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Abstract: Based on the background of the implementation of China's "Dual Carbon" strategy and closely focusing on the practical needs of carbon market risk governance, this paper systematically explores the internal logic and practical paths of accounting tools empowering carbon market risk governance. The research first conducts risk identification and measurement analysis, and then clarifies the characteristics and impacts of four types of core risks in the carbon market: (1) Market manipulation and price fluctuation risks impact the market pricing mechanism and the financial stability of enterprises; (2) Data quality and integrity risks weaken the credibility of transactions and lead to regulatory failure; (3) Policy arbitrage and carbon leakage risks damage market fairness and hinder the achievement of emission reduction targets; (4) Quota allocation and market imbalance risks result in resource misallocation and inhibit market liquidity. On this basis, a multi-dimensional risk governance path system of accounting tools is constructed: fair value measurement, hedge accounting and other tools are used to stabilize price fluctuations; carbon accounting information systems and audit supervision are relied on to strengthen credit risk management; policy tracking and accounting adaptation are adopted to respond to policy change risks; risk transfer and sharing mechanisms are established by means of risk reserve accrual and carbon financial tool innovation. This research clarifies the core functions and application value of accounting tools in carbon market risk governance, provides theoretical support and practical reference for improving the carbon market risk governance mechanism and enhancing market operation efficiency, and helps the carbon market better play its role in resource allocation in the low-carbon transformation.

Keywords: Accounting Tools; Carbon Market; Risk Governance

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1. Introduction

1.1 Research Background

The global climate governance process is accelerating, and the in-depth implementation of China's "Dual Carbon" strategic goals has made the carbon market a core hub for guiding social resources to be allocated to the low-carbon field. As the core carrier of carbon emission rights trading, the stable operation of the carbon market is directly related to the efficiency of achieving emission reduction targets. However, the superposition and exposure of multiple risks in the current market operation have significantly restricted its governance efficiency.

In terms of risk performance, market manipulation and violent price fluctuations damage the fairness of the carbon pricing mechanism, directly lead to the distortion of the fair value measurement of enterprises' carbon assets, and trigger fluctuations

in financial statements and deviations in business decisions; frequent problems of distorted data quality and lack of integrity make carbon emission accounting deviate from the accounting recognition and measurement standards, and there are loopholes in the verification link due to the lack of systematic accounting supervision tools, which weakens the market participants' trust in carbon trading data; the existence of policy arbitrage and carbon leakage risks leads to inconsistent calibers of carbon cost accounting among different regions and industries, violates the principle of comparability of accounting information, and causes unfair competition; unreasonable quota allocation is likely to trigger market supply and demand imbalances, resulting in quota surplus or shortage, which not only increases the risk of carbon asset impairment, but also inhibits the application efficiency of accounting tools in risk hedging due to insufficient liquidity of trading targets.

Against this background, carbon market risk governance is in urgent need of systematic support from professional accounting tools. Relying on its core advantages in the recognition and measurement of carbon assets and liabilities, risk quantitative measurement, and full-process supervision and accounting, accounting tools have become a key starting point for empowering carbon market risk governance. Traditional carbon market risk governance mostly relies on administrative supervision and spontaneous market regulation, lacking quantifiable accounting standards and dynamic monitoring mechanisms, with limitations such as lagging risk early warning and single control methods, making it difficult to cope with complex and changeable risk situations.

In contrast, accounting tools can accurately capture the impact of carbon price fluctuations on corporate finance through fair value measurement, realize the full-process traceability and audit supervision of emission data relying on the carbon accounting information system, and effectively prevent and control data fraud and credit risks; the hedging accounting rules can be used to realize the hedge accounting of carbon price risks, and a risk sharing mechanism can be constructed by means of risk reserve accrual and accounting treatment of carbon financial tools, helping market entities to cope with the impact of price fluctuations and policy changes steadily.

At present, academic and practical research on the systematic empowerment of carbon market risk governance by accounting tools is still scattered, and a theoretical model and practical path covering the whole chain of risk identification, measurement, control and sharing with accounting tools as the core has not been established. This leads to the lack of systematic guidance for the application of tools such as fair value measurement, carbon audit and hedge accounting, making it difficult to give full play to the core value of accounting tools in risk quantification, process supervision and information disclosure. This practical contradiction highlights the urgency and necessity of carrying out this research.

1.2 Research Significance

The theoretical significance and practical value of this research can be expanded from multiple dimensions: at the theoretical level, by constructing a correlation framework between accounting tools and carbon market risk governance, this research can inject an interdisciplinary research perspective into the carbon market risk governance theory and enrich the theoretical system in this field; at the same time, it can expand the application boundary of environmental management accounting theory, extending environmental management accounting from the traditional level of carbon information disclosure and cost accounting to the dynamic risk control scenario of the carbon market, and providing theoretical support for the innovative development of this theory in the field of low-carbon governance.

At the practical level, the application paths of accounting tools proposed in this research for the four types of core risks in the carbon market, such as stabilizing price fluctuations with fair value measurement and strengthening credit risk control relying on carbon audit, can provide market entities such as enterprises and financial institutions with directly implementable risk governance tools, help them reduce the impact of risks on business decisions and financial stability, and assist market entities in achieving stable operation in the low-carbon transformation; at the same time, it can provide a reference for regulatory authorities to optimize the carbon market governance mechanism, which not only helps regulatory authorities improve the accuracy and efficiency of risk early warning relying on accounting tools, but also provides practical basis for improving quota allocation rules and designing risk reserve systems.

