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Research on the Path of Carbon Trading Policies Affecting Industrial Structure Upgrading

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Abstract

Carbon trading, as a market-based carbon emission management tool, has grad-ually been widely used in most regions of China. In order to effectively respond to the challenge of climate change, many countries and regions have begun to explore and implement carbon trading policies. This study is based on panel da-ta of 31 provincial-level regions from 2005 to 2023. A multi-temporal double difference model is used to assess how carbon trading policy affects regional industrial structure upgrading. The results show that the carbon trading policy significantly upgrades the level of industrial structure in the pilot regions, and this conclusion still holds after the robustness test. Moreover, the mechanism analysis shows that the policy promotes regional industrial structure upgrading by improving the resource allocation efficiency and R&D investment in each region. The moderating effect shows that government intervention plays a posi-tive moderating role in the carbon trading policy on industrial structure up-grading. The results of the heterogeneity analysis show that the promotion effect of the carbon emissions trading pilot policy on the industrial structure level of the low level of trade capacity and the eastern and western regions is more sig-nificant and more effective in playing the role of the policy.

Keywords

Carbon Trading Policy; Industrial Structure Upgrading; Resource Allocation Efficiency; Degree of Government Intervention

1. Introduction

Global warming has become a major challenge impeding the sustainable development of contemporary societies as a result of the destruction of ecological environments everywhere caused by the rapid development of current industrialized societies. At the United Nations conference in September 2020, General Secretary Xi Jinping stated the ambitious goal of achieving carbon peak by 2030 and carbon neutrality by 2060. In order to achieve this "dual carbon" goal, a variety of ways to help reduce carbon emissions need to be explored. In fact, before the "dual-carbon" goal was proposed, China had gradually established a carbon trading market in accordance with the requirements of the 12th Five-Year Plan, which also laid the policy foundation for the realization of the "dual-carbon" goal. 2013, Shanghai, Beijing, Guangdong, and Tianjin became the first batch of pilot regions, followed by the implementation of the policy in Hubei and Chongqing in 2014; and in 2016, Fujian also started to launch a carbon trading market. trading market.

The carbon emissions trading pilot policy is implemented through the reduction of greenhouse gas emissions, the use of market mechanisms, and the promotion of green and low-carbon development, and it is a key policy tool to achieve the goals of carbon peaking and carbon neutrality. According to the past practice of market-based environmental regulation, the market mechanism plays a central role in allocation, which not only improves the efficiency of resource allocation among regions, but also promotes the optimization of environmental governance. So can the implementation of carbon emissions trading pilot policy effectively enhance the industrial structure upgrade of the pilot regions? And through which ways to realize the impact on industrial structure upgrading? Answering these questions is not only closely related to the establishment of carbon trading market in the pilot regions and in the future, but also conducive to analyzing the new path of industrial structure upgrading from the perspective of carbon trading market.

In this paper, we review the literature from two perspectives: the impact of environmental regulation on industrial structure upgrading and the related research on carbon emissions trading pilot policies. Regarding the impact of environmental regulation on industrial structure upgrading, a large number of studies and analyses have been conducted by scholars on its relationship. The viewpoint of "follow the cost theory" believes that the implementation of environmental regulation policies may inhibit industrial restructuring [1]. On the other hand, Porter's hypothesis mentions that the implementation of environmental regulation can enhance the R&D investment of enterprises, which in turn promotes technological innovation and accelerates industrial structure upgrading [2]. Existing literature explores the influence between environmental regulation and industrial structure upgrading from three aspects. Some scholars believe that environmental regulation can significantly promote the upgrading of industrial structure [3], and has the role of regional heterogeneity [4]. Meanwhile, Li Yushu et al [5] argued that environmental regulation has a spatial spillover effect on regional industrial structure. Based on the empirical analysis of the Yangtze River Economic Belt, Li Qiang and Ding Chunlin [6] show that environmental regulation is not conducive to the industrial structure upgrading of the Yangtze River Economic Belt; and many scholars believe that the relationship between environmental regulation and industrial structure upgrading is nonlinear; Guan Hailing and Qu Tianyu [7] use the spatial Durbin model to conclude that the environmental regulation on the upgrading of the industrial structure presents a "U-shaped" characteristic; and Xie Yunshu et al [9] argue that environmental regulations have a spatial spillover effect on the regional industrial structure. "The research of Xie Yunfei et al.

