Research on the Impact of China's Carbon Emission Rights Trading Pilot Policies on Regional Carbon Emissions

Wenxing Xiong*

Institute of economics, ShanXi University of Finance and Economics, Taiyuan, China, 030006

*Corresponding author: 18922873259@163.com

Abstract. The carbon emission reduction effect of the carbon trading pilot policy has a profound impact on policy promotion and low-carbon development. This paper evaluates the emission reduction effect brought by the implementation of this policy by analyzing the panel data of 30 provincial-level regions from 2005 to 2021 and applying the DID method. The results show that the implementation of the policy significantly reduces carbon emission intensity by 13.2%, generating environmental benefits ranging from 263.68 billion yuan to 133.88 billion yuan. The analysis of the impact mechanism indicates that the emission reduction effect is mainly realized through two major paths: green technology progress and optimization of energy consumption structure. In addition, the heterogeneity analysis shows that the emission reduction effect of the policy is particularly significant in the western region, the region with more lagging economic development, and the region with stricter environmental regulation. Finally, this paper puts forward targeted policy recommendations.

Keywords: Carbon Trade, Carbon Reduction, Green Technological Progress, Optimization of Energy Consumption Structure, Environmental Benefits.

1. Introduction and Literature Review

Since the initiation of its reform and opening-up, China has experienced significant economic growth, achieving remarkable progress. However, in recent years, climate change has increasingly affected the country's ecological environment. The primary driver of these changes is the excessive release of carbon dioxide and the sharp increase in greenhouse gases. Currently, as the largest emitter of carbon globally, China faces substantial pressure to cut emissions.

As China continues to advance its ecological civilization, the government issued the "Notice on Carbon Emission Right Trading Pilot Work" in 2011, authorizing seven provinces and municipalities—Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Shenzhen, and Hubei—to implement carbon emission trading pilots. By 2013, carbon trading markets had been progressively established and began operating in these pilot regions. Current research on the emission reduction effects of this policy focuses on three levels: enterprise, industry and region.

The first group of studies examines how carbon trading pilots influence carbon reduction mechanisms at the enterprise level. For instance, Dong Kangyin and colleagues used a multi-temporal DID model and found that the policy significantly reduces enterprise carbon intensity, highlighting the crucial role of digital transformation in driving emission reductions[1]. Tian Chao and others employed a triple difference model to investigate the mechanisms and pathways through which the carbon trading market facilitates the low-carbon transition of enterprises[2].

The second category of research focuses on the emission reduction effects within specific industries. Wang Wei and collaborators suggest that this policy notably boosts the green innovation capacity of manufacturing enterprises in pilot regions. They emphasize the importance of increased investment in green innovation and argue for the expansion of the carbon trading system's scope and strengthened implementation[3]. Liang Dongqing applied the 3E model to analyze the carbon reduction mechanisms in the coal industry, while also examining carbon trading's contributions to cleaner, more efficient, and sustainable development[4]. In contrast, Ji Zhongyang and colleagues discovered that carbon trading effectively reduces direct carbon emissions in the construction sector, with a reduction of approximately 35.59%, although its impact on indirect emissions remains less pronounced[5].

The third category of research explores the regional impact of this policy on carbon emissions. Chen Caozao and others, using a multi-period DID model, found that carbon trading policies positively impacted emission reductions in pilot regions, mainly through optimizing industrial structures. However, while the policy has yielded some success in reducing emissions, its synergistic effects on other air pollutants remain limited[6]. Zhang Xingxiang's research showed that the pilot carbon trading policies not only foster the advancement of green, low-carbon technologies but also help alleviate overly stringent environmental regulations in the pilot regions[7]. Nevertheless, some scholars, such as Wang Xuefeng, argue that due to the late start of China's carbon market, the market mechanisms are still underdeveloped. As a result, they have not yet fully realized their regulatory potential, and carbon emission reductions in the pilot regions have been largely achieved through lower economic output and a reduction in the scale of economic activities, rather than relying directly on the carbon market's influence[8].