More importantly, by giving play to the empowering role of accounting tools in carbon market risk governance, the restrictions of risks on the fairness of the carbon pricing mechanism and the standardization of market operation can be reduced,

guiding more social capital to flow to the low-carbon industry, and providing a solid institutional and tool support for the on-schedule achievement of the “Dual Carbon” strategic goals.

2. Literature Review

2.1 Carbon Trading Theory

Against the background of intensified global climate change, reducing greenhouse gas emissions is the common responsibility of all mankind. The Kyoto Protocol first introduced market mechanisms into greenhouse gas emission reduction, and since then, carbon emissions have been endowed with commodity attributes and can be freely traded in the market. Carbon trading refers to a transaction method based on greenhouse gas emissions^[1]. Carbon emission rights trading, a form of carbon trading, is realized by the government setting emission reduction targets, allocating carbon emission quotas and limiting emissions within a certain period.

Policies related to carbon emission rights trading mainly involve the issue of “carbon emission rights trading”, that is, the policy measures adopted by the government to regulate the total carbon emissions and the division and trading of carbon emission quotas^[2]. Since “carbon trading” has become a widely used term in academia, for the sake of concise expression of the concept, this paper refers to the carbon emission rights trading policy as the “carbon trading policy”. In 2020, China announced that its carbon dioxide emissions would peak before 2030 and strive to achieve carbon neutrality before 2060. The national carbon emission rights trading market is one of the core policy tools to achieve the goals of carbon peaking and carbon neutrality.

2.2 Environmental Management Accounting Theory

In the 1970s, with the in-depth development of theoretical research such as Demsetz’s “Research on the Transformation of Social Costs of Pollution Control” and Marin’s “Pollution Accounting Issues”, environmental management accounting has gradually attracted the attention of academia. Since the 21st century, research on environmental protection-related issues in the accounting field has increased day by day.

Compared with foreign countries, China has attached less importance to the research of environmental management accounting and started late. Through literature combing, China’s environmental management accounting research mainly focuses on three aspects: first, the research on the relationship between the environment and accounting, Wu Wen studied the relationship among cost stickiness, relational transactions and corporate environmental accounting information disclosure^[3]; second, the research on the synergistic effect of the government, enterprises, environmental organizations and other subjects in environmental management, Han Zhiqing and Han Ruixue put forward the Nash equilibrium game analysis of environmental governance in operational research^[4], indicating that solving the negative externalities of environmental problems needs to rely on external forces such as the government and play a joint role with enterprises and environmental protection organizations; third, the interdisciplinary research of environmental management accounting with environmental science, operational research, management science and other disciplines, scholars such as Zheng Qiong and Liu Chunying and Wang Qinglin integrated ESG into environmental accounting, providing an important guarantee for the sustainable development strategy of enterprises^{[5][6]}.

2.3 Risk Management Theory

The economic crisis in the 1930s prompted the emergence of risk management ideas. In order to cope with the huge impact, people began to pay attention to the risk management of various activities, so as to control or reduce losses as much as possible. In the mid-20th century, after Meyer and Hersh of the United States published “Enterprise Risk Management” in the Insurance Manual, research on risk management gradually became systematic and specialized, which made “risk management” gradually develop into a discipline, and enterprises entered the stage of traditional risk management.^[7]

Operators began to attach importance to risk management activities, and the main measures were to avoid and transfer risks. The representative theories of this stage include Markowitz’s mean-variance theory, the capital asset pricing model and option pricing model. However, the relevant research is relatively single and one-sided, lacking hierarchy and systematicness, and even lacking a strategic height. Until the 1980s, with the tremendous changes in the social environment and other factors, developed capital markets and tools have become an important force promoting the development of the modern risk

management stage. Enterprises pay more attention to the combined risks of various departments and their comprehensive impacts, and carry out risk management based on this to improve operational efficiency.

At the same time, since China resumed insurance business, research and application related to risk management have emerged. Zhang Xuchu and others believe that risk management is a broad concept, whose purpose is to suppress the random economic influencing factors and ensure that business activities are in an orderly state. Therefore, they propose that when exploring advanced foreign experiences, Chinese enterprises should analyze various risks faced by enterprises from an overall perspective, especially the control and management of dynamic risks.^[8]

At the beginning of the 21st century, the development of risk management theory entered the stage of enterprise risk management (ERM). In 2004, COSO upgraded the content of the Internal Control-Integrated Framework and launched the Enterprise Risk Management-Integrated Framework, transforming the internal control of enterprises from “financial report-oriented” to “risk management-oriented”^[9]. The core of the ERM theory comes from the concepts and methods of risk management in the report. In 2017, COSO further improved the framework content, and its scope of application was clearly expanded from enterprises to organizations of any type and scale. Based on this discovery, Wang Hui proposed that the framework can provide a good opportunity for embedding risk management in the establishment and improvement of internal control of administrative institutions in China, which is conducive to the connection and integration of the new framework of government internal control and risk management, forming a late-mover advantage.^[10]

3. Carbon Market Risk Identification and Measurement

3.1 Risk Identification Methods

3.1.1 Data Analysis Method

Carbon price data analysis should be carried out from a multi-dimensional perspective: first, time series analysis (such as ARIMA model) is used to identify price trends and seasonal laws, with a focus on abnormal price fluctuations before and after the compliance period; calculate historical volatility (such as 30-day annualized volatility), and then use GARCH family models to capture volatility clustering characteristics; at the same time, conduct correlation analysis, focusing on the linkage between carbon prices and energy prices (e.g., the strong negative correlation of -0.7 between EU carbon prices and TTF natural gas prices) and macroeconomic indicators (such as PMI index); it is also necessary to carry out monitoring of market liquidity indicators, including Z-score analysis of daily trading volume, moving average monitoring of bid-ask spreads, and changes in open interest, to identify liquidity hidden dangers caused by insufficient market depth.

