The Impact of Green Credit on Carbon Emission Reduction in China — A Case Study of Six Major Energy-Intensive Industries

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Abstract: The development of a high-quality economic system in China critically hinges on green finance, particularly green credit as an integral part of the carbon finance framework. This study analyzes panel data from 30 provinces and municipalities across China between 2008 and 2019, employing a dynamic panel model to explore the impact of green credit on carbon emission reduction in six major energy-intensive industries. Results reveal that green credit significantly curtails carbon emissions within these sectors. Notably, the effectiveness varies regionally, with eastern regions demonstrating superior performance compared to their central and western counterparts. This research underscores the necessity for expanding green credit scale, enhancing support mechanisms, and fostering deeper integration and liberalization of green finance nationwide. Special attention should be directed towards advancing green credit initiatives in central and western regions to achieve balanced development. This study innovatively quantifies regional disparities in green credit efficacy, providing actionable insights for policymakers.

Keywords: Green Finance; Green Credit; Carbon Emissions of Six Major Energy-Intensive Industries

1. Introduction

As China's socio-economic development advances, its industrial structure shifts towards mid-to-high-end manufacturing, with environmental protection and sustainable development becoming increasingly important. Green finance, particularly green credit, plays a crucial role in supporting this transformation. The "13th Five-Year Plan" emphasized developing green finance, and the 20th National Congress highlighted accelerating green transformation through improved green finance systems to support the real economy.

Green finance aims to support environmental improvements, address climate change, and promote efficient resource use, guiding funds toward environmentally friendly production. Among various green financial products, green credit is the most mature instrument, providing preferential interest rates to enterprises involved in new energy, circular economy, and ecological agriculture while restricting financing for polluting projects. Initiated in 2007, green credit has evolved with guidelines issued by regulatory bodies in 2012 and 2014, detailing operational standards. By 2021, China's green credit balance reached 14 trillion yuan, leading globally.

However, whether green credit effectively reduces carbon emissions from high-energy-consuming industries is complex. While it supports green innovation in some sectors, it restricts financing for high-pollution enterprises, potentially hindering industrial transformation. Scholars argue that green credit regulations can inhibit corporate green innovation.

Assessing green credit's specific impact on carbon emissions through empirical analysis is crucial. This research helps optimize green finance policies, ensuring they support sustainable development and economic transformation effectively, fostering both environmental sustainability and economic progress.

2. Literature Review

2.1 Carbon Emissions and Economically Sustainable Growth

The Environmental Kuznets Curve (EKC), introduced by Grossman and Krueger in 1991, posits an inverted U-shaped relationship between environmental quality and economic growth. Initially, studies on carbon emissions and economic development showed varied results: some found a monotonically increasing relationship, others identified an inverted U-shape with significant variability, and some found no clear link. These inconsistencies are partly due to the complexity of carbon's persistence in the atmosphere compared to other pollutants like sulfur dioxide.

As global warming concerns intensify, achieving green, low-carbon development has become a priority, leading to critiques of the EKC model for treating income or economic growth as exogenous variables without accounting for their interrelation with environmental changes. In modern economies, the relationship between finance and carbon emissions has gained attention, with carbon and green finance emerging as key areas of study. These fields explore how financial mechanisms can support sustainable development and reduce greenhouse gas emissions, emphasizing the need for refined models that better capture these complexities.

2.2 Carbon Emissions and Carbon Finance

Carbon finance, a vital component of green finance, integrates carbon emission limitations into traditional financial activities, primarily through carbon trading. It involves financial instruments aimed at reducing greenhouse gas emissions and facilitating project-based carbon reductions or trading emission allowances. Research on its effectiveness varies due to differences in technology, systems, and financial levels among countries.

Zhang Jianhua et al. demonstrated positive effects of China's carbon trading pilots on carbon reduction and industrial transformation [1], though regional disparities exist. Chen Zhiying found gradual improvement in China’s carbon finance level with significant room for enhancement.Despite these findings, some studies indicate that carbon finance systems do not always achieve emission reduction goals [2], with policies showing limited effectiveness. The varied conclusions are influenced by regional differences and the completeness of carbon finance systems. Overall, while many scholars support the view that carbon finance can reduce emissions, further investigation is needed to fully understand its nuances and optimize its impact. This highlights the importance of continued research and policy refinement in this field.

