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# Environmental regulation and firm exports: Evidence from the eleventh Five-Year Plan in China

Xinzheng Shi*, Zhufeng Xu

*School of Economics and Management, Tsinghua University, China*

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ABSTRACT

Combining time variations, cross-province variations in policy intensity, and variations in pollution intensity across industries, we estimate the impact of environmental regulation on firm exports. We find that in more pollution-intensive industries, stricter environmental regulation reduces both the probability that a firm will export and the volume of exports. Heterogeneous tests show that the impact is smaller for SOE firms and for firms located in the central and western part of China. We also find that the reduced probability that a firm will export is driven by a decline in non-exporters entering the export market.


## 1. Introduction

In response to the growing deterioration of the environment, many governments across the world are tightening their pollution regulations in the hope that firms will adopt more environmentally friendly technology. However, variations in the stringency of these regulations across countries suggest that the cost of production for polluting industries in countries with stricter environmental regulations is relatively higher, thereby deterring exports and the inflow of foreign capital in these industries. Taylor (2004) calls this a “pollution haven effect” (PHE).

Studying the PHE has important policy implications. First, the effectiveness of global efforts to reduce greenhouse gas emissions may be undermined by the concentration of polluting industries in countries with lax environmental regulations. Second, the concentration of polluting industries in countries with lax regulations imposes a substantial health cost and therefore affects the welfare level in these countries.[1] Third, the existence of the PHE has important implications for international trade negotiations when there is debate over whether to expand trade agreements to include cooperation with domestic policies (Ederington and Minier, 2003).

* Corresponding author.
*E-mail address:* shixzh@sem.tsinghua.edu.cn (X. Shi).

[1] See Greenstone and Hanna (2011), Hanna and Oliva (2011), Chen et al. (2013), and He et al. (2016).

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Despite the importance of the PHE, there is no consensus across current studies. Some studies find small and unimportant effects,[2] while others claim more significant effects.[3] Dean et al. (2009) attribute the insignificant evidence for the PHE to the failure to account for the endogenous environmental regulations. Indeed, a meta-analysis conducted by Jeppesen et al. (2002) points out that much of the variation in findings on the effects of environmental regulations can be attributed to differences in methodology.[4]

In this paper, we take advantage of China's eleventh Five-Year Plan to investigate this question. The plan establishes a pollution reduction target for the entire country with different provinces sharing different burdens. To achieve pollution reduction targets, provinces with higher targets exert greater effort. Accordingly, this provides both before-and-after variation and cross-province variation for identification. However, a simple difference-in-differences strategy cannot exclude provincial-level time-varying variables that may bias the estimates. We therefore apply a difference-in-difference-in-differences (DDD) strategy to identify the impact. In other words, we compare the before-and-after change of firms in industries with different pollution intensities in different provinces. To further address the potential endogenous provincial pollution reduction targets, we use the ventilation coefficient, which is the product of wind speed and mixing height, as an instrumental variable (IV) for provincial pollution reduction targets. Compared with the period before the eleventh Five-Year Plan, we find that firms in more pollution-intensive industries located in provinces with higher pollution reduction targets are less likely to export, and if they do export, to export less.

Several robustness checks justify this finding. We first show that the pre-existing time trends of firm exports are similar across firms in different industries and different provinces. We then show that concurrent events, such as value-added tax reform, the 2008 Beijing Olympic Games, and the 2008–2009 financial crisis, do not affect our estimates. We also find that our results are robust for the different samples and different measurements of policy intensity.

In addition, we find smaller effects for SOE firms and firms located in the central and western part of China. Furthermore, we find that the decline in the probability of firms exporting is primarily driven by a reduced probability of non-exporters entering the export market.

Beyond the aforementioned policy implications, this paper contributes to the literature in other ways. First, compared with studies using data from developed countries such as the U.S. (Hanna, 2011; Millimet and Roy, 2016) and South Korea (Chung, 2014), investigating the PHE in the context of a developing country (i.e., China) is important because such countries have always been the focus of debate about pollution havens (Blonigen and Wang, 2004). Focusing on China is of particular importance in investigating the PHE. On the one hand, unlike developed countries such as the U.S. where the economy is in a stable stage, China has experienced fast economic growth in the past decades. China's economy growth has been accompanied by severe environmental deterioration, which is typical during rapid economic growth. On the other hand, since China entered the WTO in 2001, Chinese exports have increased dramatically. In 2016, Chinese exports were ranked the highest in the world and accounted for about 20% of GDP.[5] Investigating the PHE can shed light on the tradeoff between a stringent environmental policy and exports, which ultimately affects China's long-term economic growth. Last but not least, studying the PHE in China is advantageous because the policy change in China provides a good opportunity to circumvent the endogeneity problem, which is the greatest challenge for empirical studies.

Second, there are other studies investigating the effects of stricter environmental regulations in China. However, some of these studies focus on foreign direct investment (such as Dean et al., 2009, and Cai et al., 2016). Compared with other papers (such as Hering and Poncet, 2014) that investigate the effects of stricter environmental regulations on exports in China, we go a step further to investigate whether stricter regulations affect exports by inducing incumbents to cease exporting or by preventing non-exporters from entering the export market.

Third, our paper can also be linked with the rapidly growing body of literature on international trade in which domestic institutions or policies are treated as sources of comparative advantage. For example, using Chinese data, Gan et al. (2016) find a significant negative relationship between changes to the minimum wage and firm exports.[6] This paper extends this literature by providing evidence that domestic environmental policies are also an important source of comparative advantage.

The remainder of this paper is structured as follows. Section 2 provides background information. Section 3 describes the data. Section 4 describes the empirical strategy. Section 5 shows the main results and includes several robustness checks. Section 6 investigates the channels, and Section 7 concludes the paper.

[2] These studies include but are not limited to Tobey (1990), Grossman and Krueger (1993), Jaffe et al. (1995), Levinson (1996), Antweiler et al. (2001), and Javorcik and Wei (2004). Copeland and Taylor (2004) provide a detailed literature review.

[3] These studies include but are not limited to Henderson (1996), Becker and Henderson (2000), List and Co (2000), Keller and Levinson (2002), List et al. (2003), Ederington and Minier (2003), Levinson and Taylor (2008), Kellenberg (2009), Broner et al. (2013), Hering and Poncet (2014), and Cai et al. (2016). Copeland and Taylor (2004) and Erdogan (2014) provide literature reviews.

[4] In our paper, we find significant evidence for the PHE. This could be because we use a policy change in China (together with instrumental variable strategy) for identification, which avoids potential bias due to the endogeneity problem.

