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Environmental Regulation and Export Product Quality: Evidence from Chinese Firms

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Abstract: The Chinese government adopted a series of pollution reduction targets in its eleventh five-year (2006-2010) economic development program. Whether this program can achieve its goal of pollution reduction and quality improvement for exports is of vital importance for China's sustainable development. This paper aims to investigate the effects of these environmental regulation policies on export product quality by using the quasi-difference-in-difference method. Empirical results show that the implementation of these pollution reduction targets significantly reduces export product quality. This negative impact is more profound in western regions, capital-intensive sectors and privately-owned firms. Moreover, the negative effect is only observed among firms exporting to non-OECD countries, whereas the export quality of firms exporting to OECD countries is positively affected by the new policy. Lastly, our extended analysis shows that the negative effects can be mitigated through product switching within the firms.

Key words: Environmental regulation; Export product quality; Product switching; China

JEL codes: F10; F18; Q56

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1. Introduction

The 19th National Congress of the Communist Party of China noted that China's economy had been transitioning from a phase of rapid growth to a stage of high-quality development. As an important manifestation of national creativity and competitiveness, improving export product quality is a top priority for China. In doing so, it can generally improve product quality and increase international competitiveness. Since the launch of economic reforms and the open-door policy, export-oriented growth strategy has been successfully delivered by China over the last four decades. China has actively participated in global value chains (GVCs for short) by taking advantage of the country's low-cost labour as well as its relatively complete industrial system. The country has been referred to as "the world's factory". However, not only does this low-end embedded GVCs strategy not continually improve export product quality but it also leads to serious environmental problems. Therefore, there is a broad consensus that environmental management should be strengthened so that China can become a beautiful country with blue sky, green vegetation and clear water.

In response to the increasing deterioration of the environment, central and local governments are tightening their environmental regulations and hope that firms can reduce their pollution intensity and adopt more environmental friendly technology. The Eleventh Five-Year Plan of China (2006-2010) also incorporated an environmental goal of reducing pollution in five years. In order to carry out this reduction goal, the State Council in conjunction with the National Development and Reform Commission and other relevant departments issued the 11th Five-Year Energy Conservation and Emission Reduction Work Plan which sets the pollution reduction targets for provincial governments. Some scholars are questioning whether China's new environmental policy is not in accordance with the export-oriented growth strategy and will have an adverse effect on economic growth while other scholars consider whether pollution reduction can improve export product quality. A clear understanding of these questions has important policy implications for environmental regulation.

This paper employs a quasi-difference-in-difference method to investigate the effects of pollution reduction on export product quality. We use a uniquely detailed dataset comprising Chinese export data at the firm, product and destination levels from 2000 to 2010. The empirical results show that pollution reduction is negatively associated with export product quality. This finding remains valid after a series of robustness checks as well as consideration of endogeneity problems and sample selection bias. Further analysis indicates that this negative impact is more profound in central regions, capital-intensive sectors and private firms. Moreover, pollution reduction reduces export product quality of firms exporting to non-OECD countries, whereas it increases export product quality of firms exporting to OECD countries. We also pay special attention to the role of product switching in moderating the relationship between pollution reduction and export product quality. Our findings reveal that product switching can mitigate the negative effects of the new environmental policy and improve export product quality.

Our study contributes to the literature in three ways. First, this paper uses highly disaggregated trade transaction data at the product level to measure export product quality and investigate how product quality is affected by environmental regulation. The existing literature has focused on the effects of environmental regulation on innovation (Porter and van der Linde, 1995; Tello and Yoon, 2008; Walker et al., 2008) and total factor productivity (Tombe and Winter, 2015; Rubashkina et al., 2015; Albrizio et al., 2017; Wang et al., 2018). Some authors have investigated the role of environmental regulation in trade. However, their studies mainly examine whether environmental regulation increases the possibility of exporting or export volumes of a firm (Arouri et al., 2012; Hering and Poncet, 2014; Rubashkina et al., 2015; Sakamoto and Managi, 2017). In fact, due to the decline in trade competitiveness, upgrading product quality has been a priority for China's trade development. This paper extends the existing literature by investigating whether environmental regulation affects export product quality.

Second, we investigate how product switching may be adopted by firms to mitigate the negative effects of the new environmental policy on export product quality. The existing research on resource reallocation at the product level focuses mainly on firm entry and exit, or market share changes among surviving firms (Griliches and Regev, 1995; Melitz, 2003; Melitz and Polanec, 2015). Bernard et al. (2010) was the first to examine the frequency, pervasiveness and determinants of product switching by US manufacturing firms. After Bernard et al. (2010), scholars provided further evidence to demonstrate that product switching behaviour can improve firms' performance (Goldberg et al., 2010; Navarro, 2012; Kawakami and Miyagawa, 2013; Bernard and Okubo, 2016). In this paper, we also investigate to what extent and how product switching can mitigate the negative effects of the new environmental policy. Our study not only confirms the findings by Bernard et al. (2010), but also complements the research of Shi and Xu (2018).

Third, we employ the quasi-difference-in-difference (quasi DID) method to estimate the impact of environmental regulation on firms' export product quality. Two papers are closely related to our work. The first paper by Hering and Pocent (2014) investigated the effectiveness of the so-called Two Control Zones (TCZ) policy in export sector by using the Chinese Customs Database over the period of 1997-2003. Their findings showed that the TCZ policy has negative repercussions on exports. The second paper by Shi and Xu (2018) adopted a difference-in-difference-in-difference (DDD) strategy to identify the impact of the SO2 reduction target on firms' exports and reached the same conclusion as Hering and Pocent (2014). Our study differs from the above two studies by applying a quasi-difference-in-difference method which does not artificially identify the treatment and control groups and can provide a more objective evaluation of the policy implementation results (Yang et al., 2017). In addition, this method uses an interactive item of the continuous measure of the treatment variable (the pollution reduction target in this paper) and policy dummy variable to detect the effect of the policy on the development variable.

The remainder of this paper is structured as follows. Section 2 presents the literature review and hypotheses. Section 3 demonstrates the model specification and describes the data and choice of the variables. Section 4 presents empirical results, while Section 5 investigates how the negative effects of the new environmental policy on export quality may be reduced through product switching. Section 6 ends with conclusions and policy recommendations.

2. Literature Review and Hypotheses

The relationship between environmental regulation and exports has gained a lot of attention recently. Whether environmental regulation is good or bad for exports is very controversial. In theory, there are two contrasting views. On the one hand, the conventional viewpoint is that while environmental regulation may be desirable from a broader social perspective, its impact on exports would be negative as firms are forced to increase compliance costs (Walter, 1982; Baumol and Oates, 1988; Barbera and McConnell, 1990). In order to satisfy the requirements of environmental policy proposed by governments, local firms need to control their pollution discharges or improve pollution abatement technology, which leads to an increase in compliance costs and impedes the upgrade of export product quality (Levinson and Taylor, 2008; Ollivier, 2016). On the other hand, the Porter hypothesis argues that stringent environmental regulation triggers cost-saving innovation which can offset compliance costs and hence help improve firms' export competitiveness (Porter and Linder, 1995; Jaffe and Palmer, 1997; Iraldo et al., 2011; Elrod and Malik, 2017). The empirical studies have not reached a unanimous conclusion. Some studies showed a positive relationship between environmental regulation and exports. For example, Costantini and Crespi (2008) affirmed that stringent environmental regulation is a crucial driver of export growth in the field of energy technologies. Martin-Tapia et al. (2010) found that the proactive environmental regulation is positively related to the export intensity of small and medium enterprises (SMEs). Song and Sung (2014) showed a positive short-run linear causal relation running from environmental regulation to export growth. Similar findings were reported by Costantini and Mazzanti (2012), Tsurumi et al. (2015), and Rubashkina et al. (2015). However, Levinson and Taylor (2008) found that environmental regulation is negatively associated with exports in the US. Hwang and Kim (2017) found that environmental regulation decreases exports of OECD countries.

