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The Impact of Carbon Emissions Trading on the High Quality Development of Manufacturing Industry - The Evidence from China

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ABSTRACT

Carbon emissions trading is an important part of emission reduction policy tools, and manufacturing is the foundation of a strong country. This paper explores the impact of carbon emissions trading pilot on the high-quality development of manufacturing industry by using the double difference method. It is found that carbon emissions trading can significantly promote the high-quality development of manufacturing industry, in which the government's will of ecological environment governance, technological progress and industrial structure rationalization have significant intermediary effects. Heterogeneity analysis reveals that the impact of carbon emissions trading on the high-quality development of the manufacturing industry is most significant in the western region. Accordingly, the study proposes suggestions on how to further improve China's carbon emissions trading market and realize the high-quality development of the manufacturing industry.

KEYWORDS

Carbon emissions trading; high-quality development of the manufacturing sector; dual-carbon targets

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1. Introduction

The building of an ecological civilization is closely related to the well-being of the people, and even more so to the future of the nation and the State. However, how to ensure high-quality economic growth on the premise of building an ecological civilization while getting rid of the crude economic development model and balancing the contradictions between environmental protection and economic development is an important issue faced by every country and region in the process of economic development. At the 75th session of the United Nations General Assembly, the Chinese government proposed to achieve carbon peak by 2030 and carbon neutrality by 2060. In order to accelerate the realization of the "dual-carbon" goal, the Ministry of Ecology and Environment (MOE) implemented the "Administrative Measures for Carbon Emission Trading (for Trial Implementation)" in February 2021, which means that a unified nationwide carbon emission trading pilot program has been established. As an economic policy, it aims to address environmental issues and promote high-quality economic development through market mechanisms (Zhang et al., 2019).

China has the largest manufacturing sector in the world. At the same time, carbon emissions from manufacturing production in China pose a serious threat to the environment. As China sets carbon-neutral targets, the manufacturing sector faces even more urgent pressure to reduce carbon emissions (Lin et al., 2023). Improving energy efficiency can address the dual problems of increasing energy demand and low-carbon transition, thereby realizing China's energy conservation, emission reduction, and green development goals. Carbon emissions trading can significantly improve energy efficiency in cities through green innovation and resource allocation channels (Hong et al.,2022). As an important part of emission reduction policy tools, the carbon emissions trading market provides new ideas for China's economic development and environmental governance. Carbon emissions trading can significantly increase the economic output of China's industrial sector, while effectively reducing carbon dioxide emissions. (Zhang et al., 2020). The primary objective of this study is to assess whether the establishment and functioning of the carbon emissions trading market contribute to the advancement of high-quality development within the manufacturing industry.

This paper mainly focuses on the following questions. First, does carbon emissions trading promote the high-quality development of China's manufacturing industry? Secondly, in the event that carbon emissions trading indeed plays a substantial role in enhancing the high-quality development of China's manufacturing sector, this study seeks to elucidate the underlying mechanisms at play. Specifically, it investigates whether government initiatives aimed at ecological governance, technological advancements, and the rationalization of industrial structures serve as intermediaries in the process of promoting high-quality development within the manufacturing industry through carbon emissions trading."

The contribution of this paper is multifaceted. First, this paper adopts the double-difference (DID) method to investigate whether carbon emissions rights trading is significantly associated with the high-quality development of the manufacturing industry. Thus, our study adds new references to the theoretical and empirical studies on the high growth of China's economy and manufacturing industry, and provides meaningful references and suggestions for the Chinese government to further improve the carbon emissions trading market as well as to promote the high-quality development of the manufacturing industry. Second. We adopt the use of TOPSIS method to measure the level of high-quality development of China's manufacturing industry. Third, this paper explores the mechanism between carbon emissions trading and high-quality development of the manufacturing industry by studying the government's intention to regulate the ecological environment, technological progress and rationalization of industrial structure as mediating variables.

2. Literature Review and Research Hypothesis

Tracing the theoretical foundations of carbon emissions trading as a means of environmental regulation, we find that the 1991 Nobel Prize in Economics winner of the 1991 Nobel Prize in Economics Coase The theory of property rights is its root. The concept of carbon emissions trading was first proposed by the American economist Dales in 1968, and in 1997, more than 100 countries around the world were affected by the global warming. global warming In efforts to address global warming, including the signing of the Kyoto Protocol, a treaty that outlines obligations for developed countries. Subsequently, in 2005, with the formal entry into force of the Kyoto Protocol, carbon emission rights became an international commodity. international commodity , forward products based on carbon trading, futures products, swaps products, futures products, swaps and options products based on carbon trading have emerged continuously, and international carbon emission right trading has entered a high-speed development stage. The international carbon emissions trading has entered a stage of rapid development.

