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Does Stronger Environmental Regulation Promote Firms' Export Sophistication? A Quasi-Natural Experiment Based on Sewage Charges Standard Reform in China

Weihao Zhang, Helian Xu * and Yuanyuan Xu

School of Economics and Trade, Hunan University, Changsha 410006, China
* Correspondence: xuhelian@163.com; Tel.: +86-13037319676

Abstract: Based on the quasi-natural experiment of sewage charges standard reform, this paper adopts a staggered difference-in-difference model to empirically investigate the effect of environmental regulation on firms' export sophistication and the mechanism of the effect, using the matched data from the Chinese Annual Survey of Industrial Firms and Chinese Custom Trade databases from 2004 to 2013. The results show that (1) the environmental regulation policy of sewage charges standard reform significantly promotes the upgrading of firms' export sophistication; (2) the impact of sewage charges standard reform on firms' export sophistication is heterogeneous, in that the promotion effect of sewage charges standard reform on firms' export sophistication is mainly manifested in simultaneous import and export firms, large-sized firms, and local firms; and (3) the sewage charges standard reform mainly through the mechanisms of innovation compensation effect and product switching effect to promote firms' export sophistication. This paper provides empirical evidence and policy insights for governments to formulate and implement environmental protection policies appropriately.

Keywords: sewage charges standard reform; environmental regulation; export sophistication; staggered difference-in-difference model

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1. Introduction

Over the long term, China has relied on low-cost factors, imitation technology, and low-end international target markets to form an export-driven economic growth model, achieving a fast expansion of export scale and rapid development of the national economy [1]. However, such a growth model, which relies on excessive consumption of resources and disregards environmental costs, is not conducive to sustainable and healthy economic development and is also prone to industrial development into low-end locking and an inability to break even. Meanwhile, strengthening environmental protection and achieving emission reduction targets have become the consensus of countries around the world from a global perspective [2]. In this context, the Chinese government proposes to accelerate the transformation of the economic growth model and, on the one hand, properly handle the relationship between economic development and environmental protection and play the role of environmental protection as a precursor to and force for the transformation of economic development. On the other hand, it will rely on firm innovation and technological progress to improve the efficiency of resource utilization, promote industrial transformation and upgrading, and move to the middle and high end of the global value chain. Thus, an urgent question that needs to be answered is whether environmental protection and technological progress can reach a win-win solution.

Theoretically, according to Porter's hypothesis, moderate environmental regulation can induce firms to innovate, thus offsetting the rising costs of environmental policies [3]. In reality, however, strengthening environmental protection will inevitably have a significant impact on the existing industrial system and business production and operations. Accordingly, a large amount of literature has examined the effect of environmental regulation on firms' technology levels to verify the Porter hypothesis. The first type of literature findings supports the Porter hypothesis. Li et al. [4] found that environmental regulation significantly improves firm performance with a mediating role of technological innovation based on 2016–2020 listed companies' data from the Yangtze River Delta region of China. Zhong et al. [5] found that environmental regulation promotes industry eco-efficiency based on 36 components of industry-level data in China from 2009–2018, using industry-level environmental legislation as a proxy variable for environmental regulation. Sun et al. [6] found that environmental regulations promote domestic value being added to Chinese firms' exports through resource reallocation effects. Franco and Marin [7] found that the environmental regulation of energy tax significantly contributed to the increase of industry productivity by examining the impact of the energy tax on productivity based on industry-level data in European countries. In addition, part of the literature examines the impact of environmental regulations on firm performance from the perspective of environmental taxes [8], carbon trade taxes [9], and carbon emissions trading markets [10,11], also supporting the Porter hypothesis. The second type of literature findings are unable to support the Porter hypothesis. Cai and Ye [12] found that environmental regulations significantly inhibit the total factor productivity of firms, based on a quasi-natural experiment with new environmental legislation in China. Dechezleprêtre and Sato [13] argue that environmental regulations may adversely affect firms' international trade and productivity in the short term. Eriksson [14] found that the implementation of environmental regulations increased firms' abatement costs and weakened their competitiveness in the product market. Combined with the above literature, even though there has been a considerable amount of research related to environmental regulations and firms' technological progress, the findings are still divergent, and fewer studies have been conducted on market-incentive-based environmental regulations.

In the area of international economics, export sophistication, which reflects the technological content of a country's exports, is widely used to measure the level of technology in a country [15,16]. It has been shown to play an important role in driving a country's economic growth [17–19]. Some studies have found that the export sophistication of China has increased rapidly since its accession to the WTO, using OECD developed countries as a comparator, and its export competitiveness has improved significantly [20]. However, some scholars argue that the higher export sophistication in China is due to the relatively large share of processing trade [21], and that the export sophistication has not increased significantly after excluding the contribution of processing trade [22]. In addition, some literature focuses on the factors influencing export sophistication, ranging from intermediate goods trade [23], value chains and supply chains [24], FDI [25,26], human capital [27], financial development [28], and minimum wage [29], investigating the impact on export sophistication. However, a common feature of the above literature is that the studies are mainly at the regional or industry level, ignoring the effects of firm heterogeneity on export sophistication, while a few pieces of literature have examined the impact on firm export performance from the perspective of environmental costs.

Based on this, this paper takes an entry point with China's sewage charges standard reform and adopts a staggered DID model to examine the effect of environmental regulations on the firms' export sophistication and its mechanism by using a sample of Chinese manufacturing firms from 2004 to 2013. The possible marginal contributions of this paper are as follows: first, previous literature has mainly examined the effect of the SCSR on economic green growth [30] and industrial green development [31] at the macro level; this paper is the first to examine the effect of the SCSR on firms' export performance from the micro firm perspective and further investigates the mechanisms and firm heterogeneity of the effect, which provides new empirical evidence for the assessment of the policy effects of the SCSR. Second, the existing literature has not reached a unified conclusion on the impact of environmental regulations on firm performance. This paper uses the quasi-natural experiment of China's SCSR to better address the endogeneity issue by adopting a staggered DID model, and the findings show that the SCSR improves firms' export sophistication through a mechanism of innovation compensation, which supports Porter's hypothesis at the micro level and complements the literature in this area. Third, this paper examines the impact of environmental regulations on export sophistication at the firm level, while the existing literature mainly focuses on the macro level, and findings indicate that there is heterogeneity in the impact of environmental regulations on firms' export sophistication in terms of firm trade patterns, firm size, and firm ownership, which provides a new perspective for future research on export sophistication. Finally, the findings of this paper demonstrate that market-incentivized environmental regulation represented by the SCSR can achieve a win-win situation for both environmental protection and technological progress, which provides policy insights for China and other developing countries to formulate and implement environmental protection policies appropriately.

