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China's Carbon Emission Trading Pilot Policy and China's Export Technical Sophistication: Based on DID Analysis

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Abstract: This paper takes China's carbon emission trading pilot policy as a quasi-natural experiment, and adopts a difference-in-difference approach and data from 30 provinces in China from 2008 to 2016 to empirically study the influence of this policy on China's export technical sophistication. The empirical analysis revealed that the policy can generate a Porter effect and progressively promote China's export technical sophistication by reinforcing carbon productivity. By analyzing the regional heterogeneity and influence channels, the policy is found to work better in the central-western region than in the eastern region. The reason for this finding is that the policy has brought innovation offset effects to the central-western region and increased carbon productivity, but the policy has not improved carbon productivity in the eastern region. By studying the effect of three measures of policy implementation on export technical sophistication, we found that restricting carbon emission quotas distributed to participating enterprises is necessary. In addition, we found that the financial punishment method for non-performance is advantageous to the enhancement of export technical sophistication. These research conclusions can provide directions and policy recommendations for upgrading the emissions trading market, as well as a learning case and some experience for countries that have not yet established carbon trading markets.

Keywords: China's carbon emission trading pilot policy; difference-in-difference model; export technical sophistication; carbon productivity

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1. Introduction

Statistics from 1990 to 2018 show that although the world economy had maintained growth, the natural capital worldwide had been shrinking at an average annual rate of 0.7% [1]. In other words, humanity had used one-fifth of the world's natural resources in less than 30 years. As a result, global warming caused by massive carbon dioxide emissions has become one of the main challenges threatening the world [2]. To delay—or even reverse—global warming, global carbon emissions need to be drastically reduced. Many developed and developing countries have been struggling with this challenge. The main goal of the Paris Agreement is to contain the global average temperature, which is the consensus and direction of the participating countries [3]. In 2009, the Chinese government pledged at the United Nations Climate Change conference that carbon intensity would be reduced by 40% to 45% by 2020, compared with 2005. For governments, low-carbon policy tools, including administrative methods and market methods, are desperately needed. The Chinese government not only adopted conventional administrative methods but also imported a superior method, namely, carbon emission trading, to control domestic greenhouse gas emissions. The start of this initiative was the Notice on Carrying out Pilot Work on Carbon Emission Trading issued by China's National Development and Reform Commission (NDRC) in 2011. This notice approved two provinces and five municipalities (They are Beijing City, Shanghai City, Tianjin City, Chongqing City, Shenzhen City, and Hubei Province, and Guangdong Province) to conduct the Carbon Emission Trading Pilot Scheme. These seven regions produce one-quarter of the GDP and one-fifth of carbon emissions produced by 31 provinces and municipalities of China [4]. The first pilot area to build an emission trading market was Shenzhen City in 2013, with the remaining six carbon emission trading markets launched later.

Simultaneously, the Chinese government has been working hard to change China's economic development model from high-speed to high-quality. One of the important aspects of these efforts is to strengthen the technical level of export commodities. China's foreign trade, one of the most powerful economic drivers in this country, is attempting to shift products provided to international markets from the low value-added type to the high-tech and innovative type. Export technical sophistication, a key indicator for measuring the technology level of exports, determines the future internationally competitive advantages of a country. Its improvement can help a country to achieve sustainable economic development [5]. Since 1995, China's overall export technical sophistication has been promoted, but remains uncompetitive compared with developed countries [6]. Raising the export technical sophistication is one way for China or other developing countries to enhance their competitiveness in international trade and achieve high-quality economic development against the background of frequent international trade frictions.

As the largest developing country, the influence of emissions trading on industrial upgrading and energy saving in the pilot areas has received widespread attention worldwide since the launch of carbon emissions trading. China's carbon emission trading pilot policy is a market-driven environmental regulation. Nevertheless, the number of studies on the influence of the policy on China's export technical sophistication has been insufficient. Therefore, answering the following questions is important. Can the carbon emission trading pilot policy improve China's export technical sophistication? If it can, what are the influence channels? Does the influence of carbon emissions trading on the export technical sophistication have regional heterogeneity? How do the different measures implemented by the policy affect export technical sophistication? Exploring these puzzles can provide policy recommendations for governments to improve the carbon emissions trading market and assist policymakers in designing a national unified market.

The rest of this paper is arranged as follows: Section 2 recapitulates the relevant literature, including the effect of the pilot policy on macroeconomic variables and the effect of environmental regulations on international trade. Section 3 puts forward the methodology. Section 4 provides empirical results and discusses them. Section 5 concludes this paper with policy recommendations.

2. Literature Review

This paper is categorized alongside research that evaluates the influence of the pilot policy on macroeconomic variables. With the exception of export technical sophistication, this article is still related to two such variables. The first is carbon emission reduction, which is a concern of many scholars. For instance, Chen et al. [7] adopted a difference-in-difference (DID) method to find that the emission trading pilot program can effectively reduce carbon emissions in pilot regions. They found that this effect continued to increase over time. Using provincial industry panel data from 2005 to 2015, Hu et al. [8] considered that the carbon emissions in the pilot regions were reduced by 15.5% compared with the non-pilot regions for the same industry.