[8] shows that environmental regulation has an ”inverted U-shape" on industrial structure upgrading. In addition, Zhu and Fang et al. [9] show that environmental regulation has an impact on industrial structure, and the impact effect varies depending on the type of environmental regulation.

For the carbon trading pilot policy, the current academic community mainly focuses on its empirical research. And from the micro and macro perspectives to explore the effect of carbon emissions trading pilot policy. At the micro level, numerous scholars have examined the implementation effects of this policy from various perspectives, including corporate ESG performance [10], financing constraints [11], and green innovation [12]. At the macro level, Shao Shuai et al.[13] employed a difference-in-differences model to examine the policy's impact on high-quality economic development. Zhou et al.[14] demonstrated that the policy enhances green total factor energy efficiency by elevating technological innovation levels. Furthermore, numerous scholars have shown that the pilot carbon emissions trading policy influences carbon reduction through green technological innovation[15] and energy structure transformation[16].

By organizing the existing literature, it is found that the research on the impact of environmental regulation on industrial structure upgrading is relatively comprehensive, but there is less literature on the impact of carbon trading policy on industrial structure upgrading. Therefore, based on the panel data of 31 provincial regions from 2005 to 2023, this paper adopts the asymptotic double-difference model to explore the impact between the carbon emissions trading pilot policy and industrial structure upgrading and its path of action.

2. Theoretical Analysis and Research Hypothesis

2.1. Carbon Trading Pilot Policies and Industrial Structure Upgrading

Existing environmental regulations are mainly divided into market-incentivized and command-oriented, and the carbon trading policy, as a market-incentivized environmental regulation, is a measure proposed in order to achieve the goal of “double carbon”. The so-called carbon trading is a market mechanism to control carbon dioxide emission by treating carbon dioxide emission right as a commodity, and the buyer purchases carbon dioxide emission right from the seller, thus controlling carbon dioxide emission. Upgrading the industrial structure of a region indicates the process of transforming its industrial structure from low-level to high-level and from unreasonable to reasonable [17]. The emergence of the carbon trading market makes enterprises in each region face two choices when facing policy constraints, one is to buy carbon emission quotas from other enterprises in the market, and the other is to carry out technological innovation on the production equipment of enterprises. In the long run, the latter will bring more favorable development to enterprises and enhance regional industrial structure upgrading.

Hypothesis 1 . The carbon emissions trading pilot policy can significantly improve the industrial structure upgrading.

2.2. Resource Allocation and R&D Investment

The carbon trading pilot policy internalizes the environmental costs of carbon emissions into the production costs of enterprises by setting carbon emission quotas and introducing a market trading mechanism. As the price of carbon fluctuates, an enterprise's carbon emission rights become a scarce resource that needs to be purchased at a cost, putting pressure on high-emission enterprises and prompting them to reduce emissions through technological transformation and cleaner production. This process improves the resource allocation efficiency of enterprises and reduces inefficient resource consumption. At the same time, the carbon trading policy promotes the reallocation of resources between high-carbon and low-carbon industries. High-carbon emission industries have limited profits due to high carbon costs, and resources gradually flow to low-carbon industries encouraged by the policy, which promotes the concentration of capital, technology and other resources to environmental protection and high value-added industries [18]. This market-based redistribution mechanism enhances the overall resource allocation efficiency of the pilot region and lays the foundation for industrial structure optimization. In addition, the rising costs faced by high-carbon enterprises weakened their competitiveness, and some high-carbon enterprises withdrew from the market or transformed to low-carbon, which made the resource space released, and the emerging low-carbon industries absorbed more capital and manpower, which promoted the upgrading of industrial structure. Liu Chuanzhe et al [19] analyzed the spatial spillover effect of resource allocation on industrial structure upgrading by constructing a spatial Dubin model. The results of the study show that improving the local resource allocation efficiency helps to promote the upgrading of the industrial structure in the region, but negatively affects the industrial structure of the neighboring regions. Meanwhile, Li Bin [20] empirically analyzed the impact of credit resource allocation on industrial structure optimization based on 30 provincial panel data in China, and the results showed that credit resource allocation can significantly promote the optimization of regional industrial structure.

