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Can green credit promote the synergy of carbon reduction and efficiency improvement in enterprises?—The transmission mechanism and contextual effect of green technology innovation

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Abstract. Against the background of the "Dual Carbon" goal, enterprises, as the key subjects of economic growth and carbon emission reduction, face the challenge of realizing the coordinated development of environmental performance and economic benefits. Green technology innovation is the core path to resolve the contradiction between "growth and emission reduction", but its features of high input and high risk leave enterprises insufficient motivation. As an important policy tool, green credit provides impetus for enterprises' green transformation through financial support and incentive-restraint mechanisms. Based on the data of listed companies in China's power industry from 2010 to 2021, this paper constructs a theoretical framework of "green credit—green technology innovation—synergy of carbon reduction and efficiency improvement", and verifies the positive effect of green credit on enterprises' carbon reduction and efficiency synergy as well as its functioning mechanism through empirical analysis. The study finds that green credit can significantly improve enterprises' level of green technology innovation, and further promote the synergy of carbon reduction and efficiency improvement; green technology innovation plays a vital intermediary role between green credit and enterprises' carbon reduction-efficiency synergy; the positive effect of green credit varies notably under different internal and external contexts, such as internal governance level. The conclusions of this paper not only expand the theoretical boundary in the fields of green finance and technological innovation, but also provide practical reference for the government to optimize green credit policies and for enterprises to formulate low-carbon strategies.

Keywords: carbon emission, green credit, green technology innovation, synergy of carbon reduction and efficiency improvement, internal governance level

1. Introduction

On September 22, 2020, Xi Jinping, President of the People's Republic of China, put forward the "Dual Carbon" goal of "carbon peaking by 2030 and carbon neutrality by 2060", marking the full transition of China's economic and social development mode toward green and low-carbon development [1]. As the main body of economic activities, enterprises are both the core contributors to economic growth and the key parties responsible for carbon emission reduction. How to realize the coordinated development of environmental performance and economic benefits through green transformation has become a vital direction for the sustainable development of enterprises. Green technology innovation in enterprises is regarded as the core path to resolve the contradiction between "growth and emission reduction" due to its dual externality, yet its long cycle, high input and high risk expose enterprises to the dual challenges of insufficient motivation and limited capacity. On this basis, the green credit policy provides important impetus for enterprises' green transformation through targeted financial support and incentive-restraint mechanisms. As the core driving force for green transformation, green technology innovation can help enterprises reduce carbon emission intensity, optimize resource utilization efficiency, and meanwhile enhance market competitiveness and financial performance, serving as a key breakthrough to address the lack of motivation for enterprises' green innovation.

Since the Industrial Revolution, the surge of global greenhouse gas emissions has accelerated the imbalance of the global climate system [2]. Under the "Dual Carbon" goal, how to achieve green transformation concerns the long-term development of enterprises. As a critical approach to advancing enterprises' green transformation, green technology innovation is an effective measure for enterprises to achieve a "win-win" outcome of economic benefits and environmental protection [3]. Existing studies mostly discuss the role of green finance in boosting the low-carbon economy from a policy perspective, such as the emission reduction effect of macro policies like carbon emission trading pilots [4] and green finance reform [5]. At the micro level, scholars focus on the roles of mechanisms such as enterprises' internal carbon pricing [6] and clean technology investment in carbon reduction and efficiency improvement. Notably, both macro and micro studies emphasize the core position of green technology innovation in realizing the synergy of carbon reduction and efficiency improvement [7-9]. However, green technology innovation has dual externality [10], and there has not been a systematic analysis of the transmission mechanism of how green credit promotes the synergy of enterprises' carbon reduction and efficiency improvement by supporting green technology innovation. Green credit is a type of financial policy: banks and other financial institutions provide loan support for projects in green industrial sectors such as energy conservation and environmental protection, clean production, clean energy, ecological environment and green upgrading of infrastructure in accordance with national environmental protection and industrial policies. In addition, the effect of green credit may present heterogeneity due to differences in enterprises' internal and external contexts [11], such as the nature of property rights, governance level and market competition intensity, all of which call for in-depth discussion.

Most existing literature studies the synergy of carbon reduction and efficiency improvement at the national and regional levels from a macro perspective [12, 13], while few works examine enterprises' carbon reduction and efficiency improvement from the micro perspective of listed enterprises in the power industry. Therefore, this paper takes A-share listed enterprises in China's power industry from 2010 to 2021 as samples, constructs a theoretical framework of "green credit—green technology innovation—synergy of carbon reduction and efficiency improvement", and focuses on the following questions: First, can green credit significantly improve the level of enterprises' green technology innovation? Second, does green technology innovation play an intermediary role between green credit and the synergy of carbon reduction and efficiency improvement? Third, do the positive effects of green credit differ significantly under different internal contexts? The research conclusions can not only expand the theoretical boundary in the fields of green finance and technological innovation, but also provide practical reference for the government to optimize green credit policies and for enterprises to formulate low-carbon strategies.

2. Literature review

2.1. Policy effects and micro impacts

Green credit refers to preferential loans provided by financial institutions to low-carbon projects in accordance with environmental standards. Its core goal is to guide capital flow to green industries through differentiated interest rates and credit quotas. Early studies focused on the macro emission reduction effect of green credit. For example, Zheng Ye found that green finance reform significantly reduced the unit GDP energy consumption of pilot cities [14]. At the micro level, scholars have gradually paid attention to the regulatory effect of green credit on enterprise behavior. Wang Haijie et al. pointed out that green credit can encourage enterprises to increase investment in environmental protection equipment by alleviating financing constraints [15]; Li Jicheng et al. further proved that green credit exerts a "forced effect" on the technological innovation of high-pollution enterprises, meaning that under the pressure of environmental regulation, enterprises tend to reduce compliance costs through innovation [16]. However, existing literature has not reached a consensus on the direct correlation between green credit and green technology innovation. Some studies hold that the short-term profit-seeking nature of credit funds may weaken its support for long-term innovation.

2.2. Dual effects and driving factors of green technology innovation

Green technology innovation can advance the coordinated progress of economic growth and environmental improvement, and realize the benign interaction between carbon reduction and efficiency improvement [17]. Nevertheless, green technology innovation also has certain negative effects. For instance, its high R&D cost and high risk may damage enterprises' short-term economic benefits, and the market's limited recognition and acceptance of green technologies will hinder their popularization and application. The driving factors of green technology innovation include policy impetus, market demand, technological progress and internal enterprise factors. Among them, green credit exerts a significant impact on green technology innovation [18]. On the one hand, the implementation of green credit policy has notably increased the number of green innovations in industries restricted by green credit, which benefits from its role in reducing agency costs and improving investment efficiency. On the other hand, with the strengthening of regional environmental law enforcement, the role of green credit policy in promoting green innovation is enhanced.