The remainder of this paper is as follows: Section 2 introduces the policy background and presents the theoretical hypotheses; Section 3 provides the research design, introducing the model setting, data sources, and variable selection; Section 4 provides the empirical analysis, including the basic regression, parallel trend test, and robustness test; Section 5 provides further analysis, analyzing firm heterogeneity and the influence mechanism; and finally, the conclusion and policy recommendations end the paper.

2. Policy Background and Theoretical Hypothesis

2.1. Policy Background

The sewage charges system is the main market-based incentive policy instrument for environmental regulation in China. Since the promulgation of the "Measures for the Administration of Sewage Charging Standards" and "Regulations for the Administration of Sewage Charges" in 2003, China has shifted from charging for sewage emissions on a concentration basis to charging for total emissions. Although the regulations state that if the water pollution discharge exceeds the national or local standards, it is required to double the excess sewage charges on top of the amount of sewage charges, there are no excess emissions levy instructions for air pollution. Thus, the relationship between the collection of SO_2 emission charges and pollution emissions can be regarded as linear, and the policy effect of environmental regulation is optimal when the emission charges and the marginal emission costs of firms are equal. However, in 2003, the implementation of the "Measures for the Administration of Sewage Charging Standards" for SO_2 was 0.63 RMB/kg, which is only 50% of the cost of operating pollution control facilities in firms, and even less than 10% for some firms or projects. The State Council of China, in 2007, issued a notification on the issuance of a comprehensive work program for energy conservation and emission reduction, which called for the SO_2 emission fee to be increased from 0.63 RMB/kg to 1.26 RMB/kg in the following years. Subsequently, 12 provinces in China raised the SO_2 emission fee charges during 2007–2013. The above policy adjustments to increase the price of SO_2 emissions by the central government and local governments are collectively referred to as the sewage charges standard reform (SCSR). The specific time of implementation of the SCSR in each province is shown in Table 1.

Table 1. The timing of the SCSR in China by province.

Province	Time
Jiangsu	1 July 2007
Anhui	1 January 2008
Shandong	1 July 2008
Hebei	1 July 2008
Inner Mongolia	10 July 2008
Guangxi	1 January 2009
Shanghai	1 January 2009
Yunnan	1 January 2009

Table 1. *Cont.*

Province	Time
Guangdong	1 April 2010
Liaoning	1 August 2010
Tianjin	20 December 2010
Xinjiang	1 August 2012

2.2. Theoretical Hypothesis

2.2.1. Innovation Compensation Effect

In previous economics studies, it was argued that environmental regulation would adversely affect firms' export competitiveness. Under the assumption that firms' production arrangements, consumption demand, and technology levels remain unchanged, environmental regulation would raise firms' production costs in the short run, especially for highly polluting firms, and firms would often have to reduce their capital investment in technological R and D and innovation to compensate for the environmental regulation paid "compliance costs", which will to some extent hinder firms' productivity improvement and product innovation [32–34], thus weakening firms' export competitiveness and negatively affecting export sophistication. However, from a long-term dynamic perspective, the strengthening of environmental regulations will have a positive impact on firm innovation. The Porter hypothesis proposes that appropriate environmental regulation can promote firm innovation. On the one hand, environmental regulations can exert external pressure on firms to accelerate innovation by setting environmental constraints. When the marginal cost of technological innovation is less than the marginal cost of pollution abatement, firms will compensate for innovation by innovating on their own, increasing their productivity or promoting green technology development [35,36]. On the other hand, environmental regulation can reduce the uncertainty of firms' innovation, focus their innovation direction on improving processes and technologies and cleaner production, promote the rational allocation of firms' innovation resources, reduce their exploration costs to a certain extent, provide incentives for firms to innovate, and achieve the improvement of their productivity and competitiveness through innovation [37], which in turn improves firms' export sophistication [38]. Accordingly, we propose Hypothesis 1.

Hypothesis 1. *The SCSR may increase firms' export sophistication through the mechanism of innovation compensation.*

2.2.2. Product Switching Effect

In the context of economic globalization, to adapt to the complicated changes in the globalized commodity market, it is common for companies to produce multiple products to hedge business risks. Studies have found that the majority of firms involved in international trade are multi-product manufacturers [39,40]. In the case of strengthened environmental regulations, firms are required to pay more sewage charges, which increases operating costs, squeezes their profit margins, and leads to restrictions on their reproduction scale. Firms will adjust their product mix to control operating costs and environmental pollution costs while reallocating resources among products within the firm, driven by the constraints of emission costs and maximizing operating profit. In terms of product factor inputs, different raw materials produce different forms of pollution during the production process, and firms in the same industry may use different raw materials and technologies to produce products for the same purpose. Strict environmental regulation may lead firms to choose more environment-friendly factor inputs and change product mixes [41]. From the perspective of product market demand, the implementation and strengthening of environmental regulation policies will gradually affect consumers' environmental awareness and consumption preferences. Consumer demand for low-technology polluting products will gradually decrease, while consumer demand for high-technology green and clean products will keep increasing, which will lead to an overall change in market consumer demand [42,43]. In response to changes in market demand, firms have updated their products by reducing or eliminating the production of pollution-intensive products and increasing the share of clean products in their product mix to meet changes in environmental enforcement and market demand [44].

As environmental regulations force companies to switch products, they also contribute to the improvement of productivity levels and product competitiveness. He and Tang argue that tight environmental regulations force firms to eliminate highly polluting products and reallocate the resources released from the eliminated products to the new products' manufacturing, thus improving the competitiveness of firms' products [45]. Manova and Yu also found that firms' product switching behavior significantly improves the quality of their products [46]. Accordingly, we propose Hypothesis 2.