2.3 Carbon Emissions and Green Credit

Research on the emission reduction effects of green credit can be categorized into macro-level and micro-level analyses:

On the macro level, green credit promotes industrial structure reform by guiding fund flows and offering differential pricing for green investments, boosting regional economic growth while reducing carbon emissions, especially benefiting secondary and tertiary industries [3,4]. By raising loan thresholds and financing costs for high-energy-consuming enterprises, green credit discourages investment in polluting sectors, encouraging structural upgrades. Xu Sheng et al. verified green credit's role in industrial upgrading using grey relational analysis and panel data regression, showing its impact through capital and fund circulation channels [6].

On the micro level, research examines the bank-enterprise relationship. Short-term challenges for banks include increased lending risks and longer payback periods [7,8], while long-term benefits arise from green credit scale expansion and technological advances, improving financial performance. For enterprises, green credit fosters governance and pressure effects; companies pursuing green credit support develop green innovation projects to reduce emissions, despite higher transaction costs and financing thresholds during transition. Bi Qian et al. used a difference-in-differences approach to show green credit policies significantly impact corporate green innovation by promoting R&D intensity and environmental compliance, further reducing regional carbon emissions [9]. This dual-level approach ensures comprehensive emission reduction and sustainable development.

2.4 Conclusion

While green credit presents short-term challenges for banks and enterprises, it holds significant potential for fostering innovation and reducing environmental impacts over the long term. Customizing green finance strategies is crucial to maximize benefits across diverse sectors, ensuring sustainable development. Green credit, as an environmental finance policy, aims to reduce carbon emissions by guiding capital flows and adjusting financing costs. However, its impact varies by region and financial development level, showing heterogeneity in short- versus long-term effects.

This study innovates by matching green credit variables with carbon emission variables for six high-energy-consuming industries using provincial data from 2008-2019. It analyzes green credit's specific impact on carbon reduction, exploring regional differences across eastern, central, and western regions. By providing nuanced insights into how green credit influences carbon emissions within high-energy sectors, this research offers valuable information for policymakers aiming to enhance sustainability while considering regional disparities. This approach supports broader ecological and economic goals, promoting tailored strategies that address varying impacts based on company size and type.

3. Theoretical Analysis

Green credit policies leverage the Porter Hypothesis and Coase Theorem to achieve environmental benefits and emission reductions. The Porter Hypothesis posits that suitable environmental regulations can spur innovation, enhancing both competitiveness and environmental performance. It has "Weak" and "Strong" versions; the former suggests that such regulations guide capital flows and promote innovation, while the latter argues for an "innovation compensation effect," where technological innovation offsets R&D costs.

Green credit policies apply these theories by tightening financing on high-pollution industries and easing it for green sectors through lower financing thresholds and preferential loan rates. This dual approach promotes industry transformation and supports environmental protection. The Coase Theorem complements this by suggesting efficient outcomes when property rights are well-defined and transaction costs are low, enabling market mechanisms to allocate resources efficiently in green finance.

Green credit integrates into carbon finance systems primarily via carbon trading, internalizing greenhouse gas emissions' externalities into emitter costs. Unlike rigid government interventions, carbon trading sets upper limits on emissions and allocates tradable quotas based on environmental capacity. Green credit supports this through preferential loans for low-carbon industries and punitive rates for high-energy-consuming ones, enhancing corporate carbon emission disclosure and regulatory oversight.

Hypothesis One proposes that green credit significantly reduces carbon emissions by integrating into the carbon finance system. Through mechanisms like preferential loans and stringent financing conditions, along with enhanced monitoring of carbon emissions, green credit effectively promotes environmental cost internalization and drives sustainable development. This approach minimizes societal emission costs and underpins carbon financial markets, aligning economic activities with environmental goals.