China's carbon emissions trading market is less mature, the system is highly volatile and less efficient than that of the European Union. (Sun et al., 2020). Although there is a large body of literature focusing on market-oriented environmental regulations in China, there is still relatively little research on the impact of China's carbon emissions trading pilot on the high-quality development of the manufacturing sector. While the high-quality development of China's manufacturing industry initially lags, but carbon emissions trading significantly improves the level of high-quality development of the manufacturing industry. In addition, technological innovation plays an important role in the process of carbon emissions trading to promote the high-quality development of the manufacturing industry (Wang et al., 2022). We can find that although the research on the impact mechanism of carbon emissions trading has been relatively abundant, there is little research on the relationship between high-quality development of the manufacturing industry and carbon emissions trading, as well as the impact mechanism between the two. In view of this, this paper proposes the following research hypotheses.

Hypothesis 1: The implementation of carbon emissions trading policy can significantly promote the high-quality development of China's manufacturing industry.

In the manufacturing sector, Carbon Emissions Trading (CET) is an important measure to combat climate change. There are many scholars who have studied the impact of Carbon Emissions Trading on the economy.

At the firm level. Carbon emissions trading negatively affects firms' environmental investment, and the reduction in environmental investment generated by carbon emissions trading policies is particularly pronounced among non-state-owned firms and large mature firms. The reason for this may be that carbon regulation leads to productive investment crowding out green investment (Yang., 2023). After the establishment and operation of a carbon emissions trading market, the level of corporate risk-taking of the relevant firms will increase significantly (Lin et al., 2022). Carbon emissions trading will expand firms' fixed asset investments, reduce fixed asset turnover, and increase government credit support and green subsidies to firms, which will lead to disorderly expansion of production capacity (Wang et al., 2023). Antoine (2023) investigates the impact of the European Union Emissions Trading System (EU ETS) on carbon emissions and the economy. EU ETS does not have a significant impact on profits and employment, but leads to an increase in revenues and fixed assets of regulated firms. Carbon emissions trading can dampen firms' total factor productivity through cost effects and improve their total factor productivity through, for example, innovation effects. Overall, carbon emissions trading can significantly improve corporate total factor productivity (Cheng et al., 2023). In addition to the direct impacts on enterprises, can carbon trading promote high-quality development of enterprises through the government's willingness to govern the ecological environment? So, this paper puts forward the following hypotheses.

Hypothesis 2: Carbon emissions trading can promote the government's will for ecological and environmental governance, thus promoting the high-quality development of the manufacturing industry.

In terms of impact mechanisms. Carbon emissions trading can significantly improve energy efficiency through industrial structure and R&D investment, and it is more significant in regions with high population and high wages (Tan et al.,2022). Carbon emissions trading significantly improves green development efficiency and regional carbon equality. Green total factor productivity (GTFP) and reduced investment in carbon-intensive industries in pilot provinces are two important channels to promote regional carbon equality (Zhang et al.,2021). Firm size and R&D investment have positive moderating and mediating effects in promoting green innovation through carbon trading (Zhao et al.,2023). Carbon trading policies can improve carbon efficiency by stimulating green technological innovation, reducing misallocation of energy and optimizing transportation networks (Du et al.,2023). Evaluating the effectiveness of carbon emissions trading policies from the perspective of corporate innovation, it can be found that carbon emissions trading policies significantly promote corporate carbon emission reduction through innovation (Lv et al.,2021). Carbon trading positively affects urban carbon emission reduction through foreign direct investment, industrial structure and technology effects (Ma et al., 2023). In view of this, this paper would like to further explore whether industrial structure has a mediating role in the impact of carbon trading on the high-quality development of the manufacturing industry, and therefore proposes the following hypothesis.

Hypothesis 3: Carbon emissions trading can promote the rationalization of industrial structure, thus promoting the high-quality development of manufacturing industry.

On the relationship between carbon trading and technological progress. Carbon emissions rights trading promotes green invention and innovation of enterprises. Moreover, carbon trading is more conducive to promoting green innovation in SOEs than in non-SOEs (Deng et al., 2023). China's carbon emissions trading pilot policy triggered green innovation in firms in the pilot areas, and the positive impact was greater for large, non-state-owned firms (Liu et al., 2022). Carbon emissions trading reduces green technological innovation in the energy sector to some extent due to the high cost of compliance with environmental regulations (Sun et al.,2023). Technological progress is the mediating variable of carbon emissions trading policy to reduce carbon intensity in neighboring regions (Dai et al.,2022). Carbon emissions trading greatly encourages green technological innovation in industrial enterprises. This positive effect is greater for firms with larger capitalization and better corporate governance, especially for firms in the mining and manufacturing sectors (Liu et al.,2023). China's carbon emissions trading policy can greatly promote green technology innovation in pilot cities. And environmental regulation and development strategies can greatly enhance this positive effect (Zhou et al., 2022). In view of this, this paper proposes the following research hypotheses.

