8-2020

Three chapters on Environmental Regulation, Pollution, and Trade Liberalization

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To the Graduate Council:

I am submitting herewith a dissertation written by Tingsi Wang entitled "Three chapters on Environmental Regulation, Pollution, and Trade Liberalization." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.

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Three chapters on Environmental Regulation, Pollution, and Trade Liberalization

A Dissertation Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Tingsi Wang

August 2020

Acknowledgments

I want to thank Dr. Georg Schaur for his mentorship throughout this long process. He always gave me insightful ideas and suggestions. I cannot imagine myself going this far without his guidance. I also want to thank Dr. James Scott Holladay for his encouragement, patience, and mentorship. His guidance helped me go through difficult times. I also want to thank my committee members, Dr. Charles Sims and Dr. Chris Clark. I am grateful to Sherri Pinkston for helping me with so many school things when I am lost. Special thanks to my parents for their encouragement and love, Ethan Li for his motivation, and my husband Dr. Li who can make any difficult things easy.

Abstract

The dissertation consists of three chapters in environmental economics and international trade. The first chapter identifies the effects of environmental regulation on Chinese manufacturing firms' markups. Difference-in-difference and triple-differenced estimates show that more stringent environmental regulation decreases firms' markups. Furthermore, environmental regulation has a significant impact on non-exporters' markups, but it has no impact on exporters. Examining pre-trends, we find that SOEs did not change their behavior in anticipation of environmental regulation, but non-SOEs started to adjust before the regulation was implemented. The second chapter evaluates how the market size affects the impact of environmental stringency on firms' economic activity. The empirical example and theoretical model imply that the relative abatement pollution cost has a deterrent impact on foreign direct investment inflows to China's provinces. The results also indicate that the impact of environmental regulation is weaker in the large region but stronger in the small region. The third chapter examines the effects of import competition from China on environmental performance in the US at both industry and commuting-zone levels. The main results indicate that the US import exposure from China significantly decreases pounds released and hazard at the industry level. I construct the difference between actual and counterfactual emissions. Results suggest that Chinese import competition results in losses of 35.7 million and 82.9 million pounds released over two subperiods 1991-1999 and 1999-2007. It also results in losses of 0.714 trillion and 2.29 trillion units in hazard over these two periods. Using data at the commuting-zone level, I find the US import exposure from China decreases pounds released per employment and hazard per employment but the estimates are statistically insignificant.

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Introduction

This dissertation consists of three chapters in environmental regulation, pollution, and trade liberalization. The first chapter is based on the co-authored paper with Shanshan Ying, from Shanghai University of Finance and Economics. In the first chapter, we identify the effects of environmental regulation on firms' markups in the Chinese manufacturing sector. China's Eleventh Five-Year Plan mandated SO_2 reduction targets. This policy experiment provided a precise measure of environmental regulation, which varies across province and time. We use detailed firm-level data including information on revenues and quantities from 1998-2007 to estimate markups. Difference-in-difference estimates show that more stringent environmental regulation decreases firms' markups. Furthermore, estimates vary across firms' export status and ownership. Environmental regulation has a significant impact on non-exporters' markups, but it has no impact on exporters. Examining pre-trends, we find that SOEs did not change their behavior in anticipation of environmental regulation, but non-SOEs started to adjust before the regulation was implemented. Our evidence shows that adjustments in markups are important to understand the effects of environmental regulation.

The second chapter evaluates how the market size affects the impact of environmental stringency on firms' economic activity. The empirical example implies that the relative abatement pollution cost has a deterrent impact on foreign direct investment (FDI) inflows to China's provinces. The results also indicate that the impact of environmental regulation is weaker in the large region but stronger in the small region. I further develop a spatial economy model with emissions as a negative externality in the light of firm heterogeneity. I simulate the model and find the effects of environmental regulation on the investment in firms' creation depends on the regions' size. Specifically, the impact of environmental stringency on the number of firms is stronger in the small region compared with the impact in the large region. The result is consistent with the empirical findings.

The third chapter provides empirical evidence of the effects of import competition from China on emissions in the US. Using the Risk-Screening Environmental Indicators (RSEI) derived from the Toxic Release Inventory (TRI), I examine the effects of import competition from China on environmental performance in the US at industry level and commuting-zone level. Environmental performance is measured by pounds released and hazard. Hazard is an indicator of the discharged chemicals' toxicity. The main results indicate that the US import exposure from China significantly decreases pounds released and hazard at the industry level. I construct the difference between actual and counterfactual emissions. Results suggest that Chinese import competition results in losses of 35.7 million and 82.9 million pounds released over two subperiods 1991-1999 and 1999-2007. It also results in losses of 0.714 trillion and 2.29 trillion units in hazard over these two periods. Using data at the commuting-zone level, I find the US import exposure from China decreases pounds released per employment and hazard per employment but the estimates are statistically insignificant.

Chapter 1

Environmental Regulation and Performance of Chinese Manufacturing Firms

1.1 Introduction

The consumption of large amount of fossil fuel has driven the rapid development of the Chinese economy, contributing to high emissions of SO_2. From 2000 to 2005, the total emissions of SO_2 increased by approximately 27.5%. There are concerns that severe environmental pollution may slow economic growth.[1] On the other hand, regulations designed to improve air quality may affect firms' performance through adjustments in productivity, export status, and investments.[2] This paper explores if and how firms adjust markups, prices relative to marginal production costs, to respond to changes in environmental regulation.

To answer this research question, we address two key identification challenges. First, markups are not directly observable in standard data sources. Instead, they must be estimated. We use data from the Annual Survey of Industrial Firms between 1998 and 2007 to estimate firm-level markups that vary over time applying standard approaches from

[1] Chinadialogue: "The terrible cost of China's growth", source)

[2] Studies include but are not limited to [38], [36], [46], [11], [6], [3], [41], [10], [51], [37], [4], [2], [28], [43]

the existing literature ([25], [12]). A key advantage of our data sources is that we can observe firm-level revenues and quantities.[3]

The second identification challenge is that economies are prone to multiple environmental regulations that are not simultaneously observable ([15]). In general, available environmental regulation (abatement costs) is correlated with potentially unobserved factors in determining markups ([39]). In linear regressions, this challenge raises concerns of omitted variable bias. To address these concerns, we exploit the unique identifying variation provided by China's Eleventh Five Year Plan. Introduced in 2006, the Eleventh Five Year Plan mandated SO_2 reduction targets, which vary across provinces. We exploit this variation in difference-in-difference and triple-differenced specifications. Conditional on the parallel trends hypothesis, i.e., firm-level markups follow similar trends before the Five-Year Plan, this approach mitigates concerns about omitted variable bias.

Our results show that a more stringent environmental policy results in lower markups. Specifically, the analysis in this paper indicates that markups fall by 0.38 percent when the SO_2 reduction target is one standard deviation above the mean, suggesting that firms bear a substantial amount of the environmental regulation costs in terms of lower profitability. In addition, the results imply that adjustments in markups are important to understand the environmental regulation's consequences. Our results also suggest that environmental regulation has distributional consequences. The Five Year Plan significantly decreases non-exporters' markups but has no impact on exporters' markups.

We perform several robustness checks and examine the validity of our difference-in-difference approach. If the firm in the control group already charges different markups than the firm in the treatment group before this plan's implementation, our difference-in-difference estimates are biased. To address this concern, we examine trends in markups of firms located in the provinces with stricter reduction targets and those located in the provinces with laxer reduction targets. Based on our data, both groups of firms follow the same trend before the policy's implementation. However, the results also reveal some heterogeneity across different ownership. State-owned enterprises and non-SOEs responded differently in anticipation of

[3]Unfortunately, we do not observe detailed product level information which prevents the application of the more novel [23] approach.

the Eleventh Five-Year Plan. SOEs did not change their markups for the upcoming policy while non-SOEs did. Finally, an additional concern is that other province-level policies were implemented at the same time, resulting in an omitted variable bias. To examine this concern, we eliminate six provinces that were impacted by the Beijing Blue Sky Project.

This paper contributes to the discussions exploring the effects of environmental regulation on firms' performance in several ways. The environmental literature has a long tradition of examining environmental stringency's impact on productivity ([4], [28], [18]). However, environmental regulation's effect on markups has not been extensively examined ([69]). Existing literature outside of environmental economics clarifies the importance of studying markups as an aspect of firm performance to examine regulation's economic effects ([24]). In fact, productivity estimates that do not account for changes in prices and markups may end up convoluting productivity with markup effects. To avoid these estimation problems, our approach separates markup changes from productivity changes. Our results show that even if firms become more efficient as suggested by the Porter Hypothesis, they pay at least part of the regulation in terms of lower markups.

As far as we know, our results present the first direct empirical evidence on the impacts of environmental regulation on markups. [53] find that ignoring environmental regulation will overstate 12% of market power measured by markups in Korea's steel industry. [67] find 1990 Clean Air Act Amendments (CAAA) Amendment led to an increased entry cost, resulting in a welfare loss of about $810 million. His result implies markups need to be high to cover high fixed costs. [71] find the impact of 1990 CAAA has the opposite impact on markups in reformulated gasoline products and low sulfur diesel products. All those studies focus on developed countries and use structural models to simulate counterfactuals, which is to compare the changes in markups before and after environmental regulation was implemented. Instead, we employ detailed firm-level data to measure markups and to estimate the relationship directly.