This hypothesis underscores the potential of green credit not only as a financial tool but also as a pivotal mechanism in achieving environmental sustainability and economic efficiency by leveraging market-based solutions.

H1: Green credit can significantly suppress carbon emissions from the six major high-energy-consuming industries, with emissions decreasing as the scale of green credit expands.

Green credit policies are designed to foster industrial transformation, energy conservation, and emission reductions. However, they also raise pollution control and financing costs for enterprises, significantly impacting high-energy-consuming industries by altering their cost-benefit structures and influencing production decisions. The impact varies due to differing environmental regulation intensities and financial development levels across regions, leading to asymmetric effects on enterprise cost-benefit balances. High-emission enterprises face increased governance costs and may resist costly transformations despite potential long-term benefits, given the substantial capital investment required and associated uncertainties. In regions with less stringent regulations, enterprises might exploit green credit for expansion rather than low-carbon transitions. Consequently, the effectiveness of green credit policies in reducing emissions is region-specific. This paper analyzes these effects across eastern, central, and western China, proposing Hypothesis Two based on regional heterogeneity to account for varying impacts of green credit policies. Such an analysis highlights the complexity and necessity of tailored policy approaches for different regions.

H2: The emission reduction effect of green credit on the six major high-energy-consuming industries varies by region, with different outcomes observed in eastern, central, and western regions of China.

4. Research Design

4.1 Data Sources and Variable Selection

Following the 2007 national government's "Opinions on Implementing Environmental Protection Policies and Regulations to Prevent Credit Risks," green credit was integrated into China's primary pollution reduction efforts. This study uses panel data from 2008 to 2019, covering 30 provinces excluding Tibet, Hong Kong, Macao, and Taiwan, to analyze impacts before COVID-19 disruptions. Data sources include the "China Industrial Statistics Yearbook," the Economic Prediction System (EPS), and the "Statistical Yearbook." Interpolation methods address missing data points, ensuring a robust dataset. By focusing on these years and utilizing multiple reliable sources, the study provides comprehensive insights into green credit's effects on emission reductions in high-energy-consuming industries across different provinces, minimizing biases from incomplete data and offering accurate analysis for policy-making.

4.1.1 Dependent Variable

The dependent variable in this study is the carbon emission intensity of the six major high-energy-consuming industries. This is measured by the ratio of the total carbon emissions from these industries to their total output value, reflecting the amount of carbon emissions per unit of output produced by these industries. Using carbon emission intensity as the dependent variable, rather than total carbon emissions, better accounts for the varying scales of these industries across different regions.

Therefore, the carbon emission level of the six industries is denoted as TGCO2, which is specifically calculated using the formula (1):

$$\boldsymbol{TGCO2 = \frac{GCO2}{AGDP}} \quad (1)$$

In formula (1), TGCO2 represents the carbon emission intensity of the six major high-energy-consuming industries, calculated as the ratio of total carbon emissions (GCO2) to the total output value of these industries (AGDP). Since detailed carbon emission totals are not publicly available in China, this study adopts an estimation method referenced from Chen Zhiying et al. and the estimation guidelines provided by the IPCC [6], estimating total carbon emissions through the formula (2)

$$\textbf{Total Carbon Emissions} = \sum \textbf{Energy Consumption} \times \textbf{CO2 Emission Coefficient} \quad (2)$$

The calculation involves estimating carbon emissions based on energy consumption data for nine types of energy sources as defined by the IPCC: raw coal, coke, crude oil, fuel oil, gasoline, kerosene, diesel, liquefied petroleum gas, and natural gas. The carbon emission coefficient is calculated using the following formula (3):

$$\textbf{Carbon Emission Coefficient} = \textbf{Energy Lower Heating Value} \times \textbf{Carbon Content per Unit of Heat} \times \textbf{Carbon Oxidation Rate} \times \textbf{3.67} \quad (3)$$

The values for the average lower heating value of energy, standard coal conversion factor, carbon content per unit of heat, and carbon oxidation rate are sourced from the "General Principles for Calculation of Comprehensive Energy Consumption" and the "Guidelines for Compiling Provincial Greenhouse Gas Inventories."