[5] The 2016 export data are extracted from the United Nations Comtrade Database (https://comtrade.un.org/). The percentage of exports in GDP is taken from the World Bank database (https://data.worldbank.org/indicator/NE.EXP.GNFS.ZS).

[6] For a more detailed survey of the literature, readers are referred to Nunn and Trefler (2014).

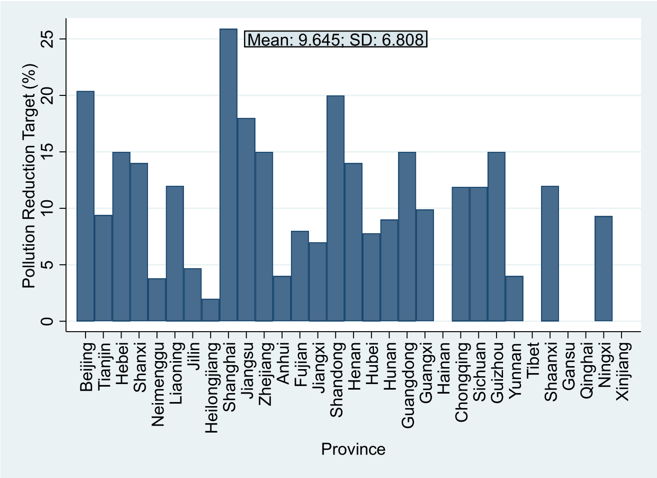


**Fig. 1.** Distribution of Pollution Reduction Targets. Note: The province names in the x-axis are sorted by their codes assigned by National Bureau of Statistics. Source: Pollution targets are taken from the document "Reply to *Pollution Control Plan During the Eleventh Five-Year Plan*," issued by the China State Council in 2006.

## 2. Background

China's five-year plans are a series of countrywide social and economic development initiatives containing detailed guidelines for economic and social development. The first Five-Year Plan ran from 1953 to 1957 and the eleventh Five-Year Plan (under study) ran from 2006 to 2010. Although economic growth was originally the central task of the five-year plans, the tenth Five-Year Plan (2001–2005) was the first to include an environmental policy by setting a 10% $SO_2$ reduction target. However, the tenth Five-Year Plan did not set pollution reduction target for each province and it lacked a clearly defined evaluation scheme, implementation of the target was completely ineffective. Total $SO_2$ emission increased by roughly 28% from 20 million tons in 2000 to 25.5 million tons in 2005.[7]

The eleventh Five-Year Plan also set 10% as its $SO_2$ reduction target. In establishing the $SO_2$ reduction goals, two factors were the most important: long-term goals and designated achievement years. To determine its long-term $SO_2$ emission goals, the Chinese government relied on environmental carrying capacity, i.e., the maximum emissions allowable without degrading environmental quality below a minimum level (Yang et al., 1998, 1999). Based on sophisticated scientific calculations, the long-term goal was an ambient $SO_2$ concentration of 0.060 mg/m$^3$ within grid boxes of $1^{\circ} * 1^{\circ}$ (i.e., about 111 km * 111 km), requiring that $SO_2$ emissions be reduced to 18 million tons by 2020. Thus, the 10% $SO_2$ reduction goal was proposed in the eleventh Five-Year Plan (Xu, 2011).

After the national goal was established, the provinces negotiated with the central government for their share of the burden (Xu, 2011). The China State Council issued a document named "Reply to *Pollution Control Plan During the Eleventh Five-Year Plan*" in 2006, which handed down national goal to pollution reduction targets in provincial level.[8] Formal contracts for the provincial pollution reduction targets were signed by the provincial vice presidents (State Environment Protection Administration, 2006). As shown in Fig. 1, the mean of the reduction targets is 9.6% and the standard deviation is 6.8%. However, the negotiation process is not publicly available. Using other publicly available data, Xu (2011) shows that the 2005 provincial $SO_2$ emissions and non-power sector $SO_2$ emission density are significantly correlated with the provinces' shared target. We therefore deduce that initial environmental quality was the most important factor in determining pollution reduction target for each province.

Unlike the tenth Five-Year Plan, where no evaluation scheme was clearly defined, provincial goal attainment in the eleventh Five-Year Plan was evaluated based on three dimensions: (1) the quantitative target and general environmental quality; (2) the establishment and operation of environmental institutions; and (3) the measures to reduce pollution (Xu, 2011). More importantly, it was the first to explicitly link local government performance in environmental protection with the promotion of local leaders (Wang, 2013).

Indeed, provincial government efforts to reduce pollution emissions increased. Fig. 2 shows the correlation between increased provincial investment in eliminating gas emissions and pollution reduction targets.[9] We can see that provinces

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7 The $SO_2$ emission data are from the China Statistical Yearbook (2001, 2006).

8 This document lists total $SO_2$ emission for each province in 2005, $SO_2$ emission target for each province in 2010, $SO_2$ emission target for electricity sector in each province in 2010, and the reduction percentage target for each province.

9 The increase in provincial investment is the difference between the average values in 2006–2010 versus 2001–2005. Provincial investment in eliminating gas emissions is taken from the China Statistical Yearbook (2002–2011).

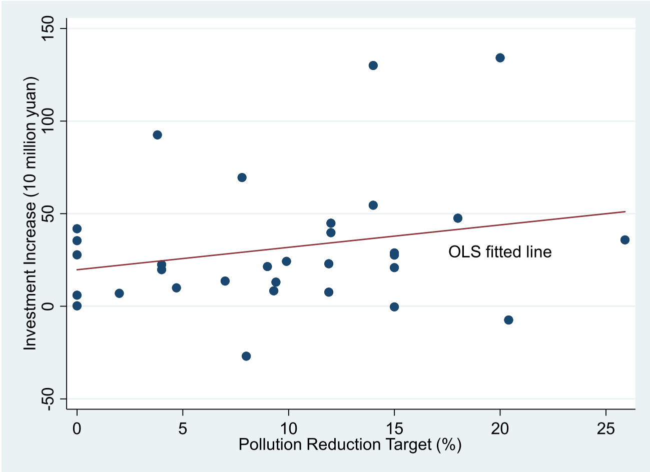


**Fig. 2.** Pollution Reduction Targets and Pollution Elimination Investment. Note: The investment increase in the Y-axis is the average investment to eliminate gas emissions during 2006–2010 minus that during 2001–2005. The value is deflated using the provincial CPI (with 1998 as the base year). The line is fitted by OLS. Source: Investment to eliminate gas emissions is taken from the China Statistical Yearbooks (2002–2011).