2.3. Measurement and realization path of carbon reduction-efficiency synergy

The synergy of carbon reduction and efficiency improvement emphasizes the simultaneous realization of lower carbon emission intensity and better financial performance, and its core lies in breaking the binary opposition between "environmental protection and growth". Scholars quantify the coordination level of the two aspects through the coupling coordination degree model, and find that green technology innovation is the key bridge connecting environmental performance and economic performance. For example, Pan Ying et al. confirmed that the new energy demonstration city policy has significantly improved enterprises' carbon reduction efficiency and profitability by promoting technological iteration [19]. However, most existing literature carries out analysis from the perspective of macro policies or internal management, and lacks systematic research on how financial tools such as green credit empower carbon reduction and efficiency improvement. Existing studies lay an important foundation for understanding the relationship between green credit, green technology innovation and the synergy of carbon reduction and efficiency improvement [20], but there are still the following deficiencies: First, the specific path of green credit affecting enterprises' green technology innovation remains unclear, and its mechanism needs to be further analyzed from the dual perspectives of financial support and incentive-restraint. Second, the intermediary effect of green technology innovation lacks empirical testing, especially the discussion on multi-link (energy, production, sales, recycling) action chains. Third, research on the heterogeneity effect of green credit is insufficient, and the regulatory role of enterprises' internal and external contexts needs to be revealed. This paper attempts to fill the above research gaps by constructing an integrated theoretical framework and conducting empirical tests.

3. Theoretical analysis and research hypotheses

3.1. Green credit improves enterprises' green technology innovation level

Green technology innovation faces the dual constraints of capital shortage and risk aversion [21], while green credit can effectively address these two problems by providing low-cost capital and strengthening environmental constraints.

From the perspective of financial support, green credit enhances enterprises' innovation motivation through two mechanisms: First, targeted financing reduces innovation costs. Green credit usually provides loans for environmental protection projects at interest rates lower than the market level, directly easing enterprises' pressure on R&D funds [22]. For example, photovoltaic enterprises can accelerate the commercial application of photovoltaic cell efficiency improvement technologies by obtaining low-interest loans through green credit. Second, long-term capital ensures the sustainability of innovation. Green technology innovation has a long return cycle, and traditional credit tends to support short-term profitable projects, while green credit provides stable cash flow support for enterprises by extending repayment terms and flexibly adjusting repayment methods.

From the perspective of incentive-restraint, green credit forms a "carrot and stick" effect on enterprises by linking environmental performance assessment with credit conditions. On the one hand, enterprises with excellent environmental performance can obtain higher credit lines and interest rate discounts, which incentivizes them to continuously invest in green R&D; on the other hand, high-pollution enterprises that fail to meet standards will face the risk of credit tightening or even loan cutoff, which forces them to achieve emission reduction through technological innovation.

In addition, the signal transmission function of green credit cannot be ignored. Enterprises that obtain green credit are more likely to be recognized as "environmentally friendly" entities by the outside world, thus attracting support from stakeholders such as strategic investors and green consumers, and further expanding channels for acquiring innovation resources. Based on the above analysis, this paper puts forward the hypothesis:

H1: Green credit can significantly improve the level of enterprises' green technology innovation.

3.2. Green technology innovation promotes enterprises' carbon reduction-efficiency synergy

Green technology innovation synchronously reduces carbon emission intensity and improves financial performance by optimizing production processes, improving resource efficiency and expanding green markets.

In the energy supply link, the application of clean energy technologies (such as wind power and energy storage systems) reduces fossil energy consumption and cuts carbon emissions at the source. Meanwhile, improved energy efficiency directly reduces enterprises' energy costs. For example, iron and steel enterprises can reduce energy consumption by 15% to 20% through waste heat recovery technology, significantly widening profit margins.

In the production and manufacturing link, green process innovation (such as low-carbon metallurgy and biodegradable materials) reduces waste emissions in the production process, and improves capacity utilization through automation and intelligent transformation. Taking the papermaking industry as an example, chlorinefree bleaching technology can not only reduce dioxin emissions, but also lower chemical procurement costs, achieving a win-win outcome of environmental and economic benefits.

In the product sales link, green products occupy emerging markets through differentiated positioning. For instance, new energy vehicles have gained policy subsidies and consumer favor for their low-carbon attributes, and the rapid expansion of their market share has driven the growth of enterprise revenue. In addition, green certification and labeling can create a premium effect and further improve product profit margins.

In the recycling and treatment link, carbon capture and resource utilization technologies convert carbon dioxide into industrial raw materials (such as methanol and building materials), which both reduces emissions and creates new income sources. Some enterprises obtain additional revenue by selling carbon quotas, which feeds back the development of core businesses. Through the synergistic effect of multiple links, green technology innovation helps enterprises realize the coupled development of "carbon reduction" and "efficiency improvement". Accordingly, the hypothesis is proposed:

H2: Green technology innovation significantly promotes the synergy of enterprises' carbon reduction and efficiency improvement.

3.3. Green credit achieves carbon reduction-efficiency synergy through green technology innovation

The financial support and incentive-restraint functions of green credit provide necessary resources and institutional guarantees for enterprises' green technology innovation. As a key medium, green technology innovation transforms external financial resources into internal technological capabilities, and ultimately promotes the coordinated realization of carbon reduction and efficiency improvement. Specifically, green credit plays its role through the following paths:

First, it alleviates financing constraints. Green credit lowers the capital threshold for innovation projects, enabling enterprises to undertake high-risk and long-cycle R&D activities. For example, chemical enterprises use green credit to invest in the R&D of catalytic cracking technology, which significantly reduces the carbon emission intensity in the oil refining process and increases added value through the deep processing of by-products. Second, it strengthens environmental responsibility. The evaluation mechanism of green credit binds enterprises' environmental performance with financing costs, prompting management to incorporate emission reduction targets into strategic decision-making. For example, to meet green credit standards, thermal power enterprises proactively introduce ultra-low emission technologies to reduce their carbon footprint while improving power generation efficiency.

Third, it optimizes resource allocation. Green credit guides capital to flow to high-efficiency innovation projects to avoid resource waste. For example, textile enterprises prioritize upgrading printing and dyeing equipment through green credit, phasing out high energy-consuming production capacity, and realizing the simultaneous decline of carbon emission intensity and unit cost.