3.1.2 Model Construction Method

Model construction should adopt a multi-level method: improved ARIMA models (such as SARIMA considering seasonal factors) combined with XGBoost feature selection can be used for short-term forecasting, with a forecasting accuracy of more than 85%; EGARCH (1,1) model is recommended for volatility modeling, which can effectively capture the asymmetric characteristics of “sharp rise and slow fall” of carbon prices; for medium and long-term analysis, a dynamic CGE model needs to be constructed, incorporating more than 50 parameters such as policy variables (e.g., quota reduction rate) and technology learning curves (e.g., photovoltaic cost decline); in terms of machine learning, LSTM neural network performs well in processing nonlinear relationships, but attention should be paid to preventing overfitting, and Bayesian optimization is recommended for hyperparameter tuning.

3.2 Risk Measurement Methods

In the context of the carbon market, commonly used risk measurement methods mainly include two categories: relative risk measurement methods and absolute risk measurement methods.

3.2.1 Relative Risk Measurement Method

The relative risk measurement method is mainly used to reflect the sensitivity relationship between the fluctuation of market factors and the price change of financial assets^[11]. Commonly used relative risk measurement indicators include Duration and Convexity. As a measurement indicator, Duration reflects the sensitivity of bond prices to interest rate changes. Although it is not common to directly use Duration to measure market risks in the carbon market, similar concepts can be used to analyze the sensitivity of carbon emission rights prices to policy changes, market supply and demand changes and other factors. By

calculating the Duration of carbon emission rights prices, the degree and direction of the impact of market factors on price changes can be grasped.

Convexity is an indicator to measure the nonlinear relationship between bond price changes and interest rate changes. In the carbon market system, Convexity can be used to analyze the nonlinear relationship between carbon emission rights price changes and market factor changes. When market factors change significantly, Convexity can reflect the acceleration or deceleration effect of price changes, thereby helping market participants to evaluate market risks more appropriately.

As an important way to assess risks, stress testing and scenario analysis play an extremely critical role in the carbon market. Stress testing focuses on evaluating the risk status of the market under extreme market conditions. Through carefully designed simulation scenarios, such as an immediate change in the policy environment or a sharp decline in market demand, it analyzes in detail the effects of these extreme scenarios on carbon emission rights prices and the overall market stability.

Scenario analysis focuses on the prospective setting and analysis of possible future market scenarios. It comprehensively considers multiple dimensions such as changes in the macroeconomic environment, forecasts of policy orientation and the trend of technological progress, aiming to compare the performance of market risks under different scenarios and provide richer and more comprehensive decision-making reference for market participants. These two methods jointly constitute the main part of risk measurement in the carbon market, helping investors and policymakers grasp market changes more accurately and formulate effective risk control strategies.

3.3 Methods for Quantitative Analysis of Core Market Risks

3.3.1 Financial Engineering Methods

Financial engineering methods combine finance theory with mathematics, statistics, computer science and other technologies to solve financial problems. In the quantitative analysis of market risks, commonly used financial engineering methods include VaR model, CVaR model and Copula model.

3.3.1.1 VaR Model

VaR (Value at Risk) refers to the maximum possible loss of the value of a financial asset or securities portfolio within a specific period in the future at a certain probability level (confidence level). The VaR model is widely used in financial risk management due to its simplicity and easy understanding. The calculation of the VaR model is usually based on historical simulation method, variance-covariance method or Monte Carlo simulation method.

In the carbon market, the VaR model can also be used to measure market risks. By setting an appropriate confidence level and holding period, the maximum possible loss value of the carbon emission rights portfolio in the future period can be calculated, thus providing important risk reference information for market participants^[12].

The mathematical expression of the VaR model is:

$$\text{Prob}(\Delta P > \text{VaR}) = \alpha$$

Among them, ΔP is the loss of the investment portfolio during the holding period, and α is the confidence level.

The calculation of the VaR model usually involves the following steps: Determine the asset portfolio:

clarify the carbon emission rights portfolio for which risks need to be measured; Select historical data: collect historical transaction data related to the carbon emission rights portfolio, which should include information such as price, trading volume and time;

Determine the confidence level and holding period: set an appropriate confidence level and holding period according to risk management objectives and market environment. The confidence level indicates the reliability of the calculation results, generally choosing 95% or 99%; the holding period represents the time range under investigation, which can be one day, one week, one month, etc;

Calculate the statistical distribution: use historical data to fit the statistical distribution of the returns of the carbon emission rights portfolio, usually choosing normal distribution, t-distribution or historical simulation method.

Calculate the VaR value: calculate the VaR value according to the selected confidence level and statistical distribution. Taking the normal distribution as an example, if the confidence level is set to 95%, the corresponding α value is 0.05, that is, the 5% right quantile under the normal distribution. The corresponding quantile z value can be obtained by looking up

the table, and then the VaR value is calculated by the formula $VaR = z \times \sigma \times W$, where σ is the standard deviation of the returns of the carbon emission rights portfolio, and W is the initial investment amount;

Result analysis and reporting: analyze the market risk level of the carbon emission rights portfolio according to the calculated VaR value, and write a risk report to provide risk disclosure and decision support to relevant parties.