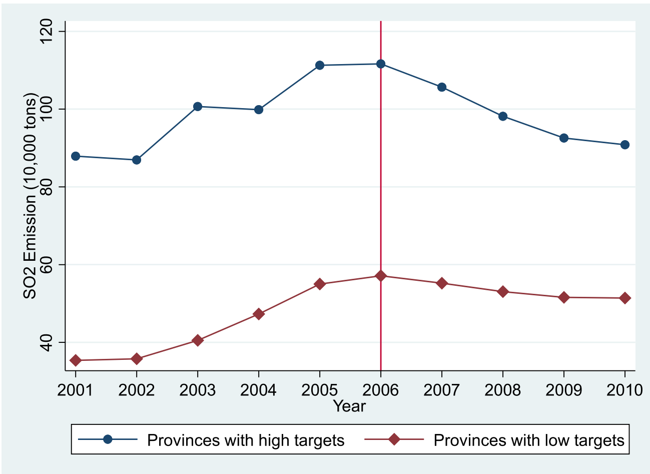


**Fig. 3.** $SO_2$ Emissions. Note: Provinces with pollution reduction targets higher than the median (9.4%) are referred to as provinces with high targets. Provinces with pollution reduction targets below the median (9.4%) are referred to as provinces with low targets. The vertical line in the figure denotes the start of the eleventh Five-Year Plan.
Source: Provincial SO2 emissions are taken from the China Statistical Yearbooks (2002–2011).

with high pollution reduction targets invested more after the eleventh Five-Year Plan to reduce pollution, and their efforts brought returns. Total $SO_2$ emission decreased by roughly 14% from 25.5 million tons in 2005 to 21.9 million tons in 2010.[10] Fig. 3 shows the $SO_2$ emission trends for provinces with pollution reduction targets above and below the median, with greater $SO_2$ emission decreases after the start of the eleventh Five-Year Plan for provinces with high pollution reduction targets.

Enforcement varied across the provinces. Fig. 4 shows $SO_2$ emissions for each province in 2005 and 2010. We can see that $SO_2$ emissions in 2010 are lower than those in 2005 for most provinces, while a few have higher $SO_2$ emissions in 2010. Fig. 5 shows the relation between the actual $SO_2$ emission reductions and the targets. We can see that most provinces achieved or even exceeded their targets, while a few did not.[11]

[10] The total $SO_2$ emissions data is from the China Statistical Yearbook (2006, 2011).

[11] However, except for setting the $SO_2$ emission target in 2010 for electricity sector in each province, there is no evidence showing that the central government had guidance for what industries or sub-provincial entities for local governments to target. It is reasonable to speculate that local governments would focus on pollution intensive industries or sub-entities.

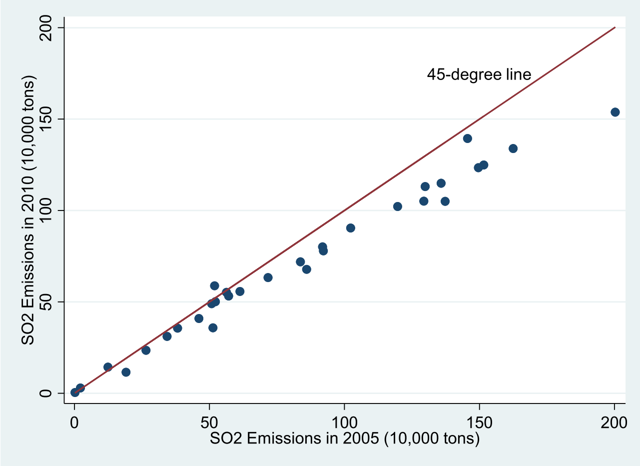


**Fig. 4.** $SO_2$ Emissions in 2005 and 2010. Note: Points in the figures represent provinces. The line in the figure is the 45° line.
Source: Provincial SO2 emissions are taken from the China Statistical Yearbooks (2006, 2011).

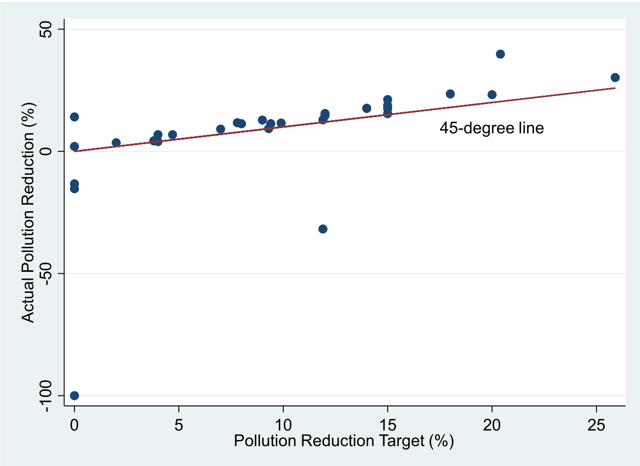


**Fig. 5.** $SO_2$ Reduction Targets and Actual Reduction. Note: Points in the figures represent provinces. Y-axis is ($SO_2$ emission in 2005-$SO_2$ emission in 2010)/($SO_2$ emission in 2005). The line in the figure is 45° line (it does not look like 45° line because of different scales in Y-axis and X-axis).
Source: Provincial SO2 emissions are taken from the China Statistical Yearbooks (2006, 2011).

## 3. Data

The data on pollution reduction targets was collected from a document named "Reply to *Pollution Control Plan During the Eleventh Five-Year Plan*," issued by the China State Council in 2006.[12] Fig. 1 shows the distribution of the pollution reduction targets, which vary from 0 to more than 25% with a mean and standard deviation of 9.645% and 6.808%, respectively. We obtain the 2-digit-industry level $SO_2$ emissions for 2003–2005 from the China Statistical Yearbook (2004–2006).[13] Fig. 6 shows the three-year average (2003–2005) of $SO_2$ emissions for industries. This also varies considerably, with a mean and standard deviation of 22.353 thousand tons and 40.686 thousand tons, respectively. We also obtain provincial $SO_2$ emissions and provincial investment to eliminate gas pollution from China Statistical Yearbook (2002–2011).

In this paper, we also use manufacturing firm data collected by the National Bureau of Statistics of China (NBS). Every year, all SOEs and non-SOEs with sales above RMB5 million (roughly $769,000) are required to file a report with the NBS on their production activities, including their accounting and financial information. This is the most comprehensive firm-level dataset

[12] This document lists total $SO_2$ emission for each province in 2005, $SO_2$ emission target for each province in 2010, $SO_2$ emission target for electricity sector in each province in 2010, and the reduction percentage target for each province (which is what we use in the paper). Online Appendix Table 1 shows the details (translated from Chinese).