The second variable is economic effects. From some scholars' perspectives, the pilot program is beneficial to a country's economic growth. Tan and Zhang [9] found that the pilot policy can significantly force pilot areas to upgrade their industrial structure, based on the synthetic control method and China's provincial panel data from 2005 to 2016. By using the panel data, Wang et al. [10] believed that the carbon trading program can help pilot regions nurture green innovation and benefit locals. However, not every study agrees. Dong et al. [11] used China's provincial panel data from 2006 to 2015 and DID analysis. They found that the pilot policy successfully alleviated the carbon emissions in the short term, but it could not stimulate the local economy to grow and not generate a Porter effect.

Although the existing literature does not study carbon trading programs from the perspective of the export technical sophistication, some studies have been used the pollution haven and Porter hypotheses to discuss the effect of environmental regulations on international trade. Three main conclusions were found.

The first conclusion is that strict environmental regulations incur compliance costs to enterprises and undermine their international competitiveness. Cole et al. [12] studied the effect of environmental and industrial regulations on Japanese net imports through data from 41 industries in Japan from 1989 to 2003 and concluded that the regulations abated industrial export competitiveness. Dong et al. [13] held that the international trade competitiveness of China's manufacturing industry has been softened by environmental regulations based on the input–output model with pollution abatement cost. Greenstone et al. [14] found that environmental regulations exerted a large adverse impact on productivity in the U.S. Du and Li [15] believed that China's environmental regulations block export trade through the Heckman model by analyzing data from Chinese industrial enterprises.

The second conclusion is that appropriate environmental regulations are advantageous in encouraging enterprises to carry out green innovations that reduce production costs and ultimately cause foreign trade to flourish [16]. Zhang and Bu [17] believed that environmental regulations are proportional to the productivity of enterprises in China, because regulations generate a Porter effect on China's manufacturing industry. Millimet and Roy [18] empirically studied the relationship between environmental regulations and export trade and found that proper environmental regulations are formidable weapons for the industry to obtain an export competitive advantage. Bu et al. [19] empirically studied the influence of environmental regulations from 2006 to 2010 on the export of 30 manufacturing industries in China and proposed that environmental regulations can force the local manufacturing industry to improve the technical level of exports.

The third conclusion is that the effect of environmental regulations on foreign trade is determined by the net effect combined with compliance cost and innovation offset. Environmental regulations can only be helpful when the innovation compensation brought by the regulations is greater than the environmental costs paid by enterprises. Yu [20] empirically studied the influence of environmental regulations on the export technical sophistication in 27 Chinese industries by calculating combined effects. They found that the connection between the intensity of environmental regulation and export technical sophistication is a U-type feature, which was an adverse effect first and a positive effect later. Based on the non-linear panel data threshold model, Xiao and Chen [21] found that the connection between environmental regulations and export technical sophistication is an inverted N-type, meaning that appropriate environmental regulations can improve export technical sophistication.

To sum up, the existing literature discussed the implementation effect of the pilot policy and the influence of environmental regulations on foreign trade. They have drawn some meaningful conclusions. However, studies on the influence of emissions trading on export technical sophistication are not only insufficient but also controversial. Therefore, the effect of the pilot policy on macroeconomic variables is worthy of research.

Different from other literature, this article introduces three innovations. (1) By analyzing the data from 30 Chinese provinces and cities, this study empirically examined the influence of the pilot policy on export technical sophistication, which verified the Porter effect hypothesis to a certain extent. (2) This article explored the influence channels of the pilot policy on export technical sophistication by a mediation variable and further evaluated the regional heterogeneity. (3) This study examined the performance of three policy implementation measures, potentially providing suggestions for China to expand the carbon market.

3. Methodology

In this section, we will introduce the research hypothesis, specific models, core variables, control variables, and data sources used in this paper.

3.1. Research Hypothesis

On the one hand, the Porter hypothesis believes that suitable environmental regulations help companies in technological innovation. Technological innovation leads to the improvement of productivity by compensating for the compliance cost and making the companies more competitive than those not constrained by environmental regulations. Therefore, proper environmental regulations can improve productivity and output level and create export advantages [16]. The carbon trading program, as an effective market-driven environmental regulation, helps rather than forces enterprises to innovate, ultimately improving the level of total factor productivity of carbon [22].

On the other hand, carbon emission permits have certain commodity attributes so they can be traded in the market. The emissions trading market works as follows: A government will give a specific amount of carbon emission quotas to every participating enterprise annually. Enterprises that generate fewer carbon emissions than the quotas can earn additional benefits by selling the remaining quotas. However, some enterprises need to bear compliance costs caused by the lack of quotas when they generate more carbon emissions than the quotas.