3.3.1.2 CVaR Model

CVaR (Conditional Value at Risk) model refers to the average level of losses exceeding the VaR value at a certain confidence level. CVaR is a further improvement of VaR, which considers the size of the average loss exceeding the VaR level. In other words, CVaR gives the expected average loss that may be suffered when the VaR value has been determined and the market conditions are worse than the VaR setting. CVaR can capture extreme market risks better than VaR, so it is regarded as a more robust risk measurement indicator in some occasions.

The calculation of CVaR is relatively complex and usually needs to be realized through simulation methods or optimization technologies. Specifically, on the basis of generating a large number of market scenarios, all loss values exceeding the VaR threshold can be calculated, and the average of these loss values is taken as the estimated value of CVaR.

The mathematical expression of the CVaR model is:

$$CVaR = E[X|X > VaR]$$

Among them, (X) is the loss of the investment portfolio.

CVaR can be obtained by first calculating VaR and then calculating the average of losses exceeding the VaR part. The specific calculation method varies according to the adopted model. In the Monte Carlo simulation, after calculating the VaR, for all samples in the simulation results where the loss exceeds the VaR, their average loss is calculated, and this average loss is the value of CVaR.

3.3.1.3 Copula Model

The core of the Copula model is to “separate the marginal distribution from the correlation structure”, that is, first fit the return distribution (marginal distribution) of each asset in the portfolio separately, then describe the correlation (including linear and nonlinear correlation) between assets through the Copula function, and finally construct the joint distribution of the multi-asset portfolio to realize the accurate quantification of portfolio risks. It breaks through the assumption of “linear correlation between assets” in traditional methods and is more in line with the complexity of asset correlation in the actual market (such as the nonlinear linkage between carbon prices, coal prices and electricity prices).

The basic mathematical expression of the Copula model is:

For an n -dimensional random vector $X = (X_1, X_2, \dots, X_n)$, its joint distribution function $H(x)$ can be expressed as:

$$H(x_1, x_2, \dots, x_n) = C(F_1(x_1), F_2(x_2), \dots, F_n(x_n))$$

Among them: $F_i(x_i)$ is the marginal distribution function of X_i ($i = 1, 2, 3, \dots, n$);

$C: [0,1]^n \rightarrow [0,1]$ is the Copula function, which captures the dependence structure between variables.

The calculation of the Copula model usually involves the following steps:

Marginal distribution fitting: for the yields of each asset in the portfolio (such as EUA, CCER, coal futures), select appropriate marginal distributions (such as t-distribution, dynamic distribution fitted by GARCH model) respectively;

Copula function selection: select a suitable Copula function according to the correlation characteristics between assets;

Parameter estimation and testing: estimate the parameters of the Copula function by the maximum likelihood estimation method, and select the optimal Copula model by the AIC and BIC criteria;

Portfolio risk quantification: based on the joint distribution, calculate the VaR and CVaR of the portfolio, or simulate the risk-return curve under different asset weights to provide a basis for portfolio optimization.

4. Types of Carbon Market Risks

4.1 Market Manipulation and Price Fluctuation Risks

Market manipulation and price fluctuation risks directly impact the market pricing mechanism and corporate financial stability, and are one of the most prominent risk types in the operation of the carbon market. Manipulation behaviors in the carbon market are mainly manifested in large institutions or traders using their capital advantages, information advantages

and market dominant positions to artificially intervene in the supply and demand of carbon quotas through centralized trading, related transactions and other means, thereby manipulating the trend of carbon prices.

This behavior was particularly typical in the early stage of the European Union Emission Trading System (EU ETS). In 2006, the system experienced an extreme case where the carbon price plummeted from 30 euros to 1 euro due to the superposition of factors such as centralized selling by institutions and quota surplus, which directly led to the instant shrinkage of the value of a large number of corporate carbon assets, and some enterprises relying on carbon asset pledge financing fell into financial difficulties.

The core means of manipulators can be divided into two categories: first, “cornering the market”, that is, continuously buying a large number of carbon quotas and holding them for a long time to artificially create an atmosphere of tight market supply, push the carbon price to rise irrationally, and sell them centrally to make profits when the price reaches the expected level; second, “centralized selling”, that is, selling a huge amount of held quotas in a short time to form a market panic selling sentiment, suppress the carbon price rapidly, and then buy back to cover positions at a low price.

In addition, the wide application of high-frequency trading algorithms has further aggravated the short-term volatility of the market. Its millisecond-level trading speed and automated trading logic may amplify the impact of market sentiment without fundamental support, leading to abnormal fluctuations of “sharp rise and sharp fall” in carbon prices, making them deviate from the reasonable range reflecting the actual emission reduction costs of the industry.

4.2 Data Quality and Integrity Risks

Data quality and integrity risks weaken the credibility of carbon transactions and lead to regulatory failure, which are core risks threatening the sustainable operation of the carbon market. The accuracy of emission data is the premise for the effective operation of the carbon market. Key links such as carbon quota allocation, transaction pricing and compliance assessment all rely on true and complete emission data support. Once the data is distorted, the operation logic of the entire carbon market will have a fundamental deviation. However, from the practice of the global carbon market, data fraud problems have occurred frequently, which have become a prominent bottleneck restricting market efficiency.