[13] The industries used in our paper are listed in Table 2 of the online appendix.

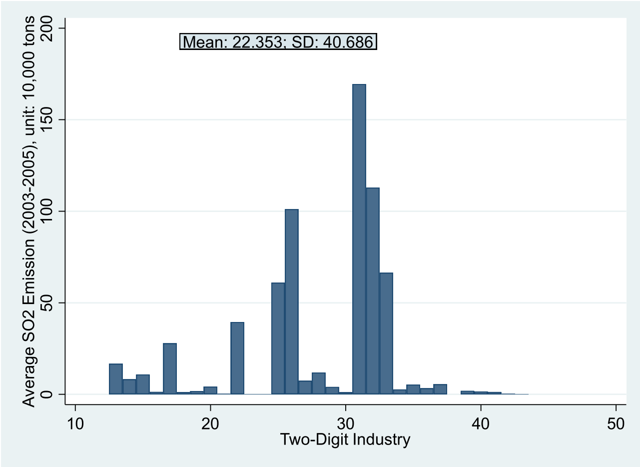


**Fig. 6.** Distribution of industrial $SO_2$ emissions (2003–2005 average).
Source: Chinese Statistical Yearbooks (2004–2006).

in China, and is used to calculate matrices for the national income account and major statistics published in the China Statistical Yearbooks. The data collected by this survey are widely used by researchers such as Brandt et al. (2012), Brandt et al. (2017), Yu (2015), Lu et al. (2010), and Lu and Yu (2015).

The NBS assigns a four-digit Chinese industrial classification (CIC) code to each firm. However, the classification system for the industry code changed from GB/T 4754-1994 for 1995–2002 to GB/T 4754-2002 after 2002. To achieve consistency among industry codes for the entire period, we convert them to GB/T 4754-1994. We then clean the data following the procedures in the literature (Cai and Liu, 2009; Lu and Yu, 2015; Yu, 2015). All of the monetary values are deflated to 1998 values. We use data from 2002 to 2009, spanning four years before the eleventh Five-Year Plan (2002–2005) and four years after the eleventh Five-Year Plan (2006–2009). Because the variations used for identification are at the province-industry-year level, which are discussed in more detail in Section 4, we collapse all firm level variables into the mean of each province-industry-year cell. Finally, we have 7137 province-industry-year cells generated from 2,109,196 firm level observations.

In this paper, we also use the ventilation coefficient, a variable based on the product of wind speed and the mixing height, for each province. We use the wind speed information at the 10-m height and the boundary layer height (used to measure mixing height for the grid of 75°*75° cells) from the European Center for Medium-Term Weather Forecasting ERA-interim dataset. We match the ERA-interim dataset with the capital city of each province by its latitude and longitude. The ventilation coefficient is the product of the wind speed and boundary layer height for each cell. The ventilation coefficient we use is the average coefficient from 1998 to 2004 for the nearest cells to the capital city of each province.

Table 1 shows the summary statistics for the variables used in the analysis. On average, 26.3% of the firms are exporters, with an export value of 17,640 thousand yuan and average fixed assets of 25,739 thousand yuan. The average provincial policy intensity (measured by the $SO_2$ emission reduction target) is 9.6%. The industrial $SO_2$ emissions (2003–2005 average) is 22.4 thousand tons, and the average ventilation coefficient is 1747.

**Table 1**
Summary statistics.

| | Mean | S.D. | OBS |
|---|---|---|---|
| **Panel A. Province-industry-year level** | | | |
| Exporter | 0.263 | 0.186 | 7137 |
| Exports (1000 yuan) | 17640.213 | 38257.866 | 6039 |
| Fixed assets (1000 yuan) | 25738.953 | 41223.838 | 7137 |
| **Panel B. Province level** | | | |
| Provincial pollution reduction target (%) | 9.645 | 6.808 | 31 |
| Ventilation coefficient | 1746.680 | 564.939 | 31 |
| **Panel C. Two-digit industry level** | | | |
| Industry $SO_2$ emissions (2003–2005 average) (1000 tons) | 22.353 | 40.686 | 30 |

Notes:
(1) The number of firms in each province-industry-year cell is used as the weight for the mean and standard deviation in Panel A.
(2) Exports include only province-industry-year cells with positive export values.

## 4. Empirical strategy

Combining the variation in pollution reduction targets across provinces and the before-and-after change, we can estimate the impact of environmental regulations on firm exports using a difference-in-differences (DID) strategy. However, a concern about the DID strategy is that some time-varying provincial characteristics may be correlated with the outcome variable and the regressor at the same time, leading to bias in our estimates.

In light of this concern, we exploit the fact that industries that have different pollution intensities are affected differently, and carry out a difference-in-difference-in-differences (DDD) strategy. In other words, we combine three types of variation: the time variation (i.e., before and after the start of the eleventh Five-Year Plan), the provincial variation (i.e., provinces with high pollution reduction targets versus provinces with low targets), and the industrial variation (i.e., more polluting versus less polluting industries).[14] The following regression is estimated:

$$Y_{ipt} = \beta * Ln(Target_p) * Post_t * Ln(SO2_i) + \mu_{pt} + \delta_{pi} + \gamma_{ti} + \varepsilon_{ipt}. \tag{1}$$

Given that we exploit the variations over province-industry-year, we collapse the variables and conduct the analysis at the provincial, 2-digit industry, and year levels.[15] $Y_{ipt}$ is a vector including the proportion of exporting firms in province p, industry i, and year t, and the natural logarithm form of the average export value of exporters in province p, industry i, and year t ($\text{Ln}(\text{export}_{ipt})$). $Target_p$ is the pollution reduction target for province p; $Post_t$ is a dummy variable equal to 0 for 2002–2005 and 1 for 2006–2009; $SO2_i$ is the average $SO_2$ emissions from 2003 to 2005 for each industry; and $\varepsilon_{ipt}$ is an error term with a mean equal to zero. To deal with heterogeneity and serial correlations, we calculate the standard error by clustering over province-industry to allow for the possible correlation of firms within the province-industry. In all of the regressions, we use the number of firms in each province-industry-year cell as a weight.[16]

The DDD strategy makes it feasible to control for the entire set of province-year fixed effects ($\mu_{pt}$), province-industry fixed effects ($\delta_{pi}$), and industry-year fixed effects ($\gamma_{ti}$). In other words, we can control for all time-invariant and time-varying provincial characteristics and all time-invariant and time-varying industry characteristics. We also control for any time-invariant differences for industries in different provinces.