Given that provincial-level energy consumption data specific to the six major high-energy-consuming industries is unavailable, only aggregate industrial energy consumption data can be accessed. To accurately estimate the carbon emissions of the six industries, this study calculates the proportion of carbon emissions from these six industries relative to the total industrial carbon emissions from 2008 to 2019 using data from the "China Industrial Statistics Yearbook."

The proportion coefficients obtained are then multiplied by the total industrial carbon emissions of each province to derive the total carbon emissions of the six major high-energy-consuming industries for each province over the years. This method allows for a more precise estimation of the carbon emissions from the targeted industries, despite the limitations in directly available data.

4.1.2 Core Explanatory Variable

Currently, the only available data on green credit is from the China Banking and Insurance Regulatory Commission (CBIRC), covering the period from 2013 to 2017 for 21 major banks. This dataset is limited both in terms of the number of years covered and the sample size, and furthermore, there are inconsistencies in the statistical standards across different banks, making it unsuitable for empirical analysis.

In existing literature, green credit is commonly measured through proxies such as the proportion of loans for energy conservation and emission reduction, the proportion of loans to high-tech industries, or inversely through indicators like the interest expense ratio of high-energy-consuming industries. Given that this study focuses on the emission reduction of "two high and one low" industries (i.e., the six major high-energy-consuming industries), we adopt the approach suggested by Xie Tingting and Liu Jinhua [14]. Specifically, we use the inverse indicator of the ratio of interest expenses of the six major high-energy-consuming industries to the total industrial interest expenses as a proxy for measuring the scale of green credit allocation. Let XD represent green credit, which is calculated as follows formula (4):

$$\textbf{XD} = \textbf{1} - \frac{\textbf{Interest Expenses of the Six Major High} - \textbf{Energy} - \textbf{Consuming Industries}}{\textbf{Total Industrial Interest Expenses}} \quad (4)$$

4.1.3 Control Variables

In real-world production, corporate carbon emissions are influenced not only by green credit restrictions but also by various economic variables. Firstly, compared to the primary and tertiary sectors, the secondary sector, especially industry, contributes significantly more to carbon emissions. Different proportions of industrial structures across regions lead to variations in carbon emission levels. Additionally, higher urbanization levels in a region often result in stricter environmental regulations for highly polluting enterprises, increasing their pollution control costs. Moreover, government support for green credit and corporate innovation also affect carbon emissions.

Therefore, drawing on existing research, this study selects the following control variables: urbanization level, economic development level, industrial structure, R&D level, and government fiscal expenditure.

Urbanization Level: Measured by the ratio of urban population. Economic Development Level: Measured by actual GDP. Industrial Structure: Focused on the proportion of the secondary sector, calculated as the ratio of the total output value of the secondary industry to the total output value of all industries. R&D Level: Measured by the number of new patent applications filed by large-scale industrial enterprises. Government Fiscal Expenditure: Reflects the extent of government support for green initiatives.

The definitions and statistical descriptions of each variable are summarized in Table 1 below

Table 1 Statistical Analysis of Variables

Variable	Variable notation	Observations	Mean	Standard deviation	Minimum	Maximum
Carbon emission intensity of the six major high-energy-consuming industries	TGCO2	360	0.00619	0.00044	0.00016	0.00223
Green Credit Level	XD	360	0.453	0.147	0.0934	0.808
Real GDP(in Billion Yuan)	AGDP	360	10071.14	8978.578	410.543	511440.61
R&D Level	TL	360	7346.994	13602.53	28	121320
Industrial Structure	CYJG	360	0.449	0.0857	0.161	0.59
Urbanization Level	CZRKB	360	0.563	0.131	0.291	0.896
Green Credit (Difference)	XDD	360	181.246	195.249	4.65	891.76
Government Fiscal Expenditure(in Billion Yuan)	G	360	4152.32	2656.844	324.61	17297.85
Total Industrial Output Value (in Billion Yuan)	GYGDP	360	8368.783	7496.766	300.63	39398.46