The ideal scenario is that some enterprises develop low-carbon technological innovations to maximize their profits. In this case, carbon productivity will be improved. Others pay for the environmental pollution they cause. Given that export technical sophistication is a comprehensive reflection of technological level and production efficiency, it primarily depends on technological innovation and productivity [23]. A country's productivity is directly proportional to its export technical sophistication [24]. Carbon productivity, an advanced factor describing the connection between economic growth and carbon emissions, also positively affects the foreign trade of a country [25]. Therefore, governments can promote export technical sophistication by improving carbon productivity. For this theoretical analysis, this article extracts that the pilot policy can improve carbon productivity under the stimulus of innovation compensation. Simultaneously, the increase in carbon productivity brings about an increase in export technical sophistication. Furthermore, this analysis comprises and tests the following hypothesis: China's carbon emission trading pilot policy can promote China's export technical sophistication by reinforcing carbon productivity.

3.2. Difference-in-Difference Model

The DID approach was first proposed by Ashenfelter and Card [26]. It is widely used to evaluate the effectiveness of public policy implementation in econometrics, due to its ability to avoid possible endogenous problems by comparing the differences between the experimental group and the control group before and after the policy. Existing studies widely use the DID approach when evaluating the environmental and economic effects of China's carbon emission trading policy. Thus, we adopted the following DID model to measure the influence of the pilot policy on China's export technical sophistication:

$$lnexts_{it} = \alpha_0 + \alpha_1 pilot_i \times post_t + \alpha_2 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where $pilot_i$ is a dummy variable, which denotes the province i where the policy is implemented and assigns a value of 1 or 0 for the province implementing the policy and non-implementing the policy, respectively. $post_t$ is a dummy variable, which denotes the year t when the policy is implemented and assigns a value of 1 or 0 for the period after ($t \geq 2013$) and before ($t < 2013$) the policy implementation, respectively. α_1 denotes the influence of the policy on the export technical sophistication. $lnexts_{it}$ is the export technical sophistication of province i in year t. X denotes the control variables. μ_i denotes the fixed effect in the control province, γ_t denotes the fixed effect in control time and ε_{it} denotes the residual. α_0 is a constant, α_1 represents the influence of the carbon emissions trading policy on the export technical sophistication, and α_2 is the coefficient of the control variables.

3.3. Robustness Test

The experimental and control groups must conform to the parallel trend hypothesis to use the DID approach. Specifically, before the policy is implemented, both groups have the same trend on export technical sophistication. To ensure that the DID method is feasible, Equation (2) is constructed to conduct a parallel trend test:

$$lnexts_{it} = \beta_0 + \sum_{t=2010}^{2016} \beta_t pilot_i \times d_t + \beta_1 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (2)$$

where the d_t is a dummy variable and denotes year t (t = 2010, 2011, . . . , 2016). For example, if the year is 2010, d_{2010} is designed a value 1, and $d_{2011}, \ldots, d_{2016}$ are designed a value 0. β_t, in Equation (2), is what we need to focus on. Methodologically, when β_{2013}, β_{2014}, β_{2015}, and β_{2016} are significant but β_{2010}, β_{2011}, and β_{2012} are not, the DID model meets the parallel trend test.

3.4. Mediation Effect Model

Based on the previous analysis, we believe that the policy can promote China's export technical sophistication by reinforcing carbon productivity. Consequently, we extracted carbon productivity as a potential mediation variable to study the influence channel by which the pilot policy promotes China's export technical sophistication. Equations (3)–(5) are the mediation effect models that we established to empirically analyze this influence channel.

$$lnexts_{it} = \alpha_0 + \alpha_1 pilot_i \times post_t + \alpha_2 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (3)$$

$$lncp_{it} = \alpha_0 + \beta_1 pilot_i \times post_t + \beta_2 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (4)$$

$$lnexts_{it} = \alpha_0 + \lambda_1 pilot_i \times post_t + \lambda_2 lncp_{\mathrm{it}} + \lambda_3 X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (5)$$

We established Equation (3) as a benchmark DID model. $lncp_{it}$ in Equation (4) denotes the carbon productivity of province i in time t. We add the variable $lncp_{it}$ to the benchmark DID model to obtain Equation (5). This article adopts stepwise regression to test the mediation effect. First, we test the coefficient β_1. If β_1 is not significant, the causal relationship between the carbon emission trading policy and carbon productivity is invalid, so the mediation effect test should be stopped. If β_1 is significant, Equation (5) is constructed to continue the test. If the coefficient λ_2 is significant, but the regression coefficient λ_1 is not, the carbon productivity is a mediation variable for the carbon emission trading policy to affect export technical sophistication, and the mediation effect is full. If the coefficients λ_1 and λ_2 are significant, the carbon productivity is still a mediation variable for the policy to impact export technical sophistication, and the mediation effect is partial. If neither of them is significant, carbon productivity is not considered a mediation variable.

3.5. Implementation Measures Analysis Model

The policy implementation measures differ among pilot regions. They are mainly the carbon emission quota management systems, carbon emissions offset mechanisms, and punishment methods for non-performance. Concerning carbon emission quota management systems, each pilot region has its annual carbon emission quotas, and they assign the quotas to participate enterprises in different ways. Local governments in some pilot areas adopted a free distribution method, while the other areas adopted a mixed distribution method that combined a quota auction and quota-free distribution. Concerning carbon emission offset mechanisms, the dominant offset mechanism in China's carbon market is currently Chinese Certified Emission Reduction (CCER) whose volume in each pilot area is different. Concerning punishment methods for non-performance, pilot areas adopt various punishments for enterprises that fail to submit verification reports on time. For example, Beijing City, Shanghai City, and Hubei Province impose financial punishment on enterprises, whereas Tianjin City and Chongqing City only require rectification within a time limit.