Hypothesis 2. *The SCSR may increase firms' export sophistication through the mechanism of product switching.*

3. Research Design

3.1. Model Specification

The institutional arrangement of the SCSR in China creates good identification conditions for using the DID model since the implementation of the SCSR is inconsistent across provinces. In this paper, we refer to Beck et al. to construct a staggered DID model to identify the average treatment effect of the SCSR on the firms' export sophistication since the implementation of the SCSR is inconsistent across provinces [47]. The specification is as follows:

$$lnESI_{ipt} = \alpha_0 + \alpha_1 DID_{it} + \beta X_i + \gamma M_p + \lambda_i + \mu_t + \varepsilon_{ipt} \quad (1)$$

where i and p refer to firms and provinces, respectively, and t refers to years; $lnESI_{ipt}$ represents firms' export sophistication; and DID_{it} is the core independent variable and equals 1 when the province where firm i is located has implemented the SCSR in year t or equals 0 otherwise. The coefficient α_1 is the average treatment effect of the SCSR on firms' export sophistication. X_i and M_p are the sets of firm-level and province-level control variables; α_0 denotes the constant term; λ_i and γ_t represent firm fixed effect and year fixed effect; ε_{ipt} denotes the random disturbance term.

3.2. Data Source

According to the description of the policy background in the previous section, China released a policy in 2003 to start charging emission fees based on the volume of emissions; therefore, the sample interval of this paper is chosen as 2004–2013. The data used in this paper are mainly derived from the following four sources: first, the HS6 code product-level export data of each country are obtained from the UN Comtrade database and are is used to calculate the export sophistication at the product level of each country; second, the HS6 code product-level export data of Chinese firms are obtained from the Chinese Customs Trade database (CCTD) and are matched with the UN Comtrade database and used to calculate the exports sophistication at the firm level; third, the data for characteristics of Chinese firms are obtained from the Chinese Annual Survey of Industrial Firms (CASIF) and used to calculate the control variables at the firm level; fourth, the economic development data at the Chinese provinces level are obtained from the China Statistical Yearbook and used to calculate the control variables at the province level.

We processed the raw data as follows: first, we unified the versions of HS codes and used the unified HS six-digit codes to match the UN Comtrade database and the CCTD; second, we cleaned and organized the CASIF by referring to Brandt et al. [48], reconstructed panels of firms, and removed samples with missing or incorrect financial data; third, we used information such as firm names and legal person codes to match the CASIF and CCTD by referring to Yu [49].

3.3. Variables

3.3.1. Dependent Variable

The dependent variable in this paper is the firm's export sophistication (*lnESI*). Referring to Hausmann et al. [50], the export sophistication of product k for each country in the UN Comtrade database was first calculated according to Equation (2):

$$PRODY_k = \sum_c \frac{x_{ck}/X_C}{\sum_C x_{ck}/X_c} \times pgdp_c \quad (2)$$

where the subscripts k and c denote the product of HS6 code and countries, respectively; x_{ck} refers to the export value of product k in the country c; X_c represents the total export values of the country c; x_{ck}/X_c denotes the export share of product k in the country c; and $pgdp_c$ represents the per capita GDP of the country c.

Then, using the export data at the product level of firm i in the CCTD, we calculated the share of product k of each firm i in the total exports of firm i, and used this share as the weight to obtain the export sophistication (ESI_i) of firm i. The equation is as follows:

$$ESI_i = \sum_k \frac{x_{ik}}{X_i} \times PRODY_k \quad (3)$$

where the subscripts k and i denote the product of HS6 code and firms, respectively; x_{ik} refers to the export value of product k of each firm i; X_i represents the total export values of the firm i; x_{ik}/X_i denotes the export share of product k in firm i; and $PRODY_k$ represents the export sophistication of product k.

3.3.2. Independent Variable

The core explanatory variable of this paper is the SCSR (DID_{it}), which can be expressed as $DID_{it} = Policy_i \times Post_t$, where $Policy_i$ is used to identify the treatment and control groups and is assigned a value of 1 (treatment group) if the province where the firm is located implemented the SCSR during the sample period and 0 (control group) otherwise. $post_t$ distinguishes between before and after the implementation of the SCSR. Observations are assigned a value of 1 for all years after the implementation of the SCSR in a province and 0 otherwise.

3.3.3. Mediating Variables

Innovation level (*IL*). We use the natural logarithm of the total number of patent applications filed by the firms in a given year plus 1 to measure the innovation level of the firms. This is due to two main reasons: first, there are a large number of missing values in the CASIF for measuring firms' innovation investment; second, the number of patent applications is more reflective of the current innovation level of firms because firms are likely to have applied the patented technologies to actual production before they are granted.

Product switching (*PS*). We use the natural logarithm of the absolute value of the number of products exported by a firm in the current year minus the number of products in the previous year plus 1 to measure this. Firms can achieve optimal resource allocation by adding new products, abandoning existing products, or even changing their core products through product switching [51]. The adjustment of the total number of product categories reflects the change in the product range of the firms, which is the final result of product switching. Therefore, we chose the change in the number of exported products to measure product switching.

3.3.4. Control Variables

Referring to Li et al. [29], Gan et al. [52], Wang and Shen [53], and other literature, the following control variables are selected in this paper: firm total factor productivity (TFP), which is estimated by the LP method; firm durations (AGE), which is measured by the logarithm of the difference between the current year and the year the firm was established +1; firm size (SIZE), which is measured by the logarithm of the average number of employees per year of the firm; capital intensity (CAP), measured by the natural logarithm of the ratio of total fixed assets to the number of employees; financial constraint (FIN), measured by the liquidity of the firm, i.e., (current assets–current liabilities)/total assets of the firm; capital structure (CS), measured by the asset-liability ratio; return on assets (ROA), measured by the ratio of net profit to total assets; industry competition (HHI), reflected by the Herfindahl index calculated at the 4-digit code industry level using the amount of the firm's main business revenue and the degree of competition in the industry in which the firm is located; the level of technical facilities (INF), measured by taking the natural logarithm of the number of graded road miles per capita in each province; the foreign trade dependence (OPEN), which is reflected by the ratio of import and export volume to GDP of each province; and the strength of environmental enforcement (STR), measured by the ratio of a province's pollution control costs to its industrial output value.