Hypothesis 4: Carbon emissions trading can promote technological progress and thus high-quality development of the manufacturing industry.

These literatures have examined the impact of carbon emissions trading on the high-quality development of the manufacturing sector and put forward related policy recommendations and management strategies. They cover the impacts of carbon trading on manufacturing costs, technological progress, innovation, energy efficiency, green production and enforcement. These studies are of great significance in guiding the manufacturing industry to achieve sustainable development, promote carbon emission reduction and respond to climate change.

3. Methodology and Data Selection

3.1. Data Selection

In 2011, China launched a pilot carbon emissions trading program in seven provinces, including Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong and Shenzhen. In December 2014, the Interim Method for the Administration of Carbon Emission Rights Trading Management Interim Method" was released to clarify the general framework of the national carbon market construction from the institutional level. In September 2015, it was first confirmed that a unified national carbon market trading system would be opened in 2017.In 2016, after the first seven pilots, Fujian and Sichuan also launched the construction of their own provincial carbon emissions trading pilots. This provides a quasi-natural experimental sample for the analysis and research of this paper. To ensure the accuracy of the results regarding the impact of establishing carbon emissions trading pilots on manufacturing industry's high-quality development, the article excludes Tibet and Hong Kong, Macao and Taiwan, which are difficult to obtain data, and ultimately selects 30 provincial panel data from 2011 to 2020 to examine the impact of carbon emissions trading on the high-quality growth of the manufacturing industry, and in order to avoid heteroskedasticity, we use the logarithmic form of the variables. The relevant data come from CEADS database, China Carbon Emission Right Trading website, Shanghai Environment and Energy Exchange, as well as China Statistical Yearbook, China Energy Statistical Yearbook, and China Industrial Economy Yearbook of past years. The descriptive statistics of each variable are shown in **Table 2**. After comparing the difference data between the experimental group and the control group, it is found that there is a significant difference between the data indicators of the two groups during the study period.

Table 1. Descriptive Statistics.

VARIABLES	control subjects			experimental group		
	N	mean	sd	N	mean	sd
HQID	230	0.169	0.150	70	0.240	0.169
PGDP	230	45,084	18,304	70	83,645	32,650
OPEN	230	52700000	88150000	70	206700000	207000000
GI	230	0.285	0.121	70	0.196	0.0453
GW	230	0.0405	0.0141	70	0.0244	0.0259
TA	230	3,004	4,967	70	5,999	6,825
RIS	230	0.237	0.140	70	0.106	0.0889

With reference to the relevant literature on the level of high-quality development of the manufacturing industry (Wang et al., 2022), this paper uses the TOPSIS method to measure the level of high-quality development of the manufacturing industry (HQID) from the four dimensions of scale, innovation, efficiency and environmental protection. The scale dimension includes five secondary indicators: investment in fixed assets in the manufacturing industry, the number of industrial enterprises above designated size, the value added of the manufacturing industry, the value added of the industry, and the value added of the high-end manufacturing industry. The innovation dimension includes three secondary indicators: R&D expenditure of industrial enterprises above scale, full-time equivalents of R&D personnel of industrial enterprises above designated size, and the number of new product development projects of industrial enterprises above designated size. Efficiency dimension includes four secondary indicators: selling expenses, administrative expenses, financial expenses and total profits of industrial enterprises above designated size. The environmental protection dimension includes three secondary indicators: electricity consumption, wastewater emissions and carbon dioxide emissions. Specific indicators are shown in Table 2, where positive indicators represent positive correlation with the level of high-quality development of manufacturing industry, and negative indicators represent negative correlation with the level of high-quality development of manufacturing industry. After obtaining the data of the above indicators, the data are first standardized and the entropy value method is used to determine the weights of each secondary indicator, and finally the results of the manufacturing high-quality development level are calculated.

The basic principle and calculation process of entropy weight method is as follows: Assuming that the research object consists of n sample units, and there are m evaluation indexes reflecting the quality of the sample, respectively x_i (i =1, ..., m), the original data matrix can be obtained as follows.

$$R' = (r'ij)m \times n(i = 1, \dots, m;\ j = 1, \dots, n) \tag{1}$$

R' is standardized to eliminate the influence of different units and measures among indicators in order to obtain the standardized score matrix of each indicator. Considering that the standardized data r_{ij} is affected by r'_{ij}, Min $|r'_{ij}|$ and Max $|r'_{ij}|$, the original data is standardized using the extreme value method. Let the original data matrix be R' = $(r'_{ij})_{m\times n}$, the standardized matrix be R = $(r'_{ij})_{m\times n}$, and the standardized formulas for the positive and negative indexes are respectively:

$$Rij = \frac{r'\ ij}{\sum_{j=1}^{n} r'\ ij} \tag{2}$$

The information entropy of each indicator can be calculated after normalizing the raw data. The entropy Hi of the ith indicator can be defined as.