However, if the exports of heavily polluted industries were taken into account when the provincial pollution reduction targets were being set, our estimates would still be biased. To address this issue, we adopt an IV strategy. Specifically, we use the ventilation coefficient as the IV for policy intensity. According to the Box model (Jacobson, 2002), two variables determine pollution dispersion. One is wind speed, as a faster wind speed helps the horizontal dispersion of pollution, and the second is mixing height, which influences the vertical dispersion of pollution. The ventilation coefficient is the product of wind speed and mixing height. Higher ventilation coefficient values mean faster dispersion of pollution, leading to a lower policy intensity in our context. The ventilation coefficient has been widely used as an IV for environmental policies in other studies (e.g., Broner et al., 2013; Cai et al., 2016; Hering and Poncet, 2014). We construct the ventilation coefficient using the procedure described in Section 3.

To further check the validity of the empirical strategy, we conduct a battery of sensitivity tests. These include checking for the existence of pre-trend and expectation effects, controlling for the value-added tax reform, the 2008–2009 financial crisis, and the 2008 Beijing Olympic Games, using firms in the same province and industry that existed both before and after the eleventh Five-Year Plan, and using alternative measures of policy intensity. In all of the robustness checks, the IV strategy is used unless stated otherwise.[17]

## 5. Results

### 5.1. Main results

As a benchmark, we first show the OLS estimates of Equation (1) in Table 2. Column 1 shows the results using the proportion of exporters as the outcome variable and column 2 shows Ln(export). Due to limited space, only the coefficient of $Ln(Target_p)*Post_t*Ln(SO2_i)$ is presented. The coefficients are −0.004 (column 1) and −0.042 (column 2), the former being statistically significant at the 1% level and the latter at the 5% level.

[14] Another possibility is to explore the variation in city-level pollution within each province, that is, to combine the time variation, variation in provincial pollution reduction targets, and city level variation in pollution to estimate the effects. Unfortunately, we cannot find city-level pollution data.

[15] As we only have information on pollution intensity at the 2-digit industry level, we cannot exploit industrial variations at a more disaggregated level, which could lead to bias in our estimates. On the one hand, if one sector includes one highly polluting industry but all of the rest are clean industries, our estimates will be downward biased, as the small change in export for clean industries could offset the change in exports for the highly polluting industry; on the other hand, clean industries could see their exports increase because of a trade agreement or a change in world prices, leading to upward bias in our estimates.

[16] Each observation in our analysis is an average value for the province-industry-year cell. Therefore, a cell with more firms will be under-represented in the analysis. The number of firms in each province-industry-year cell is used as a weight for the representation of each cell. Stata syntax *aweight* is used.

[17] The first stage results are presented in the online-appendix.

**Table 2**
Impact of environmental regulations on firm exports (OLS estimates).

| | (1) | (2) |
|---|---|---|
| **Dependent Variable:** | Proportion of exporters | Average Ln(export) |
| Ln(Policy intensity)*Post*Ln(Industry $SO_2$) | −0.004*** | −0.042** |
| | (0.001) | (0.020) |
| Year-Province FE | Yes | Yes |
| Year-Industry FE | Yes | Yes |
| Province-Industry FE | Yes | Yes |
| Observations | 7137 | 6039 |
| R-squared | 0.984 | 0.889 |

Notes:
(1) Standard errors in parentheses are calculated by clustering over province-industry. The number of firms in the cell of province-industry-year is used as a weight.
(2) ***, **, and * represent the significance levels at 1%, 5%, and 10%, respectively.
(3) Variables are collapsed to the province-industry-year level.

**Table 3**
Impact of environmental regulations on firm exports (IV estimates).

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | First Stage | | Second Stage | |
| **Dependent Variable:** | Ln(Policy intensity) *Post*Ln(Industry $SO_2$) | | Proportion of exporters | Average Ln(export) |
| Ln(Ventilation)*Post*Ln(Industry $SO_2$) | −3.932*** | −4.503*** | | |
| | (0.222) | (0.331) | | |
| Ln(Policy intensity)*Post*Ln(Industry $SO_2$) | | | −0.005*** | −0.069*** |
| (Ln(Ventilation)*Post*Ln(Industry $SO_2$) as IV) | | | (0.001) | (0.021) |
| Year-Province FE | Yes | Yes | Yes | Yes |
| Year-Industry FE | Yes | Yes | Yes | Yes |
| Province-Industry FE | Yes | Yes | Yes | Yes |
| Observations | 7137 | 6039 | 7137 | 6039 |
| R-squared | 0.984 | 0.975 | 0.984 | 0.888 |
| F-test | 313.7 | 184.5 | | |

Notes:
(1) Robust standard errors in parentheses are calculated by clustering over province-industry. The number of firms in the province-industry-year cell is used as a weight.
(2) ***, **, and * represent the significance levels at 1%, 5%, and 10%, respectively.
(3) Variables are collapsed to province-industry-year level.

OLS estimates could be biased if the exports of different industries in different provinces were taken into account when setting provincial pollution reduction targets. We therefore rely on the IV strategy, using the ventilation coefficient as the IV for pollution reduction targets. Estimation results are shown in Table 3.

Columns 1–2 in Table 3 report the first-stage results. Column 1 is for proportion of exporters and column 2 is for Ln(export). The IV is a very strong predictor of policy intensity with F-values of 313.7 and 184.5, respectively. The second-stage results are shown in columns 3–4 of Table 3. We continue to find significant negative effects of the eleventh Five-Year Plan on the probability of firms exporting and export value, with coefficients of −0.005 (column 3) and −0.069 (column 4), respectively.

The results show that when the pollution reduction target is one standard deviation above the mean, there are one percentage point fewer exporting firms in industries with $SO_2$ emissions 10% above the mean and the value of exports is 13% lower.[18] Given the average number of firms per year (roughly 263,650) and the average value of exports (17,640 thousand yuan), it means 2637 fewer firms exporting and a 2293 thousand yuan reduction in export value.

[18] The formula is $\Delta = \widehat{\beta}*Ln(Target_{mean} + Target_{sd})*Ln(SO2_{mean}*(1+10\%)) - \widehat{\beta}*Ln(Target_{mean})*Ln(SO2_{mean}))$. Here, Δ represents change in the proportion of exporters or Ln(export), $\widehat{\beta}$ is the estimated coefficient in equation (1), $Target_{mean}$ is average value of pollution reduction target, $Target_{sd}$ is the standard deviation of pollution reduction target, and $SO2_{mean}$ is the average industry pollution level.