Developing countries are often constrained by their relatively low-level technology. As a result, pollution-intensive industries are their first choice at the early stage of economic development and the resultant environmental costs are huge. Thus, the implementation of environmental regulation will increase compliance costs and reduce export quality according to Stavropoulos et al. (2017). Hering and Poncet (2014) considered the impact of stricter environmental regulation on export activities in China. They showed that there was a relative fall in exports in targeted cities and that the more polluting the industry is, the sharper the fall. Shi and Xu (2018) found that firms in more pollution-intensive industries located in provinces with higher pollution reduction targets were less likely to export. Based on the above discussion, we propose the following hypothesis.

Hypothesis 1: Export product quality is negatively correlated with environmental regulation

Significant differences exist among regions with different development conditions, environmental protection and export intensity and hence lead to regional variation in the effects of environmental regulation on export product quality. Strict environmental regulation may incentivise firms to innovate. However, whether firms ultimately choose to innovate or adopt green technologies is dependent on their innovation capacity as well as the external environment (Mohr, 2002; André et al., 2009; Dangelico and Pujari, 2010; Qiu et al., 2018). The superior institutional environment in eastern areas can alleviate the negative effects of environmental regulation on export quality. Lower technology, poorer financial ability and weaker innovation are the three major problems that firms in the central and western areas faced in recent years (Bai, 2013; Guariglia and Liu, 2014). In addition, owing to the limited financial resources, local governments in the central and western areas do not have enough resources to support green technological innovation vigorously (Fan et al., 2011; Liu et al., 2018). A weaker external environment as well as poorer innovation ability leads to the export of lower-quality products. Moreover, environmental regulation in central and western areas is less strict than that in eastern ones. Along with increasing labour costs and land prices in eastern areas, strict environmental regulation causes some enterprises to relocate from the coastal areas to central and western China. The pollution-intensive firms find it hard to have breakthrough innovations in the short term. Instead they opt to purchase emission control devices passively (Milani, 2017; Stavropoulos et al., 2018). Thus, strengthening environmental regulation will significantly increase the production costs of firms located in the central and western areas where export products are of lower quality than those in the eastern areas. Therefore, we extend hypothesis 1 as follows

Hypothesis 1a: The negative correlation in the central and western areas is more profound than that in the eastern ones.

Significant differences also exist among industries with different pollution discharges, leading to industrial variation in the effects of environmental regulation on export product quality. Generally speaking, capital-intensive industries are pollution-intensive. Stringent environmental regulation will increase the production costs of capital-intensive firms and weaken their export competitiveness and price advantage, leading to a decline in export volume and export product quality (Hummels and Klenow, 2005; Bernard et al., 2006; Hering and Poncet, 2014). In addition, capital-intensive firms are easily restrained by compliance costs, mainly because their technological improvements need massive capital investment (Acemoglu, 2003; Cole et al., 2010; Lannelongue et al., 2017). Thus, an increase in environmental abatement will have crowding-out effects on their R&D expenditures and reduce export product quality (Hottenrott & Rexhauser, 2015). Compared to capital-intensive firms, technology-intensive firms are more flexible in upgrading their technology. Environmental regulation will promote these firms to actively carry out activities of technological innovation to minimise their cost under conditions that their pollution discharges are restricted (Hamamoto, 2006; Krysiak, 2011). For labour-intensive firms which are dominated by standardised and modularised production, their intra-industry technologies tend to be homogeneous and low-end (Ritchie, 2005; Chen and Xue, 2010). So the capacity of labour-intensive firms to upgrade technology is smaller than that of technology-intensive ones. Thus, we propose the following hypothesis:

Hypothesis 1b: Export product quality is most negatively linked with pollution reduction in capital-intensive industries and least in technology-intensive ones.

Ownership structure plays an important role especially in determining the enforcement of environmental regulation which affects the export product quality. The state-owned firms where the state has significant control through full, majority or significant minority ownership have great bargaining power in negotiating enforcement of environmental regulation (Pargal and Wheeler, 1996; Wang and Jin, 2007; Maung et al., 2016). For economic and political reasons, local governments may soften their environmental policies on state-owned firms for the sake of economic growth and political promotion (Hering and Poncet, 2014). So state-owned firms are less sensitive to environmental regulation and their export product quality is least negatively affected by environmental regulation. Foreign firms, which can also be classified into firms owned by investors from Hong Kong, Macao and Taiwan (HMT) and non-HMT firms, have the advantage in technology and management (Cheung and Lin, 2004; Javorcik and Spatareanu, 2008; Jeon et al., 2013). Hence, they are able to bear the burden of stricter environmental regulation (Wang and Wheeler, 2005; Cole et al., 2008; McGuire, 2014). Moreover, bank credit prefers to flow into foreign-owned firms with more efficient resource allocations (Manova et al., 2015). Sufficient financial supports make foreign-owned firms respond positively to the environmental regulation and their export product quality changes slightly. In contrast, private firms face not only three major problems in talent scarcity, innovation difficulties and sustained low productivity, but also the dilemma of financial difficulties (Cull and Xu, 2005; Poncet et al., 2010; Chen and Zhang, 2016). Financial constraints incentivise private firms to give priority to productive investment and the tendency to adopt end-of-pipe treatment, which eventually produces crowding-out effects on innovation investment and reduces their export quality (Gorodnichenko and Schnitzer, 2013; Fan et al., 2015). We summarise the above discussion with the following hypothesis:

Hypothesis 1c: Export product quality is least negatively associated with environmental regulation in state-owned firms and most in private firms.

The differences in export destinations are another major determinant that result in the effects of environmental regulation on export quality being distinctly different. Generally speaking, consumers in OECD countries have higher environmental requirements for imported products, which will motivate firms to improve their product qualities (Saikawa, 2013; Costantini and Mazzanti, 2012). Fierce international competition forces firms exporting to OECD countries to enhance the quality of their exporting products (Harrison and Rodriguez-Clare, 2010; Atkin et al., 2017). In contrast, laxer environmental regulation in non-OECD countries facilitates the export of pollution-intensive goods. If the exporting countries tighten their environmental regulation, increasing costs of pollution-intensive goods may lead to a decline in export product quality (Ryan, 2012; Stavropoulos et al., 2018). Thus, we propose the following hypothesis.

Hypothesis 2: The correlation between quality and environmental regulation is negative for products exported to non-OECD countries but positive for products exported to OECD countries.