The descriptive statistics of the above variables are shown in Table 2. The maximum value of firms' export sophistication is 10.8338, and the minimum value is 7.8604, while the mean value is 9.4035, indicating that the distribution of firms' export sophistication is right skewness. The mean value of *DID* is 0.3032, meaning that the ratio of the treatment group to the total sample size is about 30.32%.

Table 2. Definitions of Variables and Summary Statistics.

Variables	Definition	Mean	S.D.	Min	Max
lnESI	Firms' export sophistication	9.4035	0.5325	7.8604	10.8338
DID	Sewage charges standard reform (SCSR) for each province	0.3032	0.4596	0.0000	1.0000
IL	Innocation leve	0.1914	0.6864	0.0000	5.9540
PS	Product switching	0.8164	0.7141	0.0000	6.2146
TFP	Total factor productivity	5.1941	1.1862	−5.8932	13.3540
CAP	Capital intensity	11.0258	1.3736	0.6425	21.1318
SIZE	Firm size	5.2999	1.0695	2.0794	11.7688
AGE	Firm durations	2.1686	0.6226	0.0000	4.1744
FIN	Financial constrains	0.1003	0.3114	−19.9232	0.9951
CS	Capital structure	0.5436	0.2846	−0.0044	20.1371
ROA	Return on assets	0.0780	0.1792	−3.7265	9.3092
HHI	Industry competition	0.0341	0.0611	0.0015	1.0000
INF	Level of infrastructure	2.7375	0.4165	1.4445	5.0500
OPEN	Foreign trade dependence	0.7349	0.4603	0.0348	1.7705
STR	Strength of environmental enforcement	0.3004	0.2162	0.0307	2.2864

4. Main Results

4.1. Baseline Analysis

Table 3 reports the estimated results of the baseline model. Column (1) shows the regression results without adding any control variables, and the coefficient of *DID* is significantly positive at the 1% statistical level. In column (2), we sequentially add control variables at the firm level, and in column (3), we further add control variables at the industry level and province level; the coefficient of *DID* is positive and passes the significance test at the 1% level. This implies that the SCSR significantly contributes to the firms' export sophistication, while other factors are constant. Based on the regression results in column (3), we can calculate the economic effect of the SCSR, which has an average treatment effect of 1.06% on firms' export sophistication.

Table 3. The Baseline Modeling Results.

Variable	(1)	(2)	(3)
DID	0.0115 ***	0.0117 ***	0.0106 ***
	(0.0040)	(0.0040)	(0.0040)
TFP		0.0066 ***	0.0069 ***
		(0.0017)	(0.0017)
CAP		0.0015	0.0003
		(0.0018)	(0.0018)
SIZE		0.0095 ***	0.0085 ***
		(0.0026)	(0.0026)
AGE		0.0166 **	0.0158 **
		(0.0072)	(0.0072)
FIN		0.0040	0.0037
		(0.0063)	(0.0063)
CS		0.0054	0.0047
		(0.0073)	(0.0073)
ROA		0.0327 ***	0.0288 ***
		(0.0066)	(0.0066)
HHI			−0.1318 ***
			(0.0319)
INF			0.0027
			(0.0094)
OPEN			0.0474 ***
			(0.0140)
STR			−0.0992 ***
			(0.0087)
Constant	9.4000 ***	9.2565 ***	9.2686 ***
	(0.0012)	(0.0332)	(0.0397)
Firm Fixed-effect	Yes	Yes	Yes
Year Fixed-effect	Yes	Yes	Yes
Observations	191,025	191,025	191,025
$adj.R^2$	0.7399	0.7402	0.7407

Notes: Standard errors are corrected for clustering at the firm level. **, and *** indicate significance at the 5%, and 1% levels, respectively.

4.2. Parallel Trend Check

An important prerequisite for the use of the difference-in-difference model is that the treatment and control groups need to meet the "parallel trend" assumption. There are two approaches to parallel trend testing: one is suitable for a difference-in-difference model at a single policy point in time, where a parallel trend is satisfied by plotting the change in trend between the treatment group and the control group before and after the policy shock; the second is suitable for a difference-in-difference model at multiple points in time, where regressions are performed by using the event study method with the inclusion of interaction terms for the treatment group and year dummy variables. We use the event study method for parallel trend testing since the SCSR is a multi-time policy shock and there are multiple treatment and control groups. The model for the parallel trend test is as follows:

$$lnESI_{ipt} = a + \delta D_{it}^{-7} + \eta D_{it}^{+5} + \beta X_i + \gamma M_p + \lambda_i + \mu_t + \varepsilon_{ipt} \quad (4)$$

where $D_{it}^{\pm q}$ is a series of dummy variables, and D_{it}^{-q} is equal to 1 when the time is q years before the implementation of the SCSR in the province where the firm is located. D_{it}^{+q} is equal to 1 when the time is q years after the implementation of the SCSR in the province where the firm is located. Otherwise, $D_{it}^{\pm q}$ is equal to 0. We set the year of implementation of the SCSR as the benchmark group. The estimate coefficients of $D_{it}^{\pm q}$ reflect whether there is a significant difference in the trend of change in the export sophistication between the treatment and control group in year q before or after the implementation of the SCSR. To visualize the statistical results, we plot the trend of the coefficients in Figure 1. We can see that none of the coefficients of $D_{it}^{\pm q}$ are significant before the implementation of the SCSR, indicating that there is no significant difference in export sophistication between the firms of treatment and control groups before the policy adaptation, which is consistent with the parallel trend hypothesis. However, the firms' export sophistication of the treatment group is significantly greater than the export sophistication of those in the control group in the four periods following the implementation of the SCSR. The estimated coefficient of $D_{it}^{\pm q}$ is no longer significant by period 5, indicating that there is no time lag effect on the impact of the SCSR on firms' export sophistication, and the duration of the impact reaches 4 years.