Finally, this paper contributes to a large amount of literature analyzing relationships among environmental regulation, pollution, and exports. [64] and [70] provide evidence that environmental regulation in China adversely impacts export volume at the firm and sector levels. However, [66] provide evidence that, for the time between 1999-2005, entry into export markets is associated with a decrease in physical emission-intensity. Therefore, exporters may have employed technology to mitigate environmental externalities before the Eleventh Five-Year Plan was implemented. In this case, we expect that exporters and non-exporters respond differently to changes in environmental regulation. We provide evidence that exporters do not adjust markups in response to the Eleventh Five Year Plan.

The paper proceeds as follows. Section 2 discusses the related literature and background of the Eleventh Five-Year Plan. In section 3, we present data and the measure of markups. Section 4 shows the main specifications. Section 5 shows the results. Section 6 is the conclusion of this paper.

1.2 Background

1.2.1 Related literature

Some theories predict the reaction of markups to different types of competitive forces. Most of them consider the effects of commercial policy, especially trade policy ([74]). Trade models with imperfect competition use profit maximization to determine firms' pricing decisions. Hence, the markups are the decreasing function of the elasticity of demand. When trade liberalization increases the elasticity of demand, markups will fall. [5] find the firms charge lower prices and markups when the market becomes more competitive. He also finds firms will increase their markups if the range of products' quality differentiation increases. The overall impact on markups depends on firm productivity. Empirical studies evaluate the impact of various trade policies on firm-level markups. [23] and [12] find cutoff in input tariff raises markups. In [12], they find new evidence that cutoff in output tariff reduces markups.

However, we have little theoretical and empirical evidence on how markups respond to environmental policy. [67] estimate a dynamic structural model to evaluate the impact of the 1990 Clean Air Act Amendments (CAAA) on the Portland cement industry. He finds the marginal cost didn't change with the regulation, but prices became higher, which results in higher markups. [71] estimate the impact of CAAA to the refined petroleum product markets. He finds refineries producing reformulated gasoline observed markups increase, and refineries producing low sulfur diesel saw markups decrease. [31] assess firms' incentive to adjust markups triggered by emissions cost shocks in the Spanish electricity market. They find firms have a weak incentive to adjust markups after the cost shocks. The result can be explained by the highly inelastic demand in the electricity market. Previous literature uses structural models to simulate policy counterfactuals while not provide direct empirical evidence. Based on [31], firms may adjust markups differently across industries after the environmental regulation shock. Our goal is to make clear how environmental regulation impacts markups by providing empirical support.

1.2.2 Background on sulfur dioxide control in China

In the past 30 years, the Chinese government has implemented many measures to control SO_2 emissions. The first complete environmental legislation to control the SO_2 was conducted in 1987 and was established in the Law "Preventing and Controlling Atmospheric Pollution". In 1998, the state council implemented "Acid Rain and Sulfur Dioxide Emission Zones",[4] which is a new policy to control sulfur dioxide emissions. However, these environmental policies failed to yield expected outcomes for multiple reasons. First, the pollution fee for SO_2 was much lower than average abatement costs ([48]),[5] resulting in firms' paying the pollution fee instead of reducing emissions. Second, these policies did not specify which government department was responsible for supervising the implementation, leaving these measures with little impact. As a result, the total emissions of SO_2 in China increased by approximately 27.5% between 2000 and 2005.

To control for the pollution, the Chinese government implemented the Eleventh Five-Year Plan in 2006, establishing reduction targets that varied across provinces to control SO_2 emissions. As an important part of national economic planning, this plan sets goals and directions for major national construction projects, distribution of productive forces, and the national economy's development. China implemented the First Five-Year Plan in

[4]From the document "The Official Reply of the State Council Concerning Acid Rain Control Areas and SO_2 Pollution Control Areas."

[5]The levy for SO_2 was 0.09 USD/kg in 2005, while the average abatement costs were around 0.7 USD/kg

1953. The Eleventh Five-Year Plan was the first Five-Year Plan that established specific sulfur dioxide reduction targets and an evaluation scheme for each province and province-equivalent municipality. The Eleventh Five-Year Plan established 22 goals covering four major areas: economic growth, economic structure, public service and population, and resource and environment. One of the goals is to reduce the total discharge of SO_2 to 10% by 2010. Since the government failed to control the emissions of SO_2 in the Tenth Five-Year Plan, attaining the goal in the Eleventh Five-Year Plan become a political task ([77]).

To achieve the goals set by the Eleventh Five-Year Plan, provinces and province-equivalent municipalities share the burden in terms of the national goal. Provincial governments signed pollution mitigation contracts and committed to achieving the reduction target ([76]). Table 1.1 summarizes SO_2 emissions and reduction targets for each province and province-equivalent municipality. According to the document published by the State Council, the allocation principle of totally controlling SO_2 was based on each province's environmental quality and past emission levels (Figure 1.1).

Table 1.1: Provincial SO_2 reduction target

Province	Emission (2005)	Targeted Emission (2010)	Reduction target (2006)	Actual emission (2010)
North China				
Beijing	19.1	15.2	20.4%	11.5
Tianjin	26.5	24.0	9.4%	23.5
Hebei	149.6	127.1	15.0%	123.5
Shanxi	151.6	130.4	14.0%	124.9
Inner Mongolia	145.6	140	3.8%	139.4
Northeast				
Liaoning	119.7	105.3	12.0%	102.2
Jilin	38.2	36.4	4.7%	35.6
Heilongjiang	50.8	49.8	2.0%	49.0
East China				
Shanghai	51.3	38.0	25.9%	35.8
Jiangsu	137.3	112.6	18.0%	105.0
Zhejiang	86.0	73.1	15.0%	67.8
Anhui	57.1	54.8	4.0%	53.2
Fujian	46.1	42.4	8.0%	40.9
Jiangxi	61.3	57.0	7.0%	55.7
Shandong	200.3	160.2	20.0%	153.8
Central South				
Henan	162.5	139.7	14.0%	133.9
Hubei	71.7	66.1	7.8%	63.3
Hunan	91.9	83.6	9.0%	80.1
Guangdong	129.4	110.0	15.0%	105.1
Guangxi	102.3	92.2	9.9%	90.4
Hainan	2.2	2.2	0%	2.9
Southwest				
Chongqing	83.7	73.7	11.9%	71.9
Sichuan	129.9	114.4	11.9%	113.1
Guizhou	135.8	115.4	15.0%	114.9
Yunnan	52.2	50.1	4.0%	50.1
Tibet	0.2	0.2	0%	0.4
Northwest				
Shannxi	92.2	81.1	12.0%	77.9
Gansu	56.3	56.3	0%	55.2
Ningxia	34.3	31.1	9.3%	31.1
Qinghai	12.4	12.4	0%	14.3
Xinjiang	51.9	51.9	0%	58.8
Total	2549.4	2246.7	11.9%	2185.1

Notes: Data is collected from "Reply to Pollution Control Plan During the Eleventh Five-Year plan" maintained by China State Council. Unit: 10,000 Tons.

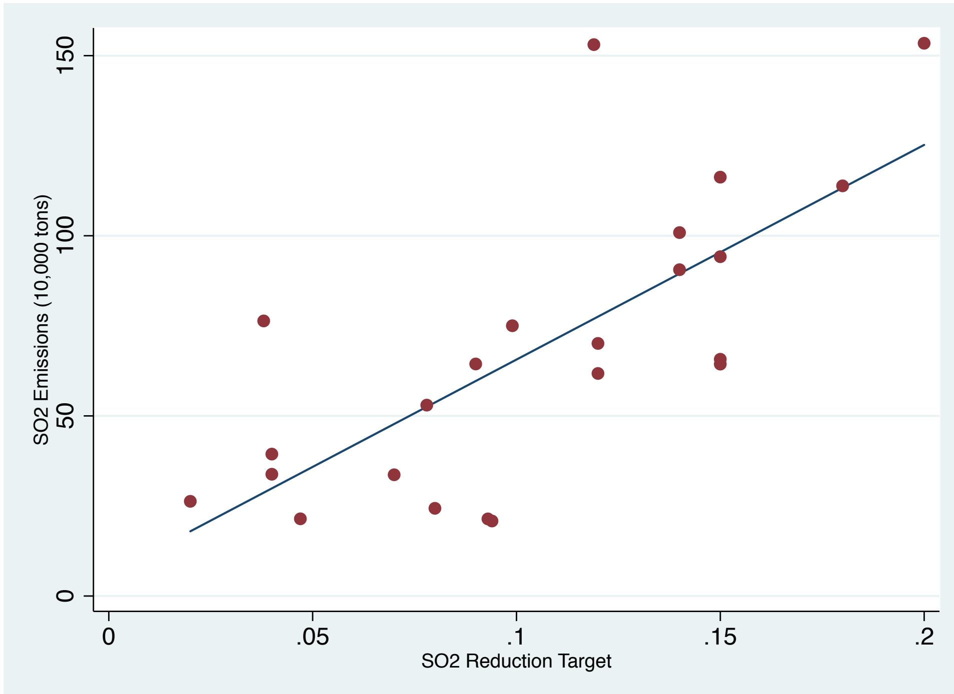

Figure 1.1: Relationship between SO_2 emissions and reduction target

To achieve the reduction goal, central and local governments had used multiple tools, including administrative instruments, command and control, and market-based. First, the state council reformed SO_2 levy. The new levy was imposed on the total emissions of SO_2 instead of those above the threshold. Second, the levy was increased from 0.033 USD/kg in 1998 to 0.196 USD/kg in 2006 (MEP and US EPA 2007).