Driven by compliance costs and profit maximisation, tightening environmental regulation induces firms to adjust internal resource allocation. On the one hand, tightening environmental regulation encourages firms to reduce pollution-intensive product supply, or transform their export destinations from OECD countries to non-OECD ones (Cole and Fredriksson, 2009; Kheder and Zugravu, 2012; Chung, 2014). On the other hand, tightening environmental regulation forces firms to employ more environment-friendly resources to adjust their product type (Bernard et al., 2010; Elrod and Malik, 2017). Product switching will significantly affect product quality, mainly because product switching contributes to a reallocation of resources within firms towards their most efficient use (Goldberg et al., 2010; Kawakami and Miyagawa, 2013; Bernard & Okubo, 2016). For example, firms in markets where they offer fewer products may concentrate on their core varieties by dropping low-quality goods and by shifting sales towards top-quality goods (Bernard et al., 2010; Choi and Hahn, 2013; Manova and Yu, 2017). Thus, we can test the following hypothesis.

Hypothesis 3: The negative link between export product quality and environmental regulation may be reduced through product switching by the firms.

3. Research Design

3.1 Background of Pollution Reduction Plan

The cost of China's pollution damage roughly quadrupled from 2004 to 2013, and has accounted for up to 3% of annual GDP over the past decade (Wang, 2017). Environmental pollution has become a serious problem that cannot be ignored during China's economic transition. Since the late 1970s, when the system of environmental regulation was set up, China has committed to environmental pollution control. In 1987, the Chinese government issued "The Atmospheric Pollution Prevention and Control Law" which aimed to reduce sulfur dioxide (SO2) and soot emissions. Then in 1998, the State Council approved the setup of Two Control Zones (TCZ) in its document "The Official Reply of the State Council Concerning Acid Rain Control Areas and SO2 Pollution Control Areas". Among 380 prefecture-cities, 175 cities were designated as TCZ cities (Cai et al., 2016). After that the Tenth Five-Year Plan (2001-2005) was the first to set total SO2 reduction target of 10% at a national level. However, it did not set a reduction target for each province and lacked a clearly defined evaluation scheme and implementation of this target was completely ineffective eventually (Shi and Xu, 2018).

In 2006, the State Council issued the "*11th Five Year Energy Conservation and Emission Reduction Work Plan*", in which the major pollutant reduction targets were proposed and linked with local officials' promotion. Subsequently, authorised by the State Council, the National Environmental Protection Agency signed a contract named "*The Documents of Objectives and Responsibilities in Reducing the Total Amount of Major Pollutants During the Eleventh Five-Year Plan*" (the Documents hereafter) with local governments of the 31 provinces, municipalities and autonomous regions, which stipulated the emission reduction targets of SO2 and chemical oxygen demand (COD) in each province (as shown in Fig.1). The allocation principle of major emission reduction targets is to comprehensively consider provincial differences in environmental quality, environmental capacity, emission amounts and economic growth on the premise that the national reduction target can be achieved. Another principle is that the eastern, central and western areas are treated differently and required to implement differentiated reduction targets. In addition, the Documents reported that total target amount of SO2 emissions was 22.944 million tons, among which 22.467 million tons were allocated to each province and 477 thousand tons were reserved to carry out a pilot program of tradeable pollution rights and emissions trading. The total target amount of COD emissions was 12.728 million tons, among which 12.639 million tons were allocated to each province and 89 thousand tons were reserved.

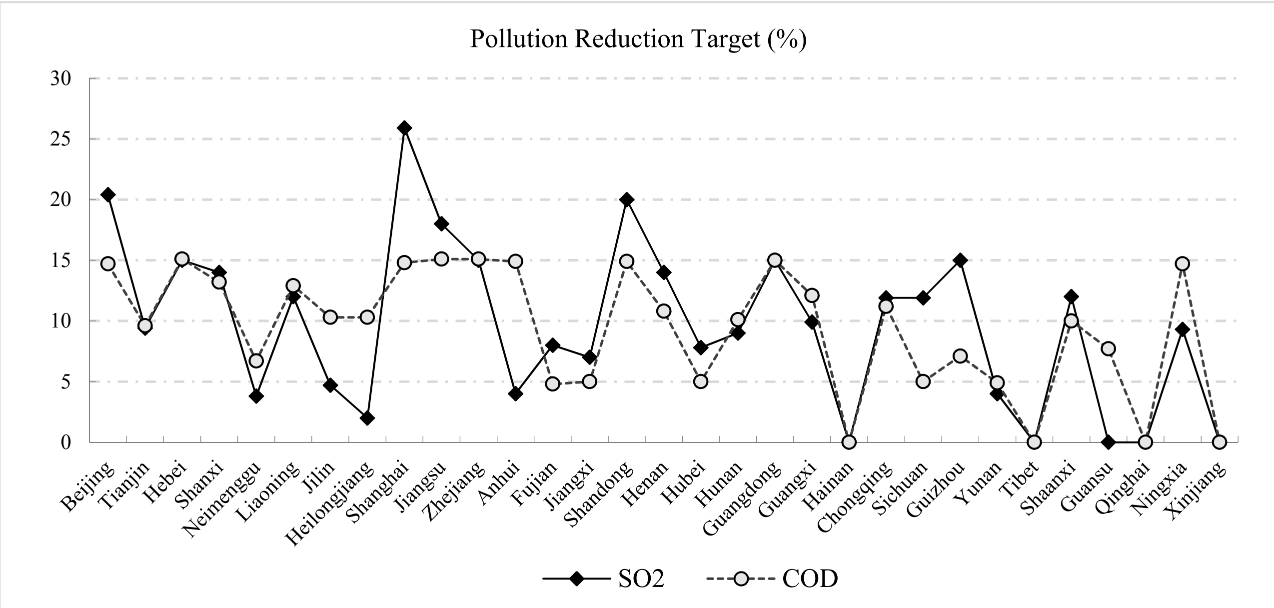

Fig.1 Allocation of Pollution Reduction Targets.

Moreover, the National Environmental Protection Agency, the National Statistics Bureau and the National Development and Reform Commission needed to disclose discharge data every six months and conduct annual inspections and assessment from 2006. An interim assessment on the implementation of pollution reduction targets was conducted in 2008, and the final assessments were conducted in 2010. The assessment result was an essential component of cadre selection and appointment, and the "one-vote veto" system for areas and units where significant ecological damage and environmental pollution occurred was implemented in cadre appointments and awards. Thus, the pollution reduction target led to the implementation of a variety of environmental regulations in all regions of the country (rather than the TCZ areas only).

3.2 Empirical Specifications

The time and regional variations in pollution reduction targets provide an opportunity to estimate the impact of environmental regulation on firms' export product quality using a quasi-difference-in-differences (quasi-DID) strategy. The difference between our method and the standard DID model is that we use a continuous treatment to capture the relative impact of the pollution reduction targets proposed in the Eleventh Five-Year Plan. The DID specification is as follows:

$$LnQuality_{fhct} = \beta_0 + \beta_1 Ln(Target_{pt}) \times Post_t + \beta_2 LnZ_{ft} + \mu_{fhc} + \eta_t + \varepsilon_{fhct} \quad (1)$$

where $Quality_{fhct}$ is the export quality of product in HS6 digit industry h exported by firm f to destination country c at time t; $Target_p$ is the pollution reduction target for province p where firm f is located; $Post_t$ is a dummy variable equal to 0 for 2001-2005 and 1 for 2006-2010; Z is firm-specific control variable; μ_{fhc} and η_t are firm-industry-destination triple fixed effects and year fixed effects; and ε_{fhct} is the error term.

3.3 Data Sources

We construct data samples from four major sources. The data on pollution reduction targets are collected from a document named "*The Documents of Objectives and Responsibilities in Reducing the Total Amount of Major Pollutants During the Eleventh Five-Year Plan*", issued by the China State Council in 2006.