In conclusion, there remains considerable debate on whether the carbon trading pilot policy achieves reductions by limiting economic activities in the pilot areas, or whether it effectively lowers emissions by reducing carbon intensity. At present, the majority of existing studies suggest that the policy mainly achieves emission reductions through the optimization of industrial structures, while overlooking the significant contributions of green technology advancements, particularly the optimization of energy consumption structures. To address these gaps, this paper employs the DID model to explore the impact of the carbon trading pilot policy on carbon emissions in pilot regions, as well as the underlying mechanisms. The study also investigates how regional heterogeneity influences the policy effects, followed by an assessment of the environmental benefits resulting from the implementation of the policy.

The primary contributions of this paper are as follows: First of all, it has supplemented and expanded the types of emission reduction mechanisms of the carbon trading pilot policy, providing a detailed analysis of the roles played by green technology progress and energy consumption structure optimization. Second, the paper explores the environmental benefits that arise from the implementation of this policy. Third, the research extends the analysis period to 2021 and conducts various robustness checks, such as parallel trend analysis, excluding the impacts of concurrent policies, and substituting the dependent variable, to ensure the reliability and robustness of the findings.

2. Methods and Datas

2.1. Methods

2.1.1 Benchmark regression model

This study treats the 2013 official launch of the carbon trading pilot policy as a quasi-natural experiment, utilizing the DID approach to empirically examine the policy's impact on carbon emissions. The analysis is based on panel data from 30 Chinese provinces spanning from 2005 to 2021, excluding Tibet due to incomplete data. In this framework, the six provinces and municipalities involved in the pilot program—Beijing, Tianjin, Shanghai, Chongqing, Hubei, and Guangdong—are designated as the treatment group, while the remaining 24 provinces form the control group. Since the policy officially took effect in 2013, the period from 2013 to 2021 is considered the implementation phase. Using this structure, the paper constructs a difference-in-differences model (the baseline model), as outlined below:

$$C_{it} = \beta_0 + \beta_1 DID_{it} + \beta_2 X_{it} + \varphi_i + \omega_t + \varepsilon_{it} \tag{1}$$

In the above equation, Subscripts i, t denote year t in area i; CEI_{it} represents the carbon emission intensity of the explanatory variable; DID_{it} represents the core explanatory variable, $DID_{it} = treat_i \times post_t$, which $treat_i$ indicates whether it is a treatment group, $post_t$ indicating whether the implementation of the carbon trading pilot policy starts; X_{it} represents a series of control variables;φ_i is the region fixed effect;$\omega_t$is the time fixed effect; and ε_{it} is the random disturbance term.

2.1.2 Mediation model

Building on the work of Wang Hai et al[9]. and Fang Wenjun et al[10]., this study constructs the following mediation model by selecting green technology innovation and energy consumption structure as mediating variables, which are then integrated into the baseline model for empirical testing.

$$M_{it} = \gamma_0 + \gamma_1 DID_{it} + \gamma_2 X_{it} + \varphi_i + \omega_t + \varepsilon_{it} \quad (2)$$

$$C_{it} = \delta_0 + \delta_1 DID_{it} + \vartheta M_{it} + \delta_2 X_{it} + \varphi_i + \omega_t + \varepsilon_{it} \quad (3)$$

In equation (2), the dependent variables correspond to the mediating factors—green technology innovation (GTI) and energy consumption structure (ECS), respectively.

2.2. Variable selection and data description

2.2.1 Dependent and Key Independent Variables

In this study, the dependent variable is regional carbon emission intensity (CEI) represented in its logarithmic form (lnCEI) in the model. The key independent variable is the DID variable, which indicates whether the region has adopted the carbon emissions trading pilot policy.

2.2.2 Control Variables

Following the approaches of Cheng Qiongwen et al[11] and Mao Ying et al.[12], several control variables are incorporated into the model. These include per capita regional GDP (PGDP), measured as the logarithm of the region's real GDP per capita (lnPGDP). The share of foreign investment (STWZ) is represented as the proportion of foreign investment in the region's GDP for the year. Fiscal dependence (STUB) is the ratio of the region's general public budget revenue to its GDP for the year. Lastly, the level of urbanization (LEVER) is expressed as the ratio of the urban population to the total regional population at the end of the year.