In the production process of enterprises, due to the limitation of carbon trading policy, at this time, enterprises will buy carbon emission quotas in the trading market, which will lead to an increase in the production cost of enterprises. In order to consider this situation from a long-term perspective, enterprises will increase R & D investment to improve the production process. While reducing carbon emissions, they can also sell the remaining carbon allowances on the trading market, thus obtaining a greater expected return. Endogenous growth theory suggests that innovation is not only a fundamental source of economic growth, but also a key driver of endogenous economic evolution. Increased investment in R&D promotes technological innovation, which in turn improves the utilization efficiency of factors of production and leads to an increase in corporate output, ultimately promoting the upgrading of industrial structure. Wang Weilong et al [21] and Zhao Xicang et al [22] used the generalized least squares method to conclude that R&D investment can significantly promote industrial structure upgrading from the perspectives of venture capital and technological innovation; and Xia Jiechang et al [23] used 31 provinces as the object of study to conclude that R&D investment and its flow has a significant impact on the upgrading of the industrial structure of the tourism industry.

Hypothesis 2. The carbon trading pilot policy can promote the industrial structure upgrading level in the pilot area by improving the resource allocation efficiency and increasing the intensity of R&D investment.

2.3. Level of Government Intervention

Carbon trading policies establish a carbon emissions quota trading market, holding enterprises accountable for their carbon emission costs while providing economic incentives to drive technological upgrades or industrial transformation. This market mechanism operates on the assumption that enterprises will autonomously identify the most cost-effective emission reduction methods, thereby guiding the efficient allocation and rational flow of resources.

Firstly, according to market failure theory, as a policy-driven market, the carbon trading market faces issues such as information asymmetry and externalities. Relying solely on market forces makes it difficult to form effective carbon price signals, leading to resource misallocation or inefficient allocation. Government intervention—by setting emission standards, allocating quotas, or guiding carbon prices—can effectively correct these market failures. This enhances the stability and predictability of carbon trading, providing clear policy guidance to regions and driving industrial structures toward low-carbon and high-efficiency transformation. Secondly, given the positive externalities of low-carbon technologies and green innovation, enterprises in various regions often lack sufficient incentive for autonomous investment. Government compensation through fiscal support and tax incentives promotes widespread technology adoption, thereby elevating the overall technological level and green competitiveness of industries. Finally, government intervention helps reduce uncertainties in policy implementation across regions, providing clear policy direction for the market and mitigating risks for enterprises undergoing industrial restructuring.

Based on this, Hypothesis 3 is proposed: Government intervention exerts a positive moderating effect on the impact of carbon trading pilot policies on regional industrial upgrading.

3. Research Design

3.1. Model Setting

This paper focuses on the impact of the implementation of carbon emissions trading pilot policy on the upgrading of the industrial structure of each province. According to the 12th Five-Year Plan, the state requires the “gradual establishment of the carbon emissions trading market”, and China started to implement the policy in seven regions, including Beijing and Shanghai, one after another in 2013, In 2013, China started to implement the policy in seven regions, including Beijing and Shanghai. Due to the different time points of policy implementation, if the traditional DID model is used for analysis, the values of year dummy variables may lead to endogeneity problems if they are not accurate enough. Therefore, this paper adopts a multi-temporal double-difference model to solve the problem of inconsistency in the time point of the occurrence of carbon emissions trading pilot policies. This paper constructs the following multi-temporal double difference model:

$$UIS_{it} = \alpha_0 + \alpha_1 DID_{it} + \alpha_2 control_{it} + year_t + province_i + \varepsilon_{it} \quad (1)$$

$$\mathrm{DID}_{it} = treat_i \cdot post_t \quad (2)$$

Among these, i and t denote the provinces and years for which experimental groups were established; UIS represents industrial structure upgrading; the core explanatory variable is the implementation of carbon trading policies; where treat takes a value of 1 if the region implements carbon trading policies and 0 otherwise. post is a time dummy variable, taking a value of 0 prior to policy implementation and 1 thereafter. Control includes control variables: economic development level, demand structure, human capital stock, degree of openness, human capital level, fixed asset investment level, and marketization level. Year and Province represent fixed effects for year and province, respectively. Standard errors are clustered at the provincial level, and ε denotes the random disturbance term.

3.2. Variable Declaration

3.2.1. Dependent Variable

Industrial Structure Upgrading: This refers to a dynamic developmental process where the industrial structure progressively advances from lower to higher levels. Drawing upon Zhang Xinyan et al. [25], this paper constructs an index system for industrial structure upgrading that encompasses both the sophistication and rationalization of industrial structure. The entropy method is employed to calculate the industrial structure upgrading indicators and corresponding weights for each provincial region, with specific values presented in Table 1.