The second measure to reduce the total amount of SO_2 emissions was to hasten and strengthen the supervision and construction of desulfurization facilities in existing and newly built coal-fired power plants. A coal-fired plant exceeding the national SO_2 emission standard must install a desulfurization facility. The new and expanded coal-fired power plant had to build the reserve denitration sites and desulfurization facilities simultaneously. To encourage the installation of desulfurization technology, many local governments have applied a price premium for those plants who installed facilities. In large and medium-sized cities and their suburbs, the new and expanded construction of coal-fired plants is strictly controlled. The reform on desulfurization facilities has impacted those firms with coal-fired power plants that work with metal products, non-metallic mineral products, raw chemical materials and chemical products, ferrous metals, and non-ferrous metals. At the end of 2010, the installed capacity of desulfurization facilities was 576 million kilowatts, and the proportion of desulfurization facilities had increased from 12% to 82.6.%[6] The electric and heat power industry decreased SO_2 emissions by 22.9% and achieved 74% reduction toward the national target during the Eleventh Five-Year Plan.[7]

Beginning with the Eleventh Five-Year Plan, the central government published "The Environmental Quality Administrative Leadership Accountability System" and announced that achieving the reduction target was one of the criteria for promoting local leaders ([68]). For the first time, the province's performance to achieve the SO_2 reduction target was linked with local leaders' promotion ([54]). This announcement enhanced the achievement of the SO_2 reduction in the Eleventh Five-Year Plan from a political aspect.

1.3 Data

1.3.1 Firm-level data and markups

The main data used in this study come from the Annual Surveys of Industrial Firms (ASIF) over the period 1998-2007.[8] ASIF includes all SOEs and non-stated-owned industrial firms with sales of more than 5 million RMB (about $700,000). It provides the most detailed firm-level data of the Chinese firm. An average of 200,000 firms per year was included. Firms covered in the ASIF produce 85-90% of China's industrial value-added and cover 20% of China's urban employment ([45]). Researchers have widely used this data in recent years ([56], [13], [14], [57], [12], and [70]).

The ASIF provides two types of information about firms. The first type includes ID number, name, ownership, industry affiliation, start date, and location. The second type covers firms' production sales and financial information including, but not limited to, industrial output value, industrial sales, long-term investment, paid-up capital, fixed assets'

[6] http://politics.people.com.cn/n/2013/1015/c70731-23206224.html

[7] National Bureau of Statistics: Environmental Statistics

[8] The ASIF data is used in collaboration with my coauthor Shanshan Ying from Shanghai University of Economics and Finance, the School of Economics. The results and data are based on our joint working paper "Environmental Regulation and Performance of Chinese Manufacturing Firms".

net value, export, wage, employment, and intermediate materials. Some firms have missing observations for some variables. To obtain a clean sample, we follow the procedure in [12] and the Generally Accepted Accounting Principles (GAAP) to delete the following observations: firms with missing key variables (including output, inputs, net fixed assets, and total assets, employment); firms with total assets less than the net value of fixed assets; firms with total assets less than total fixed assets; firms with total assets less than liquid assets; firms with multiple identification numbers; firms with negative interest payment; and firms with employment less than 8 employees.

We use the unique ID number to match the firm over time. For some conditions, a firm receives a new ID if it has been merged or restructured. An additional step links the firm with its legal representative's name, phone number, and zip code to ensure we correctly identify those firms. To handle alternations in the 2003 Chinese Industry Classification, we follow [12] and convert codes between 1998-2002 to a new classification system to maintain the consistency in industry codes. Also, firms' markups are incomparable if they switched industry over the sample period. We eliminate firms that switched between 4-digit industries at least once. Each firm's registered type is used to construct ownership. In China, there are four major types: state, domestic private,[9] foreign, and HMT (firms from Hong Kong, Macao, and Taiwan). Our final data consist of 978,676 observations, spanning 422 four-digit manufacturing industries, 10 years, and 25 provinces and province-equivalent municipalities.[10] Table 1.2 provides summary statistics for the sample data.

[9] Domestic private owned firm includes village and township enterprises and collectively owned firms [12].

[10] The data includes 4 municipalities: Beijing, Tianjin, Shanghai, Guangzhou.

Table 1.2: Summary statistics

Year	Number of firms	Output	Employment	Export	Intermediate materials	Net value of fixed assets
1998	58,698	4.02	31.3	0.66	3.10	3.92
1999	73,168	4.94	35.3	0.85	3.80	4.40
2000	70,307	5.74	34.5	1.03	4.50	4.76
2001	60,725	5.79	29.9	0.84	4.47	5.00
2002	71,873	7.39	34.4	1.34	5.68	5.39
2003	77,319	9.42	36.9	1.80	7.24	6.02
2004	111,843	12.1	39.6	2.52	9.23	6.77
2005	137,636	16.3	45.8	3.21	12.40	8.23
2006	162,878	20.5	49.1	3.98	15.60	9.55
2007	154,229	24.4	47.3	4.35	18.50	11.30
Total	978,676					

Data source: Annual Sales Industrial Firms. All values are denoted in billion RMB and employment in millions of workers.

Markups are defined as the price-cost ratio. As in [25] and [12], we derive markups, which are obtained using output, revenue, and expenditures of firm-level inputs. The methodology relies on standard cost minimization conditions for variable inputs free of adjustment costs. The production function for a firm i at time t is :

$$Q_{it} = Q_{it}(X_{it}^1, ..., X_{it}^V, K_{it}, \omega_{it}) \tag{1.1}$$

The production relies on V inputs including capital (K_{it}), labor, and intermediate inputs. ω_{it} denotes firm-level productivity. We assume producers are cost-minimizing and define markups as $u_{it} = \frac{P_{it}}{\lambda_{it}}$, where P_{it} is input price and λ_{it} is marginal cost. Since the labor choice is, to some extent, constrained by government policy in China and the use of capital is more dynamic, we use intermediate materials as the variable input. When firms are cost-minimizing, the Lagrangian function is:

$$L(L_{it}, M_{it}, K_{it}, \lambda_{it}) = P_{it}^L L_{it} + P_{it}^M M_{it} + r_{it} K_{it} + \lambda_{it}(Q_{it} - Q_{it}(L_{it}, M_{it}, K_{it}, \omega_{it}) \tag{1.2}$$

where P_{it}^{L}, P_{it}^{M}, and r_{it} are prices for labor, intermediate materials and capital. The first-order condition for intermediate materials is:

$$\frac{\partial L_{it}}{\partial M_{it}} = P_{it}^{M} - \lambda_{it}\frac{\partial Q_{it}}{\partial M_{it}} = 0 \tag{1.3}$$

Rearranging function 1.3 and multiplying $\frac{M_{it}}{Q_{it}}$ on both sides generate the subsequent equation:

$$\frac{\partial Q_{it}}{\partial M_{it}}\frac{M_{it}}{Q_{it}} = \frac{1}{\lambda_{it}}\frac{P_{it}^{M}M_{it}}{Q_{it}} \tag{1.4}$$

$\frac{\partial Q_{it}}{\partial M_{it}}\frac{M_{it}}{Q_{it}}$ is the output elasticity of intermediate materials. θ_{it}^{M} is used to denote it. λ_{it} is production's marginal cost. We then multiply both the denominator and the numerator on the right hand of the equation by P_{it}. The markup can be derived as in the following form:

$$u_{it} = \frac{\theta_{it}^{M}}{\alpha_{it}} \tag{1.5}$$

where α_{it} is the ratio of intermediate materials' expenditures in firm's sales, and $\alpha_{it} = \frac{p_{it}^{V}V_{it}}{P_{it}Q_{it}}$. Information on α_{it} is available from the data. To obtain the measure of θ_{it}^{M}, we estimate the production function to derive the output elasticity of intermediate materials. We use a Cobb-Douglas production function:

$$q_{it} = f(l_{it}, m_{it}, k_{it}; \beta) + \omega_{it} + \epsilon_{it}$$

where

$$f(l_{it}, m_{it}, k_{it}; \beta) = \beta_{l}\tilde{l}_{it} + \beta_{m}\tilde{m}_{it} + \beta_{k}\tilde{k}_{it} \tag{1.6}$$

We estimate the output elasticity of inputs β_l, β_m, and β_k across firms in the two-digit sector. Labor is measured by the number of workers. We use fixed assets' net value as the measure of capital. The intermediate materials' value is the measure of inputs. Nominal values of intermediate materials and capital are deflated by sector-level price indices provided by [12].

1.3.2 Aggregate emissions

The second dataset for this analysis is SO_2 emissions by industry and province from 1998-2007. We downloaded the data from the China Statistical Yearbook. We follow the industry concordance provided in [13] to link the four-digit CIC code to the two-digit sector code. We collect the SO_2 reduction target from the document named "Reply to Pollution Control Plan During the Eleventh Five-Year Plan".[11] Table 1.3 shows the SO_2 emissions in the two-digit sector level.