Common data fraud means show diversified and hidden characteristics: at the enterprise level, they are mainly manifested in falsifying activity level data, tampering with emission factors, and manipulating monitoring equipment; in the early stage of China’s carbon market, some high-energy-consuming enterprises artificially reduced the accounting emissions by falsifying the calorific value of coal burning and concealing the consumption of purchased electricity, and obtained quota surplus in violation of regulations; in the voluntary carbon market, fraud behaviors of project developers are more concentrated, including falsifying the baseline emissions of emission reduction, exaggerating the emission reduction effect of projects, or registering and trading the same emission reduction across markets repeatedly, which seriously disrupts the market order.

4.3 Policy Arbitrage and Carbon Leakage Risks

Policy arbitrage and carbon leakage risks damage market fairness and hinder the achievement of emission reduction targets, which are typical systemic risks under the background of the coexistence of globalization and regionalization of the carbon market. The core function of the carbon market is to guide enterprises to reduce emissions through price signals. However, the differences in policy implementation and the limitations of regulatory scope provide opportunities for enterprises to evade emission reduction responsibilities, ultimately leading to the impairment of the fairness of the carbon market and the significant reduction of the overall emission reduction effect.

The manifestations of policy arbitrage are diversified, and the core can be divided into two categories: first, “carbon leakage”, that is, high-carbon enterprises transfer their production bases and high-emission links to regions with low carbon pricing and loose control standards to avoid strict carbon constraint policies, resulting in the offset of local emission reduction efforts by newly added emissions in other places. Relevant research data from the European Union shows that carbon leakage may lead to the invalidation of up to 25% of emission reductions in the region, forming an embarrassing situation of “emission reduction without consumption reduction”; second, “industry arbitrage”, enterprises take advantage of the policy differences between carbon market regulated industries and unregulated industries, strip high-emission businesses to affiliated enterprises not included in the regulation, or transfer emission responsibilities through upstream and downstream transactions in the

industrial chain, so that their own quota compliance pressure is reduced, while the total carbon emissions do not decrease. In addition, there is “time period arbitrage”, that is, enterprises take advantage of the rule loopholes in the policy transition period and emission reduction target adjustment period to delay emission reduction investment or suddenly increase emissions to obtain short-term quota benefits.

4.4 Quota Allocation and Market Imbalance Risks

Quota allocation and market imbalance risks lead to resource misallocation and inhibit market liquidity, which are core structural risks affecting the play of the carbon market’s resource allocation function. As the core trading target of the carbon market, the rationality of quota allocation directly determines the market supply and demand balance and the effectiveness of price signals. Once the allocation mechanism has defects, it will trigger a chain reaction and hinder the healthy development of the carbon market.

Market imbalances caused by improper quota allocation are mainly reflected in two dimensions: first, “total amount imbalance”, that is, the total amount of quotas does not match the actual emission demand. If the proportion of free allocation is too high and the total amount setting is loose, it will cause a serious surplus of quotas. At this time, the carbon price signal is severely suppressed, unable to form an effective emission reduction incentive, and low-carbon technology investment and emission reduction behaviors are shelved due to the lack of income support; if the quota allocation is too tight and the total amount setting is strict, it will greatly increase the compliance costs of enterprises, especially for enterprises in traditional industries with high energy consumption and low profits, which may exceed their bearing capacity, trigger operational pressure and even industry recession risks, and instead hinder the low-carbon transformation of the industry.

Second, “structural imbalance”, that is, the uneven distribution of quotas among different industries and enterprises. If the differentiated factors such as enterprises’ emission reduction potential, technical level and production scale are not fully considered, and a “one-size-fits-all” allocation standard is adopted, it will lead to inefficient enterprises obtaining excess quotas for idle waste, while efficient emission reduction enterprises face quota shortages and need additional procurement. This unfair allocation directly causes the misallocation of carbon emission rights resources, violating the core original intention of the carbon market to optimize resource allocation.

The “stock effect” caused by quota allocation further aggravates market imbalance: some enterprises hoard unused quotas for a long time based on the prediction of future carbon price increases or to avoid compliance risks, resulting in a large number of quotas stranded in enterprise accounts and difficult to circulate in the market. This behavior directly reduces the effective market supply, suppresses trading activity and liquidity, makes it difficult for the carbon market to form a continuous and fair price marker, and thus affects enterprises’ emission reduction decision-making and the actual efficiency of carbon asset operation.

5. Carbon Market Risk Governance Paths under Accounting Tools

5.1 Price Fluctuation Risk Governance

5.1.1 Improve the Market Mechanism

Enhance market transparency. For example, the EU ETS regularly publishes carbon emission data, transaction information and quota supply and demand forecasts to alleviate information asymmetry, provide clearer decision-making basis for market participants, and reduce irrational trading behaviors caused by information deviation. Enriching trading varieties is the core point: introducing derivative transactions such as futures and options to provide basic tools for hedging price risks; the standardized application of fair value measurement, hedge accounting and other tools can further reduce the impact of price fluctuations on corporate finance-fair value measurement can timely reflect the specific changes in the value of carbon assets and support enterprises to accurately grasp risk exposure; hedge accounting enables qualified derivative transactions to achieve risk hedging with carbon assets, maintain the stability of corporate profits, and reduce financial fluctuations caused by price shocks.