$$Hi = -k \sum_{i=1}^{n} f\ ij\ lnfij\ , i = 1, \ldots, m; j = 1, \ldots, n \tag{3}$$

$\text{fij} = \frac{\text{rij}}{\sum_{j=1}^{n} \text{rij}}$, which is the ratio of the standardized matrix indicator to each of its column sums. $k=\frac{1}{\ln N}$ which is the ratio of 1 to the logarithmic value of the number of items of each indicator. After the entropy value of the indicator is determined the entropy weight w of the ith indicator can be determined according to the following equationi:

$$Wi = \frac{1 - Hi}{m - \sum_{i=1}^{m} Hi}, i = 1, \ldots, m \tag{4}$$

Table 2. Comprehensive evaluation indicators for high-quality development of manufacturing.

Level 1 indicators	Secondary indicators	causality
Scale dimension	Investment in fixed assets in manufacturing	positive
	Number of industrial enterprises above designated size	positive
	Manufacturing value added	positive
	value added by industry	positive
	Value added of high-end manufacturing	positive
Innovation Dimension	R&D Expenditures of Industrial Enterprises Above Scale	positive
	Full-time equivalents of R&D personnel in industrial enterprises above designated size	positive
	Number of new product development projects in enterprises above designated size	positive
Efficiency dimension	Selling expenses of industrial enterprises above designated size	negative
	Administrative expenses of industrial enterprises above designated size	negative
	Finance costs of industrial enterprises above designated size	negative
	Total profit of industrial enterprises above designated size	positive
Environmental dimension	Electricity consumption	negative
	Wastewater discharge	negative
	Carbon dioxide emissions	negative

In addition to the fact that the establishment of carbon emissions trading pilot will affect the high quality development of regional manufacturing industry, the level of high quality development of regional manufacturing industry may also be affected by other factors. Therefore, this paper introduces three control variables: the level of economic development, the degree of openness to the outside world, and the level of government intervention.

First is the level of economic development (PGDP), the level of economic development in the region is often closely related to the level of manufacturing development. This paper uses the per capita GDP of each province to measure the regional economic development level. Second is the level of opening up to the outside world (OPEN), the manufacturing industry has always been an important industry for foreign investment and import and export, and the improvement of the level of openness in the field of manufacturing can inject a strong impetus for the high-quality development of the manufacturing industry. This paper uses the total amount of import and export to measure the level of regional openness. Third is the level of government intervention (GI), government behavior and industrial development are closely related, this paper uses the ratio of general public budget expenditure to GDP to measure the level of government intervention.

In addition, this paper also introduces three mediating variables, namely, the government's ecological and environmental governance will, technological progress and industrial structure rationalization, as a way to study the mechanism of the role between carbon emissions trading and high-quality development of the manufacturing industry. First is the government's ecological and environmental governance will (GW), an important consideration for high-quality growth of the manufacturing industry is the improvement of the green level, and the increase of the government's ecological and environmental governance will as well as the guidance at the policy level can promote the green transformation and upgrading of the manufacturing industry. In this paper, the frequency of words related to the word "environmental protection" in the work reports of local governments of 297 prefectural-level cities across the country is counted and summarized by province to measure the ecological and environmental governance will of the government in each province. Then, technological progress (TA), technological progress is necessary to support manufacturing enterprises to high-quality development, this paper uses the number of green utility model patents obtained in each province to measure technological progress. Third, industrial structure rationalization (RIS), this paper uses Theil's index to measure industrial structure rationalization. Thiel index was first proposed by Theil, some scholars use it for the study of regional income disparity, and we find that Thiel index is indeed a good indicator to measure the rationality of industrial structure. Therefore, this paper redefines Theil's index, Theil's index is 0, which indicates that the industrial structure is in equilibrium and the industrial structure is reasonable, and Theil's index is not 0, which indicates that the industrial structure deviates from the equilibrium and the industrial structure is unreasonable. Its calculation formula is as follows.

$$TL = \sum_{i=1}^{n} (\frac{Y_i}{i}) \ln (\frac{Y_i}{L_i} / \frac{Y}{L}) \tag{5}$$

3.2. Methodology

3.2.1. Baseline Model

In order to test whether the establishment of the carbon emissions trading pilot can promote the high-quality development of the manufacturing industry, this paper uses a double-difference model to conduct an empirical study. Considering the completeness, systematicity and lag of the policy implementation, the period before 2016 is taken as the period before the policy implementation, and 2016 and after is taken as the policy implementation period. Seven provinces, including Chongqing, Tianjin, Hubei, Shanghai, Guangdong, Beijing and Fujian, are taken as the experimental group, and the other 23 non-pilot provinces except Tibet, Hong Kong, Macao and Taiwan are taken as the control group. The specific model settings are as follows:

$$LnHQID_{it} = \beta_0 + \beta_1 TREAT_i \times AFTER_t + \beta_2 Ctr_{it} + \psi_t + \gamma_i + \varepsilon_{it} \tag{6}$$