Table 1. Evaluation indicator system for industrial structure upgrading

	Index layer	Weights
Indicators for upgrading the industrial structure	Advanced industrial structure	0.887
	Rationalization of industrial structure	0.113

The index of advanced industrial structure is measured with reference to the product of the ratio of the utilization of labor productivity and output value proposed by Liu Wei et al [26]. The calculation formula is:

$$AIS_{it} = \sum_{m=1}^{3} y_{imt} \cdot E_{imt} \tag{3}$$

$$E_{imt} = \frac{Y_{imt}}{I_{imt}} \tag{4}$$

Here, i represents the province, t represents the year, and m represents the industrial sector. AIS_{it} denotes the industrial structure upgrading index for region i in year t; y_{imt} indicates the proportion of value added from sector m in region i relative to its provincial GDP in year t; E_{imt} represents labor productivity in sector m for region i during period t; Y_{imt} denotes industrial value added; and I_{imt} represents the number of employees across all sectors. Since y_{imt} is not quantifiable, E_{imt} requires non-quantitative treatment. In formula (3), a higher value of AIS_{it} indicates a more advanced industrial structure in the region, serving as a positive indicator.

The industrial structure rationalization index refers to the practice of Gan Chunhui et al [27], and uses the Thiel index to measure it. The calculation formula is:

$$RIS_{it} = \sum_{m=1}^{3} \frac{X_{imt}}{X_{it}} \cdot \ln\left(\frac{X_{imt}}{L_{imt}} \Big/ \frac{X_{it}}{L_{it}}\right) \tag{5}$$

Where RIS_{it} is the index of rationalization of industrial structure; X_{imt} is the output value of industry m of region i in year t; X_{it} is the total output value of region i in year t; L_{imt} is the number of employees in industry m of region i in year t; L_{it} is the total number of employees in region i in year t. In Equation (3), the larger the value of RIS_{it}, the more irrational the industrial structure of the region is, which is a negative indicator.

3.2.2. Explanatory Variable

Explanatory variables are dummy variables describing whether the provinces implemented carbon emissions trading policies during the period. Since Shenzhen, one of the pilot cities for carbon emissions trading in 2013, belongs to Guangdong Province, this paper takes Shanghai, Beijing, Guangdong, Tianjin, Chongqing, Hubei and Fujian as the experimental group. Therefore, seven provinces, namely Shanghai, Beijing, Guangdong, Tianjin, Chongqing, Hubei, and Fujian, are used as the experimental group in this paper, and other regions are used as the control group.

Table 2. Variable definitions

Variable type	Variable symbol	Variable name	Measuring method
Explaned variable	UIS	Upgrading of industrial structure	Entropy rights method
Explanatory variable	DID	Carbon emissions trading policy	Whether or not to include carbon trading
Control variables	SC	Demand structure	Log of total retail sales of consumer goods
	SL	Level of financial development	Balance of deposits and loans/GDP

	FAL	Level of fixed asset investment	Log of total fixed-asset investment
	lnGDPer	Level of economic development	Log of per capita GDP
	ML	Level of marketization	Fanzang 2018 marketization index
	OP	Level of opening to the outside world	Total imports and exports/GDP

3.2.3. Control Variables

Referring to Fan [28] and Zhang Xinyan et al [25], the marketization level (ML) and fixed asset investment level (FAI) are selected as the control variables in this paper. The definitions of the main variables are shown in Table 2.

3.3. Data Sources and Descriptive Statistical Analysis

Panel data of 31 provinces from 2005 to 2023 are selected as the research samples of this paper. The panel data of each province are from China Statistical Yearbook, Carbon Market Annual Report, statistical yearbook of each province and statistical bulletin. And the missing data are filled in by interpolation.

The descriptive results in the empirical research of this paper are shown in Table 3, the minimum value of the explanatory variable industrial structure upgrading has a relatively large gap with the maximum value, and its mean value is 0.181, and the variance is 0.126. It indicates that there is a relatively large difference in the degree of upgrading of industrial structure among different provinces. From the point of view of control variables, there are obvious differences in the level of economic development, degree of opening up to the outside world, level of marketization, and level of fixed asset investment in different provinces at the same time.