5.1.2 Strengthen Policy Guidance and Supervision

The government needs to set long-term and clear carbon emission reduction targets and phased promotion plans to reduce market expectation disorders caused by frequent policy changes, provide policy support to stabilize carbon prices, and form

a sound regulatory pattern. For example, the Supreme People's Court issued guiding opinions on the trial of carbon market-related cases, clarifying the identification standards and penalty basis for illegal acts such as market manipulation and insider trading, and severely punishing acts that intentionally affect carbon prices; build a price fluctuation early warning mechanism, and implement temporary regulatory measures when the carbon price deviates from the reasonable range to the preset critical value to ensure the fairness, impartiality and information transparency of the market.

5.1.3 Strengthen Policy Guidance and Supervision

Market participants should use technical means such as big data and artificial intelligence to integrate multi-dimensional information such as policy trends, industry emission data and market transaction trends, build carbon price prediction models, and improve the accuracy and timeliness of decision-making. Establishing a sound risk management mechanism is also crucial: enterprises should integrate carbon price risks into the overall risk management system, evaluate the size of risk exposure combined with fair value measurement results, and adopt diversified investment, hedging and other ways to reduce risks caused by single price fluctuations.

5.1.4 Adopt Financial Tools for Risk Hedging

Market participants can lock in costs and obtain benefits by buying or selling futures contracts or option contracts linked to carbon emission rights, thereby reducing the impact of price fluctuation risks; from the perspective of enterprises, they can match and account for derivative transactions with their own carbon asset risks in accordance with the corresponding norms of hedge accounting to ensure that the hedging effect is accurately reflected in the financial statements. In the field of carbon asset management and investment portfolio optimization, enterprises should regard carbon emission rights as a core asset and carry out full-life cycle management practices, including procurement, holding, transaction and exit stages. Based on changes in fair value, adjust asset allocation strategies in a timely manner, and realize risk diversification and reduction by building a diversified investment portfolio with carbon assets and related derivatives of different risk levels.

5.2 Credit Risk Management

5.2.1 Unify Monitoring, Accounting and Reporting Standards

Formulate a national unified and transparent MRV standard system, refine the monitoring scope, data collection caliber, accounting methods and report formats of various industries and emission sources, and ensure the consistency and comparability of data accounting among different enterprises and regions. At the same time, clarify the selection rules and dynamic update mechanism of emission factors, and regularly revise the emission factor database in combination with the progress of industrial technology and the upgrading of environmental protection standards to reduce the fraud space caused by the flexibility of artificial selection and ensure the accuracy of data from the source.

5.2.2 Strengthen the Independence and Professionalism of the Verification Mechanism

Implement a qualification certification and dynamic supervision system for verification institutions, strictly select third-party institutions with professional capabilities to participate in verification work, and establish a rotation mechanism for verification institutions to prohibit the same institution from providing continuous verification services for the same enterprise, so as to avoid verification inaccuracy caused by interest correlation from the system. Establish a cross-review and random spot check mechanism for verification results, and the regulatory authorities or independent third-party audit institutions shall conduct sample verification of the completed verification reports, focusing on verifying the integrity of data collection and the compliance of accounting methods; for doubts found in the verification process, require enterprises to supplement explanations and provide supporting materials to effectively improve the credibility of verification conclusions.

5.2.3 Establish a Strict Legal Liability Investigation System

Construct a stepped punishment system of "administrative punishment + civil compensation + criminal liability", and clarify the legal boundary and liability consequences of data fraud behaviors: for enterprises that commit data fraud, in addition to imposing heavy fines and recovering illegally obtained quotas, include them in the list of dishonest enterprises in the national credit information sharing platform, and restrict their carbon market transaction rights and relevant policy support qualifications; for those that cause losses to other market entities due to data fraud, order them to bear civil compensation liabilities; if the circumstances are serious and suspected of a crime, pursue the criminal liability of the relevant responsible

persons in accordance with the law.

At the same time, clarify the joint compensation liability of verification institutions. If false data flows into the market due to verification negligence, the verification institutions shall bear corresponding compensation liabilities, forcing them to standardize their practice processes and adhere to professional bottom lines.

5.3 Response to Policy Change Risks

5.3.1 Strengthen Policy Research and Prediction

Enterprises need to set up a professional policy research team, which is specially engaged in closely following the domestic and foreign policy trends. The team should use a variety of channels and methods to conduct an all-round and in-depth analysis of the policy trend, accurately predict the possible impact of policy adjustments on the carbon market, and actively establish close cooperative relations with government departments, industry associations and research institutions to obtain the most timely and accurate first-hand policy information and authoritative interpretations.

The policy research team shall regularly conduct a scientific assessment of the impact of policy changes on enterprises' carbon emission management, cost control and market competitiveness, comprehensively predict various risks and challenges that may be brought by policy changes by adopting professional means such as simulation analysis and risk assessment, and put forward targeted and operable response measures accordingly^[13]. If a policy that may affect carbon emission costs is predicted to be introduced soon, formulate cost control measures or adjust production methods in advance.

5.3.2 Improve the Risk Early Warning and Response Mechanism

Enterprises should use modern advanced information technology to create an efficient risk early warning platform. The system can monitor policy trends and market changes in real time, timely identify potential policy change hidden dangers, and ensure that enterprises can quickly take feasible measures to respond before risks break out by scientifically formulating early warning indicators, reasonably selecting thresholds and building an effective response mechanism.

For various types of policy change risks, enterprises should formulate detailed and comprehensive emergency plans, clarify the structure of the emergency organization system, the division of responsibilities of each member and the clear processing process and other key contents. In addition, through regular simulation drills and emergency training, continuously improve the enterprise's emergency response capacity and efficiency, and ensure that when risks really come, they can be handled quickly and in an orderly manner to minimize losses.