In the formula LHQIDit is an explanatory variable indicating the level of high-quality development of manufacturing industry in province i at year t, and$TREAT_i$ denotes the dummy variable for the pilot province i of carbon emissions trading, which takes the value of 1 if the value is 1 to indicate the pilot province, and 0 if the value is 0 to indicate the non-pilot province, the $AFTER_t$ denotes the dummy variable of the policy when it is implemented in period t, which takes the value of 1 after the establishment of the pilot and 0 before the establishment of the pilot, and Ctrit denotes a set of control variables affecting the level of carbon emissions in the region; ψ t , γi denote the fixed effects of time and region, respectively, and εit is the random error term. In addition, the regression coefficient of the interaction term (dei × pet), β1, is mainly used to observe the causal effect of the establishment of the carbon emissions trading pilot on the high-quality development of the manufacturing industry. Hypothesis 1 implies $\alpha_1 >$ 0. In other words, carbon emission right trading promotes the high-quality development of manufacturing industry.

3.2.2. Mediating Effect

In order to test Hypotheses 2-4 and explore the mechanism of carbon trading and high quality development of manufacturing industry, we consider the three-step approach, proposed by Baron and Kenny (1986), which aims to evaluate the role of mediating variables between the explanatory and dependent variables in a regression model. In a nutshell, this approach consists of three steps, outlined below. In a nutshell, this approach consists of three steps, outlined below.

Step 1. The dependent/outcome variable Y is regressed on the independent variable X The independent variable is regressed on the independent variable.

$$Y = AX + e_1 \tag{7}$$

where the estimate of A is expected to be significant.

Step 2. The mediator M is regressed on the independent variable X The mediator is regressed on the independent variable.

$$M = BX + e_2 \tag{8}$$

where the estimate of B is expected to take on values that significantly different from zero.

Step 3. The dependent/outcome variable is regressed on both the independent variable X and the mediator variable M The dependent/outcome variable is regressed on both the independent variable and the mediator variable, as indicated in the following equation.

$$\mathrm{Y} = CX + DM + e_3 \tag{9}$$

Hypotheses 2-4 suggest that the variables of governmental ecological and environmental governance will, technological progress and industrial structure rationalization can effectively regulate the relationship between carbon emissions trading and manufacturing high-quality development. We try to determine whether carbon emissions right trading can promote the high-quality development of manufacturing industry through these three ways. Equation 1 describes Step 1. in Step 2, we test the effects of carbon emissions rights trading on the government's will to govern the ecological environment, technological progress, and industrial structure rationalization, and we control for a vector of variables Ctr_{it}.

$$LnGW_{it} = \beta_0 + \beta_1 TREAT_i \times AFTER_t + \beta_2 Ctr_{it} + \psi_t + \gamma_i + \varepsilon_{it} \tag{10}$$

$$LnTA_{it} = \beta_0 + \beta_1 TREAT_i \times AFTER_t + \beta_2 Ctr_{it} + \psi_t + \gamma_i + \varepsilon_{it} \tag{11}$$

$$LnRIS_{it} = \beta_0 + \beta_1 TREAT_i \times AFTER_t + \beta_2 Ctr_{it} + \psi_t + \gamma_i + \varepsilon_{it} \tag{12}$$

Step 3 considers the regression of the government's will to govern the ecological environment, technological progress and industrial structure rationalization in the BASELINE MODEL.

$$LnHQID_{it} = \beta_0 + \beta_1 TREAT_i \times AFTER_t + \beta_2 LnGW_{it} + \beta_3 Ctr_{it} + \psi_t + \gamma_i + \varepsilon_{it} \quad (13)$$

$$LnHQID_{it} = \beta_0 + \beta_1 TREAT_i \times AFTER_t + \beta_2 LnTA_{it} + \beta_3 Ctr_{it} + \psi_t +. \gamma_i + \varepsilon_{it} \quad (14)$$

$$LnHQID_{it} = \beta_0 + \beta_1 TREAT_i \times AFTER_t + \beta_2 LnRIS_{it} + \beta_3 Ctr_{it} + \psi_t + \gamma_i + \varepsilon_{it} \quad (15)$$

4. Results and Discussion

An important prerequisite for applying double differencing is to satisfy the parallel trend assumption, i.e., to require the treatment and control groups to have the same trend of change before the implementation of the policy. Although it can be seen from the data in this paper that the trend of changes in the explanatory variables of the experimental group and the control group before the implementation of the policy remains basically parallel, in order to verify the parallel trend assumption more accurately, this paper adopts empirical analysis to test it. As shown in Table 3, the regression coefficients of the treatment group and the control group are basically near the value of 0 and insignificant before the base year of the carbon emissions trading policy selected in this paper. After the implementation of the policy, there is a certain lag in the first year of the policy implementation effect, and from the second year onwards the absolute value has a tendency to increase year by year, and the significance is increasing. This indicates on the one hand that the parallel trend hypothesis is satisfied before the implementation of the policy, and on the other hand, it also confirms that carbon emissions trading has a significant and sustained impact on the high-quality development of the manufacturing industry.