Table 3. Descriptive statistical analysis

Variables	Obs	Mean	SD	Min	Max
UIS	589	0.181	0.126	-0.980	0.772
DID	744	0.097	0.296	0.000	1.000
ML	589	7.662	2.229	-0.161	13.356
SL	589	3.259	1.148	1.454	8.164
FAI	589	9.108	1.142	5.201	11.134
lnGDPer	589	1.353	0.720	-1.818	4.883
SC	589	8.445	1.231	4.292	10.768
OP	589	0.303	0.414	0.010	6.070

4. Empirical Results and Analysis

4.1. Parallel Trend Test

The parallel trend test is a key prerequisite for asymptotic double-difference studies to ensure that the trend of changes in industrial structure upgrading in non-pilot and pilot regions before the implementation of the policy is the same. Based on the different time points of policy occurrence in this paper, the event study method proposed by Beck et al. [29] is borrowed to conduct the parallel trend test.

$$UIS_{it} = \alpha_0 + \sum_{t=-6}^{6} \delta_t D_{it} + \alpha_2 control_{it} + year_t + province_i + \varepsilon_{it} \tag{6}$$

Where D_{it} denotes a set of dummy variables, which takes 1 if region i has implemented the carbon emissions trading pilot policy in year t, and 0 otherwise. The sign meanings of other variables are the same as those in equation (1). Among them, δ_t is the core variable, reflecting the difference in industrial structure upgrading indicators between pilot and non-pilot regions in year t of the implementation of the carbon emissions trading pilot policy.

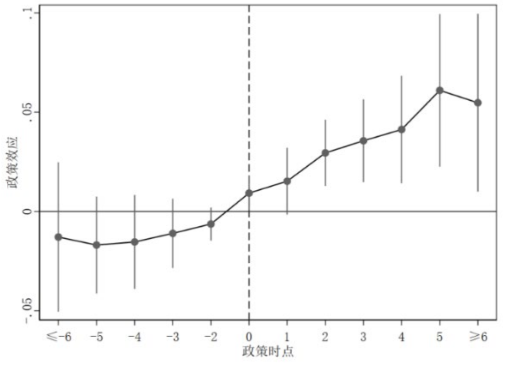

Fig. 1. Parallel trend test.

Since the research sample involves multiple years, this study integrates the data of the six years before the policy implementation into the -6th period, and the data of the six years after the policy implementation into the 6th period, and takes the year before the policy implementation as the base year to avoid the problem of multicollinearity. The results in Figure 1 show that before the implementation of the policy, there is no significant difference in the change trend of industrial structure upgrading index between pilot and non-pilot regions, which meets the requirements of parallel trend test. After the implementation of the policy, the effect of the carbon emissions trading pilot on industrial structure upgrading in the pilot areas increases year by year and becomes significant in the 2nd year after the implementation of the policy, indicating that the carbon emissions trading policy has a lagged effect on industrial structure upgrading.

4.2. Benchmark Regression and Result Analysis

In order to explore the impact of carbon emissions trading pilot policy on industrial structure upgrading in each province, asymptotic double-difference estimation is carried out based on equation (1). The regression results are shown in Table 4 below, where column (1) demonstrates the results without control variables and with the addition of fixed effects, indicating that the level of industrial structure upgrading is significantly positive at the 1% condition. Column (2), on the other hand, shows the regression results after adding fixed effects and control variables, and the coefficient of UIS is 0.052, which is significant at 1%, indicating that the carbon trading policy can significantly promote industrial structure upgrading. Thus hypothesis 1 is verified.

4.3. Robustness Test

The results of the benchmark regression show that the implementation of the carbon emissions trading policy significantly improves the level of industrial structure upgrading in the pilot region. In order to exclude the interference of other factors on the conclusions, the relevant robustness test is needed.