Equation (6) is constructed to study whether the policy implementation measures generate a heterogeneous effect on export technical sophistication in the pilot areas.

$$lnexts_{it} = \alpha_0 + \alpha_1 lnpe + \alpha_2 mode + \alpha_3 lnccer + \alpha_4 punish + \alpha_5 X_{\mathrm{it}} + \mu_i + \gamma_t + \varepsilon_{it} \quad (6)$$

where $lnexts_{it}$ is the export technical sophistication of province i in year t. $lnpe$ is the logarithm of volume of carbon emission quotas in each pilot area. The dummy variable *mode* is the distribution method of carbon emission quotas, and is assigned a value of 1 or 0 for the mixed and free distribution methods, respectively. *lnccer* is the logarithm of trading volume of CCER. The dummy variable *punish* is the punishment method for non-performance, and is assigned a value of 1 or 0 for financial punishment and non-financial punishment, respectively. The data used in this section are only from the pilot areas.

3.6. Variable Selection

The first core variable is export technical sophistication (*lnexts*). This article used the methods from Hausmann et al. [5] and Sun [27] to measure provincial export technical sophistication in China. The calculation process consists of two steps. The first step is to use Equation (7) to measure the export technical sophistication of a certain commodity from the trade export sub-items in provinces. The second step is to use Equation (8) to measure the overall export technical sophistication in a certain province.

$$exts_k = \sum_i \frac{X_{ik}/X_{\mathrm{i}}}{\sum_i X_{ik}/X_i} Y_i \quad (7)$$

$$exts_i = \sum_k \frac{X_{ik}}{X_i} exts_k \quad (8)$$

In Equations (7) and (8), i represents provinces and k represents export commodities. In Equation (7), $exts_k$ represents the export technical sophistication of commodity k. X_{ik} and X_i represent the export value of commodity k and the total export value of commodities, respectively. Y represents the GDP per capita. In Equation (8), $exts_i$ represents the export technical sophistication of province i. This article takes the logarithm of the export technical sophistication (*lnexts*) to reduce heteroscedasticity.

The second core variable is carbon productivity. Carbon productivity is an indicator that can reflect the relationship between carbon emissions reduction and economic development [28]. Two perspectives are used to define carbon productivity. Traditional carbon productivity is calculated by the ratio of GDP to carbon emissions. Given that it only considers the relationship between economic outputs and carbon emissions, carbon productivity in this definition is a narrow concept. With the development of research, more and more scholars use data envelopment analysis (DEA). The main advantages of DEA are that it does not need to set a specific production function form and it can take into account input factors such as capital, labor, and energy, and output factors such as output value and carbon emissions to measure regional carbon productivity [29,30]. Compared with carbon productivity in a narrow sense, carbon productivity in a general sense is more suitable and specific [31]. Therefore, integrating the experience of Li et al. [30] and Chung et al. [32], this paper adopted the global Malmquist–Luenberger index that considers the slacks-based measure directional distance function with unsatisfactory outputs to measure carbon productivity under a total factor framework.

We used MaxDEA software to measure carbon productivity, but it was a relative value. For obtaining the absolute value of carbon productivity, we calculated it with multiplication by using 2007 as the base year. For reducing the heteroscedasticity, we used the logarithm of the carbon productivity (*lncp*). The expected output indicator is the total GDP of the province. All GDP-related data are adjusted to 2007 by the provincial GDP deflator. The undesirable output indicator is carbon emissions, which are calculated on the final energy consumption of provinces, following the calculation method of Tian et al. [33]. The input indicators include total energy consumption, employed population, and capital stock. The capital stock is calculated by the perpetual inventory method [34], and it is adjusted by the fixed assets deflator to 2007.

We also selected other indicators that may influence the pilot policy on export technical sophistication, including trade openness, foreign direct investment, R&D intensity, economic development level, urbanization level, human capital, and transportation infrastructure as control variables [35].

Specifically, trade openness (*to*) is the ratio of total import and export value to GDP. FDI (*fdi*) is the ratio of the net value of fixed assets of foreign-funded enterprises to GDP. Economic development level (*lned*) is the logarithm of per capita GDP. Human capital (*hc*) is the ratio of the number of students enrolled in ordinary colleges and universities to the total population. R&D intensity (*rd*) is the ratio of R&D internal expenditure to GDP. Urbanization level (*urban*) is the ratio of urban population to the total population. Transportation infrastructure (*lnti*) is the logarithm of the per capita road and railway mileages.