Based on the above logical chain, green credit indirectly promotes the synergy of enterprises' carbon reduction and efficiency improvement by improving the level of green technology innovation. Therefore, the hypothesis is put forward:

H3: Green credit can promote the synergy of enterprises' carbon reduction and efficiency improvement, and green technology innovation plays an intermediary role in this process.

In summary, the theoretical analysis framework constructed in this paper is shown in Figure 1.

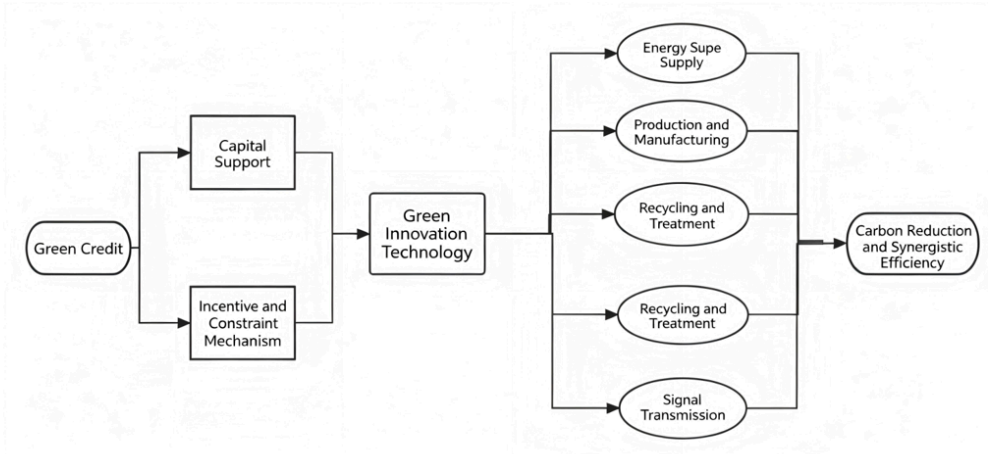

Figure 1. Theoretical framework

4. Research design

4.1. Mann-Kendall trend analysis method

Mann-Kendall trend analysis is a non-parametric statistical test method widely used in hydrology, climatology, chemical and mineral composition testing and other fields [23]. This method is suitable for analyzing whether time series data have a significant trend. The Mann-Kendall test is based on the rank of data rather than the data values themselves, and judges whether the data shows an upward or downward trend by calculating the statistic *S*. Applying the Mann-Kendall trend test to analyze the trend and characteristics of carbon peaking in resource-based cities can provide support for policy formulation on energy transformation, climate goal setting and regional carbon emission reduction measures [24]. Its advantage is that it does not require data to follow a specific distribution (such as normal distribution), and is not affected by outliers and missing values, making it suitable for significance testing of long time series data [25]. Therefore, it is evidently applicable to research on issues related to urban carbon emission peaking. According to the Mann-Kendall trend analysis model, the calculation formula of S is formula (1):

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(X_j - X_k) \tag{1}$$

where S is the sign function. After calculating S , the test statistic Z is obtained through standardization. The formula is as follows: The null hypothesis of the Mann-Kendall test is that there is no significant trend in the data, and the alternative hypothesis is that the data shows an upward or downward trend. At a given significance level α, the critical value is obtained by checking the normal distribution table. If the condition is satisfied, the null hypothesis is rejected and the trend is considered significant.

When the sample size $n \geq 8$, S follows a normal distribution with a mean of 0, and its variance is formula (2):

$$V(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{g} t_i(i-1)(2i+5)}{18} \tag{2}$$

In the two-sided test, given the confidence level α, if $Z_{mk} > Z_{1-a/2}$, the null hypothesis *H*0 is rejected, indicating that at the α confidence level, the sample data shows an obvious time series trend. For confidence levels of 90%, 95% and 99%, the significance level is reached when Z_{mk} is greater than or equal to 1.64, 1.96

and 2.57 respectively. The magnitude of the time series trend can be described by the index β, which shows in formula (3):

$$\beta = Median(\frac{X_i - X_j}{i-j}), \forall j < i \tag{3}$$

where $Median()$ is the median function, satisfying $1 < j < i < n$. When $\beta > 0$, the sample data shows an upward trend; when $\beta < 0$, the sample data shows a downward trend. The selection of confidence level α is based on sample size: for small samples (tens of samples), $\alpha = 0.05$ is optional; for large samples (hundreds of samples), $\alpha = 0.01$ is recommended; for very large samples (thousands or more), $\alpha = 0.001$ or smaller can be selected.

4.2. Construction of econometric model

4.2.1. Benchmark regression model

To verify the impact of green credit on the synergy of enterprises' carbon reduction and efficiency improvement, the following benchmark regression model is constructed in formula (4):

$$Y_{it} = \alpha_0 + \alpha_1 TEXEC_{it} + \sum c_i Control_{it-1} + IndustryDums + YearDums + \varepsilon_{it} \tag{4}$$

Model description: In this model, the explained variable (Y_{it}) is replaced by carbon emission intensity (INT_{it}), financial performance ($EPER_{it}$) and coordination degree of carbon reduction and efficiency improvement (CCD_{it}) in specific regressions.

Hypothesis setting: According to the previous theoretical analysis, green credit can reduce enterprises' carbon emission intensity, improve financial performance, and promote enterprises to achieve the synergy of carbon reduction and efficiency improvement. Therefore, when the explained variable is carbon emission intensity (INT_{it}), α_1 is expected to be negative; when the explained variables are financial performance ($EPER_{it}$) and coordination degree of carbon reduction and efficiency improvement (CCD_{it}), α_1 is expected to be positive.

4.2.2. Intermediary effect test model

Considering the diversity of intermediary effect tests, this paper adopts the two-step method to test the intermediary role of green technology innovation. Step 1: The impact of green credit on green technology innovation shows in formula (5):

$$GRD_{it} = \beta_0 + \beta_1 TEXEC_{it} + \sum d_i Control_{it-1} + IndustryDums + YearDums + \varepsilon_{it} \tag{5}$$

Step 2: The impact of green technology innovation on the synergy of enterprises' carbon reduction and efficiency improvement shows in formula (6):

$$Y_{it} = \gamma_0 + \gamma_1 GRD_{it} + \sum e_i Control_{it-1} + IndustryDums + \varepsilon_{it} \tag{6}$$

Model description: The intermediary variable (GRD_{it}) is enterprises' green technology innovation, measured by the natural logarithm of the number of authorized green patents plus 1. Green technology innovation is the core driving force for enterprises to achieve green transformation and sustainable development, which can effectively reduce carbon emission intensity and improve financial performance. First-step regression: test the impact of Green Credit (GreenCreditit) on enterprises' green technology innovation (GRD_{it}). If β_1 is significantly positive, it indicates that green credit can promote enterprises' green technology innovation. Second-step regression: test the impact of green technology innovation (GRD_{it}) on the synergy of enterprises' carbon reduction and efficiency improvement ($INT_{it}, EPER_{it}, CCD_{it}$). If γ_1 is significantly negative (when $Yit = INTit$) $Y_{it} = INT_{it}$ or significantly positive (when

$Y_{it} = EPER_{it}$ *or* CCD_{it}), it indicates that green technology innovation plays an intermediary role between green credit and the synergy of enterprises' carbon reduction and efficiency improvement.