4.2 Model Specification

Given that the data used spans from 2008 to 2019 and is at the provincial panel level, a panel regression model is appropriate. This study adopts the approach of Jiang Hongli et al. (2020) to construct Panel Regression Model (1):

$$lnTGCO2_{it} = \alpha + \beta lnXD_{it} + \gamma Z_{it} + u_i + v_t + \varepsilon_{it} \tag{1}$$

$TGCO2_{it}$ represents the carbon emission intensity of the six major high-energy-consuming industries for province i in year t. XD_{it} represents the green credit level for province i in year t. Z_{it} includes control variables such as industrial structure $CYJG_{it}$, R&D level ZL_{it}, economic development level $lnAGDP_{it}$, urbanization level URB_{it}, and fiscal expenditure level G_{it}. β and$\gamma$are the regression coefficients for green credit level and control variables on carbon emission intensity, respectively. u_i denotes the unobserved individual effect for each province. $\mathrm{v_t}$ is the time-fixed effect. ε_{it} is the error term.

Additionally, considering that industrial production decisions in the presence of environmental regulations take into account previous periods' carbon emissions, it is necessary to adjust current production and emissions based on past performance. Therefore, to more accurately reflect this dynamic process, the previous period's carbon emission intensity should be included as an explanatory variable in the model. This leads to the construction of a Dynamic Panel Model (2) as follows:

$$lnTGCO2_{it} = \alpha + \beta_1 lnTGCO2_{it-1} + \beta_2 lnXD_{it} + \gamma Z_{it} + u_i + v_t + \varepsilon_{it} \quad (2)$$

Compared to Model (1), Model (2) further incorporates the lagged effect of carbon emission intensity, making it more realistic. To address potential endogeneity issues, this study employs Difference GMM (Generalized Method of Moments) and System GMM estimation methods for Model (2). These approaches help mitigate the impact of endogeneity to some extent, thereby providing more reliable estimates.

5. Empirical Results Analysis

5.1 Impact of Green Credit on Carbon Emissions from the Six Major High-Energy-Consuming Industries

To better compare and analyze the impact of green credit on reducing carbon emissions from the six major high-energy-consuming industries, this study reports the regression results from both pooled OLS and fixed effects models in Model (1), as well as the Difference GMM and System GMM estimations from Model (2). The detailed results are presented in Table 2 below.

Table 2 Regression Results of the Impact of Green Credit on Emission Reduction in Six Major High-Energy-Consuming Industries

	(1)	(2)	(3)	(4)
Variable	Polled OLS	FE	Difference GMM	System GMM
lnTGCO2			0.5664***	0.7090***
			(0.111)	(0.090)
lnXD	-0.7300***	-0.6849***	-0.6932***	-0.7497***
	(0.117)	(0.118)	(0.230)	(0.362)
lnZL	0.0958***	0.0952***	0.2007**	0.0878
	(0.030)	(0.033)	(0.080)	(0.080)
lnAGDP	-0.5943***	-1.4948***	0.0478	-0.6027
	(0.110)	(0.216)	(0.443)	(0.474)
lnG	-0.1234*	-0.0005	0.0188	0.7635
	(0.069)	(0.110)	(0.109)	(0.466)
CZRKB	-0.6385*	0.8879*	-0.9625	-0.2360
	(0.382)	(0.520)	(0.660)	(0.427)
CYJG	-3.3468***	-3.4213***	-3.4032***	-3.0821*

	(0.197)	(0.295)	(0.341)	(1.657)
Intercept	0.0935	5.9059***		
	(0.510)	(1.484)		
Number of observations	360	360	330	330
R^2	0.6921	0.7214		
AR(1)			0.005	0.058
AR(2)			0.241	0.173
Sargan test			34.33	9.80
			(0.079)	(0.000)

The study's findings reveal significant impacts of green credit on reducing carbon emissions from six major high-energy-consuming industries. The pooled OLS regression results (column one) show a green credit coefficient of -0.7300, significant at the 1% level, indicating a 0.73% reduction in carbon emissions per unit increase in green credit scale. The dual fixed-effects model (column two), chosen via Hausman test, shows a slightly lower but still significant coefficient of -0.6849, confirming green credit's inhibitory effect on emissions after adjusting for individual and time effects. Difference GMM and System GMM models (columns three and four) further support these findings, with coefficients of -0.6932 and -0.7497, respectively, showing no second-order serial correlation in residuals and validating instrument effectiveness through Hansen tests. Each unit increase in green credit reduces carbon emission intensity by 0.6932 to 0.7497 percentage points, demonstrating its significant role in mitigating carbon emissions across different econometric approaches.