In 2017, the NDRC issued the *national carbon emission trading market construction plan (power generation industry)*, marking the launch of the national carbon emission trading market. To eliminate the interference of this event on the results of this paper, and better identify the effect of the carbon trading pilot policy on export technical sophistication, this paper uses 30 Chinese provinces and cities from 2008 to 2016 (limited to data integrity, excluding Tibet, Macao, Hong Kong, and Taiwan) are used as samples to estimate the policy influence. The data are from *China Statistical Yearbook* and *China Energy Statistical Yearbook* from 2008 to 2017, as well as Development Research Centre Net. The descriptive statistical values of the main variables are shown in Table 1.

Table 1. Descriptive statistics.

VARIABLES	Obs	Mean	Std. Dev.	Min	Max
lnexts	270	10.4629	0.2004	10.0304	10.9199
lncp	270	−0.4866	0.0217	−1.0987	0.0001
to	270	0.2781	0.3337	0.0294	1.5269
fdi	270	0.0225	0.0175	0.0004	0.0819
rd	270	0.0148	0.0106	0.0022	0.0601
lned	270	10.5337	0.5073	9.1957	11.6801
urban	270	0.5414	0.1332	0.2912	0.8961
hc	270	0.0052	0.0014	0.0023	0.0099
lnti	270	3.4357	0.5925	1.679288	4.9162

4. Empirical Test and Analysis

4.1. Benchmark Regression Results

This study empirically analyzes the effect of the carbon emission trading pilot policy on export technical sophistication by using Equation (1). The DID estimation results are summarized in Table 2. No control variable is present in column (1), then control variables are gradually added from columns (2) to (8). All regression coefficients of pilot × post are significantly positive, meaning that the policy exerted a benign effect on export technical sophistication. The pilot policy has promoted China's export technical sophistication, supporting our opinion.

4.2. Robustness Test

To ensure the reliability of the research conclusions, three robustness tests were conducted in this study. The test results are summarized in Table 3. The robustness tests proved that the empirical results from the DID estimation are reliable.

According to the theoretical analysis, a parallel trend hypothesis test is conducted by Equation (2). The regression results of the parallel trend hypothesis test are summarized in Column (1). Before the policy implementation in 2013, the regression coefficients of the pilot × post, namely *pilot* × *t*2010, *pilot* × *t*2011, and *pilot* × *t*2012, are not significantly negative, indicating that between the experimental group and the control group, export technical sophistication shows no significant difference. Therefore, the policy conforms to the parallel trend hypothesis test. After the policy implementation in 2014, the regression coefficients of pilot × post, namely *pilot* × *t*2014, *pilot* × *t*2015, and *pilot* × *t*2016, are significantly positive, whereas the coefficient of *pilot* × *t*2013 is not significantly positive. This finding shows that the policy is beneficial to improving export technical sophistication in the pilot areas with a one-year time lag. The policy delay does not affect the conclusion of this paper. In Figure 1, the visible line reflects the marginal effect of the multiplicative interaction term of *pilot* and *post* on export technical sophistication. The figure indicates that the carbon emission trading pilot policy has a significant positive effect on export technical sophistication in the pilot areas. This effect has been increasing year by year.

Table 2. DID estimation results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	*lnexts*	*lnexts*	*lnexts*	*lnexts*	*lnexts*	*lnexts*	*lnexts*	*lnexts*
pilot × *post*	0.0399 ***	0.0427 ***	0.0430 ***	0.0333 ***	0.0330 ***	0.0339 ***	0.0340 ***	0.0328 ***
	(0.00806)	(0.00770)	(0.00777)	(0.00861)	(0.00826)	(0.00908)	(0.00917)	(0.00916)
to		0.0505 *	0.0496 *	0.0690 *	0.0574	0.0558	0.0551	0.0609 *
		(0.0301)	(0.0299)	(0.0352)	(0.0357)	(0.0359)	(0.0361)	(0.0358)
fdi			0.173	0.158	0.0974	0.0992	0.0983	0.0892
			(0.306)	(0.313)	(0.332)	(0.331)	(0.331)	(0.334)
rd				3.915 **	4.594 ***	4.534 ***	4.556 ***	4.455 ***
				(1.519)	(1.568)	(1.583)	(1.583)	(1.589)
lned					0.0483	0.0437	0.0428	0.0519
					(0.0378)	(0.0460)	(0.0475)	(0.0485)
urban						0.0451	0.0403	0.0493
						(0.210)	(0.215)	(0.215)
hp							0.637	1.512
							(7.213)	(7.430)
lnti								−0.0425
								(0.0554)
Province FE	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	270	270	270	270	270	270	270	270
R-squared	0.984	0.984	0.984	0.985	0.985	0.985	0.985	0.985

Note: the robust standard errors are shown in brackets; ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively. Limited to space, the following tables are the same.