Table 4. Benchmark regression and robustness test

Variables	(1)	(2)	(3)	(4)	(5)
	UIS	UIS	UIS	IS	UIS
DID	0.057***	0.052***		0.260*	
	(2.86)	(3.00)		(1.70)	
L.DID					0.053***
					(3.17)
DID_P			0.001**		
			(2.69)		
ML		-0.004	-0.004	-0.019	-0.002
		(-0.71)	(-0.62)	(-0.76)	(-0.46)
SL		-0.004	-0.008	0.057	-0.006
		(-0.24)	(-0.52)	(1.66)	(-0.43)
lnGDPer		0.013*	0.010	-0.027	0.011*
		(1.93)	(1.31)	(-1.04)	(1.96)
SC		-0.057	-0.060	0.043	-0.057
		(-1.52)	(-1.59)	(0.46)	(-1.59)
OP		-0.009	-0.007	-0.077	-0.010
		(-1.31)	(-1.03)	(-1.00)	(-1.47)
Constant	0.174***	1.007***	1.013***	2.317**	1.013***
	(71.42)	(3.11)	(3.12)	(2.49)	(3.12)
id	YES	YES	YES	YES	YES
year	YES	YES	YES	YES	YES
Observations	589	589	589	589	558
R-squared	0.789	0.808	0.807	0.925	0.801

4.3.1. Intensity DID

In the baseline regression, this paper uses the differences between the implementation of carbon trading pilot policies in each region to distinguish between experimental and control groups. However, since the control group may also be affected by the policy, this will have an impact on the experimental results. Therefore, this paper adopts the intensity DID to conduct robustness tests, and replaces the grouping variable treat with a continuous variable that can reflect the intensity of the carbon trading pilot policy. In this paper, the carbon trading price in each pilot region is chosen as the continuous variable reflecting the intensity of the policy. The final results are shown in column (3) of Table 4, which shows that the coefficient of DID_P is still significantly positive.

4.3.2. Placebo Test

The significance of industrial structure upgrading in each province may be due to the influence of some random factors. Therefore this paper draws on the method of Liu and Lu et al [30] to implement the placebo test. The main idea of the method is to utilize fictitious policy time or treatment group for estimation. If the regression is still significant under a different approach, it can be inferred that the original results may be biased, indicating that the changes in the explained variables may be affected by random factors or other policies.

Thus to rule out the possibility that there are some unobservables influencing carbon trading policies. This paper utilizes a randomly generated experimental group to conduct the test.The results are shown in Figure 2. Most of the final estimates are distributed around 0 and obey the normal distribution, which indicates that the spurious policy has no significant impact on industrial structure upgrading, suggesting that the impact effect in this paper's baseline analysis of industrial structure upgrading is indeed caused by the implementation of the carbon emissions trading pilot policy. Moreover, it can be seen from the figure that the regression coefficients of this paper are located on the right side of the kernel density curve and close to the tail, indicating that the actual estimates fall in the highly significant region of the distribution.

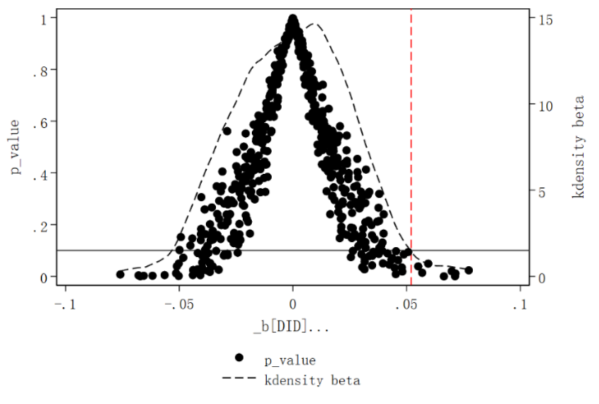

Fig 2. Placebo test.

4.3.3. Replacement of Explained Variables

To ensure the robustness of the regression, the test is conducted by replacing UIS. For the measurement of industrial structure upgrading, this paper refers to the measure of Lu Zhaoyang and Li Shu [31], which measures industrial structure upgrading based on the share of the value added of the tertiary industry in the sum of the value added of the primary and secondary industries. The test results are shown in (4) in Table 4, and the coefficient of IS is significantly positive. This indicates that the research results remain unchanged and the implementation of carbon trading policy has a significant promotion effect on industrial structure upgrading in the pilot region, and this result is also consistent with the benchmark regression results.

4.3.4. Lagged Explanatory Variables

Since it takes a certain amount of time for the industrial structure upgrading index of each pilot region to improve after the implementation of the carbon trading pilot policy, the effects of the policy tend to have a certain lag. In order to identify this effect, the explanatory variables are lagged by one period to explore the impact on industrial structure upgrading. The final results are shown in column (5) of Table 4, indicating that the carbon trading policy still significantly improves the level of industrial structure upgrading in the pilot regions, which also indicates that the regression results of this paper are robust.