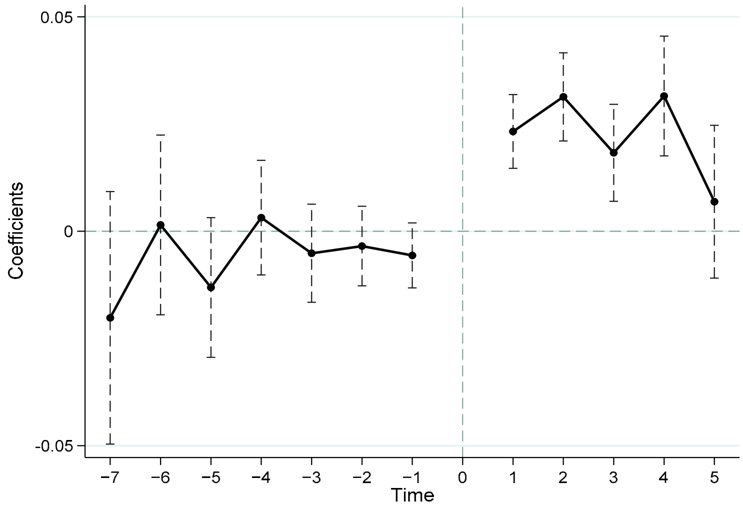

Figure 1. Parallel Trend Check.

4.3. Robustness Checks

4.3.1. Alternative Measurement of ESI

We refer to the method of Hausmann et al. [50], which uses product-level export data to calculate the firms' export sophistication; however, the export sophistication calculated by this method only reflects the difference in product prices and may underestimate the firms' export sophistication to a certain extent. Therefore, we refer to Song et al. [23] and modify the export sophistication of firms by using the total factor productivity (*TFP*). Specifically, the adjusted export sophistication (ESI_i^{adj}) is recalculated by using the ratio of the TFP of export firm *i* to the average TFP of its industry *j* as weights. The calculation equation is as follows:

$$ESI_i^{adj} = \frac{TFP_i}{TFP_j} \times ESI_i \quad (5)$$

Column (1) of Table 4 reports the regression result by using the adjusted firms' export sophistication (ESI_i^{adj}) as the dependent variable. The results show that the coefficient of *DID* is significantly positive at the 1% statistical level, which is consistent with the results of the baseline regression in the previous paper, indicating the robustness of our findings.

Table 4. Results of Robustness Checks.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
DID	0.0219 ***	0.0081 *	0.0104 **	0.0106 ***	0.0110 ***	0.0110 ***
	(0.0017)	(0.0043)	(0.0043)	(0.0040)	(0.0040)	(0.0040)
TCZ				0.0032		0.0063
				(0.0621)		(0.0620)
ETP					−0.0227 ***	−0.0227 ***
					(0.0048)	(0.0048)

Table 4. *Cont.*

Variable	(1)	(2)	(3)	(4)	(5)	(6)
TFP	0.1352 ***	0.0068 ***	0.0075 ***	0.0069 ***	0.0066 ***	0.0066 ***
	(0.0014)	(0.0017)	(0.0018)	(0.0017)	(0.0017)	(0.0017)
CAP	0.0100 ***	0.0003	0.0005	0.0004	0.0005	0.0005
	(0.0009)	(0.0018)	(0.0019)	(0.0018)	(0.0018)	(0.0018)
SIZE	−0.0114 ***	0.0085 ***	0.0107 ***	0.0085 ***	0.0087 ***	0.0087 ***
	(0.0013)	(0.0026)	(0.0027)	(0.0026)	(0.0026)	(0.0026)
AGE	0.0529 ***	0.0158 **	0.0143 *	0.0158 **	0.0157 **	0.0157 **
	(0.0035)	(0.0072)	(0.0075)	(0.0072)	(0.0072)	(0.0072)
FIN	0.0361 ***	0.0036	0.0049	0.0037	0.0036	0.0036
	(0.0029)	(0.0063)	(0.0066)	(0.0063)	(0.0063)	(0.0063)
CS	0.0319 ***	0.0046	0.0049	0.0047	0.0049	0.0049
	(0.0033)	(0.0073)	(0.0077)	(0.0073)	(0.0073)	(0.0073)
ROA	0.0461 ***	0.0289 ***	0.0310 ***	0.0288 ***	0.0283 ***	0.0283 ***
	(0.0035)	(0.0066)	(0.0068)	(0.0066)	(0.0065)	(0.0065)
HHI	−0.3364 ***	−0.1323 ***	−0.1449 ***	−0.1318 ***	−0.1309 ***	−0.1308 ***
	(0.0224)	(0.0319)	(0.0346)	(0.0319)	(0.0318)	(0.0318)
INF	0.0092 **	0.0031	−0.0076	0.0027	0.0103	0.0103
	(0.0038)	(0.0094)	(0.0111)	(0.0094)	(0.0096)	(0.0096)
OPEN	0.0534 ***	0.0449 ***	0.0676 ***	0.0473 ***	0.0502 ***	0.0501 ***
	(0.0060)	(0.0140)	(0.0163)	(0.0140)	(0.0141)	(0.0141)
STR	−0.0517 ***	−0.1008 ***	−0.1027 ***	−0.0992 ***	−0.0906 ***	−0.0906 ***
	(0.0035)	(0.0086)	(0.0094)	(0.0087)	(0.0086)	(0.0086)
Constant	1.8251 ***	9.2709 ***	9.2610 ***	9.2658 ***	9.2488 ***	9.2433 ***
	(0.0180)	(0.0397)	(0.0442)	(0.0665)	(0.0400)	(0.0668)
Firm Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes
Observartions	160,540	191,025	170,627	191,025	191,025	191,025
$adj.R^2$	0.9338	0.7407	0.7400	0.7407	0.7408	0.7408

Notes: Standard errors are corrected for clustering at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

4.3.2. Adjusting Identification of Policy Year

The baseline regression regards the year in which the SCSR is implemented as the base year and the subsequent years as the policy years (*Post* = 1). In fact, the implementation of the SCSR in most provinces is not on December 31 of the year. To identify the timing of policy implementation more precisely, we adjust the identification method by following the approach in Lu (2017) [54]. Specifically, for example, in Jiangsu Province, the SCSR was implemented in July 2007, so *Post* equals 0 if the year of observations is before 2007, *Post* equals 1 if the year of observations is after 2007, and *Post* equals 1/2 in the year 2007 (according to the proportion of the actual implementation month of the year to determine the value of *Post* in a given year). The regression result after re-identifying the policy years is reported in Column (2) of Table 4. The coefficient of *DID* is positive and passes the 10% significance test, implying that the conclusions of the baseline regression are unaffected by the policy year identification method and are robust.