5.3.3 Improve Internal Management and Construction

Enterprises should establish a sound institutional system related to carbon emission management, clearly present the carbon emission rights management process, carefully divide the responsibilities of each party, and establish a strict supervision and assessment mechanism. By strengthening internal control management, the enterprise's carbon emission activities are strictly in accordance with the relevant laws, regulations and policy requirements, standardized and legal, and the risks caused by policy changes are truly reduced.

Pay attention to improving the quality and ability of employees, enhance their in-depth understanding and proficient application of carbon market policies, and improve their sensitivity and response level to policies. Use various means such as organizational training and interactive exchange activities to comprehensively enhance the professional quality and comprehensive capabilities of employees, and build a solid talent support system for enterprises to successfully resist policy change risks.

5.3.4 Enhance International Exchange and Cooperation

Enterprises should actively participate in the cooperative exchange activities of the international carbon market, keep a close eye on the policy trends and development trends of the international carbon market, form good cooperative relations with international counterparts, jointly study effective ways to deal with policy change risks and market challenges, and actively learn from the rich experience and mature measures of advanced international countries in carbon market policy formulation, regulatory mechanisms and risk management.

In combination with the national conditions and the actual situation of the enterprise itself, continuously improve and optimize its own carbon emission management and risk management system, and enhance the competitiveness and

adaptability of the enterprise in the global carbon market. At the same time, enterprises can pay attention to the latest research results in the field of international carbon market research, such as the research on carbon trading pricing based on the B-S pricing model by Zhu Yuezhao, Chen Hongxi and Zhao Zhimin, understand the advanced international theories and methods on carbon emission rights pricing^[14], and provide a reference for enterprises to reasonably price and reduce risks in international carbon market transactions^[15].

5.4 Improvement of Quota Governance Efficiency

5.4.1 Establish a Scientific Baseline Allocation Method

Taking the advanced emission level of the industry as the core benchmark, combined with differentiated factors such as the actual production scale, product structure, energy type and emission reduction potential of enterprises, a mixed allocation mode combining the “baseline method + historical intensity method” is adopted. For industries with mature technologies and complete emission data, the baseline method is given priority, and quotas are accounted according to the emission benchmark value per unit product; for industries with a concentration of small and micro enterprises and large emission fluctuations, the historical intensity method can be appropriately retained and gradually transitioned to the baseline method.

At the same time, introduce an industry emission reduction coefficient, give additional quota rewards to enterprises that overfulfill the emission reduction targets, and reduce the subsequent quotas for enterprises that fail to meet the standards, so as to ensure that the quota allocation matches the enterprises’ emission reduction responsibilities and capabilities, guide the flow of carbon emission rights resources to efficient emission reduction enterprises, and reduce resource misallocation.

5.4.2 Implement a Dynamic Adjustment Mechanism for the Total Quota

Establish a normalized quota total assessment and adjustment mechanism, and flexibly revise the total quota every 2-3 compliance cycles in combination with factors such as the progress of national emission reduction targets, changes in industry production capacity and the effectiveness of energy structure transformation. Build a quota surplus recovery and shortage supplement channel: for the excess quotas idle by enterprises for a long time (such as unused for more than one compliance cycle), the regulatory authorities will recover them at the market fair price and auction them publicly; for enterprises with compliance difficulties affected by policy adjustments and sudden operational pressure, provide transitional quota lending or short-term supplementary support to avoid severe market fluctuations caused by short-term supply and demand imbalances.

In this process, realize risk transfer and sharing by means of risk reserve accrual and carbon financial tool innovation - require market entities to accrue risk reserves according to the scale of quota holdings or transaction volume to cope with sudden risks such as sharp fluctuations in quota prices and enterprise compliance defaults; encourage financial institutions to innovate products such as quota pledge financing, quota repurchase and carbon asset securitization to help enterprises activate stock quotas and diversify the risks of quota holding and compliance.

5.4.3 Set Quota Validity Period and Circulation Incentive Policies

Clarify the service life of quotas, stipulate that the validity period of unused quotas after compliance is 2-3 years, and they will be automatically cancelled after the expiration, so as to prevent enterprises from hoarding quotas for a long time and artificially creating a shortage of market supply from the system. At the same time, introduce targeted circulation incentive policies: reduce part of the transaction handling fees or give credit points for carbon market transactions to enterprises that take the initiative to put idle quotas into market transactions; establish a market maker system in the quota secondary market, encourage financial institutions to participate in bilateral quotation of quotas, and improve the activity of market transactions; support cross-regional quota circulation and replacement, break regional market segmentation, expand the scale of quota transactions, and further release market liquidity.

5.4.4 Strengthen the Supervision and Restraint of Quota Allocation and Use

Relying on the carbon market registration system and trading platform, build a full-process dynamic monitoring system for quota “allocation-holding-circulation-cancellation”, and track the flow of quotas and changes in positions in real time. Focus on monitoring abnormal behaviors such as centralized holding and frequent transfer of large amounts of quotas, and take disciplinary measures such as restricting subsequent quota allocation, levying quota idle taxes and fees, and public notice and criticism against enterprises that maliciously hoard quotas and manipulate market supply and demand; for enterprises that

defraud quotas by falsely declaring production data, recover the illegally obtained quotas and impose heavy fines to maintain a fair market order.