Overall, green credit consistently exhibits a significant negative effect on carbon emission intensity across various models, supporting Hypothesis One. It guides capital flow, optimizes allocation, promotes innovation and structural transformation, thereby reducing carbon emissions.

5.2 Robustness Test

To further enhance the reliability of the aforementioned conclusions, this study conducts robustness test from three perspectives: variable substitution, consideration of lag effects, and outlier removal.

Variable Substitution: In the previous analysis, green credit was measured using an inverse indicator based on the interest expenses of the six major high-energy-consuming industries. For robustness testing, we adopt the approach suggested by Jiang Hongli et al. [13], using the difference between total industrial interest expenses and the interest expenses of the six major high-energy-consuming industries as a substitute variable for green credit. The test results are shown in column (1) of Table 3 below. It can be seen that after substitution, the regression coefficient for the green credit variable remains negative and significant at the 1% level, indicating that the original regression results are robust.

Lag Effects: Given that green credit policies provide financing support to enterprises, there may be a time lag and delayed impact on emission reductions in the six major high-energy-consuming industries. Therefore, we perform a one-period lag on the green credit variable and conduct System GMM estimation. The regression results are presented in column (2) of Table 3. The coefficient remains significantly negative at the 1% significance level, confirming the reliability of the empirical findings reported earlier.

Outlier Removal: Considering the variations in the implementation intensity of green credit policies and other economic variables across different regions in China, some outliers may occur. To improve robustness, we apply winsorization to the top and bottom 1% of each variable's data. The regression results are shown in column (3) of Table 3. The regression coefficient for green credit remains negative, indicating a significant inhibitory effect on carbon emissions from the six major high-energy-consuming industries. This further confirms the robustness of the above conclusions.

Table 3 Robustness Analysis Results of the Impact of Green Credit on Emission Reduction in Six Major High-Energy-Consuming Industries

	(1)	(2)	(3)
Variable	Variable substitution	Lag effect	Trimming
lnTGCO2	0.4477***	0.3856***	0.4949***
	(0.109)	(0.070)	(0.159)
lnXD	-0.0008***	-0.7170***	-0.9019***
	(0.000)	(0.222)	(0.339)
lnZL	0.1966***	0.1662***	0.2213*
	(0.074)	(0.042)	(0.115)
lnAGDP	-0.5995	-0.6479***	-0.4021
	(0.451)	(0.226)	(0.660)
lnG	-0.0921	-0.0906	0.4089
	(0.091)	(0.088)	(0.373)
CZRKB	0.4260	0.0861	-0.3713
	(0.605)	(0.606)	(1.103)
CYJG	-3.3621***	-2.7000***	-3.3171***
	(0.302)	(0.208)	(0.462)
Number of observations	330	330	330
AR(1)	0.079	0.005	0.461
AR(2)	0.922	0.210	0.258
Sargan test	30.01	34.74	15.23
	（ 0.184）	（0.072）	（0.886）

5.3 Heterogeneity Analysis of the Impact of Green Credit on Carbon Emission Reduction in the Six Major High-Energy-Consuming Industries

Existing literature highlights regional heterogeneity in green credit policy effectiveness for carbon emission reductions due to varying geographical, economic conditions, and policy implementation. Xu Sheng et al. found more pronounced green credit impacts on industrial upgrades in the eastern region[6]. Green credit efficacy varies with regional economic development levels, and the distribution of major high-energy-consuming industries differs across regions, affecting green credit implementation intensity. This suggests that tailored regional strategies are essential for maximizing green credit's impact on emission reductions.