4.3.3. Excluding the Sample of Municipalities

Under the existing administrative system of China, although municipalities directly under the Central Government (Beijing, Shanghai, Tianjin, Chongqing) are all administrative regions at the same level as other provinces, they have natural advantages in terms of policy implementation, resource allocation, and regional positioning. Considering the potential interference of the differences between municipalities and other provinces on the empirical results, we exclude the sample of firms from the four municipalities of Beijing, Shanghai, Tianjin, and Chongqing and estimate the baseline model again. The estimated result is presented in Column (3) of Table 4. As shown, the coefficient of *DID* is also significantly positive, indicating that our baseline results are robust.

4.3.4. Excluding Interference from Other Environmental Regulations

During the sample period of this paper, China introduced many environmental protection policies to improve the ecological environment, some of which are similar to those discussed in this paper and were implemented at the regional level and may interfere with the empirical results of this paper. Therefore, it is necessary to exclude interference from other environmental regulations. We select two important environmental regulations that are active during the sample period of this paper. One is the "Two Control Zones" policy (implemented in 1998), and the other is the "Emission Trading Pilot" policy (implemented in 2007). Referring to Tanaka [55] and Wang et al. [56], we construct "Two Control Zones" (*TCZ*) and "Emission Trading Pilot" (*ETP*) variables. Then, we add these two variables to the empirical model. The regression results are reported in Columns (4)–(6) of Table 4. The results show that the coefficient of DID remains significant at the 1% level whether the two environmental regulation policies are controlled independently or simultaneously. Thus, the conclusion of the baseline regression remains robust.

4.3.5. Placebo Test

We refer to Liu and Mao [57] and conduct a placebo test by screening provinces implementing emission fee increases randomly and assigning a random year of policy implementation. Specifically, there are 12 provinces in this paper that implemented the SCSR during the sample period; therefore, we first select 12 provinces randomly from 31 provinces as the treatment group and use the remaining provinces as the control group. Each of the 12 provinces is assigned a random year within the sample period as its policy occurrence time, and a placebo experiment is constructed to test the effect of the SCSR on the firms' export sophistication. To further enhance the validity of the placebo test, we repeated the above procedure 500 times and plotted the distribution of the estimated coefficients of *DID*. If the coefficient estimates of the core independent variable *DID* remain consistent with those in the baseline regression, it suggests that the increase in firms' export sophistication may not be caused by the SCSR. Otherwise, it indicates that the conclusions of the baseline regression are not obtained randomly but robustly. Figure 2 reports the coefficient distribution of *DID*. It is shown that the estimated coefficients are concentrated around 0, and most of them do not pass the significance test. None of the coefficients are greater than the baseline regression results, so it can be assumed that our results are not randomly generated, which provides robustness to the core findings of this paper.

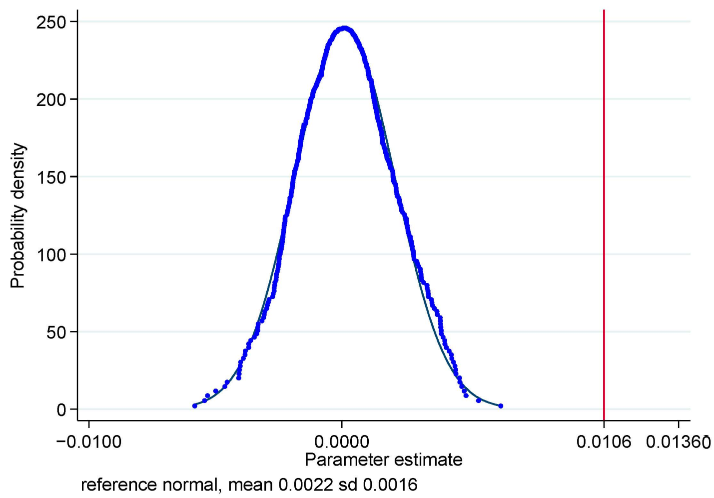

Figure 2. Placebo Test.

5. Further Analysis

5.1. Heterogeneity Analysis

5.1.1. Heterogeneity of Trade Mode

Compared to pure export firms, simultaneous import and export firms have more options in the production process to face the constraints of environmental regulations, which may increase their productivity levels by importing advanced production equipment, environmentally friendly production materials, etc., thus potentially improving the firms' export sophistication. We divide the sample into two subsamples of simultaneous import and export firms and pure export firms based on the trade data from the China Customs Trade Database (CCTD). The estimation results of subsamples are reported in Columns (1) and (2) of Table 5. The results show that the coefficient of *DID* is only significantly positive in subsamples of simultaneous import and export firms, indicating that the promotion effect of the SCSR on firms' export sophistication is more effective in the sample of simultaneous import and export firms.