Table 3. Parallel Trend Test.

Independent Variables	Dependent Variable: LnHQID
TREAT*2013	0.0194
	(0.0400)
TREAT*2014	0.0396
	(0.0400)
TREAT*2015	0.0436
	(0.0399)
TREAT*2016	0.00793
	(0.0399)
TREAT*2017	0.00675**
	(0.0398)
TREAT*2018	0.0896**
	(0.0398)
TREAT*2019	0.0963**
	(0.0400)
TREAT*2020	0.163***
	(0.0406)
LnOPEN	0.0663***
	(0.0210)
LnPGDP	1.190***
	(0.0958)
LnGI	0.455***
	(0.0811)
Year fixed	YES
City fixed	YES
Observations	300
R-squared	0.991

*Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.*

4.1. Baseline Model Results

After validating the parallel trend hypothesis, Table 3 reports the baseline results of the DID method. Without adding any control variables in column (1), the estimated coefficient on the interaction term TREAT*AFTER is significantly positive at the 1% level, indicating that the establishment of the carbon emissions trading pilot has a positive promotion effect on the high-quality development of the manufacturing industry. The implementation of the carbon emissions trading policy leads to an average increase of 7.75% in the level of high-quality development of the manufacturing industry in the pilot provinces and cities. Column (2) adds three control variables of economic development level, openness to the outside world and government intervention level on the basis of column (1), and it was found that the coefficient of the interaction term TREAT*AFTER remained significantly positive at the 1% significance level. The magnitude of the coefficient indicates that, given all other conditions being equal, the implementation of the carbon emissions trading policy increases the level of high-quality development of the manufacturing industry in the pilot provinces and cities by 4.67% on average. Table 3 also shows that the effect of the level of economic development on the level of high-quality development of the manufacturing industry is significant at the 1% level, indicating that the increase in the level of economic development in the region does have a significant role in promoting the high-quality development of the manufacturing industry. The impact of the level of openness to the outside world on the level of high-quality development of the manufacturing industry is also significant at the 1% level, indicating that the improvement of the level of openness to the outside world can effectively promote the high-quality development of the manufacturing industry. Finally, the effect of the level of government intervention on the level of high-quality development of the manufacturing industry is also significant at the 1% level, which indicates that the government's support and guidance play a crucial role in the high-quality development of the manufacturing industry. Thus, we verify hypothesis 1.

Table 4. Baseline Results.

Independent Variables	(1)	(2)
	Dependent Variable: LnHQID	Dependent Variable: LnHQID
TREAT*AFTER	0.0775***	0.0467***
	(0.0275)	(0.0211)
LnOPEN		0.0690***
		(0.0214)
LnPGDP		1.108***
		(0.0954)
LnGI		0.351***
		(0.0786)
Constant	1.964***	14.61***
	(0.00665)	(0.928)
Year fixed	YES	YES
City fixed	YES	YES
Observations	300	300
R-squared	0.982	0.990

*Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.*

4.2. Robustness Check

In order to test the robustness of the results, this paper uses the replacement of explanatory variables and placebo test to test their robustness, and the results are shown in Table 6 and Figure 1. First, the explanatory variables are replaced. While keeping the indicators of the level of economic development, the level of openness to the outside world and the level of government intervention unchanged, the index of high-quality development of the manufacturing industry is replaced by using the value added of high-end manufacturing industry (VAHM), and a benchmark regression is conducted to test the robustness of the results of this paper. According to columns (1) and (2), the results pass the 1% significance test after replacing the explanatory variables, indicating that carbon emissions trading is robust to the promotion of high-quality development of the manufacturing industry.

Next, a placebo test is conducted. As seen in Figure 1, the distribution of randomly assigned spurious estimated coefficients are all clustered around the zero point, with most of the estimates having p-values greater than 0.1. Meanwhile, the true estimated coefficients of the dei*pet in this paper (red vertical dashed line position) are clear outliers in the placebo test. The results of this test suggest that the significant impact of carbon emissions trading on the high-quality development of the manufacturing industry in the treatment group only appeared after the implementation of the carbon trading pilot policy, according to which the possibility that the estimates in this paper are influenced by other unobserved factors can be further ruled out. It is also reasonable to assume that the double-difference identification setup of this paper is reasonable and effective, and the results are robust.

Table 5. The Impact of carbon trading on LnVAHM.