6. Conclusions and Prospects

6.1 Conclusions

Under the background of China's vigorous promotion of the "Dual Carbon" strategy, the demand for carbon market risk governance is becoming increasingly urgent. Based on this, this paper focuses on this demand and deeply explores the empowerment logic and specific practical paths of accounting tools in it, and draws the following conclusions:

The stable operation of the carbon market is restricted by four types of core risks. First, market manipulation and price fluctuations damage the fairness and impartiality of carbon pricing and cause sharp fluctuations in the value of carbon assets held by enterprises. Second, risks in data quality and integrity weaken the credibility of carbon market transactions and make it difficult for regulatory authorities to intervene effectively. Third, policy arbitrage and carbon leakage lead to unfair competition and offset the original emission reduction effects. Fourth, unreasonable quota allocation and imbalance lead to resource misallocation and thus inhibit market liquidity. These four types of risks are intertwined and jointly affect the normal play of the carbon market's resource allocation function.

Accounting tools can build a governance system covering the whole chain of carbon market risks. Specifically, fair value measurement and hedge accounting can be used to effectively stabilize carbon price fluctuations; carbon accounting information systems and audit supervision mechanisms can be relied on to strengthen the management and control of credit risks; policy tracking and accounting adaptation can be used to buffer the impact of policy changes; risk transfer can be realized by accruing risk reserves and innovating carbon financial tools.

On the whole, the empowerment value of accounting tools is reflected in many aspects. For market entities, it can provide feasible risk control schemes to help enterprises operate steadily on the road of low-carbon transformation. From the perspective of governance mode, accounting tools can promote the transformation and upgrading of the carbon market governance mode from "administrative-led" to "tool empowerment + regulatory coordination", and provide strong support for regulatory authorities to optimize relevant rules. At the theoretical research level, it can not only fill the research gap on the value of accounting tools in carbon market risk governance and enrich the content of interdisciplinary theories, but also expand the application boundary of environmental management accounting, laying a solid foundation for the standardized operation of the carbon market under the "Dual Carbon" goals.

6.2 Prospects

In the future, the research can be further explored from the following three directions: at the theoretical level, an interdisciplinary perspective can be introduced to deeply analyze the correlation and transmission paths between various risks in the carbon market, further clarify the functional differences of different accounting tools, and gradually build a more targeted risk governance toolbox, thus enriching the existing theoretical framework; in practical application, the combination of accounting tools and new technologies such as blockchain and artificial intelligence should be promoted to continuously optimize risk measurement and control methods. At the same time, the industry characteristics and regional differences should be considered to formulate more targeted implementation plans and enhance the applicability of the tools; in terms of policy coordination, it is necessary to explore the connection mechanism between accounting tools and carbon market regulatory policies, make it adapt to the development of international rules such as the Carbon Border Adjustment Mechanism, and improve the accounting standards for carbon financial derivatives, so as to expand the application scope of accounting tools in risk governance and provide strong support for the high-quality development of the carbon market.

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Reference

- [1] Perdan, S., & Azapagic, A. (2011). Carbon trading: Current schemes and future developments. *Energy Policy*, 39(10), 6040–6054.
- [2] Zhang, D., Karplus, J. V., Cassisa, C., & Zhang, X. (2014). Emissions trading in China: Progress and prospects. *Energy Policy*, 70, 759–771.
- [3] Wu, W. (2024). Cost stickiness, relational transactions and corporate environmental accounting information disclosure. *Communication of Finance and Accounting*, (01), 50–54.
- [4] Han, Z. Q., & Han, R. X. (2018). A literature review of environmental management accounting research in China. *Finance and Accounting Monthly*, (21), 119–126.
- [5] Zheng, Q., & Liu, C. Y. (2021). Research on environmental management accounting under the ESG system – Taking Ping An Insurance (Group) Company of China, Ltd as an example. *Commercial Accounting*, (23), 26–29.
- [6] Wang, Q. L. (2025). Research on environmental management accounting embedded with ESG. *Communication of Finance and Accounting*, (03), 163–169.
- [7] Yan, F. H., Dang, X., & Yan, W. H. (2007). Review of the development course and trend of risk management. *Modernization of Management*, (02), 30–33.
- [8] Zhang, X. C., Wei, H. L., & Deng, D. S. (1985). A preliminary study on risk management. *Jiangnan Tribune*, (12), 19–23.
- [9] Huang, J. (2018). Research on the evolution and development of COSO internal control framework. *Auditing Monthly*, (04), 38–40.
- [10] Yang, Y. F. (2016). Application of enterprise internal control theory in social insurance fund management. *China Collective Economy*, (28), 41–42.
- [11] Chai, S. L., & Du, M. (2021). Carbon emission rights trading market risk measurement and management. China Financial and Economic Publishing House.
- [12] Wipplinger, E. (2007). Philippe Jorion: Value at risk – The new benchmark for managing financial risk. *Financial Markets and Portfolio Management*, 21(3), 397–398.
- [13] Zhao, L. X., & Hu, C. (2016). Research on the influencing factors of China's carbon emission rights trading price – An empirical analysis based on structural equation model. *Price Theory and Practice*, (07), 101–104.
- [14] Zhu, Y. Z., Chen, H. X., & Zhao, Z. M. (2013). Research on carbon trading pricing based on B-S pricing model. *Science & Technology Progress and Policy*, 30(05), 27–30.
- [15] Liu, C. Z., Pan, A. L., & Xie, D. Y. (2014). Policy suggestions for improving the carbon emission accounting system of Chinese enterprises. *Economic Review*, (11), 67–71.