Table 5. Results of Heterogeneity Analysis.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
DID	0.0208 ***	0.0056	0.0084	0.0163 **	0.0182 ***	−0.0030
	(0.0063)	(0.0053)	(0.0053)	(0.0064)	(0.0061)	(0.0059)
TFP	0.0123 ***	0.0028	0.0043 *	0.0105 ***	0.0080 ***	0.0067 ***
	(0.0026)	(0.0025)	(0.0023)	(0.0027)	(0.0030)	(0.0024)
CAP	0.0002	0.0008	−0.0005	0.0015	0.0042	−0.0004
	(0.0026)	(0.0028)	(0.0027)	(0.0025)	(0.0042)	(0.0028)
SIZE	0.0073 *	0.0091 **	0.0087 **	0.0088 **	0.0144 ***	0.0045
	(0.0039)	(0.0037)	(0.0037)	(0.0037)	(0.0051)	(0.0040)
AGE	0.0106	0.0201 **	0.0087	0.0251 **	−0.0135	0.0186 *
	(0.0109)	(0.0100)	(0.0097)	(0.0108)	(0.0119)	(0.0104)
FIN	0.0069	0.0017	−0.0008	0.0063	0.0150	0.0062
	(0.0093)	(0.0091)	(0.0091)	(0.0090)	(0.0107)	(0.0090)
CS	0.0004	0.0060	0.0024	0.0069	0.0247 *	0.0089
	(0.0110)	(0.0102)	(0.0101)	(0.0109)	(0.0127)	(0.0103)
ROA	0.0279 ***	0.0220 **	0.0263 ***	0.0340 ***	0.0420 ***	0.0155 *
	(0.0093)	(0.0095)	(0.0089)	(0.0102)	(0.0155)	(0.0083)
HHI	−0.1466 ***	−0.1130 **	−0.1039 **	−0.1554 ***	−0.1878 ***	−0.0508
	(0.0449)	(0.0483)	(0.0474)	(0.0437)	(0.0490)	(0.0452)
INF	−0.0029	0.0060	0.0184	−0.0030	−0.0264 *	0.0139
	(0.0156)	(0.0126)	(0.0121)	(0.0155)	(0.0151)	(0.0134)
OPEN	0.0774 ***	0.0250	0.0263	0.0842 ***	0.0215	0.0327
	(0.0241)	(0.0186)	(0.0183)	(0.0241)	(0.0212)	(0.0205)
STR	−0.0728 ***	−0.1092 ***	−0.1157 ***	−0.0734 ***	−0.0623 ***	−0.1442 ***
	(0.0141)	(0.0112)	(0.0112)	(0.0141)	(0.0127)	(0.0130)
Constant	9.1944 ***	9.3336 ***	9.2943 ***	9.1919 ***	9.3865 ***	9.2222 ***
	(0.0619)	(0.0575)	(0.0544)	(0.0631)	(0.0836)	(0.0568)
Firm Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	90,126	102,378	101,990	90,514	92,561	99,943
adj.R^2	0.7272	0.7576	0.7481	0.7347	0.7326	0.7505

Notes: Standard errors are corrected for clustering at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

5.1.2. Heterogeneity of Ownership

In view of the preferential treatment that foreign firms enjoy in China, which is not available to other types of firms, it is possible that local governments in each province also adopt different yardsticks for foreign firms in environmental enforcement. In addition, Chinese local firms, especially state-owned firms, tend to take on heavier tasks of energy conservation and emission reduction assigned by local governments due to the specificity of their ownership and are subject to more binding environmental regulations [58]. With this consideration, we divide the full sample into a subsample of foreign-owned firms and a subsample of local-owned firms. The estimated results are presented in Columns (3) and (4) of Table 5. The results show that the coefficient of *DID* is not significant for foreign-owned firms, while the coefficient of *DID* is 0.0163 and passes the 1% significance tests for local firms. It is suggested that the impact of the SCSR on the firms' export sophistication is mainly reflected in local firms.

5.1.3. Heterogeneity of Firm Size

As the province where the firm is located begins to implement a policy of higher emission fees, both large-sized and medium- or small-sized firms will face higher "compliance costs" of environmental regulations. However, since large-sized firms have a scale effect, the cost of technological innovation is relatively lower and may bring higher profit margins through the adjustment of equipment, technology, and production arrangements, so the SCSR may have a greater impact on the promotion of export sophistication of larger firms. With reference to Brandt et al. [59], we divide the firms into two groups of large-sized and medium- or small-sized firms according to the size of fixed assets, and the estimated results are shown in Columns (5) and (6) in Table 5. From the regression results, the coefficient of *DID* is 0.0182, and it passes the 1% significance test for large-sized firms, while the coefficient of *DID* for medium- or small-sized firms is negative and not significant. Thus, the positive effects of the SCSR are more profound in large-sized firms.

5.2. Mechanism Analysis

As mentioned in the theoretical analysis of the previous paper, the emission fee reform mainly promotes the firms' export sophistication through two alternative impact mechanisms: innovation compensation and product switching. We then proposed Hypothesis 1 and Hypothesis 2. To test these hypotheses, following Fairchild and MacKinnon [60], we use a mediating effect model for this paper, which is set as follows:

$$lnESI_{ipt} = \alpha_0 + \alpha_1 DID_{it} + \beta X_i + \gamma M_p + \lambda_i + \mu_t + \varepsilon_{ipt} \quad (6)$$

$$MV_{it} = b_0 + b_1 DID_{it} + \beta X_i + \gamma M_p + \lambda_i + \mu_t + \varepsilon_{ipt} \quad (7)$$

$$lnESI_{ipt} = c_0 + c_1 DID_{it} + c_2 MV_{it} + \beta X_i + \gamma M_p + \lambda_i + \mu_t + \varepsilon_{ipt} \quad (8)$$

where the subscripts i and t denote firms and year, respectively, and M_{it} represents the mediating variables, including innovation level and product switching of firms. The rest of the settings are consistent with the baseline regression model.

Table 6 reports the regression results of the mediating effect model. The result of Column (1) is based on Equation (6) and is same to the baseline result. The results of Columns (2) and (3) test the innovative compensation mechanism. In Column (2), the coefficient of *DID* is 0.0157 and passes the significance test at the 5% level, indicating that the SCSR significantly promotes firms' innovation level. The coefficient of *IL* is also significantly positive in Column (3). Thus, empirical evidence supports Hypothesis 1 and suggests that the SCSR promotes firms' export sophistication by increasing the innovation level of firms. The results of Columns (4) and (5) test the product switching mechanism. In Column (4), the coefficient of *DID* is 0.0299 and passes the significance test at the 1% level, indicating that the SCSR significantly promotes the product switching of firms. The coefficient of *PS* is also significantly positive in Column (5). Accordingly, Hypothesis 2 can be verified, indicating that the SCSR promotes the firms' export sophistication through the product switching mechanism.