**Table 4**
Testing pre-existing time trends.

| | (1) | (2) |
|---|---|---|
| **Dependent Variable:** | Proportion of exporters | Average Ln(export) |
| Ln(Policy intensity)*Year2003 Dummy*Ln(Industry $SO_2$) | −0.000 | −0.004 |
| (Ln(Ventilation)*Year2003 Dummy*Ln(Industry $SO_2$) as IV) | (0.001) | (0.006) |
| Ln(Policy intensity)*Year2004 Dummy*Ln(Industry $SO_2$) | 0.002 | −0.010 |
| (Ln(Ventilation)*Year2004 Dummy*Ln(Industry $SO_2$) as IV) | (0.001) | (0.008) |
| Ln(Policy intensity)*Year2005 Dummy*Ln(Industry $SO_2$) | −0.001 | 0.014 |
| (Ln(Ventilation)*Year2005 Dummy*Ln(Industry $SO_2$) as IV) | (0.001) | (0.016) |
| Ln(Policy intensity)*Year2006 Dummy*Ln(Industry $SO_2$) | −0.003*** | −0.082*** |
| (Ln(Ventilation)*Year2006 Dummy*Ln(Industry $SO_2$) as IV) | (0.001) | (0.023) |
| Ln(Policy intensity)*Year2007 Dummy*Ln(Industry $SO_2$) | −0.004*** | −0.062*** |
| (Ln(Ventilation)*Year2007 Dummy*Ln(Industry $SO_2$) as IV) | (0.001) | (0.017) |
| Ln(Policy intensity)*Year2008 Dummy*Ln(Industry $SO_2$) | −0.005*** | −0.059*** |
| (Ln(Ventilation)*Year2008 Dummy*Ln(Industry $SO_2$) as IV) | (0.001) | (0.018) |
| Ln(Policy intensity)*Year2009 Dummy*Ln(Industry $SO_2$) | −0.005*** | −0.070*** |
| (Ln(Ventilation)*Year2009 Dummy*Ln(Industry $SO_2$) as IV) | (0.002) | (0.018) |
| Year-Province FE | Yes | Yes |
| Year-Industry FE | Yes | Yes |
| Province-Industry FE | Yes | Yes |
| Observations | 7137 | 6039 |
| R-squared | 0.984 | 0.888 |

Notes:
(1) Standard errors in parentheses are calculated by clustering over province-industry. The number of firms in the province-industry-year cell is used as a weight.
(2) ***, **, and * represent the significance levels at 1%, 5%, and 10%, respectively.
(3) Variables are collapsed to province-industry-year level.

### 5.2. Justification of identification

*Pre-existing Time Trends.* Our estimates would be biased if different time trends in the absence of the eleventh Five-Year Plan are correlated with firm export behavior and our IV. To investigate this, we replace the post dummy in Equation (1) with dummies for 2003–2009 (the base year is 2002) and use the interactions of Ln(Ventilation), year dummies, and Ln(Industry $SO_2$) as the relevant IVs. The results are shown in columns 1 (proportion of exporters) and 2 (Ln(export)) in Table 4. None of the coefficients of the triple interaction between 2003 and 2005 are significant, which validates our empirical strategy.[19]

*Expectation Effects.* Firms in industries with more intense pollution in provinces with higher reduction targets could have expected the event under study and changed their behavior even before the eleventh Five-Year Plan. However, the results in Table 4 suggest that the expectation effects do not exist because none of the coefficients of the triple interaction between 2003 and 2005 are significant.[20]

*Concurrent Events.* If any other events during the period of the eleventh Five-Year Plan affected different industries across provinces, our estimates could be biased. Three such events stand out: the value-added tax reform, the 2008–2009 financial crisis, and the 2008 Beijing Olympic Games.

The value-added tax reform during the mid-2000s allowed firms in specific industries (mainly heavy industries) in selected provinces to deduct the purchase of fixed assets from their tax base (see Liu and Lu, 2015, and Chen et al., 2017, for a detailed description of the background). This reform significantly increased firm investment (Chen et al., 2017) and therefore raised both the probability of firms exporting and the export value (Liu and Lu, 2015). As heavy industries are more pollution intensive, our results may be biased upward. To address this concern, we include the log value of fixed assets in the regression. As shown in column 1 of Panel A in Table 5 (using the proportion of exporters as the outcome variable), the coefficient of the

[19] One might also be concerned that there could be some variables with different time trends across industries and provinces. These variables might not affect exports immediately but rather a few years later. If so, we should also see significant interaction coefficients during 2003–2005, as the aforementioned variables before 2003 could affect exports during 2003–2005. However, Table 4 shows no significant interactions during 2003–2005, providing no evidence of such variables. It is also possible that some other event during 2003–2005 could have led to different time trends for firm exports in different polluting industries and different provinces, and if this only affected exports a few years later, our estimates could be biased. One such event is the tax reform during the mid-2000s discussed in Section 5.2. However, as shown in Section 5.2, this reform does not affect our estimates.

[20] One caveat we need to bear in mind is that, despite the statistical insignificance, the coefficients of the triple interaction terms in 2005 could still indicate that some changes might have started to be made in 2005. For example, the positive (but insignificant) coefficient of the triple interaction term in 2005 for Ln(export) could suggest that exporters might export more in expectation of higher production costs in the next year.

**Table 5**
Testing for concurrent events.

| | (1) | (2) | (3) |
|---|---|---|---|
| | Value added tax reform | Financial crisis | 2008 Beijing Olympic Games |
| **Panel A: Proportion of exporters** | | | |
| Ln(Policy intensity)*Post*Ln(Industry $SO_2$) | −0.005*** | −0.004*** | −0.004*** |
| (Ln(Ventilation)*Post*Ln(Industry $SO_2$) as IV) | (0.001) | (0.001) | (0.001) |
| Ln(fixed asset) | 0.018*** | | |
| | (0.004) | | |
| Year-Province FE | Yes | Yes | Yes |
| Year-Industry FE | Yes | Yes | Yes |
| Province-Industry FE | Yes | Yes | Yes |
| Observations | 7137 | 5384 | 6787 |
| R-squared | 0.985 | 0.986 | 0.985 |
| **Panel B: Average Ln(export)** | | | |
| Ln(Policy intensity)*Post*Ln(Industry $SO_2$) | −0.070*** | −0.073*** | −0.065*** |
| (Ln(Ventilation)*Post*Ln(Industry $SO_2$) as IV) | (0.021) | (0.023) | (0.021) |
| Ln(fixed asset) | 0.192*** | | |
| | (0.026) | | |
| Year-Province FE | Yes | Yes | Yes |
| Year-Industry FE | Yes | Yes | Yes |
| Province-Industry FE | Yes | Yes | Yes |
| Observations | 6039 | 4574 | 5760 |
| R-squared | 0.891 | 0.897 | 0.893 |