Table 1.3: SO_2 emissions by sector

Sector	2005	2010
Processing of Food from Agricultural Products	15.6	16.93
Manufacture of Foods	9.4	11.56
Manufacture of Beverages	10.7	11.18
Manufacture of Tobacco	1.31	1.00
Manufacture of Textile	29.6	24.72
Manufacture of Textile Wearing Apparel, Footwear, and Caps	1.5	1.12
Manufacture of Leather, Fur, Feather and Related Products	2.1	1.40
Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products	4.8	3.26
Manufacture of Furniture	0.4	0.22
Manufacture of Paper and Paper Products	43.1	50.82
Printing,Reproduction of Recording Media	0.2	0.30
Manufacture of Articles For Culture, Education and Sport Activity	0.3	0.11
Processing of Petroleum, Coking, Processing of Nuclear Fuel	70.9	63.53
Manufacture of Raw Chemical Materials and Chemical Products	116.8	104.00
Manufacture of Medicines	6.4	7.94
Manufacture of Chemical Fibers	11.5	10.69
Manufacture of Rubber	4.4	3.95
Manufacture of Plastics	1.3	2.95
Manufacture of Non-metallic Mineral Products	178.4	168.62
Smelting and Pressing of Ferrous Metals	142.2	176.65
Smelting and Pressing of Non-ferrous Metals	70.7	80.33
Manufacture of Metal Products	2.6	3.5
Manufacture of General Purpose Machinery	5.5	5.05
Manufacture of Special Purpose Machinery	3.3	3.91
Manufacture of Transport Equipment	4.1	3.39
Manufacture of Electrical Machinery and Equipment	2.7	1.35
Manufacture of Communication Equipment, Computers and Other Electronic Equipment	1.7	0.65
Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work	1.3	0.14
Manufacture of Artwork and Other Manufacturing	0.5	0.88
Total	743.31	760.15

Notes: Data is collected from China Statistical Yearbook. Unit of emission: 10,000 Tons. www.stats.gov.cn

[11] All emissions data were manually collected from China Statistical Yearbook. The table number is different in each year, e.g., in 1998, province-level SO_2 is reported under 21-61, and industry-level SO_2 is reported under 21-65.

1.4 Empirics

In this section, we identify the impact of the Eleventh Five-Year Plan on the markups of Chinese manufacturers. Y_{fpt} denotes the log level of markup of firm f located in province p charges in year t. Our difference-in-difference specification is:

$$Y_{fpt} = \beta(Post_{2006} \cdot Target_p) + X_{ft}^{'}\delta + \gamma_f + \lambda_t + \varepsilon_{fpt} \tag{1.7}$$

where $Post_{2006}$ is a time dummy variable, which equals 0 before 2006 and 1 after 2006. $Target_p$ is the SO_2 reduction target in province p. To isolate the SO_2 reduction policy's effect, we consider a set of firm characteristics, X_{ft}, that might impact firms' performance including employment, lagged employment, export status, and age. The regression function includes firm fixed effects, γ_f, to control for all time-invariant differences across firms. Note that firms do not change locations. Therefore, firm fixed effects also account for all province-level characteristics that do not change over time. λ_t is the year fixed effect. ε_{fpt} is an error term. β measures the impact of the Eleventh Five-Year Plan on firms' performance measured by markups. To deal with the heteroskedasticity and serial correlation, we cluster the standard errors at the firm level.

The difference-in-difference specification's validity is based on two assumptions. First, markups of firms should follow the same time trends in both the treatment group and the control group before the Eleventh Five-Year Plan was implemented. The identifying assumption associated with the difference-in-difference estimation is that the regressor of interest is uncorrelated with the error term:

$$E[\varepsilon_{fpt}|Post_{2006} \cdot Target_p, X_{ft}, \gamma_f, \lambda_t] = E[\varepsilon_{fpt}|X_{ft}, \gamma_f, \lambda_t] \tag{1.8}$$

To examine our difference-in-difference strategy's validity, we plot the time trends of markups in figure 1.2, which compares the markups of a firm located in a province with a high SO_2 reduction target and a firm in a province with a low SO_2 reduction target. The result shows that the markups of firms in two groups followed the same trend during the pre-policy period and then diverged. The parallel pretreatment trend mitigates our concern that the two groups are incomparable.

Second, the difference-in-difference strategy's validity hinges on the assumption that no other regulation or policy impacts treatment group and control group differentially when the Eleventh Five-Year Plan was implemented. One environmental policy that was enacted during the same period was the Beijing Blue Sky Project. To evaluate this project's potential effect, we exclude targeted provinces covered by the project to determine whether the concurrent event impacts our estimation.

Next we extend our specification to accommodate anticipation effects ([57], [70]). China's central government has written a new Five-Year Plan every five years since 1953. Local governments are aware of the content in the new Plan before it is implemented.[12] Because the Eleventh Five-Year Plan is the first to set strict emission-reduction targets, the government's goal was to encourage firms to implement technological innovation and offset environmental regulation's adverse effects on corporate profit through innovation compensation. Firms may anticipate each new Five-Year Plan and adjust their behavior to avoid strict punishment if they fail to achieve the goal.

As a check, we include additional controls and estimate the following equation:

$$\begin{aligned} Y_{fpt} = &\beta_1 \cdot Post_{2006} \cdot Target_p + \beta_2 \cdot Post_{2005} \cdot Target_p + \beta_3 \cdot Post_{2004} \cdot Target_p \\ &+ \beta_4 \cdot Post_{2003} \cdot Target_p + X'_{ft}\beta + \gamma_f + \lambda_t + \varepsilon_{fpt} \end{aligned} \tag{1.9}$$

Thus, we can investigate whether the firm changed its behavior before the Eleventh Five-Year Plan was implemented.

To examine whether this plan differently impacted industries with different emission intensities, we estimate the Plan's impact on firms' performance by conducting a triple differenced estimation. We compare the change of firms' performance in higher reduction target provinces and more polluting industries after 2006 to the change in firms located in lower reduction target provinces and less polluting industries (for a similar approach, [57],

[12]In 2005, the Communist Party held the Fifth Plenary Session of the 16th Central Committee Conference. On behalf of the Political Bureau of the Central Committee, the Prime Minister made a note on "the formulation of the Eleventh Five-Year Plan for national economic and social development". The note is a draft for the Eleventh Five-Year Plan. Source: State Council.

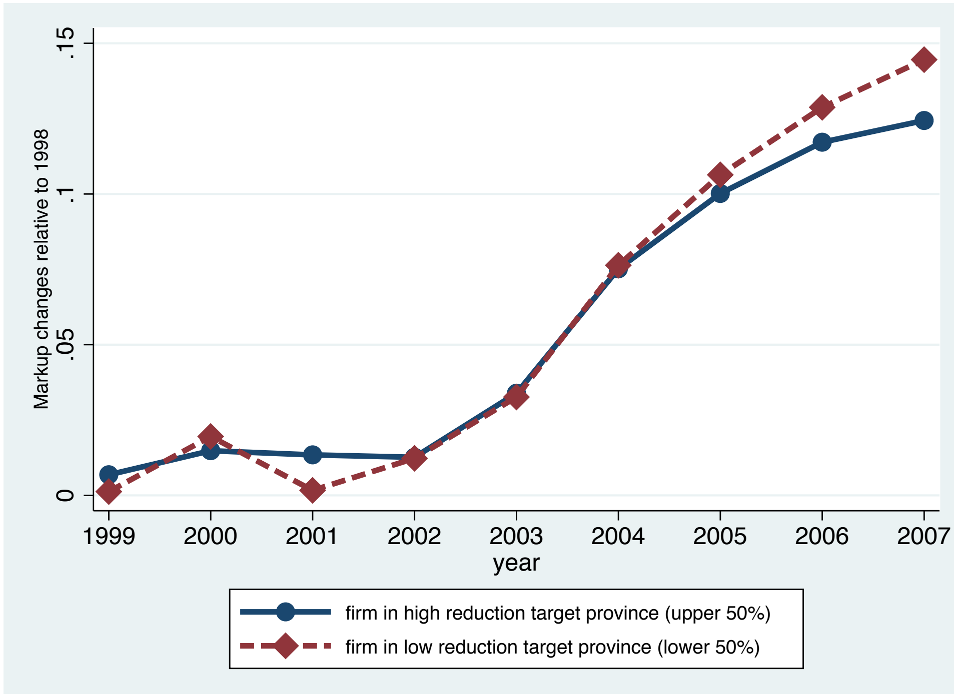

Figure 1.2: Changes of firms markups: Difference-in-difference

[70], [75]). The following is the specification for the triple differenced estimation:

$$Y_{fipt} = \beta \cdot Post_{2006} \cdot Target_p \cdot SO2_i + X'_{ft}\delta + \gamma_{it} + \lambda_{pt} + \theta_{pi} + \varepsilon_{fipt} \tag{1.10}$$

where SO2_i is the average SO_2 emission level in industry i over 1998-2005. The regression function controls for industry-specific year effects that are common across provinces γ_{it}, time-varying province effects λ_{pt}, and province-specific industry effects θ_{pi}. ε_{fipt} is an idiosyncratic error term. The main coefficient β measures the Eleventh Five-Year Plan's impact on firms' markups. This coefficient was identified based on the correlation between markups' average growth rate across all firms in industry i and province p *and* the level of reduction target imposed on province p. We cluster standard errors at the firm level.