Independent Variables	(1) Dependent Variable: LnVAHM	(2) Dependent Variable: LnVAHM
TREAT*AFTER	0.0280***	0.0286***
	(0.0857)	(0.0864)
LnOPEN		-0.00174
		(0.0877)
LnPGDP		0.0572**
		(0.0390)
LnGI		-0.506
		(0.321)
Constant	8.063***	6.763*
	(0.0207)	(3.794)
Year fixed	YES	YES
City fixed	YES	YES
Observations	300	300
R-squared	0.940	0.941

*Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.*

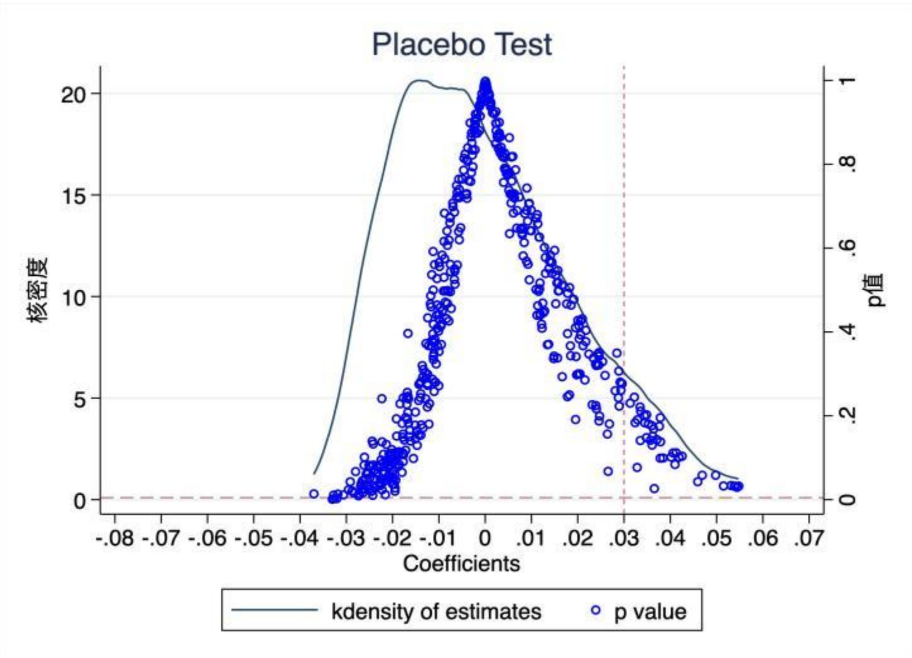

Figure 1. Placebo test.

4.3. Heterogeneity Analysis

In economics research, China is usually divided into three regions: eastern, central and western, as shown in Figure 2. There are obvious regional differences in the level of high-quality development in China. The eastern region is significantly higher than the central and western regions. Therefore, we investigated whether the impact of carbon emissions trading on the high-quality development of the manufacturing industry is significant in different regions. For this purpose, we divided the sample into eastern, central and western regions and studied the effect of carbon emissions rights trading separately, and the results are shown in Table 6.

The coefficient estimates of TTREAT*AFTER are 0.0115,0.0170 and 0.0893, respectively. The sign and magnitude of this coefficient varies across geographic regions, which suggests regional heterogeneity. The impact of carbon emissions trading on the high-quality development of the manufacturing industry is most significant in the western region. As for the control variables, the coefficient estimate of the level of openness to the outside world is positive, but it is significant only in the central and western regions. This suggests that in regions where the level of openness to the outside world is already relatively high, a further increase in the level of openness to the outside world does not lead to an equivalent increase in the level of high-quality development of the manufacturing sector. The coefficient estimates for the level of economic development are all positive and significant in all three regions. It indicates that the level of economic development increases the level of high-quality development of the manufacturing industry through efficient resource allocation. In addition, the level of government intervention is significantly positive only in the eastern region, not significant in the western region, and the estimated coefficient is negative in the central region. This indicates that the eastern region is the most effective in promoting high quality development of manufacturing industry through government intervention. As for the western region, it may be due to the relative backwardness of the manufacturing development level compared to the central and eastern regions, and the lack of industrial base and effective policy support. The negative estimated coefficients for the central region may be due to the fact that government intervention policies have limited attraction for capital and labor, and even inhibit the effective use of resources to some extent, compared to the eastern region.

Table 6. Heterogeneity Analysis.

Independent Variables	Dependent Variable: LnHQID		
	(1)	(2)	(3)
	Central Region	Eastern Region	Western Region
TREAT*AFTER	0.0115**	0.0170**	0.0839***
	(0.0248)	(0.0317)	(0.0215)
LnOPEN	0.117***	0.106	0.0473**
	(0.0409)	(0.0729)	(0.0219)
LnPGDP	0.988***	1.570***	0.845***
	(0.131)	(0.184)	(0.119)
LnGI	-0.222**	0.375***	0.0449
	(0.104)	(0.106)	(0.0973)
Year fixed	YES	YES	YES
City fixed	YES	YES	YES
Observations	140	130	170
R-squared	0.987	0.987	0.991

*Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.*

Figure 2. Distribution map of the three major regions of China.