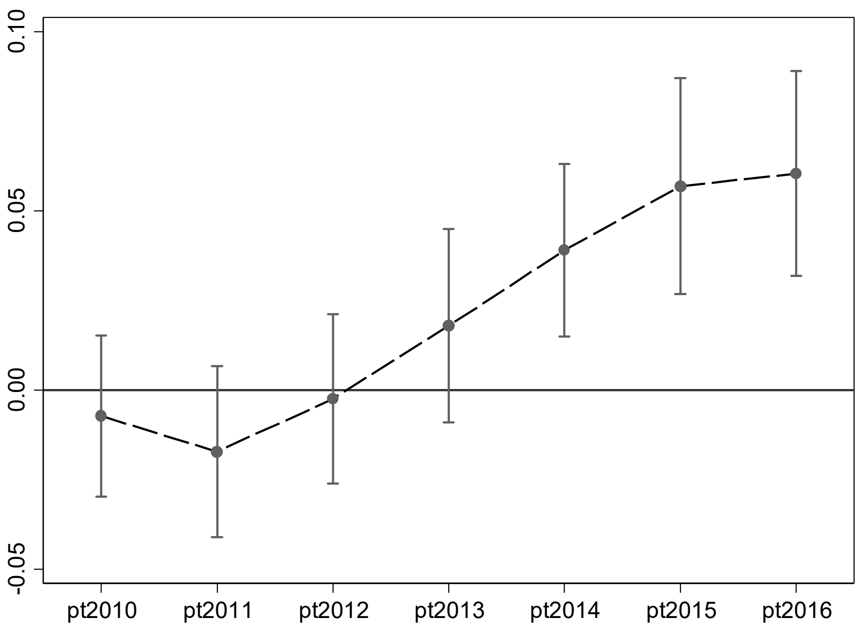

Figure 1. Dynamic effect of the carbon emission trading pilot policy on China's export technical sophistication.

Table 3. Results of robustness test.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	*lnexsp* Dynamic effect	*lnexsp* provincial time trend	*lnexsp* Excluding Chongqing samples	*lnexsp* *pilot* × *t*2009	*lnexsp* *pilot* × *t*2010	*lnexsp* *pilot* × *t*2011	*lnexsp* *pilot* × *t*2012
pilot × *post*		0.0350 *** (0.00844)	0.0292 *** (0.0108)	−0.0161 (0.0101)	0.00354 (0.00880)	−0.000246 (0.00840)	0.0103 (0.0106)
pilot × *t*2010	−0.00726 (0.0136)						
pilot × *t*2011	−0.0172 (0.0144)						
pilot × *t*2012	−0.00246 (0.0143)						
pilot × *t*2013	0.0179 (0.0163)						
pilot × *t*2014	0.0390 *** (0.0146)						
pilot × *t*2015	0.0569 *** (0.0182)						
pilot × *t*2016	0.0604 *** (0.0173)						
Control variables	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES
Observations	270	270	262	150	150	150	150
R-squared	0.987	0.987	0.985	0.991	0.990	0.990	0.990

Note: the robust standard errors are shown in brackets; *** represents significance at the 1% level. Limited to space, the following tables are the same.

Second, this study added a new control variable, namely the provincial time trend, to Equation (1). The provincial time trend is the multiplicative interaction term of pilot and year. The robustness test results are summarized in column (2). After adding the provincial time trend, the regression coefficient of *pilot* × *post* is still significantly positive, indicating that some of the time-varying provincial factors that may not have been found do not change the above conclusions. Chongqing City follows the carbon emissions trading program by self-declaring for quotas. Therefore, few enterprises purchase quotas in the Chongqing trading market. We removed the Chongqing sample and performed the regression again. The regression result in column (3) is still significantly positive.

Finally, a placebo test was conducted based on Equation (1). The test is to separately suppose that the implementation year of the carbon emission trading pilot policy is 2009, 2010, 2011, and 2012, and remove samples in 2013 and later. The regression coefficients of *pilot* × *post* in columns (4) to (7) are not significant, indicating that the conclusion that the pilot policy stimulates export technical sophistication is robust.

4.3. Regional Heterogeneity Analysis

The above analysis explored the effect of the policy on export technical sophistication from a national perspective. However, huge gaps in economic development and policy implementation efficiency exist among Chinese provinces. Therefore, this study continues to study the regional heterogeneity of the pilot policy on the export technical sophistication.

According to the classification standards of the National Bureau of Statistics (The east region comprises Beijing City, Hebei Province, Jiangsu Province, Shandong Province, Hainan Province, Shanghai City, Zhejiang Province, Fujian Province, Tianjin City, Guangdong Province, and Liaoning Province. The central region comprises Shanxi Province, Hunan Province, Jiangxi Province, Hubei Province, Jilin Province, Heilongjiang Province, Henan Province, Anhui Province, Inner Mongolia Province, Guangxi Province; The west region includes Chongqing City, Qinghai Province, Gansu Province, Guizhou Province, Ningxia Province, Shanxi Province, Yunnan Province, Xinjiang Province, and Sichuan Province), we divide China into eastern and central-western regions. The eastern region not only has a superior geographical location, but also high administrative efficiency and sufficient local government finances. However, the central-western region is rich in natural resources and has considerable development potential. Concerning the classification standard, Beijing City, Tianjin City, Shanghai City, and Guangdong Province are classified in the eastern region, but Hubei Province and Chongqing City are classified in the central-western region. This paper used the DID model, namely Equation (1), to further study the influence of the pilot policy on export technical sophistication in those two regions. The regression results are summarized in Table 4.

Table 4. Regional heterogeneity analysis.