Through the above two-step test, the intermediary mechanism of green technology innovation between green credit and the synergy of enterprises' carbon reduction and efficiency improvement can be clearly revealed.

4.3. Variable setting and analysis

4.3.1. Explained variables

(1) Carbon Emission Intensity (INT): To measure enterprises' carbon emission intensity, the ratio of enterprises' carbon dioxide emissions to their operating income is adopted as the indicator. Carbon emission intensity is the product of enterprises' operating income and enterprises' carbon dioxide emissions. Among them, enterprises' carbon dioxide emissions are calculated as the product of enterprises' operating costs, industry operating costs, total industry energy consumption and carbon dioxide conversion coefficient.

In the above calculation, the carbon dioxide conversion coefficient is converted and calculated based on the carbon dioxide emission coefficient recommended by the Energy Research Institute of the National Development and Reform Commission, which has been widely recognized in academic research [26]. This calculation method can estimate enterprises' carbon dioxide emissions relatively accurately, and thus reasonably measure enterprises' carbon emission intensity. The carbon emission intensity indicator reflects the carbon dioxide emission level corresponding to unit operating income in enterprises' production and operation. The lower the indicator, the less carbon emissions an enterprise generates while achieving the same operating income, and the stronger its low-carbon development capacity.

(2) Financial Performance (EPER): For the measurement of enterprises' financial performance, this paper refers to the research of Xie Xuemei and Zhu Qiwei [27], and selects return on total assets as the indicator. Return on total assets is a commonly used indicator to measure the overall profitability of enterprise assets, which can comprehensively reflect enterprises' ability to generate returns using all assets. It is calculated as the ratio of enterprises' investment returns to total investment. Through this indicator, we can intuitively understand the return level created by each unit of assets of an enterprise within a certain period, so as to effectively evaluate its financial performance. Enterprises with sound financial performance usually have stronger profitability and asset operation efficiency, which is of great significance for enterprises to achieve sustainable development and maintain advantages in market competition.

(3) Coordination Degree of Carbon Reduction and Efficiency Improvement (CCD): To measure the coupling coordination degree between enterprises' carbon reduction and efficiency improvement, this paper refers to the research of Zhao Yan et al. and adopts the coupling coordination degree model for calculation [7]. The coupling coordination degree model can comprehensively consider the development level of enterprises' carbon reduction and efficiency improvement as well as their mutual relationship, so as to reflect the coupling coordination degree between the two relatively accurately. The specific calculation shows in formulas (7), (8), and (9):

$$C = 2 * \left(\frac{INT\_S * EPER\_S}{(INT\_S + EPER\_S)} \right)^{1/2} \tag{7}$$

$$T = \alpha INT\_S + \beta EPER\_S \tag{8}$$

$$D = C \times T \tag{9}$$

where T is the comprehensive coordination index, C is the coupling degree, and D is the coordination degree of carbon reduction and efficiency improvement; u_i and v_j are the indicator values of the carbon reduction system and the efficiency improvement system respectively; α and β are the weight coefficients of the carbon reduction system and the efficiency improvement system respectively. In this study, considering that carbon reduction and efficiency improvement are equally important for enterprises, both α and β are set to 0.5.

The coordination degree of carbon reduction and efficiency improvement reflects the balanced development level of enterprises between the two goals of carbon reduction and efficiency improvement. A higher indicator means that enterprises achieve better financial performance while meeting carbon reduction targets, the coupling coordination degree between carbon reduction and efficiency improvement is higher, and enterprises' development mode is more in line with the requirements of sustainable development.

In the above calculation process, to ensure the comparability of each indicator value, this paper performs range standardization on carbon emission intensity (INT) and financial performance ($EPER$), obtaining standardized carbon emission intensity (INT_S) and standardized financial performance ($EPER\_S$) respectively. Range standardization is a common dimensionless data processing method, which can convert indicator values of different dimensions and magnitudes into the same magnitude range, so as to avoid unreasonable impact on the calculation results of coupling coordination degree caused by excessive differences in indicator values. This processing method enables more scientific and reasonable calculation of enterprises' coordination degree of carbon reduction and efficiency improvement, and provides a reliable data basis for subsequent empirical analysis.

4.3.2. Explanatory variable

Green credit means that financial institutions (mainly banks) give priority to supporting projects and enterprises in fields such as environmental protection, energy conservation, clean energy, clean transportation, green buildings and resource recycling in credit activities, while restricting capital support for projects and enterprises that fail to meet environmental protection requirements, such as those with high pollution and high energy consumption. Green credit is not only an important means of financial support for environmental protection industries, but also a vital tool to promote enterprises' green transformation and sustainable development [21].

Green credit provides necessary financial support for listed companies in the power industry, helping them carry out green technology R&D, equipment renewal and project implementation. For example, enterprises can use green credit funds to purchase advanced energy-saving and emission-reduction equipment and develop new energy technologies, so as to improve their green technology level. Green credit support helps enterprises expand production scale, realize the industrial application of green technologies, and further enhance their market competitiveness.

Green credit is usually accompanied by lower interest rates and more favorable loan terms, which incentivizes enterprises to actively adopt green technologies and processes to meet the green credit standards of financial institutions. When issuing green credit, financial institutions will supervise and evaluate enterprises' environmental performance and the implementation of green projects. This restraint mechanism prompts enterprises to pay more attention to the quality and effect of green development.

Therefore, this paper measures the level of enterprises' green credit by dividing the total amount of enterprises' green credit by the total amount of enterprises' credit.

4.3.3. Control variables

In empirical research, the selection of control variables is crucial to ensuring the accuracy and reliability of research results. Control variables help eliminate the interference of other potential factors on research results, making the research more focused on the relationship between the explanatory variable (green credit) and the explained variables (such as coordination degree of carbon reduction and efficiency improvement). See column (2) of Table 1 for the control variables.