Notes:
(1) Standard errors in parentheses are calculated by clustering over province-industry. The number of firms in the cell of province-industry-year is used as weight.
(2) ***, **, and * represent the significance levels at 1%, 5%, and 10%, respectively.
(3) Variables are collapsed to province-industry-year level.
(4) In column 2, samples from 2008 and 2009 are excluded. In column 3, samples from 2007 and 2008 in provinces affected by the Olympic Games, including Beijing, Tianjin, Hebei, Shanxi, Neimenggu and Liaoning, are excluded.

triple interaction is still −0.005 and significant at the 1% level. The coefficient of the triple interaction in column 1 of Panel B (using Ln(export) as the outcome variable) is −0.070 and also significant at the 1% level. Both are consistent with those shown in columns 3–4 in Table 3.

During the 2008–2009 financial crisis, firm exports declined dramatically (Ma et al., 2016). If the impact of the financial crisis was larger for firms in industries with more intensive pollution in provinces with higher pollution reduction targets, our estimates may be biased. To investigate the effects of the financial crisis, we drop 2008 and 2009 from the sample, and the results are shown in column 2 of Table 5. We can see that in Panel A (using the proportion of firms as the outcome variable) the coefficient of the triple interaction term is −0.004 and significant at the 1% level, which is similar to our main estimate. In Panel B (using Ln(export) as outcome variable), the coefficient of the triple interaction is −0.073 and significant at the 1% level, also similar to our main estimate.

The Chinese government exerted considerable effort to reduce pollution in Beijing during the 2008 Olympic Games. This might have especially affected firms in industries with heavy pollution in provinces around Beijing. Indeed, He et al. (2016) show that not only Beijing but also Hebei, Tianjin, Shanxi, Neimenggu, and Liaoning were affected. To investigate the potential effects of this event, we exclude firms in the provinces affected by the Olympic Games from 2007 and 2008 (column 3 of Table 5). The coefficients of the triple interaction for both outcome variables remain similar to the main results shown in Table 3.

The preceding results suggest that these three concurrent events do not affect our estimates.

*Firms Existing Before and After the Five-year Plan.* Tougher environmental policies following the Five-Year Plan may have induced firms to exit the market or move to other provinces and industries, leading to bias in our estimates. We therefore restrict the sample to firms existing within the same industry and province both before and after the Five-Year Plan and conduct the same analysis. The results are shown in Table 6, where the coefficient of the triple interaction remains robust.

*Alternative Measurement for Policy Intensity.* In the main analysis, we use the targeted pollution reduction percentage to measure policy intensity. One might be concerned about the precision of this measurement, as even a small percentage could represent a large burden for provinces with heavy pollution. We then construct the amount of expected pollution reduction by multiplying the percentage by the emission levels in 2005 (scaled by GDP in 2005 to account for the different economy sizes among provinces). When we re-estimate equation (1) using this newly constructed variable for policy intensity, the results shown in Table 7 remain robust.

**Table 6**
Robustness check using firms existing in the same industry and province before and after.

| | (1) | (2) |
|---|---|---|
| | Proportion of exporters | Average Ln(export) |
| Ln(Policy intensity)*Post*Ln(Industry SO2) | −0.004*** | −0.070*** |
| (Ln(Ventilation)*Post*Ln(Industry SO2) as IV) | (0.001) | (0.022) |
| Year-Province FE | Yes | Yes |
| Year-Industry FE | Yes | Yes |
| Province-Industry FE | Yes | Yes |
| Observations | 7099 | 5952 |
| R-squared | 0.984 | 0.887 |

Notes:
(1) Standard errors in parentheses are calculated by clustering over province-industry. The number of firms in the province-industry-year cell is used as a weight.
(2) ***, **, and * represent the significance levels at 1%, 5%, and 10% respectively.
(3) Variables are collapsed to province-industry-year level.

**Table 7**
Impact of environmental regulations on firm exports using alternative policy intensity measurement.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | First Stage | | Second Stage | |
| **Dependent Variable:** | Ln(Policy intensity II) *Post*Ln(Industry $SO_2$) | | Proportion of exporters | Average Ln(export) |
| Ln(Ventilation)*Post*Ln(Industry $SO_2$) | −0.296*** | −0.307*** | | |
| | (0.030) | (0.036) | | |
| Ln(Policy intensity II)*Post*Ln(Industry $SO_2$) | | | −0.059*** | −1.342*** |
| (Ln(Ventilation)*Post*Ln(Industry $SO_2$) as IV) | | | (0.013) | (0.391) |
| Year-Province FE | Yes | Yes | Yes | Yes |
| Year-Industry FE | Yes | Yes | Yes | Yes |
| Province-Industry FE | Yes | Yes | Yes | Yes |
| Observations | 7137 | 6039 | 7137 | 6039 |
| R-squared | 0.922 | 0.915 | 0.984 | 0.882 |
| F-test | 95.31 | 71.01 | | |

Notes:
(1) Robust standard errors in parentheses are calculated by clustering over province-industry. The number of firms in the cell of province-industry-year is used as weight.
(2) ***, **, and * represent the significance levels at 1%, 5%, and 10%, respectively.
(3) Variables are collapsed to province-industry-year level.
(4) Policy intensity II is the amount of expected $SO_2$ emission reduction scaled by GDP. The amount of expected $SO_2$ emission reduction is calculated as the pollution reduction target multiplied by the $SO_2$ emission level in 2005.

### 5.3. *Heterogeneous effects*

In addition to the average effects, we investigate how the effects differ in terms of firm ownership and location. Once again, the IV strategy is used, and the results are shown in Table 8.[21]

Columns 1–4 in Table 8 show the effects for SOEs, foreign invested firms, Hong Kong-Marco-Taiwan invested firms, and domestic non-SOE firms. We see that the coefficients of the triple interaction are not significant for SOE firms, whether the outcome variable is the proportion of exporters (Panel A) or Ln(export) (Panel B). These results are consistent with Hering and Poncet (2014). This could be because of the preferential treatment of SOEs in China. Indeed, as Huang (2003) points out, because the Chinese government systematically favors SOEs both financially and legally, SOEs have better access to finance (Dollar and Wei, 2007; Boyreau-Debray and Wei, 2004). As Hering and Poncet (2014) argue, better access to finance makes it easier for SOEs to adopt advanced technology such that with reduced obligations to comply with stricter regulations, SOEs can continue to produce and export.