The manufacturing firm data are sourced from the China Industrial Enterprises Database as collected by the National Bureau of Statistics of China (NBS). This database covers all state-owned firms and non-state-owned firms with sales above RMB 5 million and has been widely used in recent studies on firm behaviour, productivity and economic growth (see, for example, Brandt et al., 2012;

Hering and Poncet, 2014; Brandt et al., 2017). Consequently, the basic information for each firm such as location, establishment year, ownership, output, employment, capital and other operations-related data can be obtained.

The third major data source for our analysis is the China Customs Import and Export Database, which provides us with the record of all Chinese trade transactions by importing and exporting firms at the HS eight-digit level. The initial customs data are then aggregated to the HS6 level for the concord of the product codes because the main adjustment for Chinese HS eight-digit codes occurred before and after 2002.

Our province-level data are 2001-2010 yearly data from the Chinese Statistical Yearbook, which provides us data series for GDP growth rate and regional output for 27 provinces and 4 municipality cities as well as pollution emissions in 36 industries.

We match the data on pollution reduction targets with the China Industrial Enterprises Database according to the firms' location and statistical year. Then we merged the above matched data with China Customs Import and Export Database in accordance with firm's name and statistical year. As some firms may change their names during the sample period, we re-merged the datasets according to the zip code where the firm is located and the seven digits at the end of the firm's telephone number. Lastly, we matched the firm-level dataset with macro statistics. After matching the above-stated five datasets, we excluded firms that show a negative or zero value for their total revenue, employment, fixed assets or total sales, as well as firms with less than eight workers. Moreover, firms whose total sales are less than exports, or with current assets greater than total assets, or with a value of fixed assets greater than total assets are excluded from the sample. Finally, firms with fewer than two years of data available in the database are excluded. After data-cleaning, the final sample comprises of 58,974 firms, 236 export destinations and 5,231 product categories (HS6 level of disaggregation) covering the years from 2001 to 2010. Capital variables are deflated by using the price index of investment in fixed assets with a base year of 2000, and output are deflated by using the GDP price index.

3.4 Variable Definitions

3.4.1 Dependent Variables

The dependent variable is export product quality (*Lnquality*). The quality of an export product is the unobserved attribute that influences the way in which consumers perceive the good and their decision to purchase despite relatively high prices (Crinò and Ogliari, 2017). Following Khandelwal et al. (2013) and Fan et al. (2015), we estimate the quality of exported product *h* shipped to destination country *c* by firm *f* in year *t* via the empirical demand equation.

$$x_{fhct} = q_{fhct}^{\sigma-1} p_{fhct}^{-\sigma} P_{ct}^{\sigma-1} Y_{ct} \quad (2)$$

where x_{fhct} and q_{fhct} denote the demand and quality for firm *f*'s export of product *h* in destination country *c* in year *t* respectively. p_{fhct} denotes the unit value export price of HS6 product *h* exported by firm *f* to destination country *c* in year *t*. P_{ct} and Y_{ct} are the overall price index and total income in year *t*. σ is the elasticity of substitution across different products. Taking logs, the quality for each firm-product-country-year observation can be estimated as the residual from the following OLS regression.

$$ln(x_{fhct}) + \sigma\, ln(p_{fhct}) = \varphi_h + \varphi_{ct} + \varepsilon_{fhct} \quad (3)$$

where product fixed effect φ_h captures the difference in prices and quantities across product categories due to the inherent characteristics of products. The country-year fixed effect φ_{ct} collects the destination country's income and price index. $\varepsilon_{fhct} = (\sigma - 1)lnq_{fhct}$ is the error term. Then the estimated quality is

$$ln(\hat{q}_{fhct}) = \hat{\varepsilon}_{fhct}/(\sigma - 1) \qquad (4)$$

We allow the elasticity of substitution (σ) to vary across industries using the estimates of Broda and Weinstein (2006) because their estimates are the closest to the relevant parameter in China (see, for example, Khandelwal et al., 2013; Fan et al., 2015).

3.4.2 Main Explanatory Variable and Control Variables

Our main explanatory variable is pollution reduction targets (*Lntarget*) for each province and incorporated in its natural logarithm form into the regression equation. For provinces with 0 pollution reduction targets, *Lntarget* equals zero. Additionally, we also construct explanatory variables of *Lntarget_COD* to examine to what extent environmental regulation on COD influences export product quality as a robustness test.

To minimise estimation biases due to omitted variables, we add some firm-specific control variables that may affect export quality. These control variables are illustrated as follows.

Firm age (*Lnage*). On the one hand, old firms may have more experienced workers who are familiar with product features and know how to improve their quality (Love et al., 2016). On the other hand, firm age may be an indicator of sclerotic thinking or of inertia on the part of the management team or the firm as a whole (D'Angelo et al., 2013). So older firms are much more likely to stick to obsolete physical capital, which is not conducive to quality improvement. We use the actual ages of firms from when they started operating until the time of the survey to measure firm age.

Firm size (*Lnsize*). Firm size is proxied by the number of employees in a firm. According to the new trade theory, larger firms can lower average production costs (cost per unit of output) as outputs increase, and have lower average unit costs than smaller firms. They can also aim for economies of scope, being more efficient in the production of a number of different products and improve their export product quality (Brouthers et al., 2009; Williams, 2011).

Total factor productivity (*Lntfp*). Firms with higher total factor productivity (TFP) are more competent to bear the higher costs that higher-quality products generate (Baldwin and Harrigan, 2011; Crozet et al., 2012). We estimate a firm's TFP using the Olley and Pakes (1996) production function. The capital stock is calculated using the perpetual inventory method $K_{it} = K_{it-1} + I_{it} - D_{it}$, where K_{it} is capital stock in year t; I_{it} and D_{it} are new investment and depreciation in year t, respectively. The initial capital stock is measured by the first observation of net fixed assets in China Industrial Enterprises Database, and new investment is calculated by the difference between fixed assets in the current year and the year before. The depreciation D_{it} is directly reported by the China Industrial Enterprises Database.

Government subsidy (*Lnsubsidy*). Government subsidies can reduce average production and transaction costs via financial support (Martincus and Carballo , 2008), which contributes to export quality improvement. Government subsidy data are readily available.

Ownership structure (*Ownership*). A sizable body of research has focused on the role of ownership in export quality (Rasiah and Gachino, 2005; Bustos, 2011; Gan et al., 2016; Anwar and Sun, 2018). Following Guariglia et al. (2011), we differentiate firm ownership according to the share of a firm's equity owned by each type of investor in that year. For instance, a firm is categorised as state-owned in a given year if the proportion of its equity owned by the state in that year is greater than 50%. In our empirical models, we choose the state-owned firms as the references and incorporate the dummy variables of collective-owned firms (*Collective*), legal person owned firms (*Legal*), private firms (*Private*), foreign firms owned by investors from Hong Kong, Macao and Taiwan (*HMT*) and foreign firms owned by non-HMT foreign investors (*Foreign*). In the case that the shares of a firm's equity owned by two types of investors are the same, we further consider the type of registration to classify ownership structure.

Table 1 presents the summary statistics for major variables discussed in Section 3. It can be seen that a large variation of export product quality is shown across the sample, indicating that there are significant differences between firms' product quality. The average SO2 reduction target is 2.7154, with a standard deviation of 0.3616. The statistics of control variables show the maximum of firm size is 12.2880, which is about 6 times larger than in the smallest firm. Foreign-owned and HMT firms account for 26.24 and 24.61 percent respectively. The proportion of state-owned and collective-owned firms are relatively lower and they account for 2.48 and 2.49 percent respectively.