(1) Enterprise Size (SIZE): Enterprise size is an important indicator measuring enterprises' operation scale and market influence. In this study, Enterprise Size (SIZE) is measured by the natural logarithm of enterprises' total assets. The natural logarithm of total assets can effectively reflect enterprise size, and avoid the heteroscedasticity problem caused by excessive differences in enterprise size [26]. Enterprise size may affect enterprises' ability to obtain green credit, their level of green technology innovation and financial performance, so it is included as a control variable.

(2) Asset-Liability Ratio (LEV): Asset-liability ratio is an important indicator measuring enterprises' financial leverage and solvency, calculated as total liabilities divided by total assets. It reflects the proportion of enterprises' debt financing. A high asset-liability ratio may mean that enterprises face high financial risks, which may affect their ability to obtain green credit and their investment in green technology innovation. Therefore, the asset-liability ratio is taken as a control variable to exclude its potential impact on research results.

(3) Listing Age (AGE): Listing age refers to the number of years since an enterprise was listed, reflecting its maturity and experience in the capital market. Enterprises with longer listing age may have advantages in resource acquisition, market recognition and technological innovation capability. In this study, listing age is included as a control variable to exclude its potential impact on green credit, green technology innovation and financial performance.

(4) Enterprise Growth (GROW): Enterprise growth is an important indicator measuring enterprises' future development prospects. In this study, enterprise growth is measured by the growth rate of operating income, calculated as the difference between current operating income and previous operating income divided by the previous operating income. The growth rate of operating income reflects the speed of enterprises' business expansion within a certain period. A higher growth rate may indicate stronger market competitiveness and innovation capability. Taking enterprise growth as a control variable can exclude its potential impact on green credit and enterprise performance.

(5) Ownership Concentration (FIRST): Ownership concentration refers to the shareholding ratio of the largest shareholder, reflecting the concentration degree of an enterprise's ownership structure. High ownership concentration may mean more centralized enterprise decision-making, but may also bring agency cost problems. In this study, ownership concentration is taken as a control variable to exclude its potential impact on green credit acquisition, green technology innovation and financial performance.

(6) Proportion of Independent Directors (INDB): The proportion of independent directors refers to the share of independent directors on the board, reflecting the effectiveness of the corporate governance structure. A higher proportion of independent directors may help improve corporate governance and enhance enterprises' utilization efficiency of green credit and investment in green technology innovation. In this study, the proportion of independent directors is included as a control variable to exclude its potential impact on research results.

(7) Duality of Leadership (DUAL): Duality of leadership refers to whether the chairman and the general manager of an enterprise are held by the same person.

Duality of leadership may affect enterprises' decision-making efficiency and the effectiveness of the supervision mechanism [27]. In this study, duality of leadership is set as a dummy variable, taking the value 1 when the chairman and general manager are the same person, and 0 otherwise. Taking it as a control variable can exclude its potential impact on green credit and enterprise performance.

Table 1. Variable description

Variable Type	Variable Name	Symbol	Explanatory Variable
Explained variables	Carbon emission intensity,	INT	The carbon emission intensity per unit cost of an enterprise
	Financial performance	EPER	The return on total assets = Net profit / Total assets
	Coordination degree of carbon reduction and efficiency improvement	CCD	
Explanatory variable	Green credit	CRD	Enterprise green loans / Total enterprise loans
Control variables	Enterprise size	SIZE	Natural logarithm of total assets
	Asset-liability ratio	LEV	Total liabilities / Total assets
	Listing age	AGE	Statistical year minus listing year plus 1
	Enterprise growth	GROW	Operating income growth / Total operating income of last year
	Ownership concentration	FIRST	Shareholding ratio of the largest shareholder
	Proportion of independent directors	INDB	Number of independent directors / Total number of board members
	Duality of leadership	DUAL	1 if chairman and general manager are the same person, 0 otherwise
	Nature of property rights	NATURE	1 for state-owned enterprises, 0 otherwise

(8) Nature of Property Rights (NATURE): The nature of property rights refers to the ownership form of enterprises, including state-owned enterprises, private enterprises and foreign-funded enterprises. Enterprises with different property rights may differ in obtaining green credit, investing in green technology innovation and financial performance. In this study, the nature of property rights is set as a dummy variable, with 1 for state-owned enterprises and 0 for private enterprises. Taking it as a control variable can exclude its potential impact on research results.

4.4. Data source and processing

4.4.1. Data source

In today's data-driven era, data quality and reliability play a vital role in the accuracy and credibility of research results. In the research process, this paper selects some listed companies in China's power industry from 2010 to 2021 as the initial sample, and follows a rigorous screening process to ensure that the final data used for analysis is highly representative and applicable.

Samples with abnormal trading status (ST, PT) are excluded. This is because such enterprises may have potential problems in key aspects such as strategic planning, capital flow stability and information authenticity, which may interfere with the normal progress of the research and the accuracy of results. In addition, samples with total assets less than total liabilities are also excluded, because such enterprises are in a state of insolvency with operating conditions seriously deviating from the normal track, and their relevant data may not reflect the normal development of the industry, thus negatively affecting the universality of research conclusions. Samples with missing key data are also excluded. After all, complete and accurate data is the foundation for in-depth analysis and reliable conclusions.

To further improve data quality and avoid the adverse impact of occasional extreme values in data collection and sorting on the accuracy of empirical results, winsorize processing at the upper and lower 1% quantiles is applied to all continuous variables. This method can effectively reduce the interference of extreme values while retaining the main characteristics of the data, making the research results more robust.

In terms of data sources, a diversified strategy is adopted to ensure the comprehensiveness and authority of data. The main data sources include *China Energy Statistical Yearbook* and the National Bureau of Statistics. With their long-term accumulated rich data and rigorous statistical methods, these platforms provide a macro overview of industrial economy and energy development. Meanwhile, full use is made of professional database resources such as China Research Data Service Platform (CNRDS), WinGo Financial Text Data Platform and CSMAR Database. These databases cover multi-dimensional information from corporate financial data to industry dynamics and policies and regulations, laying a solid data foundation for this research. Through the rational integration and utilization of these data sources, we are confident to build a high-quality and high-precision dataset for this study, so as to provide strong support for in-depth exploration of relevant research issues.

4.4.2. Data preprocessing

Data preprocessing is a key step to ensure the accuracy and reliability of data analysis results. This study carries out systematic preprocessing on the relevant data of listed companies, mainly including two links: data cleaning and data standardization.

Data cleaning aims to remove noise and impurities in the data to ensure data integrity and consistency. Missing data is a common problem, especially in small and medium-sized enterprises or reports with incomplete disclosure. In this study, for records with little missing data, relevant samples are directly deleted to avoid deviation of analysis results and ensure the accuracy of data analysis.