As in the previous difference-in-difference estimation, the identifying assumption associated with triple-differenced estimation is that the regressor is uncorrelated with the error term:

$$E[\varepsilon_{fipt}|Post_{2006} \cdot Target_p \cdot SO2_i, X_{ft}, \gamma_{it}, \lambda_{pt}, \theta_{pi}] = E[\varepsilon_{fipt}|X_{ft}, \gamma_{it}, \lambda_{pt}, \theta_{pi}] \tag{1.11}$$

To examine the validity of triple-differences, we plot the markups' time trends in figure 1.3. The pretreatment trend in markups mitigates our concern that the two groups are ex-ante incomparable. Also, to capture the concurrent event's effects, we examine other policy differentially targeted treatment and control groups by controlling for the Beijing Blue Sky Project. Finally, we check the expectation effect by running the following regression:

$$\begin{aligned} Y_{fipt} =& \beta_1 \cdot Post_{2006} \cdot Target_p \cdot SO2_i + \beta_2 \cdot Post_{2005} \cdot Target_p \cdot SO2_i + \beta_3 \cdot Post_{2004} \\ & \cdot Target_p \cdot SO2_i + \beta_4 \cdot Post_{2003} \cdot Target_p \cdot SO2_i + X'_{ft}\beta + \gamma_{it} + \lambda_{pt} + \theta_{pi} + \varepsilon_{fipt} \end{aligned} \tag{1.12}$$

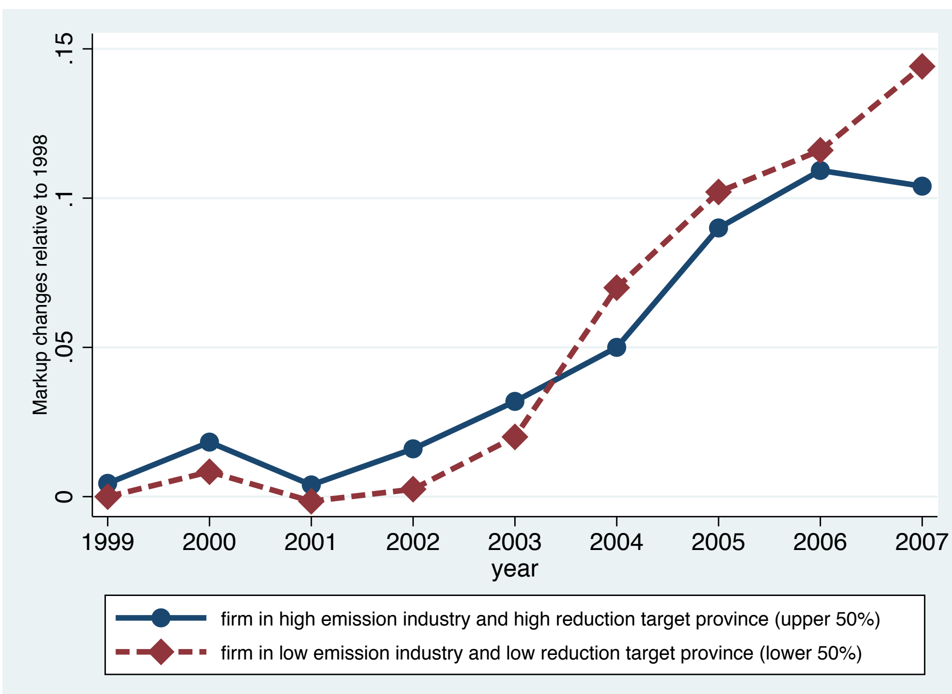

Figure 1.3: Changes of firms markups: Triple differenced

1.5 Findings

1.5.1 Main results

Table 1.4 shows the main results for the estimation in Eq. 1.7, which implies the Eleventh Five-Year Plan's effect on firm-level markups. Column 1 starts with a simple specification without any time-varying firm characteristics. The regressor is statistically significant at 1% level and negative, implying that firms' markups decreased more in provinces with greater reduction targets after 2006 than those previously located in provinces with lower reduction targets. In column 2, we add some time-varying firm characteristics, including firms' employment, export indicator, and age, that may correlate with markups. With these additional controls, the result remains robust. In column 3, we substitute employment for lagged employment. Our results remain negative and statistically significant. The implication is that firms' markups are 0.38% lower if the SO_2 reduction target is one standard deviation above the mean.[13] The export indicator's coefficient implies exporters have lower markups compared with non-exporters. This result is inconsistent with the finding in [25] that, on average, exporters charge higher markups than non-exporters. To explain this inconsistency, we found nearly half of China's exports rely on processing trade, making it hard for exporters to charge higher markups.

[13] The mean of province-level SO_2 reduction target is 9.65, and the standard deviation is 6.81. We use the function provided by [70], $\Theta = \hat{\beta} ln(target_{mean} + target_{sd}) - \hat{\beta} ln(target_{mean})$, to derive quantified results. $\hat{\beta}$ is the estimated coefficient in Eq. 1.7; $target_{mean}$ and $target_{sd}$ are average reduction target and the standard deviation of reduction target respectively; Θ is the change of firms performance measured by markups.

Table 1.4: Effects of environmental regulation: Difference-in-difference

	(1)	(2)	(3)	(4)
Markups				
$Post_{2006} * Target_p$	-0.0072***	-0.0070***	-0.0072***	-0.0051***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Employment		-0.0058***		
		(0.0011)		
Employment_{t-1}			-0.0001	-0.00002
			(0.0001)	(0.0001)
Age		-0.0016***	-0.0018***	-0.0021***
		(0.0004)	(0.0004)	(0.0004)
Export Indicator		-0.0011*	-0.0012*	-0.0004
		(0.0006)	(0.0006)	(0.0007)
R-squared	0.722	0.722	0.722	0.722
Firm fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Control for Olympic Games	No	No	No	Yes
Observations	978,676	978,676	978,676	851,192

Notes: All specifications are regressed with firm and year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.5 presents the results for triple-differenced estimation. From column 1 through 3, all regressors remain negative and statistically significant. The result in column 3 implies, if the SO_2 reduction target is one standard deviation above the mean, markups are 1.18% lower for a firm in an industry with SO_2 emissions 10% above the mean.[14]

[14] The formula is $\Theta = \hat{\beta} ln(target_{mean} + target_{sd}) ln(SO2_{mean}(1+10\%)) - \hat{\beta} ln(target_{mean}) ln(SO2_{mean})$. $SO2_{mean}$ is the average SO_2 emissions in two-digit industry level between 1998-2005, and $SO2_{mean}$=90.49 in 10,000 tons.

Table 1.5: Effects of environmental regulation: Triple differenced

	(1)	(2)	(3)	(4)
Markups				
$Post_{2006} * Target_p * SO2_i$	-0.0044***	-0.0042***	-0.0044***	-0.0033***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Employment		0.0033***		
		(0.0002)		
Employment_{t-1}			0.0016***	0.0018***
			(0.0001)	(0.0002)
Age		0.0036***	0.0036***	0.0034***
		(0.0002)	(0.0002)	(0.0002)
Export Indicator		-0.0019***	-0.0023***	-0.0018***
		(0.0005)	(0.0005)	(0.0005)
R-squared	0.384	0.385	0.385	0.386
Province by Industry fixed effects	Yes	Yes	Yes	Yes
Industry by Year fixed effects	Yes	Yes	Yes	Yes
Province by Year fixed effects	Yes	Yes	Yes	Yes
Control for Olympic Games	No	No	No	Yes
Observations	978,676	978,676	978,676	851,192

Notes: All specifications are regressed with province by industry, province by year, and industry by year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

1.5.2 Robustness checks

To bid for the 2008 Beijing Olympic Games, the Beijing government promised the International Olympic Committee that the concentration of sulfur dioxide, nitrogen dioxide, and ground-level ozone would meet the World Health Organization's standard. After Beijing won the right to host the Olympic Games, it implemented the Beijing Blue Sky Project, which aimed to decrease emissions of the main pollutants in Beijing and nearby provinces. Targeted provinces included Shanxi, Hebei, Liaoning, Tianjin, and Inner Mongolia. To control for the ongoing policy, we exclude six targeted provinces and municipalities in difference-in-difference estimation and report results in table 1.4 column 4. The result is statistically significant, implying that, after controlling for this event, markups are 0.27% lower if the reduction target is one standard deviation above the mean.

We also control the Beijing Blue Sky Project in our triple-differenced estimation in table 1.5, column 4. The result remains negative and statistically significant. It implies if the reduction target is one standard deviation above the mean, markups are 0.89% lower for the firm in an industry with SO_2 emissions 10% above the mean.

1.5.3 Heterogeneous effects

We have already established that the Eleventh Five-Year Plan decreases firms' performance measured by markups. In this section, we evaluate the heterogeneous effects by examining how the markups respond to the policy in terms of their export status and ownership.

Export status [66] find that China's exports grew faster in emission-intensive industries. However, exporters can alleviate pollution through product technology. Between 1999 and 2005, starting export was predicted to decrease physical emission-intensity by 10% to 30% for the average exporter, indicating that exporters were employing technology to mitigate these environmental externalities before the Eleventh Five-Year Plan. In this case, exporters and non-exporters should respond differently when they face environmental regulation involving the same stringency. Thus, in addition to the primary effect, we investigate whether this plan's impact on the performance of firms varied across their export status by comparing exporters' and non-exporters' markups.

In table 1.6, we divide firms based on their export status regarding the difference-in-difference specification. The results show that the Eleventh Five-Year Plan had a significant negative impact on both exporters and non-exporters. Column 2 of Table 1.6 explains the negative relationship between the implementation of air pollution control policy and China's export volumes as reported in [70] and [64]. The results in column 2 and 3 imply the impact of the Eleventh Five-Year Plan is stronger for non-exporters compared with exporters. The results imply if the reduction target is one standard deviation above the mean, exporters' markups are 0.31% lower while non-exporters' markups are 0.43% lower.

Table 1.6: Effects of environmental regulation: Difference-in-difference by export status

	All (1)	Exporter (2)	Non-exporter (3)
Markups			
$Post_{2006} * Target_p$	-0.0072***	-0.0058***	-0.0080***
	(0.0009)	(0.0021)	(0.0010)
Employment_{t-1}	-0.0001	0.0003	-0.0002
	(0.0001)	(0.0002)	(0.0002)
Age	-0.0018***	-0.0004	-0.0024
	(0.0004)	(0.0007)	(0.0004)
Export Indicator	-0.0012*		
	(0.0006)		
R-squared	0.722	0.730	0.720
Firm fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Time-varying firm characteristics	Yes	Yes	Yes
Observations	978,676	272,323	706,353

Notes: All specifications are regressed with year and firm fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.7 reports triple differenced's heterogeneous effects on export status. Results show that the Eleventh Five-Year Plan had a positive impact on exporters, but the coefficient was insignificant. Column 3 shows the Eleventh Five-Year significantly decreased non-exporters' markups, implying that if the reduction target is one standard deviation above the mean, markups are 1.4% lower for non-exporters in industries with SO_2 emissions 10% above the mean.