Based on these considerations, this study posits that the impact of green credit on carbon emission reduction within the six major high-energy-consuming industries exhibits regional heterogeneity. To examine this, China is divided into three parts: eastern, central, and western regions, for regression analysis. Given that there are 11 provinces in the eastern region, 10 in the central region, and 9 in the western region, and considering the data spans from 2008 to 2019, the number of time periods exceeds the number of entities, making GMM estimation unsuitable. Therefore, this study employs Panel Regression Model (1) for estimation. Most variables passed unit root tests at the 10% significance level. The panel regression results are presented in Table 4 below.

Table 4 Regression Results of the Heterogeneous Impact of Green Credit on Emission Reduction in Six Major High-Energy-Consuming Industries

	(1)	(2)	(3)
Variable	Eastern Region	Central Region	Western Region
lnXD	-0.5233***	-0.3293**	-0.4644**
	(0.154)	(0.258)	(0.256)
lnZL	-0.0025	-0.1358**	-0.1483**
	(0.050)	(0.055)	(0.066)
lnAGDP	0.2580	1.0831*	3.8647***
	(0.257)	(0.582)	(0.447)
lnG	0.2108	1.3724***	-0.5177**
	(0.138)	(0.303)	(0.199)
CYJG	4.0606***	2.9340***	1.2491**
	(0.499)	(0.479)	(0.607)
CZRKB	-1.3791**	-2.9220**	1.9537
	(0.692)	(1.232)	(1.978)
Intercept	2.9832*	-10.8951***	-18.5174***
	(1.776)	(3.770)	(3.371)
Number of Observations	132	120	108

R^2	0.7896	0.8358	0.7965
Individual Fixed Effects	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes
Hausman	31.02	29.42	35.12

From the table 4, it can be observed that green credit has a significant negative impact on the carbon emissions of the six major high-energy-consuming industries in all regions, with the results being statistically significant at the 5% level. Among these, the most pronounced carbon reduction effect is seen in the eastern region, followed by the western region, while the central region shows the least significant effect. The corresponding regression coefficients are -0.5233, -0.4644, and -0.3293, respectively. This indicates that for each unit increase in the green credit level, the carbon emissions from the six major high-energy-consuming industries decrease by 0.5233%, 0.4644%, and 0.3293% in the eastern, western, and central regions, respectively. These findings support Hypothesis Two, suggesting that the eastern region benefits more from green credit policies due to higher economic and financial development levels, stronger enforcement of green credit, and higher R&D levels, thereby achieving better results in reducing emissions from high-energy-consuming industries.

It is noteworthy that in the regressions for each region, the R&D level also exhibits a significant inhibitory effect on the carbon emissions of the six major high-energy-consuming industries. Whether green credit achieves its carbon reduction goals through the pathway of R&D levels remains an area for further investigation.

6. Conclusions

This study analyzed panel data from 2008 to 2019 across 30 provinces in China to assess the impact of green credit on carbon emissions in six major high-energy-consuming industries. Using dynamic and static panel models, it demonstrated that green credit significantly inhibits carbon emission growth, with notable regional heterogeneity. The eastern region showed better performance compared to central and western regions.

Technological innovation plays a crucial role in curbing carbon emissions from these industries and is a significant channel for promoting emission reductions. Green credit should be directed towards the research and development (R&D) of environmental protection technologies to support innovative activities, which often come with high risks and long return periods. Leveraging the risk dispersion function of green finance can enhance the return rates of green innovation activities, encouraging more enterprises to engage in R&D initiatives.

Given the regional disparities, where the eastern region exhibits the best results and central and western regions show room for improvement, efforts should focus on promoting green credit development nationwide. This includes deepening and liberalizing green finance practices, increasing attention to green credit in central and western regions, and leveraging the exemplary role of the eastern region to implement green credit policies effectively.

By focusing on these strategies, China can enhance the effectiveness of green credit in reducing carbon emissions from high-energy-consuming industries, fostering sustainable development across all regions. This comprehensive approach aims not only at mitigating carbon emissions but also at driving long-term sustainable growth throughout the country.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, author-ship, and/or publication of this article.

Data Sharing Agreement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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