Table 5. Excluding the effects of other policies

Variables	(1)	(2)	(3)
	UIS	UIS	UIS
DID	0.051***	0.052***	0.046***
	(3.02)	(3.13)	(3.01)
Sewage Rights	0.002		
	(0.08)		
Low Carbon		-0.015	
		(-0.65)	
Innovative Cities			0.022
			(0.90)
Constant	1.007***	1.012***	0.967***
	(3.11)	(3.10)	(2.89)
controls	YES	YES	YES
id	YES	YES	YES
year	YES	YES	YES
Observations	589	589	589
R-squared	0.808	0.808	0.809

4.3.5. Removing Other Related Policy Disturbances

Since the data in this paper covers the period 2005-2023, the time span is large. The implementation of other policies may also have an impact on regional industrial structure upgrading.

Therefore, this paper draws on the practice of Wu Yin Yin et al [32] to include the dummy variables of emissions trading in 2007, innovative city pilot in 2010, and low-carbon regional policies in the regression analysis. If the coefficients of DID are significant after the addition of these dummy variables, it indicates that the promotion of carbon trading policies on industrial structure upgrading in pilot regions is not affected by other policies. From columns (1), (2) and (3) of Table 5, it can be seen that the core explanatory variable DID is still positive at the 1% significance level after excluding the influence of other policies, which indicates the robustness of the regression results.

4.4. Heterogeneity Analysis

4.4.1 Grouping By Trade Capacity

Differences in resource endowment constitute the fundamental reason for the different trade capacity and trade status of Chinese provinces [33]. Therefore, this paper draws on the research of Qu Zhi [34] to categorize the 31 provinces into high-trade and low-trade regions in order to explore the impact of carbon trading policies on industrial structure upgrading under different trade capacity conditions. As shown in columns (1) and (2) of Table 6, the coefficients of DID are significantly positive in both low-trading and high-trading regions, which indicates that the policy has a significant role in promoting the industrial structure upgrading of both high-trading regions and low-trading regions. After the test of intergroup differences, it can be found that the promotion effect of low trade areas is more significant. The possible reason is that because of the developed economy of the high trade area, the marginal promotion effect of the policy is relatively small; while the economic development of the low trade area is relatively backward, and relatively poor in resources, technology and human capital, etc., and there is more room for improvement in the development of its industrial structure, so that this area is more obviously impacted by the policy.

Table 6. Heterogeneity analysis results

	(1)	(2)	(3)	(4)
Variables	UIS	UIS	UIS	UIS
DID	0.030*	0.123***	0.004	0.088***
	(1.81)	(4.18)	(0.27)	(4.14)
Constant	0.872**	1.173	0.262	1.148***
	(2.22)	(1.67)	(1.41)	(3.10)
controls	YES	YES	YES	YES
id	YES	YES	YES	YES
year	YES	YES	YES	YES
Observations	361	228	190	399
R-squared	0.741	0.862	0.924	0.728
Tests for differences between groups	0.093***		0.085***	

Note: The p-value for the test of difference between coefficient groups was calculated using the Fisher's combination test (1000 samples)

4.4.2 By Geographic Location

In this paper, the total sample is divided into the eastern as well as the central and western regions, and they are regressed separately. The final results are shown in (3) and (4) in Table 6. The impact of this policy on the industrial structure upgrading in the eastern region is not significant, while the industrial structure upgrading index in the central and western regions is rising significantly after the implementation of the carbon emissions trading policy. The reason for this may be due to the fact that the transformation and upgrading of the industrial structure and the economic development level of the eastern region are faster, so the effect of the policy on the eastern region is not obvious; while the technological innovation level of the central and western regions is lower than that of the eastern region, and there is more room for the development of the level of upgrading of the industrial structure, so that after the implementation of the policy, the effect of upgrading the industrial structure of the central and western regions is more significant.

5. Further Analysis

5.1. Median Analysis

Based on the analysis of the theoretical part of this paper, in order to explore the influence mechanism of carbon trading pilot policy on industrial structure upgrading. Referring to the analysis of the mediating effect in the causal inference study by Jiang Boat [35], this paper constructs the following mediating effect model based on the benchmark regression:

$$Mediator_{it} = \alpha + \beta DID_{it} + \gamma control_{it} + year_t + province_i + \varepsilon_{it} \tag{7}$$

Among them, Mediator is the mediator variable, and the measurement and definition of other variables are consistent with the previous paper.