2.2.3 Other variables

This study selects two key mediating variables for examination: green technology innovation (GTI) and energy consumption structure (ECS). Green technology innovation is quantified using green patents, which specifically focus on inventions aimed at energy efficiency, emission reduction, and pollution control. These patents serve as a direct indicator of a region's innovation in green technologies. Following the approach of Wang Hai et al., this paper utilizes data from the CNRD to extract the number of green patent applications for each province and municipality, which is then used to measure the level of green technological innovation in each region. On the other hand, the energy consumption structure (ECS) is assessed by the proportion of coal consumption relative to total energy consumption. A lower value of this ratio indicates a more optimized energy consumption structure.

In the heterogeneity analysis section, this study investigates the influences of economic development level (EDL) and environmental regulation (ES). The economic development level (EDL) is represented by PGDP, while environmental regulation (ES) is captured by the ratio of environmental protection spending to GDP.

2.2.4 Source of data

This study utilizes the panel data of 30 provinces and cities in China (excluding Tibet, Hong Kong, Macao and Taiwan) from 2005 to 2021 for empirical analysis. The data sources of the main variables are as follows: carbon emissions data from CEADs; green patents data from CNRDs; coal consumption and total energy consumption data from China Energy Statistical Yearbook and provincial and municipal statistical yearbooks; and other relevant data from China Statistical Yearbook and provincial statistical yearbooks and bulletins. In view of the existence of some missing values, this study uses the ARIMA model to fill in these missing values, thus obtaining a complete sample of 510 observations from 30 provinces and cities. The descriptive statistics of each variable are shown in Table 1.

Table.1. Descriptive statistics of variables

Variable	Definition	Obs	Mean	SD	Min	Max
CEI	Annual carbon intensity/(t/$100)	510	0.026	0.023	0.0016	0.128
lnCEI	Logarithm of standardized annual carbon emission intensity	510	0.561	0.187	0	1
PGDP	GDP per capita/yuan	510	44619	29507	5218	187526
STWZ	Share of foreign investment	510	0.639	2.716	0.052	49.593
STPUB	Fiscal dependence	510	0.106	0.032	0.052	0.245
LEVER	Urbanization level	510	0.558	0.134	0.269	0.900
GTI	Green Patent Application	510	4457	7901	8	56013
ECS	Energy Consumption Structure	510	0.951	0.466	0.018	5.246
EDL	Economic Development Level	510	10.499	0.663	8.560	12.142
ES	Environmental Regulation	510	0.001	0.001	0.000	0.011

3. Empirical results

3.1. Benchmark regression results

First, the data of explanatory variables (lnCEI) and control variables were standardized using the MIN-MAX method, and then regression analysis was conducted using the DID method. In the process of analysis, we conducted regression comparisons with and without control variables, and the results are shown in Table 2. From the regression results in Table 2, it is obvious that the DID coefficients of all models are significantly negative, indicating that the carbon trading pilot policy effectively promotes the significant reduction of carbon emission intensity in the pilot region and realizes the expected carbon emission reduction target. Specifically, the DID coefficient in column (2) of Table 2 is -0.074, indicating that compared with the non-pilot regions, the policy reduces the carbon emission intensity of the pilot regions by 0.074 units. Considering the average value of the logarithm of the standardized carbon emission intensity in the sample (0.561), the carbon reduction effect of the policy is 13.2%.

Table.2. Baseline regression results

Variable	(1） lnCEI	(2） lnCEI
DID	-0.069***	-0.074***
	(-6.93)	(-7.18)
lnPGDP		-0.781***
		(-8.78)
STWZ		0.043
		(1.16)
STPUB		0.129***
		(3.92)
LEVER		0.250***
		(3.34）
Area FE	Yes	Yes
Year FE	Yes	Yes
Constant	0.865***	0.979***
	(63.91)	(46.83)
N	510	510
R^2	0.947	0.958

Note: Values in parentheses are t-statistics, and ***, **, and * represent 1%,5% and 10% significance levels, respectively. Same as below.