Table 1.7: Effects of environmental regulation: Triple differenced by export status

	All (1)	Exporter (2)	Non-exporter (3)
Markups			
$Post_{2006} * Target_p * SO2_i$	-0.0044***	0.0010	-0.0053***
	(0.0004)	(0.0010)	(0.0004)
Employment_{t-1}	0.0016***	0.0006**	0.0020***
	(0.0001)	(0.0003)	(0.0002)
Age	0.0036***	0.0042***	0.0035***
	(0.0002)	(0.0004)	(0.0002)
Export Indicator	-0.0023***		
	(0.0005)		
R-squared	0.385	0.368	0.379
Province by Industry fixed effects	Yes	Yes	Yes
Industry by Year fixed effects	Yes	Yes	Yes
Province by Year fixed effects	Yes	Yes	Yess
Observations	978,676	272,323	706,353

Notes: All specifications are regressed with province by industry, industry by year, and province by year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Ownership In this section, we examine whether the results are stable across firms' ownership. Based on China's unique institutional background, SOEs and non-SOEs have different relationships with the government. When SOEs negotiate with local government in terms of the environmental regulation, they must follow the government's will and goals since the government controls the appointment of firms' leaders and evaluates their performance. This special relationship makes SOEs take more responsibility to accomplish the reduction goal. However, most SOEs have larger scales and more employees than non-SOEs; thus, the government favors SOEs. Since SOEs can easily access subsidies and tax exemptions, they have less incentive to invest in efficiency-improving technology. In this case, the SO_2 reduction plan's effects vary across the ownership.

Results for the difference-in-difference estimation are reported in table 1.8. We find the coefficient of interest on markups is significantly negative for state-owned, domestic private-owned, and positive for HMT-owned firms. Next, we differentiate firms based on their export status to evaluate whether the impacts reported in table 1.8 apply to different export statuses. Table 1.9 and 1.10 report results for exporters and non-exporters, respectively. The central government provides extra subsidies and tax exemption policies to SOEs; and SOEs may choose to use the subsidy for adopting cost-cutting technology or on some other initiative instead of exerting more effort to increase their efficiency. To participate in the international economic competition, the Chinese government has provided financial subsidies to SOEs on large scales, thus reducing firms' export costs. On the other hand, due to the tariff reductions from China's WTO accession, exporters become cleaner ([66]). Our results support the above fact. We find this plan significantly impacted markups of state-owned non-exporters, but it had no impact on state-owned exporters. Our results are consistent with the finding in [70] and [64] that the air pollution control policy did not significantly impact the export volume of SOEs.

Table 1.8: Heterogeneous effects for difference-in-difference: Ownership

	by ownership All (1)	SOE (2)	Domestic private (3)	Foreign (4)	HMT (5)
Markups					
$Post_{2006} * Target_p$	-0.0072***	-0.0112***	-0.0094***	-0.0011	0.0107***
	(0.0009)	(0.0026)	(0.0010)	(0.0033)	(0.0035)
Employment_{t-1}	-0.0001	0.0006	-0.001	0.0010	-0.0002
	(0.0001)	(0.0004)	(0.0001)	(0.0005)	(0.0004)
Age	-0.0018***	-0.0027***	-0.0019***	0.0017	-0.0030
	(0.0004)	(0.0010)	(0.0004)	(0.0021)	(0.0019)
Export Indicator	-0.0012***	-0.0050**	-0.0020***	-0.0004	0.0034*
	(0.0006)	(0.0022)	(0.0008)	(0.0021)	(0.0018)
R-squared	0.722	0.696	0.745	0.704	0.702
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	978,676	154,020	638,090	87,738	98,828

Notes: All specifications are regressed with firm and year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.9: Heterogeneous effects for difference-in-difference: Ownership by exporter

	by ownership All (1)	SOE (2)	Domestic private (3)	Foreign (4)	HMT (5)
Markups					
$Post_{2006} * Target_p$	-0.0058***	-0.0017	-0.0095***	-0.0027	0.0049
	(0.0021)	(0.0061)	(0.0011)	(0.0045)	(0.0050)
Employment_{t-1}	0.0003	0.0002	-4.58e-06	0.0009	-0.0001
	(0.0002)	(0.0007)	(0.0002)	(0.0006)	(0.0006)
Age	-0.0004	-0.0006	-0.0021***	0.0015	-0.0010
	(0.0007)	(0.0018)	(0.0005)	(0.0026)	(0.0027)
R-squared	0.730	0.745	0.762	0.710	0.706
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	272,323	30,232	124,222	56,743	61,126

Notes: All specifications are regressed with firm and year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.10: Heterogeneous effects for difference-in-difference: Ownership by non-exporter

	by ownership				
	All	SOE	Domestic private	Foreign	HMT
	(1)	(2)	(3)	(4)	(5)
Markups					
$Post_{2006} * Target_p$	-0.0080***	-0.0132***	-0.0089***	-0.0027	0.0133**
	(0.0010)	(0.0030)	(0.0010)	(0.0052)	(0.0053)
Employment_{t-1}	-0.0002	-0.0008*	-0.0001	0.0014	-0.0001
	(0.0002)	(0.0004)	(0.0002)	(0.0010)	(0.0007)
Age	-0.0024	-0.0036***	-0.0022***	0.0006	-0.0055*
	(0.0004)	(0.0013)	(0.0005)	(0.0039)	(0.0031)
R-squared	0.720	0.687	0.744	0.712	0.717
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	706,353	123,788	513,868	30,995	37,702

Notes: All specifications are regressed with firm and year fixed effects. Standard errors are in parentheses.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Triple-differenced results are reported in table 1.11. The results indicate the Eleventh Five-Year significantly decreased the performance of SOEs, domestic private-owned, and HMT-owned firms in terms of their markups. We also evaluate whether the impacts on markups based on ownership hold for export status. Table 1.12 and 1.13 report results for exporters and non-exporters, respectively. As a result of difference-in-difference estimation, the impact is different in these two types of firms. The Eleventh Five-Year Plan impacted the markups of state-owned non-exporters, but it had no impact on state-owned exporters.

Table 1.11: Heterogeneous effects for triple-differenced: Ownership

	by ownership				
	All	SOE	Domestic private	Foreign	HMT
	(1)	(2)	(3)	(4)	(5)
Markups					
$Post_{2006} * Target_p * SO2_i$	-0.0044***	-0.0054***	-0.0048***	0.0013	-0.0028*
	(0.0004)	(0.0011)	(0.0005)	(0.0015)	(0.0016)
Employment_{t-1}	0.0016***	0.0025***	0.0014***	0.0008	0.0012***
	(0.0001)	(0.0004)	(0.0002)	(0.0005)	(0.0005)
Age	0.0036***	0.0039***	0.0024***	0.0028***	0.0059***
	(0.0002)	(0.0005)	(0.0002)	(0.0009)	(0.0008)
Export Indicator	-0.0023***	-0.0150***	-0.0067***	-0.0019	0.0017
	(0.0005)	(0.0015)	(0.0006)	(0.0015)	(0.0013)
R-squared	0.385	0.292	0.439	0.330	0.330
Province by Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Industry by Year fixed effects	Yes	Yes	Yes	Yes	Yes
Province by Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	978,676	154,020	638,090	87,738	98,828

Notes: All specifications are regressed with province by industry, industry by year, and province by year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.12: Heterogeneous effects for triple-differenced: Ownership by exporter

	by ownership				
	All	SOE	Domestic private	Foreign	HMT
	(1)	(2)	(3)	(4)	(5)
Markups					
$Post_{2006} * Target_p * SO2_i$	0.0010	-0.0024	-0.0047***	0.0020	-0.0013
	(0.0010)	(0.0025)	(0.0005)	(0.0021)	(0.0023)
Employment_{t-1}	0.0006**	0.0009	0.0012***	-0.00002	-0.00001
	(0.0003)	(0.0008)	(0.0002)	(0.0006)	(0.0006)
Age	0.0042***	0.0020*	0.0017***	0.0044***	0.0108***
	(0.0004)	(0.0011)	(0.0003)	(0.0012)	(0.0011)
R-squared	0.368	0.372	0.458	0.321	0.304
Province by Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Industry by Year fixed effects	Yes	Yes	Yes	Yes	Yes
Province by Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	272,323	30,232	124,222	56,743	61,126

Notes: All specifications are regressed with province by industry, industry by year, and province by year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.13: Heterogeneous effects for triple-differenced: Ownership by non-exporter

	by ownership All (1)	SOE (2)	Domestic private (3)	Foreign (4)	HMT (5)
Markups					
$Post_{2006} * Target_p * SO2_i$	-0.0053***	-0.0055***	-0.0051***	0.0012	-0.0050**
	(0.0004)	(0.0013)	(0.0005)	(0.0023)	(0.0022)
Employment_{t-1}	0.0020***	0.0029***	0.0014***	0.0021**	0.0032***
	(0.0002)	(0.0004)	(0.0002)	(0.0009)	(0.0007)
Age	0.0035***	0.0044***	0.0021***	-0.0001	-0.0010
	(0.0002)	(0.0006)	(0.0002)	(0.0014)	(0.0012)
R-squared	0.379	0.278	0.436	0.361	0.381
Province by Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Industry by Year fixed effects	Yes	Yes	Yes	Yes	Yes
Province by Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	706,353	123,788	513,868	30,995,	37,702

Notes: All specifications are regressed with province by industry, province by year, and industry by year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

1.5.4 Expectation effects

To examine whether firms changed their behavior in anticipation of the Eleventh Five-Year Plan, we add three additional controls—$Post_{2005} \cdot Target_p$, $Post_{2004} \cdot Target_p$, and $Post_{2003} \cdot Target_p$—to the difference-in-difference regression. Table 1.14 column 1 presents the result. Coefficients of $Post_{2004/2003} \cdot Target_p$ are statistically insignificant; however, the regressor $Post_{2005} \cdot Target_p$ becomes significantly negative, and the coefficient of $Post_{2006} \cdot Target_p$ remains negative. These results suggest there was an expectation effect among Chinese manufacturing firms; i.e., they charged lower markups in the year before the Plan was implemented.