Table 1 Descriptive Statistics for the Major Variables

Variables	Definition	Mean	S.D	Minimum	Maximum
Lnquality	Export product quality, Calculated by Eq.(3)-(5)	1.0698	7.1557	-49.9999	49.9997
Lntarget	SO2 reduction targets for each province	2.7154	0.3616	0	3.2542
Lntarget_COD	COD reduction targets for each province	2.5730	0.3525	0	2.7147
Post	A dummy variable, equal to 0 for 2001-2005 and 1 for 2006-2010	0.5446	0.4980	0	1
Lnage	The logarithm of the age of the firm	2.2458	0.5982	0	5.0499
Lnsize	The logarithm of the number of employees by the end of year	5.8781	1.2623	2.0794	12.2880
Lntfp	The logarithm of TFP calculated by Olley and Pakes (1996) production function	1.9284	1.1616	-2.1617	3.2687
Lnsubsidy	The logarithm of government subsidies	5.1253	1.2860	2.0723	13.9198

Collective	A dummy variable, equal to one if the proportion of its equity owned by the collective is greater than 50%. and 0 otherwise.	0.0249	0.1558	0	1
Legal	A dummy variable, equal to one if the proportion of its equity owned by legal persons is greater than 50%.and 0 otherwise.	0.1801	0.3843	0	1
Private	A dummy variable, equal to one if the proportion of its equity owned by private persons is greater than 50%.and 0 otherwise.	0.2616	0.4395	0	1
Foreign	A dummy variable, equal to one if the proportion of its equity owned by non-HMT foreign investors is greater than 50%.and 0 otherwise.	0.2624	0.4399	0	1
HMT	A dummy variable, equal to one if the proportion of its equity owned by HMT investors is greater than 50%.and 0 otherwise.	0.2461	0.4307	0	1

4. Empirical Results

4.1 Baseline Estimates

Table 2 reports the estimated results of the effects of environmental regulation on export product quality. All results are estimated by year fixed effects and firm-industry-destination triple fixed effects, and regressions are corrected for clustering at firm-industry-destination level. Columns (1) and (2) present our baseline estimates based on Equation (1). The estimated result in Column (1) of Table 2 shows that the coefficient of *Lntarget×Post* is significant and negative, indicating that the implementation of pollution reduction plan is associated with lower export quality. After incorporating firm-specific control variables, we find that the coefficient of *Lntarget×Post* is -0.0781 and passes the significance test at the 1% level, which implies that stringent environmental regulation leads to a 0.0781 percentage drop in export product quality. Thus, we can draw the conclusion that the pollution reduction plan that the Chinese government put forward in the Eleventh Five-Year Plan significantly reduced the export production quality. Hence, Hypothesis 1 is confirmed.

The estimated coefficients of the control variables have the expected signs. For example, the results in Column (2) of Table 2 demonstrate that the coefficient of *Lnage* is positive and passes the significance test at the 1% level, indicating that firm age is positively associated with export quality.

Additionally, firm size has a significant and positive influence on its export product quality. More specifically, an increase in firm size will improve its export product quality by 0.0612. Increases in TFP and government subsidies are also beneficial for firms in significantly improving their export product quality. Moreover, the estimated coefficients of ownership suggest that the export product quality is significantly higher among state-owned firms, followed by HMT firms.

Table 2 Impact of environmental regulation on firms' export product quality

Variables	Dependent variable: *Lnquality*			
	(1)	(2)	(3)	(4)
Lntarget×Post	-0.0721*** (0.0214)	-0.0781*** (0.0214)		-0.1884*** (0.0302)
$Lntarget×Post_{-5}$			0.1186*** (0.0422)	
$Lntarget×Post_{-4}$			-0.0076 (0.0359)	
$Lntarget×Post_{-3}$			0.0164 (0.0314)	
$Lntarget×Post_{-2}$			0.0036 (0.0260)	
$Lntarget×Post_{-1}$			-0.0156 (0.0214)	
$Lntarget×Post_{1}$			-0.0145 (0.0441)	
$Lntarget×Post_{2}$			-0.2648*** (0.0459)	
$Lntarget×Post_{3}$			-0.2759*** (0.0518)	
$Lntarget×Post_{4}$			-0.3541*** (0.0493)	
Lntarget×Post×Central				-0.0373* (0.0189)
Lntarget×Post×West				-0.0660*** (0.0181)
Lntarget×Post×Capital				-0.0715*** (0.0075)
Lntarget×Post×Labor				-0.0396*** (0.0062)
Lntarget×Post×Collective				-0.0424* (0.0255)
Lntarget×Post×Legal				-0.0371* (0.0197)

Lntarget×Post×Private				-0.0486**
				(0.0197)
Lntarget×Post×Foreign				-0.0436**
				(0.0199)
Lntarget×Post×HMT				0.0299
				(0.0200)
Lntarget×Post×oecd				0.2179***
				(0.0056)
Lnage		0.0612***	0.0607***	0.0480**
		(0.0204)	(0.0204)	(0.0204)
Lnsize		0.1007***	0.1021***	0.1057***
		(0.0093)	(0.0093)	(0.0093)
Lntfp		0.1176***	0.1074***	0.1363***
		(0.0273)	(0.0274)	(0.0274)
Lnsubsidy		0.0033*	0.0038**	0.0038**
		(0.0018)	(0.0018)	(0.0017)
Collective		-0.1004***	-0.1009***	-0.0532
		(0.0384)	(0.0384)	(0.0398)
Legal		-0.0822**	-0.0827**	-0.0334
		(0.0328)	(0.0328)	(0.0343)
Private		-0.1086***	-0.1097***	-0.0447
		(0.0342)	(0.0342)	(0.0356)
Foreign		-0.1336***	-0.1349***	-0.0866**
		(0.0354)	(0.0354)	(0.0368)
HMT		-0.1944***	-0.1952***	-0.2128***
		(0.0352)	(0.0352)	(0.0365)
Year fixed effects	Yes	Yes	Yes	Yes
Firm-industry-destination fixed effects	Yes	Yes	Yes	Yes
Observations	2,759,184	2,759,184	2,759,184	2,759,184
R-squared	0.8067	0.8068	0.8068	0.8070

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

4.2 Lags, Leads and Time Trends

Equation (1) examines the average effect of the pollution reduction plan on export product quality after its implementation, however, we are still unable to comment whether or not this effect is advanced or delayed. The reason is that the State Council set an SO2 reduction target of 10% as early as in the Tenth Five-Year Plan. One may be concerned whether there is any expectation effect, that is, firms with more pollution discharges in provinces with higher reduction targets could have expected the event and changed their export quality before the Eleventh Five-Year Plan. Meanwhile, there is also a possibility of the lagged effect of environmental regulation on export product quality. To address these concerns, we follow Hering and Poncet (2014) by estimating all lag and lead effects of environmental regulation. Specifically, we choose the effective year of the pollution reduction plan (i.e., 2006) as the reference year and estimate the following equation:

$$LnQuality_{fhct} = \beta_0 + \beta_1 Ln(Target_{pt}) \times Post_{-5} + \beta_2 Ln(Target_{pt}) \times Post_{-4} + \cdots\cdots + \beta_5 Ln(Target_{pt}) \times Post_{-1} + \beta_6 Ln(Target_{pt}) \times Post_1 + \cdots\cdots + \beta_9 Ln(Target_{pt}) \times Post_4 + \beta_{10} LnZ_{ft} + \mu_{fhc} + \eta_t + \varepsilon_{fhct} \quad (6)$$

where $Post_{-5}$ is time dummy indicating the five-year period before the implementation of the pollution reduction plan; $Post_{-4}$ and $Post_{-1}$ are time dummies indicating the four-year period and one-year period before the implementation of environmental regulation, respectively; and $Post_1$ and $Post_4$ are time dummies indicating one year and four years after the implementation of environmental regulation.