For key indicators with much missing data, interpolation method or filling method based on industry average is adopted. For missing energy consumption data, the average value of other enterprises in the same industry is used for filling to ensure data integrity.

The purpose of data standardization is to unify data from different sources, formats and units into a standard range for comparison and analysis. To ensure consistent format of all data, SPSS data analysis software is used to convert all data into numerical format, and remove extra spaces or special characters. Secondly, energy consumption data is uniformly converted into tons of standard coal (tce) or kilowatt-hours (kWh), and carbon emission data is uniformly converted into Carbon Dioxide equivalent (CO_2e), so that all data is in unified units.

5. Analysis of empirical results

5.1. Analysis of carbon emission trend of power enterprises

According to the Mann-Kendall trend test results in Table 1, it can be concluded that all types of emissions show an upward trend, but there are obvious differences in the growth rate and significance. Among them, the total carbon emissions of listed companies and combustion energy emissions have the most significant trend

(Z = 0.735), while production process emissions and land use emissions have relatively weaker trends (Z = 0.245), and combustion and energy fuel emissions are the largest in volume (β = 16.97). Energy-related emissions (combustion, waste) show a significant trend, while production process emissions and land use emissions show a weak trend. It is suggested to implement differentiated management and control: carry out key supervision on energy emissions with significant growth, and maintain monitoring on production process emissions with weak growth. Meanwhile, take the β value as reference, set classified emission reduction targets, pay special attention to emissions with an average annual growth of more than 100,000 tons, and establish an emission trend early warning system.

It can be seen from the data in column (5) of Table 2 that the total carbon emissions of listed companies in the power industry show an obvious upward trend, and various emission indicators including combustion and energy fuel emissions, production process emissions, waste emissions and land use change emissions are increasing year by year. In particular, fuel and energy fuel emissions see the most significant upward trend, and are expected to grow at a rate of about 160,000 tons per year. This continuous increase in carbon emissions has brought huge pressure for emission reduction to the power industry, and also posed severe challenges to the realization of the "Dual Carbon" goal.

Table 2. Mann-Kendall trend test results

Category	S	V(S)	Z	β	Trend
Total carbon emissions of listed companies (10,000 tons)	4	4.0824	0.7348	26.1980	Upward trend
Combustion and energy fuel emissions	4	4.0824	0.7348	16.9746	Upward trend
Production process emissions	2	4.0824	0.2449	2.0276	Upward trend
Waste emissions	4	4.08248	0.7348	4.1771	Upward trend
Land use change emissions	2	4.0824	0.2449	3.0202	Upward trend

Against this background, as an important policy tool, green credit can provide financial support for enterprises and help them carry out green technology innovation. With the support of green credit, enterprises can increase R&D investment in fields such as energy-saving and emission-reduction technologies, clean energy utilization and resource recycling, so as to effectively reduce carbon emission intensity and improve energy utilization efficiency. For example, enterprises can use green credit funds to introduce advanced energy-saving and emission-reduction equipment, optimize production processes, and reduce the consumption of fuel and energy fuels; they can also increase R&D investment in clean energy technologies and gradually increase the proportion of clean energy in the energy structure, so as to reduce dependence on traditional fossil energy and cut combustion and energy fuel emissions.

Meanwhile, green credit can also encourage enterprises to recycle and treat waste to reduce waste emissions; optimize land use patterns and reduce carbon emissions caused by land use changes. These green technology innovation measures not only help enterprises reduce total carbon emissions, but also improve their economic benefits, realizing the coordinated promotion of carbon reduction and efficiency improvement.

Facing the current situation of rising carbon emissions of listed companies in the power industry year by year, green credit can effectively improve enterprises' capacity for carbon reduction and efficiency improvement by supporting their green technology innovation, and provide strong support for the realization of the "Dual Carbon" goal. Therefore, enterprises in the power industry should actively utilize green credit resources, increase investment in green technology innovation, accelerate the pace of green transformation, and contribute to the realization of sustainable development goals.

5.2. Descriptive statistical results of variables

Table 3 reports the descriptive statistical results of main variables. The data shows that the mean value of green credit is 0.0502, indicating that the level of green credit of listed enterprises in the power industry is still relatively low. The maximum value of enterprises' Carbon Emission Intensity (INT) is 57.535, the minimum value is 0.03152, and the standard deviation is 0.8051, indicating that carbon emission intensity varies among different enterprises. The maximum value of enterprises' Financial Performance (EPER) is 0.1638, the minimum value is -0.1758, and the standard deviation is 0.0380, which is consistent with the results of existing studies. The maximum value of the coordination degree of Carbon Reduction and Efficiency Improvement (CCD) is 75.2014, the minimum value is 69.2955, and this value is within the normal range after dimensional adjustment. The minimum value of Green Technology Innovation (GRD) is 0, meaning that some enterprises have no authorized green patents in some years; the maximum value is 477, and the standard deviation is 33.148, indicating that the level of green technology innovation varies greatly among different enterprises.

Table 3. Descriptive statistics

	N	Minimum	Maximum	Mean	Standard Deviation
NATURE	435	0	1	0.9700	0.1600
SIZE	435	20.4161	26.4522	23.6809	1.4158
LEV	435	0.2079	0.9234	0.6205	0.1541
GROW	435	-0.7377	12.4550	0.2557	1.2783
AGE	435	1.7917	3.3672	2.8582	0.3070
DUAL	435	0	1	0.0702	0.2590
INDB	435	0.3125	0.5714	0.3659	0.0440
FIRST	435	0.1117	0.7578	0.3932	0.1709
GRD	435	0	477	4.5400	33.148
EPER	435	-0.1758	0.1638	0.0254	0.0380
CARBONE	435	0.0000	1,769.1213	114.8156	198.1576
OI	435	31,083.5315	20,460,508.3056	92,23.3720	9,223.3720
GRC	435	0.0123	0.0777	0.0502	0.0146
TNT	435	2.0023	57.5353	3.5727	7.9761
CCD	435	0.0036	1.4201	0.4188	0.2291
Valid cases (listwise)	435				

5.3. Benchmark regression results

Columns (1), (2) and (3) of Table 4 respectively report the regression results of green credit on enterprises' carbon emission intensity, economic performance and coordination degree of carbon reduction and efficiency improvement. Columns (1) and (2) show that the regression coefficient of green credit on enterprises' carbon emission intensity is significantly negative, and the regression coefficient on enterprises' financial performance is significantly positive, indicating that green credit can reduce enterprises' carbon emission intensity and improve their financial performance at the same time. Meanwhile, the results of column (3) show that the regression coefficient of green credit on the coordination degree of carbon reduction and efficiency improvement is significantly positive, indicating that green credit helps improve the coupling coordination degree of enterprises' carbon reduction and efficiency improvement, and realizes the coordinated promotion of carbon reduction and efficiency improvement. It can be concluded from the data in the table that green credit can promote enterprises to achieve the synergy of carbon reduction and efficiency improvement.