3.2. Parallel trend test

When applying the DID model to evaluate policy impacts, one key assumption is that the treatment and control groups must follow parallel trends prior to the policy implementation. This assumption requires validation through a parallel trend test. To mitigate multicollinearity issues, this study adopts 2005 as the base year, incorporating eight years of data before the policy implementation (2005–2012) and eight years of data following the policy rollout (2013–2021), with 2013 marking the policy's implementation year.

As illustrated in Figure 1, the results indicate that from 2006 to 2010 (the seven to three years before policy implementation), no significant emission reduction effect was observed, confirming the validity of the parallel trend assumption. However, during the two years leading up to the policy (2011–2012), a significant negative reduction in emissions was recorded, suggesting that the policy's anticipated effects may have started to manifest earlier. This could be linked to the NDRC's approval of six pilot regions to begin carbon emissions trading market trials in 2011. Consequently, high-emission enterprises in these regions might have preemptively anticipated the policy changes and started reducing emissions by adopting green technologies and modifying their production processes.

Further analysis of the data from the year the policy was implemented (2013) to eight years after its implementation (2021) reveals a significantly negative emission reduction effect, which progressively strengthens over time. This finding suggests that the policy's emission reduction impact continues to grow dynamically, highlighting its sustained and positive role in reducing carbon emissions over the long term.

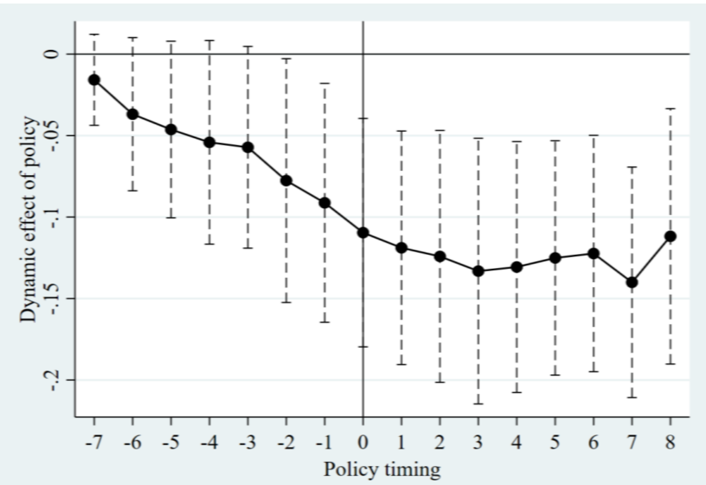

Figure.1. Parallel trend test chart

3.3. Robustness Tests

3.3.1 Excluding the effect of contemporaneous policies

According to the study of Dong Yan et al.[13], in the "SO_2Emissions Trading Pilot"policy document implemented in 2007, Jiangsu Province, Tianjin Municipality, Shanxi Province, Shaanxi Province, Zhejiang Province, Hubei Province, Hunan Province, Henan Province, Hebei Province, Chongqing Municipality, and Inner Mongolia Autonomous Region have been approved to be the pilot level of administrative units. Meanwhile, Tianjin Municipality, Chongqing Municipality and Hubei Province are also part of the carbon emissions trading pilot areas and may be disturbed by the SO_2emissions trading policy. To eliminate this potential effect, we exclude the samples from these three regions from the analysis and re-run the regression analysis. As shown in column (1) of table 3, where the DID coefficient is still significantly negative, indicating that the benchmark regression results remain robust after excluding the impact of the SO_2emissions trading policy.

3.3.2 Replacement of explanatory variables

In this paper, the logarithm of total carbon emissions (lnCE) is selected as the explanatory variable to replace the logarithm of carbon emissions intensity (lnCEI) in the benchmark regression. The explanatory variables (lnCEI), the data related to the control variables are MIN-MAX standardized, and then re-regression to get the results in column (2) of Table 3, the DID coefficient is significantly negative, and the empirical results are robust.