The estimated results in Column (3) of Table 2 show that the coefficients of $Lntarget \times Post_n$ ($n=-1,-2,-3,-4$) fail to pass the 10% significance test. However, the coefficient of $Lntarget \times Post_{-5}$ is 0.1186% and significant at the 1% level, indicating that the export product quality in the fifth year before the pollution reduction plan is implemented is 0.1186% higher than that in the effective year of the pollution reduction plan. One possible explanation for this finding is that China joined the World Trade Organization in the fifth period before the implementation of the pollution reduction plan (i.e., 2001), and the State Council first set the 10% SO2 reduction target at a national level. Thus, exporters might improve export product quality to meet the international environmental standards. After the pollution reduction plan was implemented in 2006, there was a clear increase in the absolute value of the estimates $Lntarget \times Post_n$ (n=2,3,4) and they remain significant at the 1% level , while the coefficient of $Lntarget \times Post_1$ fails to pass the 10% significance test. Therefore, there are one-year lagged effects between the pollution reduction plan implemented in the Eleventh Five-Year Period and export product quality. The negative effects of this pollution reduction plan then gradually increase.

4.3 Effects of Firm Heterogeneity

In this section, we consider heterogeneity across regions, sectors and firms. The estimated results are shown in Column (4) of Table 2. Firstly, two dummy variables identifying central and western areas are introduced to examine regional variation. It is noted that the coefficients of the triple interaction in Column (4) reveal that the export-effect of the pollution reduction plan in the eastern areas is 0.0373% higher than in the central areas and 0.0660% higher than in the western areas. Thus, the environmental regulation policy implemented during the Eleventh Five-Year Plan period led to higher export product quality in the eastern areas than that of the central and western areas. As a result, Hypothesis 1a is also supported.

Subsequently, to check whether the main effects also vary by sector, triple interaction terms among *Lntarget, Post* and industrial dummy variables are incorporated into the regressions. The labour and capital variables represent the firms in labour-intensive and capital-intensive sectors, respectively. The estimated results in Column (4) of Table 2 illustrate that export product quality in capital-intensive industries is most negatively affected by the pollution reduction plan, followed by labour-intensive industries. Specifically, export product quality in labour-intensive industries is

0.0396% lower than that in skill-intensive industries, while export product quality in capital-intensive industries is 0.0715% lower than in skill-intensive ones. Thus, Hypothesis 1b is also verified.

Then, to investigate whether the effects of the pollution reduction plan on export product quality will vary because of different ownership, triple interaction terms among *Lntarget, Post* and ownership dummy variables are incorporated into the regressions. The estimated results suggest an insignificant difference between HMT firms and state-owned ones in terms of the negative relationship between environmental regulation and export product quality. Additionally, the negative effects of pollution reduction policy on export quality are the largest in private firms, as the estimated results indicate that export product quality in private firms is 0.0486% lower than that in state-owned ones. Lastly, induced by pollution reduction policy, the export product quality in collective-owned firms is 0.024% lower than that in state-owned ones, while export product quality in foreign-owned firms owned by non-HMT foreign investors is 0.0436% lower than that in state-owned ones. Thus, the pollution reduction plan has the largest negative effects on export product quality of private firms, followed by foreign-owned firms owned by non-HMT foreign investors. This conclusion is inconsistent with the hypothesis that environmental regulation has smaller negative effects on export product quality of foreign-owned firms (Hypothesis 1c). The reason might be that the majority of foreign investment is dominated by small and medium-sized enterprises. In search of cheap labour and resources, these foreign-owned firms are mainly concentrated in labour-intensive industries and are not motivated to engage in upgrading green technology or are not interested in environmental protection. Therefore, stringent environmental regulation increases the environmental abatement costs of foreign firms and leads to lower export product quality.

Finally, the interaction terms between *Lntarget×Post* and a dummy variable capturing exporting destination are incorporated into the regressions. The dummy variable *oecd* takes the value of one if a firm's exporting destination belongs to OECD countries and zero otherwise. The estimation results in Column (4) of Table 2 show that pollution reduction plan leads to export product quality of firms exporting to OECD countries being 0.2179% higher than those exporting to non-OECD countries. Meanwhile, the coefficient of *Lntarget×Post* is -0.1884 and passes the 1% significance test, indicating that pollution reduction plan leads export product quality of firms exporting to non-OECD countries to decline by 0.1884%. Thus, the new environmental policy reduces export product quality of firms exporting to non-OECD countries, whereas it increases export product quality of firms exporting to OECD countries. Overall, Hypothesis 2 is supported.

4.4 Robustness Checks

In this section, we conduct several sensitivity tests to make sure our major findings are robust to alternative specifications.

4.4.1 Alternative Measures for Export Product Quality and Pollution Reduction Plan

The first modification considers export unit values, the ratio of total export values to quantities, as an alternative measure of export product quality. The logic behind this is that high-quality products are always associated with higher unit price, and it has been widely used in existing literature (for example, Hallak and Schott, 2011; Baldwin and Harrigan, 2011; Manova and Yu, 2017).

In addition, following Crinò and Ogliari (2017), we construct export product quality as the value-weighted average of the product-specific quality estimates. The equation is as follows.

$$r\_quality_{fhct} = \frac{quality_{fhct} - \min quality_{fhct}}{\max quality_{fhct} - \min quality_{fhct}} \quad (5)$$

where $\max quality_{fhct}$ and $\min quality_{fhct}$ are the maximum and minimum of the export quality at the six-digit product level, respectively. $\mathrm{r\_quality}_{\mathrm{fhct}}$ is the standardised estimate of export quality at the product level. Then the value-weighted average of the product-specific quality can be expressed as

$$quality'_{fhct} = \frac{v_{fhct}}{\sum_{fhct\in\Omega} v_{fhct}} \times \mathrm{r\_}quality_{fhct} \qquad (6)$$

Finally, we consider the COD reduction plan mentioned in Section 3.4 as a proxy for the new environmental policy during the Eleventh Five-Year Plan Period.

The estimated results in Columns (1)-(3) of Table 3 show that the coefficients of the interaction term between *Lntarget* and *Post* are negative and significant at the 5% level, suggesting that the pollution reduction plan has a negative effect on export product quality. Thus, we can conclude that, regardless of the way in which we measure export product quality and environmental regulation in the estimations, we find strong support that the new environmental policy leads firms to significantly reduce their export production quality.