	(1)	**(2)**
VARIABLES	Eastern Region *lnexsp*	Central-western Region *lnexsp*
pilot × *post*	0.01	0.0491 ***
	(0.015)	(0.0116)
Control variables	YES	YES
Province FE	YES	YES
Time FE	YES	YES
Observations	99	171
R-squared	0.985	0.989

Note: the robust standard errors are shown in brackets; *** represents significance at the 1% level. Limited to space, the following tables are the same.

The regression coefficients of the core variable *pilot* × *post* for the eastern region and the central-western region are in columns (1) and (2), respectively. The regression coefficient for the eastern region is not significant at 0.01, whereas for the central-western region it is significant at 0.0491. This difference indicates that the policy has a better effect on the export technical sophistication in the central-western region than in the eastern region. Therefore, we raised the following question: why is the increase of export technical sophistication in the eastern region weaker than that of the central-western region? To answer this question, we next studied the influence mechanism.

4.4. Influence Channel Analysis

The above analysis reveals that the carbon emission trading pilot policy exhibits conspicuous regional heterogeneity in the eastern and central-western regions. To be precise, the pilot policy has a weaker influence on export technical sophistication in the developed eastern region than that of the underdeveloped central-western region. Based on Equations (3)–(5), this study adopted stepwise regression to analyze the influence channel from national and regional perspectives, respectively.

The regression results from a national perspective are shown in Table 5. The explained variables in columns (1) and (3) are the export technical sophistication. The explained variable in column (2) is carbon productivity. The regression coefficients of pilot × post in columns (1) and (2) are significantly positive, indicating that the policy has promoted China's export technical sophistication and carbon productivity. The regression coefficient of *pilot* × *post* and the coefficient of *lncp* in column (3) are both significantly positive, indicating that carbon productivity is a mediation variable for the carbon emission trading pilot policy to improve export technical sophistication. The mediation effect, which accounted for 17.3%, should be classified as a partial mediation effect. To sum up, the pilot policy can promote export technical sophistication by raising carbon productivity. This finding is consistent with the theoretical assumptions that we extracted from the Porter hypothesis and previous studies.

Table 5. Influence channel from a national perspective.

	(1)	(2)	(3)
VARIABLES	*lnexsp*	*lncp*	*lnexsp*
pilot × *post*	0.0328 ***	0.0399 *	0.0272 ***
	(0.00916)	(0.024)	(0.00956)
lncp			0.142 ***
			(0.0343)
Control variables	YES	YES	YES
Province FE	YES	YES	YES
Time FE	YES	YES	YES
Province time trend	YES	YES	YES
Observations	270	270	270
R-squared	0.985	0.926	0.987

Note: the robust standard errors are shown in brackets; *** and * represent significance at the 1% and 10% levels, respectively. Limited to space, the following tables are the same.

Next, we analyzed the influence channel from a regional perspective. The regression results are summarized in Table 6. The regression coefficients of the core variable *pilot* × *post* for the eastern and the central-western regions are in columns (1) to (2) and columns (3) to (5), respectively. The empirical results in columns (1) to (2) show that the policy does not have a significant effect on export technical sophistication and carbon productivity in the eastern region. However, the empirical results in columns (3) to (5) indicate that carbon productivity is a mediation variable for the policy to promote export technical sophistication in the central-western region, and the mediation effect is partial.

Table 6. Influence channel from a regional perspective.

	(1)	(2)	(3)	(4)	(5)
	Eastern Region		Central-western Region		
VARIABLES	*lnexts*	*lncp*	*lnexts*	*lncp*	*lnexts*
pilot × *post*	0.0100	−0.0689	0.0491 ***	0.0846 ***	0.0293 ***
	(0.0150)	(0.0468)	(0.0116)	(0.0269)	(0.0110)
lncp					0.234 ***
					(0.0317)
Control variables	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
Observations	99	99	171	171	171
R-squared	0.985	0.931	0.989	0.947	0.992

Note: the robust standard errors are shown in brackets; *** represents significance at the 1% level. Limited to space, the following tables are the same.

To be precise, in the central-western region, the carbon emission trading project is beneficial to carbon productivity on account of innovation compensation, and higher carbon productivity simultaneously increases export technical sophistication. Unfortunately, the policy does not introduce innovation compensation to the eastern region, leading to the inability to increase carbon productivity in this region and the stagnation of export technical sophistication. Thus, the key to whether the policy successfully motivates export technical sophistication is carbon productivity.

The performance of the pilot policy may be influenced by the spatial layout of local industries. Given the policy of "vacating the cages and changing the birds" implemented in 2013, the central-western region has accepted more traditional high-carbon industries that moved from the domestic eastern region and abroad. As a result of this policy, the scale of high-carbon industries has surpassed the scale of low-carbon industries in the central-western region. However, the scale of low-carbon industries is larger than that of high-carbon industries in the eastern region [31]. For high-carbon industries, more space is available to lessen carbon emissions. To sell the remaining emission quotas for obtaining additional profits in the carbon emission trading market, high-carbon enterprises have the incentive to innovate technology that increases carbon productivity, benefiting export technical sophistication. However, for low-carbon industries, the motivation for technological innovation is relatively frail. In sum, the carbon trading policy can bring innovation offset effects to the central-western region where high-carbon industries are dominant, ultimately promoting more export technical sophistication by enhancing carbon productivity. However, the policy has not worked well in the eastern region where low-carbon industries dominate.