Table 4. Impact of green credit on enterprises' carbon reduction-efficiency synergy

Variable	(1) INT	(2) EPER	(3) CCD
_cons	0.0002*	0.0001***	0.0012***
	(64.7023)	(60.7900)	(31.3682)
GreenCredt	0.0432**	0.0449**	0.0403**
	(0.1785)	(0.1461)	(0.1492)
Control variables	YES	YES	YES
Year fixed effects	YES	YES	YES
Industry fixed effects	YES	YES	YES
N	435	435	435
Adj.R^2	0.0052	0.0070	0.0020
F	3.3391	4.0701	0.1623

Note: The superscript asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

6. Intermediary effect test of green technology innovation

6.1. Explanation of intermediary effect variables

Enterprises' Green Technology Innovation (GRD) refers to the innovation achievements obtained by enterprises in the process of green technology R&D, application and promotion, which are usually embodied in the form of authorized green patents. Green technology innovation is the core driving force for enterprises to achieve green transformation and sustainable development. It not only helps enterprises reduce carbon emissions, but also enhances their market competitiveness and economic benefits. When measuring the level of enterprises' green technology innovation, the number of authorized green patents is adopted as the core indicator. The number of authorized green patents can directly reflect the actual achievements of enterprises in green technology R&D and application, with high reliability and comparability.

However, the number of green patent applications often has certain lag and uncertainty, so this paper selects the number of authorized green patents as the indicator to measure the level of enterprises' green technology innovation. The specific calculation method is as follows formula (10):

$$GRD = ln(number\ of\ authorized\ green\ patents + 1) \tag{10}$$

where the number of authorized green patents refers to the number of green patents authorized by an enterprise in a specific period. To eliminate the skewed distribution and abnormal values of the data, this paper adds 1 to the number of authorized green patents and then takes the natural logarithm for processing. This method can effectively avoid the logarithm calculation problem caused by zero patent quantity, and make the data distribution more stable for subsequent statistical analysis. Enterprises' green technology innovation plays an important intermediary role between green credit and enterprises' carbon reduction and efficiency improvement. Green credit promotes enterprises to carry out green technology R&D and innovation activities by providing financial support, so as to improve the level of enterprises' green technology innovation.

6.2. Results and analysis of intermediary effect test

The above empirical results verify the positive effect of green credit on the synergy of enterprises' carbon reduction and efficiency improvement. This paper will continue to use the two-step method and three-step method to test the intermediary role of green technology innovation between green credit and the synergy of enterprises' carbon reduction and efficiency improvement.

6.2.1. Two-step test

Step 1: Test the impact of green credit on green technology innovation. First, test the impact of green credit on enterprises' green technology innovation. The results are shown in column (1) of Table 5. In column (1), the regression coefficient of green credit on enterprises' green technology innovation is significantly positive. This indicates that green credit can significantly improve the level of enterprises' green technology innovation, and hypothesis H1 is verified. Step 2: Test the impact of green technology innovation on the synergy of enterprises' carbon reduction and efficiency improvement. Second, test the impact of green technology innovation on the synergy of enterprises' carbon reduction and efficiency improvement. The results are shown in columns (2) to (4) of Table 5. It can be found that: in column (2), the regression coefficient of green technology innovation on enterprises' carbon emission intensity is significantly negative; in column (3), green technology innovation has a significant positive impact on enterprises' financial performance; in column (4), the regression coefficient of green technology innovation on the coordination degree of carbon reduction and efficiency improvement is significantly positive.

This shows that green technology innovation can significantly reduce enterprises' carbon emission intensity, improve their financial performance, enhance the coordination degree of carbon reduction and efficiency improvement, and promote the synergy of enterprises' carbon reduction and efficiency improvement. Therefore, research hypothesis H2 is verified.

Table 5. Intermediary effect test results of two-step method

Variable	(1) INT	(2) EPER	(3) CCD	(4) GRD
GreenCredt				0.0431*** (0.0146)
GRD	0.0470*** (33.1743)	0.0280*** (33.1420)	0.0180*** (34.9982)	
cons_	0.0076*** (1.7801)	0.0055 (2.8346)	0.0062*** (2.7691)	0.1211*** (1.5556)
Control variables	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES
N	435	435	435	435
t	9.7080	1.6090	5.9290	9.3250
Adj.R^2	0.0020	0.0003	0.0021	0.0010
F	0.3154	1.1432	0.1622	0.6210

Note: The superscript asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

So far, the logical chain of "green credit → green technology innovation → synergy of carbon reduction and efficiency improvement" has been verified, indicating that green credit can realize the synergy of enterprises' carbon reduction and efficiency improvement by improving the level of green technology innovation. Therefore, research hypothesis H3 is verified.

7. Further analysis

7.1. Heterogeneity of enterprises' internal context

A high level of internal governance means that enterprises have relatively complete rules and regulations and risk prevention and control systems, which provide a strong guarantee for green credit to play its role in carbon reduction and efficiency improvement, and help achieve the effect of carbon reduction and efficiency improvement. Therefore, this paper holds that the role of green credit in promoting the synergy of carbon reduction and efficiency improvement is more significant in enterprises with a high level of internal governance.

Referring to relevant studies, this paper selects 7 variables including Herfindahl index, shareholding ratio of the largest shareholder, shareholding ratio of the second to tenth largest shareholders, executive shareholding ratio, proportion of independent directors, whether the general manager and chairman are the same person, and whether the enterprise is state-controlled, uses principal component analysis to construct the measurement indicator of enterprises' internal governance level, and divides the samples into two groups with high and low internal governance levels according to the annual median for group regression. The results are shown in Table 6. The results show that the regression coefficient of green credit is significant in the high internal governance level group, but not significant in the low internal governance level group, indicating that green credit can effectively play its role in promoting the synergy of carbon reduction and efficiency improvement only when enterprises have sound internal governance.