4.4.2 Excluding Effects of Concurrent Events

Following Shi & Fu (2018), we exclude the effects of other concurrent events during the Eleventh Five-Year Plan Period. These events are the financial crisis and the Beijing Olympic Games. To investigate the effects of the global financial crisis, we drop samples in 2008 and 2009 and the estimated results are shown in Column (4) of Table 3. In addition, during the Beijing Olympic Games, the Chinese government exerted considerable effort to reduce pollution in provinces around Beijing. The specific areas involved included Tianjin, Hebei, Liaoning, Shanxi and Inner Mongolia. To investigate the potential effects of this event, we exclude firms in the provinces affected by the

Olympic Games in 2008 and the estimated results are shown in Column (5) of Table 3. It can be seen that the coefficients of the interaction term *Lntarget×Post* are still significant and negative, implying that these two concurrent events do not affect our estimates.

4.4.3 Only Measuring Firms that Existed Before and After the Eleventh Five-Year Plan

It is interesting to see that stricter environmental policy leads firms to lower their export quality. However, the evidence would be more compelling if we can demonstrate that firms turn to reduce their export product quality after they experience different environmental policies. We therefore restrict the sample to firms existing before and after the Five-Year Plan and conduct the same analysis. The results are shown in Column (6) of Table 3, where the coefficient of the interaction remains robust.

4.4.4. The Effect of Outliers

In accordance with Crinò and Ogliari (2017), all continuous variables are winsorized at the top and bottom one percent to remove the effect of outliers. The result listed in Column (7) of Table 3 implies the same set of inferences we obtained from our baseline specification. That is, the estimation results in terms of signs and significance tests are consistent with those presented in the baseline model.

Table 3 Estimation Results for Robustness Checks (I)

Variables	Dependent variable: *Lnquality*						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lntarget×post	-0.0225*** (0.0028)	-0.0185** (0.0091)	-0.0834*** (0.2196)	-0.0512** (0.0213)	-0.0791*** (0.0214)	-0.0782*** (0.0214)	-0.0732*** (0.0200)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-industry-destination fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,759,184	2,759,184	2,759,184	2,282,414	2,737,603	2,446,327	2,759,184

R-squared	0.9567	0.7900	0.8068	0.8238	0.8074	0.8014	0.8093

Note: The dependent variables are listed in the first row. The export product quality in Column (1) is estimated by export unit values; the export product quality in Column (2) is estimated by value-weighted average of the product-specific quality estimates; and the pollution reduction targets in Column (3) are constructed by COD reduction plan mentioned in Section 3.4. All continuous variables are winsorized at the top and bottom one percent in Column (7). Standard errors are corrected for clustering at the firm-industry-destination level. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

4.4.5. The Difference-in-difference-in-differences Estimation

A concern about the quasi-difference-in-differences analysis is that some time-varying regional characteristics correlate with outcome variables and the regressor at the same time, leading to bias in our estimates (Cai et al., 2016; Shi and Xu, 2018). In light of this concern, we exploit the fact that industries which have different pollution emissions are affected by environmental regulation differently, and conduct a difference-in-difference-in-differences (DDD) estimation for the robustness checks.

$$LnQuality_{f\square ct} = \beta_0 + \beta_1 Ln(Target_{pt}) \times Post_t \times Ln(SO2_i) + \beta_2 LnZ_{ft} + \mu_{f\square c} + \eta_t + \varepsilon_{f\square ct} \quad (7)$$

where SO2 is the average SO2 emissions or intensity from 2001 to 2010 for each industry. Given that the data of SO2 emissions are only available at the two-digit industry level, we convert the six-digit industry codes to two-digit industry codes according to GB/T 4754-2002. The estimated results are reported in Columns (1) and (2) of Table 4. We continue to find a negative and statistically significant effect of the pollution reduction plan on export product quality, indicating that our findings are not driven by estimation.

4.4.6. Endogeneity

Our baseline analysis relies on a quasi-DID estimate to assess the effects of the new environmental policy on export product quality. However, since pollution may be correlated with other characteristics that in turn affect exports, we may still have endogeneity problems even though we controlled for numerous other factors in the previous section (Shi and Xu, 2018). Thus, we also use the ventilation coefficient, a variable based on the product of wind speed and the mixing height, as an instrument for environmental policy. Here, provinces where pollution is dispersed more slowly are more likely to be targeted by high pollution reduction, because given local SO2 emissions, the SO2 concentration in the air remains higher for longer (Hering and Poncet, 2014). According to Jacobsen (2002), the ventilation coefficient is the product of the wind speed and boundary layer height. The ERA-Interim data provided by the European Center for Medium-Range Weather Forecasts reports the wind speed information at the 10-m height and the boundary layer height for a global grid of $75^{\circ} \times 75^{\circ}$ cells (about 83 square kilometres). We match the ERA-interim dataset with the capital city of each province by its latitude and longitude. The ventilation coefficient we use is the average coefficient of each province from 2001 to 2005 for the cells nearest to the capital city. The second-stage results are shown in Column (3) of Table 4. We continue to find significant and negative effects of the pollution reduction plan on export product quality, with a coefficient of -0.3713. Following Kleibergen and Paap (2006), we perform an underidentification test and weak-identification test to verify the validity of instrumental variables. The LM test rejects underidentification at the 1% significance level, while the Wald F test also rejects the null hypothesis that our instruments are weak at the 1% level. Thus, our instrumental variables are reasonable. Overall, our main findings hold after considering potential endogeneity problems by using an instrumental approach.

4.4.6. Sample Selection Bias

The essence of sample selection bias is the bias that results from the failure to ensure the proper randomisation of a sample. The main reasons can be summarised into two main areas: one is the availability of the data or improper sampling, the other is self-selection bias. The first problem in our study comes mainly from the fact that the China Industrial Enterprises Database does not cover non-state-owned firms with sales below RMB 5 million, leading to bias in our estimates. A feasible way forward is to exclude state-owned firms with sales above RMB 5 million. The estimated result in Column (4) of Table 4 shows that the coefficient of *Lntarget*×*Post* is negative and significant at the 1 % level, suggesting that our main conclusions still hold.

The second problem in our study is that we delete non-exporting firms and focus on the relationship between environmental regulation and export product quality, which may result in sample self-selection bias and inconsistent estimates. Thus, we use the two-stage procedure of Heckman (1979) to address this problem. In the first stage, we perform a probit regression to analyse which factors may influence firms' export decisions. According to Richter and Schiersch (2017), firms' age, size, TFP and ownership are incorporated into the probit model to control for firm characteristics. The resulting inverse Mills ratio (imr) is incorporated into the second-stage regression to correct any potential bias. Column (5) of Table 4 presents the estimated results of the second-stage regression. The coefficient of *Lntarget*×*Post* is significant and negative and hence implies that our main conclusions are still valid after the consideration of sample self-selection bias.