To explore the internal mechanism, we divide firms based on their ownership. The results are reported in table 1.14 column 2 and 3. Interestingly, results show the SOEs did not adjust their markups before the Eleventh Five-Year Plan was implemented. Non-SOEs drove the expectation effect. As mentioned in [44], SOEs have an advantage legally and politically by receiving a more substantial portion of the national subsidy budget compared with non-SOEs. With easy access to various subsidies and tax exemptions, SOEs exerted less effort in investing in cost-cutting technology. This result explains why SOEs did not change their behavior in anticipation of this plan. Non-SOEs received a smaller portion of the national and local subsidy budget; Therefore, they made moves first to prepare for the upcoming environmental policy.

To determine whether exporters and non-exporters responded differently in anticipation of this plan, we divide firms based on their export status. Results are reported for exporters in table 1.15 and for non-exporters in table 1.16. Table 1.15 shows there was no expectation effect for exporters. Results in column 2 imply the state-owned exporters did not change their behavior in anticipation of the upcoming Plan; However, non-state-owned exporters charged lower markups in 2005. Table 1.16 shows expectation effects existed for non-exporters, but the effect varies across the ownership and was driven by non-SOEs.

Table 1.14: Expectation effect for difference-difference: Ownership

	All (1)	SOEs (2)	Non-SOEs (3)
Markups			
$Post_{2006} \cdot Target_p$	-0.0053***	-0.0086***	-0.0047***
	(0.0009)	(0.0027)	(0.0010)
$Post_{2005} \cdot Target_p$	-0.0053**	-0.0015	-0.0059***
	(0.0012)	(0.0031)	(0.0013)
$Post_{2004} \cdot Target_p$	0.0046	-0.0007	-0.0059
	(0.0014)	(0.0034)	(0.0016)
$Post_{2003} \cdot Target_p$	-0.0013	-0.0053	-0.0004
	(0.0020)	(0.0026)	(0.0014)
Employment_{t-1}	-0.0001	-0.0006	0.00002
	(0.0001)	(0.0004)	(0.0001)
Age	0.0018***	0.0027***	0.0017***
	(0.0004)	(0.0010)	(0.0004)
Export Indicator	-0.0012*	-0.0049**	-0.0007
	(0.0006)	(0.0022)	(0.0007)
R-squared	0.722	0.696	0.732
Firm fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	978,676	154,020	824,656

Notes: All specifications are regressed with firm and year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.15: Expectation effect for difference-difference: Ownership by exporter

	All (1)	SOEs (2)	Non-SOEs (3)
Markups			
$Post_{2006} \cdot Target_p$	-0.0087***	-0.0119*	-0.0046***
	(0.0023)	(0.0063)	(0.0011)
$Post_{2005} \cdot Target_p$	0.0038	0.0081	-0.0057***
	(0.0028)	(0.0068)	(0.0014)
$Post_{2004} \cdot Target_p$	0.0020	0.0108	0.0062
	(0.0032)	(0.0068)	(0.0018)
$Post_{2003} \cdot Target_p$	-0.0002	-0.0014	0.0011
	(0.0027)	(0.0053)	(0.0017)
Employment$_{t-1}$	0.0003	0.0002	0.00001
	(0.0002)	(0.0007)	(0.0002)
Age	-0.0005	-0.0007	-0.0021***
	(0.0007)	(0.0018)	(0.0005)
R-squared	0.730	0.745	0.741
Firm fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	272,323	30,232	242,091

Notes: All specifications are regressed with firm and year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.16: Expectation effect for difference-difference: Ownership by non-exporter

	All (1)	SOEs (2)	Non-SOEs (3)
Markups			
$Post_{2006} \cdot Target_p$	-0.0053***	-0.0084***	-0.0044***
	(0.0010)	(0.0031)	(0.0010)
$Post_{2005} \cdot Target_p$	0.0070***	-0.0037	-0.0056***
	(0.0013)	(0.0036)	(0.0013)
$Post_{2004} \cdot Target_p$	0.0050	-0.0036	0.0064
	(0.0016)	(0.0040)	(0.0016)
$Post_{2003} \cdot Target_p$	-0.0016	-0.0060	-0.0005
	(0.0014)	(0.0030)	(0.0014)
Employment_{t-1}	-0.0002	-0.0008*	0.00001
	(0.0002)	(0.0004)	(0.0001)
Age	-0.0024***	-0.0035***	-0.0020***
	(0.0004)	(0.0013)	(0.0004)
R-squared	0.720	0.687	0.731
Firm fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Observations	706,353	123,788	582,565

Notes: All specifications are regressed with firm and year fixed effects. Standard errors are in parentheses. *** Significant at 1%, ** Significant at 5%, * Significant at 10%.

Finally, we examine the expectation effect on the triple-differenced strategy. Results in table 1.17 indicate that, considering the industry level variation, firms changed their behavior by charging lower markups in the year before the Eleventh Five-Year Plan was implemented and by increasing their markups afterward. As with the difference-in-difference strategy, all expectation effects stem from non-SOEs. Anticipation effects for exporters and non-exporters are reported in table 1.18 and 1.19.

Table 1.17: Expectation effect for triple-differenced: Ownership

	All (1)	SOEs (2)	Non-SOEs (3)
Markups			
$Post_{2006} \cdot Target_p \cdot SO2_i$	0.0019***	0.0011	0.0022***
	(0.0005)	(0.0013)	(0.0005)
$Post_{2005} \cdot Target_p \cdot SO2_i$	-0.0012**	0.0015	-0.0019***
	(0.0006)	(0.0015)	(0.0006)
$Post_{2004} \cdot Target_p \cdot SO2_i$	-0.0004	-0.0018	-0.0004
	(0.0007)	(0.0016)	(0.0007)
$Post_{2003} \cdot Target_p \cdot SO2_i$	-0.0071	-0.0083	-0.0067
	(0.0006)	(0.0013)	(0.0006)
Employment_{t-1}	0.0016***	0.0025***	0.0014***
	(0.0001)	(0.0004)	(0.0001)
Age	0.0036***	0.0039***	0.0022***
	(0.0002)	(0.0005)	(0.0002)
Export Indicator	-0.0023***	-0.0151***	0.0004
	(0.0005)	(0.0015)	(0.0005)
R-squared	0.385	0.293	0.408
Province by Industry fixed effects	Yes	Yes	Yes
Industry by Year fixed effects	Yes	Yes	Yes
Province by Year fixed effects	Yes	Yes	Yes
Observations	978,676	154,020	824,656

Notes: All specifications are regressed with province by industry, province by year, and industry by year fixed effects. Standard errors are in parentheses. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.18: Expectation effect for triple-differenced: Ownership by exporter

	All (1)	SOEs (2)	Non-SOEs (3)
Markups			
$Post_{2006} \cdot Target_p \cdot SO2_i$	0.0046***	0.0051*	0.0027***
	(0.0012)	(0.0029)	(0.0005)
$Post_{2005} \cdot Target_p \cdot SO2_i$	-0.0021	-0.0017	-0.0022***
	(0.0014)	(0.0037)	(0.0007)
$Post_{2004} \cdot Target_p \cdot SO2_i$	0.0003	-0.0006	-0.0004
	(0.0015)	(0.0036)	(0.0008)
$Post_{2003} \cdot Target_p \cdot SO2_i$	-0.0035	-0.0077	-0.0075
	(0.0013)	(0.0028)	(0.0007)
Employment_{t-1}	0.0007**	0.0010	0.0012***
	(0.0003)	(0.0008)	(0.0002)
Age	0.0042***	0.0021*	0.0021***
	(0.0004)	(0.0011)	(0.0003)
R-squared	0.368	0.373	0.416
Province-Industry fixed effects	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes
Province-Year fixed effects	Yes	Yes	Yes
Observations	272,323	30,232	242,091

Notes: Standard errors are in parentheses. All specifications are regressed with province by industry, province by year, and industry by year fixed effects. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

Table 1.19: Expectation effect for triple-differenced: Ownership by non-exporter

	All (1)	SOEs (2)	Non-SOEs (3)
Markups			
$Post_{2006} \cdot Target_p \cdot SO2_i$	0.0015***	0.0005	0.0021***
	(0.0005)	(0.0015)	(0.0005)
$Post_{2005} \cdot Target_p \cdot SO2_i$	-0.0007***	0.0019	-0.0019***
	(0.0007)	(0.0017)	(0.0006)
$Post_{2004} \cdot Target_p \cdot SO2_i$	-0.0008	-0.0022	-0.0006
	(0.0007)	(0.0018)	(0.0007)
$Post_{2003} \cdot Target_p \cdot SO2_i$	-0.0077	-0.0077	-0.0068
	(0.0006)	(0.0014)	(0.0006)
Employment$_{t-1}$	0.0021**	0.0030***	0.0014***
	(0.0002)	(0.0004)	(0.0002)
Age	0.0035***	0.0044***	0.0023***
	(0.0002)	(0.0006)	(0.0002)
R-squared	0.379	0.278	0.404
Province-Industry fixed effects	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes
Province-Year fixed effects	Yes	Yes	Yes
Observations	706,353	123,788	582,565

Notes: Standard errors are in parentheses. All specifications are regressed with province by industry, province by year, and industry by year fixed effects. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

1.6 Conclusion

Many research explored the impact of environmental regulation on firms' performance measured by productivity. This paper uses survey data covering Chinese manufacturing firms between 1998 and 2007 to recover markups. We analyzed the effects of China's SO_2 reduction plan on manufacturing firms' markups. We followed [25] to empirically estimate firm-level markups and employed the difference-in-difference strategy. Results show stricter environmental regulation decreases firms' markups.