4.4. Mediating Effects

In the above study, we found that carbon emissions trading does have a significant role in promoting the high-quality development of the manufacturing industry. Next, we selected three variables, namely, the government's will to govern the ecological environment, technological progress and rationalization of industrial structure, to analyze the mechanism of action between the two.

Table 7. The Mediating Effects test.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	LGW	LTA	LRIS	LHQID	LHQID	LHQID
TREAT*AFTER	0.0488***	0.149***	0.0708***	0.0449***	0.0460***	0.0443***
	(0.0557)	(0.0553)	(0.0592)	(0.0211)	(0.0215)	(0.0211)
LGW				0.0379**		
				(0.0588)		
LTA					0.0047***	
					(0.0539)	
LRIS						0.0336***
						(0.0522)
LOPEN	-0.0855*	-0.256***	0.112*	0.0657***	0.0678***	0.0652***
	(0.0464)	(0.0561)	(0.0601)	(0.0216)	(0.0223)	(0.0215)
LPGDP	0.313	1.135***	0.236	1.120***	1.113***	1.100***
	(0.206)	(0.250)	(0.267)	(0.0956)	(0.0993)	(0.0953)
LGI	-0.335**	0.0234	0.375*	0.338***	0.351***	0.338***
	(0.170)	(0.206)	(0.220)	(0.0791)	(0.0787)	(0.0788)
Observations	300	300	300	300	300	300
R-squared	0.970	0.982	0.944	0.990	0.990	0.990

*Notes: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.*

We use a three-step approach to test the mediating effects of the government's will to govern ecologically, technological progress, and rationalization of industrial structure. The first step consists of estimating the baseline regression equation. In the second part, we regress the government's will to govern ecologically, technological progress, and industrial structure rationalization are regressed on the three mediating variables, and the results are summarized in columns 1-3 of Table 5. In Part III, the regression equation includes TREAT*AFTER and mediating variables. The results are reported in columns 4-6. It can be seen that carbon emissions trading has a significant contribution to the government's will for ecological and environmental governance, technological progress and industrial structure rationalization. The results in columns 4-6 reveal the mediating roles of governmental ecological and environmental governance will, technological progress and industrial structure rationalization between carbon emission rights trading and high-quality development of manufacturing industry. The mediating effect of the government's ecological and environmental governance will be the strongest, followed by industrial structure rationalization and technological progress. Overall, hypotheses 2-4 are all verified.

5. Conclusion

Based on the quasi-natural experiment of carbon emissions trading market, this paper comprehensively evaluates the impact of the establishment of China's carbon emissions trading market on the high-quality development of the manufacturing industry by using the double-difference method with sample date from 30 rovinces and cities in China from 2011 to 2020. It is found that carbon emissions trading can significantly promote the level of high-quality development of the manufacturing industry in the pilot regions, and its policy effect is revealed year by year. Through the mechanism study, we also found that the government's will to govern the ecological environment, technological progress and rationalization of industrial structure all have significant mediating effects to a certain extent. The above findings provide targeted empirical evidence and policy insights for improving China's carbon emissions trading market and promoting the high-quality development of the manufacturing industry.

First of all, we should give full play to the role of government intervention. China's carbon emission right market construction is still in the early stage, and faces several challenges, These include the absence of a standardized carbon emission measurement system, limited market activity, and the need for enhancements in the regulatory framework, etc., To address these issues, it is essential to promptly introduce pertinent laws and regulations governing carbon emission rights trading management. Additionally, establishing a nationally unified system for carbon emission measurement standards is crucial to promote the widespread adoption of a standardized framework in advancing the development of the national carbon market.

It is also necessary to establish and improve the long-term management mechanism for all kinds of market players to participate in carbon market transactions from the top-level design. Expedited introduction of national-level legislation concerning carbon emissions trading, coupled with the enhancement of multi-tiered systems, will ensure that primary market actors adhere to legal compliance throughout the entire carbon emissions trading process.

Secondly, to realize the high-quality development of the manufacturing industry, we must pay close attention to innovation, strongly support the development of high-end manufacturing industry, and guide the green transformation and upgrading of the traditional manufacturing industry. The continuity of innovation investment and the guidance of innovation planning should be strengthened to create an ecological environment that is truly favorable to the innovation and development of enterprises. We should continue to vigorously cultivate and attract relevant talents, and accelerate the construction of high-end talent training mechanism combining scientific research institutes and enterprises. Finally, vigorously promote the high-quality development of the manufacturing industry, but also focus on the deep integration of manufacturing and modern service industry, and constantly optimize the industrial structure, enhance the ability of industrial synergy.

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Conflict of interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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