Table.3. Robustness test

Variable	(1) LnCEI	(2) lnCE
DID	-0.073***	-0.041***
	(-4.48)	(-5.17)
Constant	0.968***	0.518***
	(41.14)	(32.12)
Control Variables	Yes	Yes
Area FE	Yes	Yes
Year FE	Yes	Yes
Observations	459	510
R-squared	0.957	0.959

3.4. Heterogeneity analysis

3.4.1 Analysis of regional heterogeneity

Since the samples in this study come from 30 provinces and cities in China, the geographic scope of the samples spans a wide range, and considering the differences in policy implementation efforts and local environmental conditions, this paper argues that there are regional differences in the carbon emission reduction effects of the policies. Therefore, this paper divides the sample into eastern region, western region and central region according to the geographical distribution, and uses the model in Equation (1) to conduct regression analysis for each region.

Table 4 manifests that the DID coefficients for the central and western regions are significantly negative, at -0.045 and -0.082 respectively, while the coefficients for the eastern region are negative but not statistically significant. It can be seen that the policy has reduced the carbon emission intensity in all three regions, with the most obvious effect in the western region and the second in the central region.

Table.4. Analysis of regional heterogeneity

Variable	Eastern lnCEI	Central lnCEI	Western lnCEI
DID	-0.007	-0.045*	-0.082***
	(-0.42)	(-1.75)	(-4.62)
Constant	0.466***	1.565***	1.110***
	(10.21)	(13.01)	(32.48)
Control Variables	Yes	Yes	Yes
Area FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	170	102	238
R-squared	0.956	0.962	0.961

3.4.2 Heterogeneity analysis of economic development

In general, regions with better economic development usually have more funds and resources, are able to ramp up investment in research and development of green innovation technologies, and are more focused on sustainable development. Therefore, the abatement effect of policies may vary according to the differences in regional economic degree. Based on this, this paper divides the sample into economically rich and economically poor regions based on the average value of GDP per capita, and conducts regression analysis on different groups through the model of equation (1).

As displayed in Table 5, the DID coefficient of economically poor regions is significantly negative, reaching -0.067, while the DID coefficient of regions with higher levels of economic development does not show significance. This indicates that the policy shows a significant reduction effect in economically poor areas. According to Yu Yihua et al, the possible reasons for this are: the theory of EKC states that with economic growth, environmental pollution rises and then falls in an inverted U-shape curve, so that the carbon intensity of economically rich regions is inherently low and the effect of the policy is limited; whereas in economically poor regions, the policy is able to effectively promote emission reduction as it is still in the stage of high carbon intensity[14].

3.4.3 Heterogeneity analysis of environmental regulation

Environmental regulation involves the use of laws, policies, and other mechanisms to limit and control actions that may harm the public environment, all with the primary aim of safeguarding the environment. As such, it plays a crucial role in influencing regional carbon emission levels. In line with the approach adopted by Yan Fulei et al., this paper employs the ratio of environmental protection expenditure to regional GDP as a proxy for environmental regulation. Based on the median of this ratio, regions are categorized into two groups: those with stronger environmental regulation and those with weaker regulation. A group-based regression analysis is then conducted using model (1)[15].

As presented in Table 5, the DID coefficients for both groups with differing levels of environmental regulation are significantly negative, suggesting that the carbon trading pilot policy has led to a reduction in carbon emissions in both groups. However, the emission reduction effect is more pronounced in regions which have stronger environmental regulations, highlighting that stringent environmental policies can enhance the achievement of the carbon trading scheme in reducing emissions.