4.5. Implementation Measures Analysis

The results are summarized in Table 7, where the variables of implementation measures are gradually added from columns (1) to (4) and no control variables are added in column (5). The empirical results reveal that the volume of carbon emission quotas has a significant negative influence on export technical sophistication in the pilot areas. This influence could be caused by the scarcity of carbon quotas determined by the total amount of carbon quotas. Its scarcity then directly affects the price of quotas in the market. When enterprises obtain too many carbon emission quotas, their actual carbon emissions are less than the permitted quantity, resulting in extremely low market prices for the quotas. Under such circumstances, enterprises have no incentive to develop green technological innovation, leading to the fact that carbon productivity and export technical sophistication in the entire region cannot be improved. The coefficient of *punish* is significantly positive, showing that financial punishment has a significant positive effect on export technical sophistication. The empirical results are in line with reality. When financial punishment is imposed on enterprises that do not submit verification reports on time, they take the initiative to carry out low-carbon technological innovations to avoid financial punishment. Therefore, the financial punishment method is advantageous to stimulate enterprises to improve carbon productivity and to promote export technical sophistication. Finally, the coefficients of *mode* and *lnccer* are not significant, indicating that the distribution method of emission quotas and the emission offset mechanisms have no significant influence on export technical sophistication in the pilot regions.

Table 7. Performance of policy implementation measures.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
VARIABLES	*lnexsp*	*lnexsp*	*lnexsp*	*lnexsp*	*lnexsp*
lnpe	−0.00998 *	−0.00946 *	−0.0169 **	−0.0232 *	−0.0438 ***
	(0.0059)	(0.00526)	(0.00817)	(0.0115)	(0.0132)
mode		0.00704	−0.00701	−0.00942	−0.0229
		(0.0108)	(0.0112)	(0.0111)	(0.0141)
punish			0.0378 ***	0.0286 *	0.0319 *
			(0.0129)	(0.0169)	(0.0179)
lnccer				0.00484	0.00626
				(0.00415)	(0.00445)
Control variables	YES	YES	YES	YES	No
Province FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
Observations	54	54	54	54	54
R-squared	0.995	0.995	0.996	0.996	0.991

Note: the robust standard errors are shown in brackets; ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively. Limited to space, the following tables are the same.

5. Conclusions, Recommendations, and Future Work

This paper took China's carbon emission trading pilot policy as a quasi-natural experiment and adopted the DID model and data from 30 Chinese provinces to empirically study the influence of the policy on China's export technical sophistication. The main conclusions are as follows: (1) The policy can generate a Porter effect and can progressively promote export technical sophistication by reinforcing carbon productivity, showing that no conflict exists between environmental protection and economic development; (2) Carbon productivity is a mediation variable for the carbon trading pilot policy to improve export technical sophistication, and the mediation effect is partial; (3) The pilot policy has regional heterogeneity in enhancing export technical sophistication. Specifically, the policy has a better effect on export technical sophistication in the central-western region than in the eastern region, because the policy has brought innovation offset effects to the central-western region and the innovation compensation has increased carbon productivity. However, the policy failed to improve the carbon productivity in the eastern region; (4) When enterprises obtain excessive carbon emission quotas, increasing export technical sophistication is unfavorable for the carbon emission trading policy. The financial punishment method for non-performance is beneficial for the increase in export technical sophistication.

Based on the research conclusions, four recommendations are proposed for optimizing the policy: (1) The policy has generated a Porter effect in increasing China's export technical sophistication, so this policy is worthy of being promoted nationwide. Simultaneously, the government ought to improve the system design of the carbon trading market to fully use the adjustment role of prices. The energy consumption efficiency in developing countries is relatively low. As a market-driven environmental regulation, the pilot policy has made outstanding achievements in China. Therefore, other developing countries can draw lessons from China's experience and steadily construct an emissions trading market; (2) The contribution of universities and research institutions to low-carbon innovation cannot be ignored, and the government should build bridges between them and enterprises. For enterprises that actively cooperate with universities and research institutions, the NDRC can provide financial incentives to promote green technological innovation and ultimately increase domestic carbon productivity; (3) For the effectiveness of the policy, the emission quotas distributed to participating enterprises should be moderately tightened. A more stringent financial punishment mechanism should also be set up; (4) When more carbon trading markets are established, the government ought to be fully aware of the influence of carbon productivity on enterprises' export technical sophistication and regional heterogeneity. Thus, the government can make as many flexible, targeted, and effective policies as possible for enterprises in different regions.

In future research, we hope to focus the research perspective on the enterprise level, study the effect of the carbon emission trading pilot policy on export technical sophistication of enterprises, and deeply analyze the heterogeneity of enterprises to put forward more specific suggestions for improving the export technical sophistication of enterprises.

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