5.1.1. R&D investment (Invest)

The theoretical analysis of this paper points out that the carbon trading policy is conducive to strengthening the importance of R&D investment in each region in the process of implementation, which in turn enhances the upgrading of the industrial structure in each region. In this paper, the intensity of R&D investment is measured by the proportion of R&D investment in each region to the regional GDP. The results of the mediation effect test of R&D investment are shown in column (2) of Table 7, and the regression coefficient of the explanatory variable DID on the mediating variable R&D investment is significantly positive, indicating that the carbon emissions trading pilot policy has a significant promotion effect on R&D investment, i.e., regions can enhance the level of upgrading of the industrial structure by improving the intensity of R&D investment in each region when adopting the carbon trading policy.

5.1.2. Resource allocation efficiency (MIS)

The theoretical analysis of this paper points out that the carbon trading pilot policy can enhance the resource allocation efficiency of each pilot region and thus promote the level of industrial structure upgrading. The resource allocation efficiency in this paper is measured by the index of the degree of factor distortion. The smaller the degree of distortion of market factors, the higher the efficiency of market resource allocation. This paper will use the production function method to measure it. The results of the market resource allocation test are shown in column (3) of Table 8. The regression coefficient of the explanatory variable DID on the mediator variable is significantly negative, indicating that the carbon emissions trading policy exerts a significant suppressing effect on the degree of market resource distortion. That is, the carbon trading market can enhance resource allocation efficiency across regions. Therefore, it is concluded that the policy in carbon trading pilot regions can promote industrial structure upgrading by improving resource allocation efficiency in these areas.

Table 7. Results of the mediation effect and moderation effect tests

	(1)	(2)	(3)
variables	UIS	Invest	MIS
DID	0.052***	0.003**	-0.166***
	(3.00)	(2.71)	(-3.16)
Constant	1.007***	-0.023	5.590***
	(3.11)	(-1.61)	(9.91)
control	YES	YES	YES
id	YES	YES	YES
year	YES	YES	YES
Observations	589	589	588
R-squared	0.808	0.930	0.944

6. Conclusions and Recommendations

Amid rising global economic policy uncertainty, the role of carbon trading pilot programs—as market-based incentive policies—in promoting industrial upgrading across regions has drawn widespread attention. This study employs a multi-period difference-in-differences model using panel data from China's 31 provinces between 2005 and 2023 to systematically evaluate the policy's impact on industrial upgrading. Results indicate that carbon trading policies significantly enhanced industrial upgrading levels in pilot regions, with findings validated through robustness tests. Heterogeneity analysis reveals that the policy's effects are more pronounced in regions with low trade intensity and in central and western China. Mechanism tests indicate that it positively influences industrial upgrading by enhancing resource allocation efficiency and increasing R&D investment. Based on these findings, this paper proposes corresponding policy recommendations.

First, regional governments should persistently advance the implementation of carbon emissions trading pilot policies and expand their coverage. They should fully leverage the pilot policy's role in driving industrial structure upgrading across regions, learn from and disseminate green development experiences to achieve dual economic and environmental progress.

Second, recognizing the regional heterogeneity of carbon trading pilot policies in driving industrial upgrading, pilot programs should be tailored to local conditions. A gradual implementation approach should be adopted based on regional realities. Areas not yet implementing the policy should avoid blindly replicating successful pilot models but instead develop region-specific strategies to ensure flexibility. This maximizes the policy's potential benefits for each locality.

Third, governments should optimize carbon market mechanisms to ensure stable and reasonable carbon pricing that conveys effective signals, thereby incentivizing enterprises to enhance resource efficiency. Strengthened oversight is crucial to prevent market manipulation and price volatility, ensuring carbon prices accurately reflect resource scarcity and assist enterprises in optimizing resource allocation. Simultaneously, financial institutions should be encouraged to participate in carbon trading, providing enterprises with carbon asset valuation and financing support to reduce emission reduction costs and enhance resource allocation efficiency. To drive industrial upgrading, governments should increase support for R&D in low-carbon technologies and green production, establish dedicated funds, and offer tax incentives to promote green technology adoption and low-carbon industrial transformation.

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