Table.5. Other Heterogeneity Analyses

	EDL		ES	
	rich	poor	strong	weak
Variable	lnCEI	lnCEI	lnCEI	lnCEI
DID	-0.020	-0.067**	-0.083***	-0.065***
	(-1.33)	(-2.36)	(-3.40)	(-5.51)
Constant	1.302***	0.979***	0.940***	0.964***
	(18.56)	(34.11)	(26.67)	(27.57)
Control Variables	Yes	Yes	Yes	Yes
Area FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	208	302	255	255
R-squared	0.987	0.945	0.949	0.967

4. Further analysis

4.1. Influence mechanism analysis

4.1.1 Green technological innovation

This study explores the mechanism of green technology innovation in carbon emission reduction through the framework constructed by equations (2) and (3). As presented in Table 6, column (1) indicates that the policy has a significant role in promoting the level of green technological innovation in the pilot region. Column (2) further indicates that the policy contributes to the reduction of carbon emission intensity by promoting the level of green technological innovation. This indicates that green technology innovation plays a mediating role of 10.3% in the overall carbon emission intensity reduction.

4.1.2 Energy consumption structure

On this basis, the same model is used to test the mediating role played by the energy consumption structure in the emission reduction effect of the policy. As displayed in column (3) of Table 6, the implementation of the policy significantly promotes the optimization of the energy consumption structure in the pilot region and improves its energy use efficiency; column (4) manifests that the policy promotes the optimization of the energy consumption structure, which leads to the reduction of carbon emission intensity. The optimization of energy consumption structure plays a 25.9% mediating role in the carbon reduction effect of the policy.

Table.6. Influence mechanism analysis

Variable	(1) GTI	(2) lnCEI	(3) ECS	(4) lnCEI
DID	0.090***	-0.066***	-0.034***	-0.055***
	(4.34)	(-6.39)	(-3.67)	(-6.08)
GTI		-0.085***		
		(-3.77)		
ECS				0.564***
				(12.59)
Constant	0.049	0.983***	0.205***	0.864***
	(1.15)	(47.64)	(10.89)	(42.67)
Control Variables	Yes	Yes	Yes	Yes
Area FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	510	510	510	510
R-squared	0.695	0.959	0.851	0.969

4.2. Environmental benefits of the policy

This study assesses the environmental benefits of the carbon trading pilot policy by converting environmental externalities into monetary values. According to the market data on November 26, 2024, the carbon price in China's carbon trading market is RMB 103 per ton. However, as China's carbon market is still immaturity and the actual value of its carbon emission reduction may not yet be fully realized, this paper also refers to the carbon price of the mature EU carbon market during the same period, which is about RMB 523 per ton.

In 2021, the average carbon emission intensity of the sample covered in this paper is 0.017 tons/100 yuan, and the total GDP is 114 trillion yuan. Since the policy has led to a 13.2% reduction in carbon emission intensity, the carbon emission reduction resulting from the policy can be calculated as 0.017 * 13.2% * 114 * 100 = 2.56 billion tons. Based on the carbon prices of $103 and $523 per ton, the environmental benefits resulting from the implementation of the policy are estimated to be between $263.68 billion and $133.88 billion.

5. Conclusion and Policy Recommendations

According to the panel data of 30 provinces and cities from 2005 to 2021, this study uses the DID model to deeply analyze the impact of the carbon trading pilot policy on regional carbon emissions. The regression results manifest that the policy has achieved positive results in significantly reducing the carbon emission intensity in the pilot regions, and the downward trend of carbon emission intensity becomes more and more obvious with the prolongation of the policy implementation time. The conclusion remains valid after a series of robustness tests. The mechanism analysis reveals that the policy achieves carbon emission reduction through two main channels: one is to promote green technology innovation, and the other is to optimize the energy consumption structure, accounting for 10.3% and 25.9% of the overall mediating effect, respectively. From the perspective of environmental benefits, the implementation of the policy is expected to bring economic benefits to the environment ranging from 263.68 billion yuan to 133.88 billion yuan. Heterogeneity analysis further indicates that the policy has a more significant impact on carbon emission reduction in western regions, economically poorer regions, and regions with stronger environmental regulations.

On the basis of these conclusions, this paper offers the following policy suggestions:

First, accelerate the construction of a unified national carbon emissions trading market, rationalize the initial quota and trading price, and strengthen market supervision to take on the demonstration-led role of pilot regions.