Table 6. Heterogeneity test results of internal context

	Internal Governance Level	
Variable	High Internal Governance Level	Low Internal Governance Level
GreenCredt	0.0500**	0.3623***
	(33.5652)	(16.2365)
_cons	0.3265***	0.6012***
	(1.2690)	(1.9654)
Control variables	YES	YES
Year fixed effects	YES	YES
Industry fixed effects	YES	YES
Adj.R^2	0.0031	0.0027
F	0.4156	1.2761

Note: The superscript asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

7.2. Heterogeneity of enterprises' external context

The product market is one of the important factors determining enterprises' business strategies. When market competition is fierce, enterprises have low profit margins and face great pressure of market competition. To avoid performance decline and being eliminated by the market, enterprises will continuously improve the differentiation of their products to cater to and meet consumer needs. Driven by the Dual Carbon strategy, the concept of green consumption has been deeply rooted in people's hearts. To win consumers' favor, improve product competitiveness and obtain green premium, enterprises will pay more attention to the role of green credit in carbon reduction and efficiency improvement. The results in columns (2) and (3) of Table 7 show that the regression coefficient of green credit is significant in the high market competition level group, but not significant in the low market competition level group. This indicates that when market competition is fierce, green credit can better play its role in promoting the coupling coordination of enterprises' carbon reduction and efficiency improvement. In a fierce market competition environment, to improve their competitiveness and market share, enterprises are more inclined to use green credit funds to support green technology innovation and implement carbon reduction measures, so as to realize the coordinated promotion of carbon reduction and efficiency improvement.

Table 7. Heterogeneity test results of external context

	External Market Competition Level		Government Subsidy Level	
Variable	High Market Competition Level	Low Market Competition Level	High Government Subsidy Level	High Government Subsidy Level
GreenCredt	0.03250** (43.5652)	0.07623*** (86.2965)	0.0340*** (0.0001)	0.1291*** (0.5876)
_cons	0.0065*** (2.2660)	0.012*** (5.9644)	0.0001*** (0.0012)	0.0125*** (0.2165)
Control variables	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Industry fixed effects	YES	YES	YES	YES
Adj.R^2	0.0459	0.5785	0.0080	0.2578
F	6.7722	11.1548	4.5333	7.9221

Note: The superscript asterisks ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

To address the conflict between economic performance and environmental performance, the government has launched a series of fiscal and tax policies to promote emission reduction, such as renewable energy subsidies, energy conservation and emission reduction subsidies and clean development mechanism projects, to compensate for the incremental costs generated by enterprises in emission reduction and improve their enthusiasm for environmental protection. These government subsidies and tax incentives increase enterprises' available funds, providing strong resource support for enterprises to carry out green technology innovation and implement green transformation. Sufficient funds can give full play to the capacity and expertise of green credit to a greater extent, and have a greater effect on improving enterprises' carbon reduction and efficiency improvement. The results in columns (4) and (5) of Table 7 show that the positive impact of green credit on enterprises' carbon reduction and efficiency improvement is significant in enterprises with a high level of government subsidies, but not significant in the low-level group. This indicates that strong fiscal and tax support can strengthen the role of green credit in promoting the synergy of carbon reduction and efficiency improvement. In enterprises that receive more government subsidies and tax incentives, the financial support effect of green credit is more obvious. These enterprises can more effectively use green credit funds for green technology innovation and implement carbon reduction measures, so as to realize the coordinated promotion of carbon reduction and efficiency improvement.

8. Conclusion

8.1. Research conclusions

Against the background of the rapid development of green finance, green credit, as an important policy tool to promote enterprises' green transformation, is of great significance to realizing the win-win goal of high-quality economic development and environmental protection. Based on the data of A-share power enterprises in China from 2011 to 2020, this paper constructs a theoretical framework of green credit, green technology innovation and the synergy of enterprises' carbon reduction and efficiency improvement, and discusses the impact of green credit on enterprises' carbon reduction and efficiency improvement as well as its mechanism. Through theoretical analysis and empirical tests, the following main conclusions are drawn:

(1) Green credit has a significant promoting effect on the synergy of enterprises' carbon reduction and efficiency improvement. By providing low-cost capital and incentive-restraint mechanisms, green credit can effectively reduce enterprises' carbon emission intensity and improve their financial performance, realizing the coordinated development of "carbon reduction" and "efficiency improvement". This conclusion not only verifies the effectiveness of green credit policy, but also further expands the research on the role of green financial tools at the micro enterprise level.

(2) Green technology innovation plays an intermediary role between green credit and the synergy of enterprises' carbon reduction and efficiency improvement. Green credit improves the level of enterprises' green technology innovation by alleviating financing constraints and reducing the capital cost of green technology innovation. Green technology innovation can not only optimize the energy structure and improve production processes, but also enhance enterprises' green competitiveness, and ultimately realize the dual improvement of economic benefits and environmental performance. This conclusion provides micro mechanism support for the policy effect of green credit.

(3) The role of green credit in carbon reduction and efficiency improvement is heterogeneous in different contexts. From the perspective of enterprises' internal characteristics, green credit plays a more significant role in non-state-owned enterprises, enterprises with high internal governance level, enterprises with stable executive teams and enterprises with weak managerial myopia. From the perspective of external environment, the positive effect of green credit is more obvious in regions with strict environmental regulation, fierce market competition and strong government fiscal and tax support.

8.2. Management implications

Financial institutions should further improve green credit policies and optimize resource allocation. They can guide more capital to flow to green and low-carbon fields by refining green credit standards, innovating green financial products and reducing the financing cost of green projects. Meanwhile, they should strengthen support for enterprises' green technology innovation and provide long-term and stable financial guarantee for enterprises' green transformation.

Enterprises should fully recognize the strategic value of green technology innovation, and prioritize the use of green credit funds in fields such as clean energy development, production process improvement and green product R&D. Enterprises should actively use green credit funds to increase investment in green technology innovation. In addition, enterprises can build green technology innovation alliances through cooperation with universities and scientific research institutions, so as to reduce innovation risks and improve innovation efficiency.

Differentiated and gradual carbon pricing mechanisms can promote intergovernmental cooperation and realize sustainable economic development. The government should strengthen policy coordination to create a sound environment for the implementation of green credit. The government can force enterprises to attach importance to green transformation by improving environmental regulation and strengthening carbon emission supervision; globally, Europe and the United States mainly replace coal-fired power with clean or low-carbon energy [18], so we should also live a green life and use clean energy. The media and the public can promote enterprises to proactively fulfill environmental responsibilities by supervising enterprises' environmental behavior and advocating the concept of green consumption. Industry associations and research institutions can provide green technical support and policy guidance for enterprises to help them achieve sustainable development goals.

Green credit is an important tool to promote enterprises' green transformation and realize the "Dual Carbon" goal. We believe that through the joint efforts of financial institutions, enterprises, the government and all sectors of society, green credit will play a more important role in promoting high-quality economic development and ecological civilization construction.

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