[21] The first stage results are shown in the online appendix.

**Table 8**
Heterogeneous tests.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | By Ownership | | | | By Region | | |
| | SOE | FDI | HMT | Non-SOE | East | Central | West |
| **Panel A: Proportion of exporters** | | | | | | | |
| Ln(Policy intensity)*Post*Ln(Industry $SO_2$) | −0.001 | −0.005*** | −0.003 | −0.003*** | −0.009*** | −0.000 | 0.001 |
| (Ln(Ventilation)*Post*Ln(Industry $SO_2$) as IV) | (0.001) | (0.002) | (0.000) | (0.001) | (0.001) | (0.002) | (0.002) |
| Year-Province FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Industry FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Province-Industry FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 6697 | 5557 | 5357 | 6908 | 2604 | 1897 | 2636 |
| R-squared | 0.925 | 0.914 | 0.939 | 0.976 | 0.985 | 0.971 | 0.902 |
| **Panel B: Average Ln(export)** | | | | | | | |
| Ln(Policy intensity)*Post*Ln(Industry $SO_2$) | 0.006 | −0.043*** | −0.027** | −0.089*** | −0.292*** | −0.105* | 0.024 |
| (Ln(Ventilation)*Post*Ln(Industry $SO_2$) as IV) | (0.018) | (0.016) | (0.011) | (0.027) | (0.050) | (0.061) | (0.023) |
| Year-Province FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year-Industry FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Province-Industry FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 4282 | 4447 | 3827 | 5428 | 2470 | 1730 | 1839 |
| R-squared | 0.769 | 0.863 | 0.827 | 0.832 | 0.836 | 0.897 | 0.773 |

Notes:
(1) Standard errors in parentheses are calculated by clustering over province. The number of firms in the province-industry-year cell is used as a weight.
(2) ***, **, and * represent the significance levels at 1%, 5%, and 10%, respectively.
(3) Variables are collapsed to province-industry-year level.

Columns 5–7 in Table 8 show the effects for firms in the eastern, central, and western parts of China, respectively.[22] The effects are significant for firms in the east for both outcome variables. The magnitude is also larger for firms in the east. However, most of the effects on firms in the central and western areas are not significant. A possible explanation is that because pollution is most severe in the eastern part of China, the pollution reduction targets there are highest, and therefore implementation of the pollution reduction policy could be the strictest there compared with the central and western regions.[23]

## 6. What causes the declined probability of firm exporting?

In this section, we investigate the channels through which the pollution reduction policy affected the probability that a firm would export. Specifically, we investigate whether this policy induced incumbent exporters to exit the export market and/or prevented non-exporters from entering the export market.

We define incumbent exporters as firms that exported at least once before the start of the eleventh Five-Year Plan, and non-exporters as firms that never exported before the eleventh Five-Year Plan. We then obtain a panel of exporters and non-exporters, respectively. As in the previous regressions, we collapse individual firms to the province-industry-year level and use the IV strategy. The regression results are shown in Table 9.

Column 1 in Table 9 applies to incumbent exporters. The coefficient of the triple interaction is −0.002 and not significant. Column 2 in Table 9 applies to non-exporters, and here the triple interaction coefficient is −0.003 and significant at the 5% level. The results show that the pollution reduction policy decreased the probability of non-exporters entering the export market, but did not affect the probability of incumbent exporters exiting the export market. As shown in Melitz (2003), firms had to pay fixed costs to enter the export market. Stricter environmental policies reduced the ability of non-exporters to pay these costs, but may not have induced exporters to exit the export market as they had already paid these costs. This may explain why the pollution reduction policies had different effects on exporters and non-exporters.

One might still be interested in how non-exporters responded to the stricter environmental regulations. They could reduce their production output and/or introduce more advanced technology and equipment. Because we do not have data on the

[22] The eastern part of China includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan provinces. The central part of China includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan provinces. The western part of China includes Neimenggu, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang provinces.

[23] The average reduction targets are 14.4% for provinces in the eastern part of China, 7.8% for provinces in the central part of China, and 6.5% for provinces in the western part of China.

**Table 9**
Testing channels.

| | (1) | (2) | (3) |
|---|---|---|---|
| | Proportion of exporters in province-industry-year | | Ln(Total output) |
| | Exporters | Non-Exporters | Non-Exporters |
| Ln(Policy intensity)*Post*Ln(Industry SO2) | −0.002 | −0.003** | −0.012*** |
| (Ln(Ventilation)*Post*Ln(Industry $SO_2$) as IV) | (0.001) | (0.001) | (0.004) |
| Year-Province FE | Yes | Yes | Yes |
| Year-Industry FE | Yes | Yes | Yes |
| Province-Industry FE | Yes | Yes | Yes |
| Observations | 5917 | 6881 | 6881 |
| R-squared | 0.936 | 0.886 | 0.954 |

Notes:
(1) Standard errors in parentheses are calculated by clustering over province. The number of firms in the province-industry-year cell is used as a weight.
(2) ***, **, and * represent the significance levels at 1%, 5%, and 10%, respectively.

more advanced technology or equipment adopted by firms, we can only investigate how the regulations affected the output of non-exporters. The results in column 3 of Table 9 show that reducing output may have been one response of non-exporters to the stricter environmental regulations.

## 7. Conclusion

We investigate the effects of domestic environmental regulations on the export behavior of firms using China's eleventh Five-Year Plan. Applying the DDD identification strategy, we find that stricter environmental regulations reduced the likelihood that firms would export and also reduced export volume. Several robustness checks confirm our findings. We also find that SOE firms and firms located in the middle and western part of China were least affected. Finally, we show that the reduced probability of non-exporters entering the export market was the main driving force for the reduced probability of firms exporting.

It would be interesting to investigate whether exporters eventually exited the export market or bounced back after adapting to the regulations, as such long-term effects have important implications for evaluating current policy and future policy making. This is a potential topic for future research when the relevant data are available.

In developing countries like China, governments are investing large amounts of resources to reduce the increasingly severe pollution. While such investment has many benefits, our study shows that it can also bring extra costs to manufacturing firms. Policymakers therefore need to take these negative effects into account in future policymaking.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jeem.2018.03.003.

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