Second, continuously improve the innovation capacity of green technology in each region, and actively promote the optimization of energy consumption structure. Through financial subsidies, tax incentives and other incentives to promote green innovation by enterprises, and promote cooperation between industry, academia and research institutes. At the same time, formulating and implementing energy structure adjustment plans, promoting energy-saving technologies and products, and supporting the development of renewable energy are all very important initiatives.

Finally, considering the differences in the effectiveness of policies in different regions, differentiated carbon trading policies should be formulated. Specifically, the construction of a carbon trading market in the western region should be accelerated, targeted policy and financial support should be provided to less economically developed regions, and regulatory efforts should be strengthened in regions with weaker environmental regulation.

References

[1] Dong Kangyin, Deng Yuyi. Impact of carbon emissions trading pilot policy on low-carbon transformation of enterprises[J]. Research on Financial Issues, 2023, (12): 52-63.

[2] Tian Chao,Xiao Liming. Impact of carbon emissions trading on low-carbon transformation of enterprises--a quasi-natural experiment based on carbon trading pilot market[J]. East China Economic Management, 2023,37(02): 64-74.

[3] Wang Wei,JIN Meiling,Lu Jinna. Does carbon emissions trading enhance the level of green innovation quality of manufacturing enterprises in China? [J]. Macro Quality Research, 2023, 11(06): 88-101.

[4] Liang Dongqing. Research on the impact of carbon emissions trading mechanism on carbon emission reduction effect in coal industry[J]. China Coal, 2024, 50(10): 1-7.

[5] Ji Zhongyang, Pan Tingju, Yan Wenlian. Evaluation of the impact of China's carbon emissions trading pilot policy on carbon emissions in the construction industry[J]. Journal of Civil Engineering and Management, 2023, 40(03): 104-110.

[6] Chen Caozao, Yu Fengju, Zhang Yue, et al. Empirical assessment and mechanism analysis of the emission reduction effect of domestic carbon trading pilot policies[J/OL]. China Environmental Science,1-15[2025-01-22].

[7] Zhang Xingxiang, Sun Saijie. Whether Carbon Emission Trading Policy Can Promote Carbon Emission Reduction - A Study Based on Panel Data of Prefecture-level Cities[J]. Nankai Economic Research, 2024, (02): 160-178.

[8] Wang Xuefeng,Liao Zefang. Research on market mechanism, government intervention and carbon market emission reduction effect[J]. Arid Zone Resources and Environment, 2022, 36(08): 9-17.

[9] Wang Hai, Guo Guanyu, Yin Junya. Going green in transition: industrial restructuring and corporate green innovation[J/OL]. Research on Quantitative Economics and Technical Economics, 1-22[2024-11-25].

[10] Fang Wenjun, Deng Feng, Zhang Zharen, et al. Impact of environmental target constraints on low-carbon transformation of energy structure[J]. China Population-Resources and Environment, 2024, 34(01): 84-96.

[11] Cheng Qiongwen,Yang Yuting. Carbon emission reduction effects of pilot carbon emissions trading policies - mediating effects based on green technology innovation and energy structure transformation[J]. Science and Technology Management Research, 2023, 43(04): 201-210.

[12] Mao Ying, Qu Mengjie, Zeng Lizhen. Regional Emission Reduction Effect of Carbon Emission Trading Pilot Program Based on PSM-DID Model[J]. Science and Industry, 2022, 22(05): 235-240.

[13] Dong Yan, Wang Yun, Sun Kuankuan, et al. "Research on the governance effect and emission reduction mechanism of carbon trading[J]. Research Management, 2024, 45(10): 160-171.

[14] Yu Yihua, Zheng Xinye, Zhang Li. Economic development level, industrial structure and carbon emission intensity--An analysis of Chinese provincial panel data[J]. Economic Theory and Economic Management, 2011, (03): 72-81.

[15] Yan Fulei, Yang Yuxin, Chen Beibei. Research on the impact of carbon emissions trading system on energy efficiency[J]. Journal of Southwest University of Science and Technology (Philosophy and Social Science Edition), 2024, 41(03): 51-60.