Table 6. Results of Mechanism Test.

Variable	**(1)** ***lnESI***	**(2)** ***IL***	**(3)** ***lnESI***	**(4)** ***PS***	**(5)** ***lnESI***
DID	0.0106 ***	0.0157 **	0.0106 ***	0.0299 ***	0.0105 ***
	(0.0040)	(0.0069)	(0.0040)	(0.0064)	(0.0040)
IL			0.0034 **		
			(0.0015)		
PS					0.0042 ***
					(0.0013)
TFP	0.0069 ***	0.0314 ***	0.0068 ***	0.0058 *	0.0068 ***
	(0.0017)	(0.0026)	(0.0017)	(0.0030)	(0.0017)
CAP	0.0003	0.0415 ***	0.0002	−0.0033	0.0004
	(0.0018)	(0.0031)	(0.0018)	(0.0031)	(0.0018)
SIZE	0.0085 ***	0.0388 ***	0.0083 ***	0.0082 *	0.0084 ***
	(0.0026)	(0.0049)	(0.0026)	(0.0044)	(0.0026)
AGE	0.0158 **	−0.0546 ***	0.0159 **	−0.2147 ***	0.0167 **
	(0.0072)	(0.0122)	(0.0072)	(0.0111)	(0.0072)
FIN	0.0037	0.0556 ***	0.0035	0.0080	0.0036
	(0.0063)	(0.0106)	(0.0063)	(0.0112)	(0.0063)
CS	0.0047	0.0435 ***	0.0046	0.0060	0.0047
	(0.0073)	(0.0118)	(0.0073)	(0.0125)	(0.0073)
ROA	0.0288 ***	−0.0490 ***	0.0290 ***	−0.0293 **	0.0289 ***
	(0.0066)	(0.0088)	(0.0066)	(0.0116)	(0.0066)
HHI	−0.1318 ***	−0.0796	−0.1315 ***	−0.1052 **	−0.1314 ***
	(0.0319)	(0.0649)	(0.0319)	(0.0466)	(0.0319)
INF	0.0027	0.0428 ***	0.0026	−0.0616 ***	0.0030
	(0.0094)	(0.0135)	(0.0094)	(0.0155)	(0.0094)
OPEN	0.0474 ***	0.0157	0.0473 ***	−0.0431 *	0.0475 ***
	(0.0140)	(0.0235)	(0.0140)	(0.0227)	(0.0140)
STR	−0.0992 ***	0.0866 ***	−0.0995 ***	−0.0366 ***	−0.0991 ***
	(0.0087)	(0.0104)	(0.0087)	(0.0129)	(0.0087)
Constant	9.2686 ***	−0.6988 ***	9.2709 ***	1.4488 ***	9.2624 ***
	(0.0397)	(0.0631)	(0.0397)	(0.0650)	(0.0398)
Sobel Test		1.847 *		2.753 ***	
Firm Fixed-effect	Yes	Yes	Yes	Yes	Yes
Year Fixed-effect	Yes	Yes	Yes	Yes	Yes
Observations	191,025	191,025	191,025	191,025	191,025
adj.R^2	0.7407	0.4258	0. 7407	0.3985	0.7407

Notes: Standard errors are corrected for clustering at the firm level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

6. Conclusions and Policy Implications

6.1. Conclusions

Based on a quasi-natural experiment of the sewage charges standard reform (SCSR), this paper examines the impact of environmental regulation on firms' export sophistication by adopting a staggered difference-in-difference model using matched data from the Chinese Annual Survey of Industry Firms (CASIF) and Chinese Customs Trade database (CCTD) from 2004–2013. The following conclusions are drawn: first, the environmental regulation policy of the SCSR can significantly promote the firms' export sophistication, which remains robust after a series of robustness tests; second, the impact of the SCSR on firms' export sophistication is heterogeneous, and the promotion effect of the SCSR on firms' export sophistication is mainly reflected in firms that import and export simultaneously, large scale firms, and local firms; third, the SCSR promotes firms' export sophistication mainly through an innovation compensation effect and a product switching effect. The findings of this paper provide new empirical evidence for the assessment of the policy effects of the SCSR and support Porter's hypothesis at the micro level. In addition, these findings have implications for governments of developing countries to formulate and implement environmental protection policies appropriately.

6.2. Policy Implications

Based on the conclusions above, the policy recommendations proposed here are as follows:

First, keep strengthening environmental regulation policy and environmental law enforcement. Environmental regulation policies, in general, have a facilitating effect on the technical complexity of polluting firms' exports and do not lead to a decline in the competitiveness of China's product exports, so reasonable environmental regulation can achieve ecological protection and enhance the competitiveness of firm' exports. At the same time, the implementation of environmental regulation policies should be strengthened. Some regions sacrifice the environment to achieve high GDP targets, and although the state has introduced environmental regulation policies to solve the externalities of environmental pollution, localities will issue subsidies to polluting firms to compensate for the increased costs brought about by the strengthening of environmental regulations, which greatly reduces the role of environmental regulation policies. Therefore, after the change from "fee" to "tax", the implementation of the environmental protection tax needs to be strengthened, and the environmental protection tax rate can be increased appropriately.

Second, improve the supporting measures to promote environmental policies. The conclusions of this paper point out that environmental regulation mainly promotes the firms' export sophistication through mechanisms of innovation compensation effect and product conversion effect, but not all firms can achieve green technological innovation and product production conversion in the short term. Therefore, local governments need to introduce corresponding supporting measures while strengthening the intensity of environmental regulations, including the implementation of financial support policies to alleviate the financial constraints of firm innovation and the implementation of innovation guidance policies to provide technological innovation direction for firms and reduce innovation uncertainty.

Third, the environmental regulation policy should be differentiated for different firms. Firms with different business models, asset sizes, and ownership structures face different costs from environmental regulation and have different options for dealing with environmental regulation. Therefore, the formulation and implementation of environmental regulations should pay attention to the specificity of firms and industries; formulate targeted, differentiated, and hierarchical environmental regulation policies; and promote the implementation of environmental protection tax while supporting diversified environmental regulation policies so as to achieve the win-win goal of environmental protection and technological progress.

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