Table 4 Estimation Results for Robustness Checks (II)

Variables	Dependent variable: *Lnquality*				
	(1)	(2)	(3)	(4)	(5)
Lntarget×*Post*				-0.0758*** (0.0214)	-0.0762*** (0.0214)
Lntarget×*Post*×*LnSO2*	-0.0274*** (0.0011)	-0.0475*** (0.0018)			

(Lnventilation×Post) as IV			-0.3713*** (0.0409)		
Imr					-0.1677*** (0.0260)
Control variables	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Firm-industry-destination fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	2,759,184	2,759,184	2,759,184	2,755,758	2,759,184
R-squared	0.8068	0.8068	0.8067	0.8069	0.8068

Note: The dependent variables are listed in the first row. SO2 in Columns (1) and (2) are measured by average SO2 emissions and intensity from 2001 to 2010 for each industry; Column (3) reports IV estimation; Column (4) reports estimation based on samples excluding non-state-owned firms with sales below RMB 5 million; and Column (5) presents the results for the self-selection bias test using Heckman's two-stage procedure. Standard errors are corrected for clustering at the firm-industry-destination level. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

5. The Role of Product Switching

In this section, we investigate the channels through which the negative effects of the pollution reduction plan on export product quality can be mitigated. Specifically, we test the role of product switching induced by the new environmental policy in determining export product quality. We choose firms continuously exporting for at least two years in our sample, and divide them into three categories according to how firms alter their mix of products. A product add rate (*add*) in year *t* is computed as the number of product categories a firm adds in year *t* divided by the number of product categories the firm produced in year *t-1*. A product drop rate (*drop*) in year *t* is computed as the number of product categories a firm drops in year *t* divided by the number of product categories the firm produced in year *t-1*. Thus, the total product switching rate *(total) is* computed as the sum of a product add rate and drop rate. Similarly, we divide the samples into three categories according to how firms alter their exporting destinations. A destination add rate in year *t* is computed as the number of exporting destinations a firm adds in year *t* divided by the number of exporting destinations the firm had in year *t-1*. A destination drop rate in year *t* is computed as the number of exporting destinations a firm drops in year *t* divided by the number of exporting destinations the firm had in year *t-1*. The total destination switching rate is computed as the sum of the destination add rate and drop rate.

To examine whether product switching can mitigate the negative effects of new environmental policy on export product quality, we incorporate the interaction term between the pollution reduction targets and product switching into the models. The estimated results in Columns (1)-(6) show that the coefficients of the interaction terms between *Lntarget* and *Post* are significant and negative regardless of whether or not product switching is accounted for, indicating that the new environmental policy is negatively associated with export product quality. Columns (1) and (5) in Table 5 report the estimated results for firms whose number of product categories or exporting destinations remains unchanged between year *t* and year *t-1*. It can be found that the coefficients of *Lntarget*×*Post* are -0.1351 and -0.1122 respectively, both of which pass the 10% significance test. Thus, the pollution reduction plan leads the export product of firms whose number of product categories remains unchanged to reduce about 0.1351%, which is about 0.0229% higher than those whose number of exporting destinations remains unchanged.

In addition, the coefficients of *Lnadd* and *Lndrop* are significant and negative, suggesting that increasing product switching rates are beneficial to export quality improvement. One possible explanation for this finding is that the category switching and destination switching can enhance the efficiency of resource allocation within firms and improve their productivity (Melitz and Ottaviano, 2008; Bernard et al., 2010). Firms with higher productivity find it much easier to enter exporting markets and import raw materials in a more convenient way, their export value added being improved accordingly (Fan et al., 2015).

Moreover, the estimated results in Columns (2) and (6) show that the coefficients of the triple interaction *Lntarget×Post×Lntotal* are significant and positive, indicating that product switching can mitigate the negative effects of the pollution reduction plan on export quality. Our further analysis in Columns (7) and (8) shows that, induced by the new environmental policy, an increase in the number of exporting destinations or a decline in the number of exporting destinations will significantly improve export product quality, with the latter having a greater positive effect. Additionally, the results reported in Columns (3) and (4) imply that an increase in the number of product categories will significantly improve export product quality, while a decline in the number of product categories will have no significant effects on export quality. The reason might be that stricter environmental regulation leads multiple-product and multiple-destination firms to extend their product and market range to reduce average sunk costs and spread exporting risks (Zahavi and Lavie, 2013). Thus, when environmental policies are tightening, firms can improve their export product quality not only by using the appropriate product diversification strategies, but also by optimising resource allocation to realise market specialisation.

Table 5 The moderating effects of production switching

Variables	Dependent variable: *Lnquality*							
	Product Categories				Exporting Destinations			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lntarget×Post	-0.1351*** (0.0517)	-0.0493* (0.0262)	-0.0643*** (0.0260)	-0.0738*** (0.0245)	-0.1122* (0.0607)	-0.0923*** (0.0265)	-0.2181*** (0.0358)	-0.2180*** (0.0469)
Lntotal		0.0279*** (0.0052)				0.0250*** ().0048)		
Lntarget×Post×Lntotal		0.0077*** (0.0027)				0.0042* (0.0024)		
Lnadd			0.0052** (0.0023)				0.0159*** (0.0057)	

Lntarget×Post×Lnadd			0.0024*				0.0101***	
			(0.0014)				(0.0028)	
Lndrop				0.0068**				0.0218***
				(0.0027)				(0.0065)
Lntarget×Post×Lndrop				0.0007				0.0257***
				(0.0017)				(0.0040)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-industry-destination fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	456,526	2,294,498	1,646,216	648,282	103,179	2,647,845	1,943,467	704,378
R-squared	0.8494	0.8089	0.8089	0.8065	0.8925	0.8098	0.8222	0.8229

Note: The dependent variables are listed in the first row. Column (1) reports for firms whose number of product categories remains unchanged between year t and year t-1; and Column (5) reports for firms whose number of exporting destinations remains unchanged between year t and year t-1. Standard errors are corrected for clustering at the firm-industry-destination level. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

6. Conclusions and Policy Recommendations

Even though the environmental pollution accompanied the acceleration of industrialisation in China has received significant public attention, the situation is worse than we thought. As a consequence, environmental governance has become a very prominent problem which concerns the national economy and people’s livelihood, with administrative regulation being the most direct and effective method in environmental protection. At present, the objectives of environmental regulation have changed to win-win strategy in pollution reduction and energy saving. Thus, it is of great importance to examine the impacts of environmental regulation on trade. Although some literature has tested the impact of environmental regulation on firm exports, studies on the relationship between environmental regulation and product-level export quality are nearly non-existent.

In this paper, we investigate the effects of environmental regulation on export product quality. To control for the potential endogeneity of environmental regulation, we choose the pollution reduction plan that the Chinese government put forward in the Eleventh Five-Year Plan as a quasi-experiment.

By using a uniquely detailed dataset comprising Chinese export data at the firm, product and destination country levels from 2000 to 2010, we find that the pollution reduction plan is significantly and negatively associated with export product quality. This result is robust to a series of robustness checks and consideration of endogeneity problems, as well as sample selection bias. Moreover, this negative impact is more profound if: (1) the firm is located in western regions; (2) the products that firms export are in capital-intensive sectors; (3) the firm is privately-owned; or (4) the exporting destinations are concentrated in non-OECD countries. Our extended results suggest that product switching contributes to resources allocated within firms being put toward their most efficient use and mitigates the negative effects of the new environmental policy on export product quality. Firms can appropriately diversify their products and focus on their targeted exporting destinations when they face tighter environmental regulation.

Our findings have important policy implications for realising a win-win outcome in environmental protection and trade upgrading. The central government should reinforce the effects of innovation offsets through strengthening intellectual property rights protection and policy support. In addition, local governments should avoid implementing a one-size-fits-all policy in environmental regulation. More preferential policies supplemented by innovation incentive ones should be provided for undeveloped regions. For capital-intensive industries, proper R&D subsidies and command-and-control regulation (such as pollution limits, environmental standards, etc.) can be used to incentivise firms to invest in green technology innovation. Favourable credit and pollution abatement subsidies should be increased in non-state-owned firms to weaken the adverse effects induced by an increase in environmental costs. Finally, governments should formulate favourable policies to guide firms to reallocate their resources by product switching.

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Conflict of Interest

There is no conflict of interest in regard to the content discussed in this article.