Using a triple-differenced strategy, we considered industry variation. We find that firms' markups decreased more in more polluting industries and higher SO_2 reduction target provinces after 2006 than those in less polluting industries and lower reduction target provinces. By differentiating firms based on their export status, we find the Eleventh Five-Year Plan significantly decreased non-exporters' markups but has no impact on exporters.

To examine if firms changed their behavior in anticipation of the following environmental regulation, we examined firms' expectation effect and found that firms started to adjust one year before that Plan's implementation by charging lower markups. We also found that the expectation effect varied across the ownership. Although SOEs did not change their behavior in anticipation of the following Plan, non-SOEs did.

Our findings have significant implications for environmental regulation's impact in the developing countries. The government in those countries should consider the stricter environmental regulation's negative impact on markups when formulating pollution control policies. However, our data have several limitations. First, the data are truncated. In the ASIF, only non-SOEs with annual sales above five million RMB were surveyed, potentially making our estimation biased. Second, because ASIF is firm-level data, we cannot observe the location of plants and whether a firm with multi-plants locates in different provinces. Third, to recover firm-level markups, the valid data used are from 1998 to 2007. In this case, we cannot estimate the Eleventh Five-Year Plan's long-term effect. When the relevant data are available, future research can focus on environmental regulation's long-term effect.

Chapter 2

Trade Liberalization, Pollution and Agglomeration

2.1 Introduction

Since 1990, there is an emergence of trade liberalization agreements. The fall of trade barriers attracts firms to move their production to where they can get benefits. Environmentalists concern that laxer environmental regulation in developing countries will attract capital and cause an increase in local pollution. The assumption that firm or industry is sensitive to inter-regional differences in regulation stringency has been called the pollution haven hypothesis. Extensive literature has explored the pollution haven hypothesis. It has strong theoretical support, but empirical studies derive conflicting results.

Among studies attempted to explain the inconsistency between theoretical work and empirical results, [33] present an empirical example to investigate how the foreign direct investment (FDI) inflows to the US states are impacted by relative pollution abatement cost. Their empirical example implies that the impact of relative environmental stringency on foreign direct investment is negative for the small states but positive for the large states. They also build a trade model with emissions as a negative externality. In this paper, I reproduce the empirical results in [33] using Chinese data covering 31 provinces and province-equivalent municipalities. The results show that relative abatement cost has strong negative impacts for both small and large provinces. Most importantly, the effect depends on the region's size. Specifically, environmental stringency has a weaker impact on the large region and a stronger impact on the small region. To explain these results, I develop a spatial economy model closely following [61] and introduce emissions as a negative externality. I simulate the model and find the impact of environmental regulation on firms' creation depends on the regions' size, which is consistent with the empirical findings.

This paper contributes to the current literature on two aspects. First, I examine the external validity of the results in [33]. I use a 15-year panel data from 1998-2013 covering 31 Chinese provinces and municipalities. The data has all control variables in the same nature used by [33] including wages, land prices, energy prices, road mileage, market proximity, population, tax capacity, unemployment, and unionization rate. The empirical results imply relative pollution abatement cost significantly reduces FDI inflows to China's provinces regardless of the region's size. This finding is different from [33]. Most importantly, I find heterogeneous effects based on the region's size. This result is consistent with the extended spatial economy model. The consistency between empirical results and the model extends the validity of the results in [33]. Next, the empirical example of [33] focuses on the states in the US. This study highlights the provinces in China. In terms of international industrial division, China is an international manufacturing center with relatively low-end manufacturing industries. The low-end manufacturing industries requires energy consumption and emissions, which suggest the most area in China is sensitive to the change of environmental stringency. This paper contributes to public ambivalence toward concern about the pollution haven in the developing countries.

Second, this paper develops a spatial economy model with emissions as a negative externality based on the [61]. The simulation of the theoretical model shows the effect of environmental stringency on the local number of firms depends on the region's size. Consistent with the empirics, this effect is particularly strong in the small region but weak in the large region. However, [33] model didn't provide such an analysis.

In a broader sense, this paper contributes to the literature that analyzing the effect of environmental stringency on FDI. There is a large literature investigate the impact of receiving regions' environmental regulation on FDI inflows ([49], [47], [35], [27], [65], [80], [59], [33]). While, [30] and [39] investigate the relationship between the US outbound investment and environmental regulation. This paper examines how this relationship is affected by the region's size, which is highlighted in [33]. The results in this paper also contribute to the literature that examining the pollution haven hypothesis ([38], [36], [46], [11], [6]) and home market effect ([22], [40], [20], [21], [79]). I link the relationship between environmental stringency and firms' creation with region's size and show that the deterrent effect of environmental stringency on the number of firms is weaker in large regions.

This paper proceeds as follows. Section 2 provides an empirical example that evaluates the effect of relative environmental stringency on FDI in China. Section 3 presents the model. Section 4 provides simulation and the comparison with [33]. Section 5 concludes.

2.2 Empirical example

In this section, I present an empirical analysis that provides a comparison with [33]. The results present new evidence on how the market size influences the impact of environmental stringency on FDI inflows.

In [33], they employ data from [49] to evaluate the impact of manufacturers' relative abatement cost (RAC) on FDI inflows to states in the US. The data covers 48 US states over 18 years from 1977 to 1994.[1] To emphasize the role played by market size, [33] split data into two groups: large states and small states.[2] I collected data from China Statistical Yearbook and construct a 15-year panel dataset over the period 1998-2013 covering 31 Chinese provinces and province-equivalent municipal cities.[3] To construct the measure of relative pollution abatement cost (RAC), I follow [49] using the following equation:[4]

$$S^*_{pt} = \frac{S_{pt}}{\hat{S}_{pt}} \tag{2.1}$$

The S^*_{pt} is the adjusted relative province stringency index. $S_{pt} = \frac{P_{pt}}{Y_{pt}}$, which is the ratio of province-level operating expenditure and gross state product. Y_{pt} is the gross state product in province p and year t. P_{pt} is the operating expenditure in province p at year t.

[1][33] omit the year 1987 due to missing observations.
[2]The state size is ranked by the 1977 gross state product and population.
[3][29] find city size in China positively impacts the innovation measured by patent intensity.
[4][33] employ the same approach as the measure of relative abatement cost

$\hat{S}_{pt} = \frac{1}{Y_{pt}} \sum_i \frac{Y_{pit} P_{it}}{Y_{it}}$, where Y_{pit} is industry i's gross state product in province p and year t. Y_{it} is the national gross domestic product in industry i. P_{it} is the operating expenditure in industry i and year t.

Province-level and industry-level operating expenditures are collected from China Statistical Yearbook.[5] Foreign direct investment, wage, land price, energy prices, road mileage, population, tax capacity, unemployment, and unionization is also collected from China Statistical Yearbook. Wage is the average production-worker wage in each province. Land price is the land transaction price index. Energy price is fuel and electricity price index, which are published by the National Bureau of Statistics. Road mileage includes express, first-class, and second-class way in each province. Tax capacity is a province's actual revenues divided by its gross state product. Unemployment is the unemployed population as a percentage of the civilian labor force. The unionization rate is the union membership as a percentage of the civilian labor force. The market proximity measures how this province is to potential markets in other provinces. It is denoted as $M_{it} = \sum_{j \neq i} \frac{Y_{jt}}{d_{ij}}$, where Y_{jt} is the gross state product in province j and time t. d_{ij} is the distance from province i to province j. Data on the distance between each province is derived from spatial distance weight matrices of mainland China provided by [78].[6] Table 2.1 and 2.2 presents summary statistics.

[5]The operating expenditure is used on abatement.

[6]In [33], land prices are the land value per acre. Energy prices are the price of fuel and electricity for the industrial sector. They use tax effort as the measure to evaluate the extent to which a state utilizes its available tax bases. It is defined as an index of the ratio between the share of the actual tax collection in gross domestic product and taxable capacity. Since [52] indicate that the tax collection-to-gross domestic product (GDP) ratio (also called as tax capacity) is a reasonable measure of tax effort if one attempts to establish trends or to compare tax revenue performance across regions with similar economic structure, I use tax capacity to substitute the measure used in [33] due to lacking information.

Table 2.1: Summary Statistics: Averages 1998-2013

Province	RAC (1)	Unadjusted Index S (2)	FDI (3)	GSP (4)	Wage (5)	Land Prices (6)	Energy Price (7)	Road Mileage (8)
Beijing	1.20	0.0012	43.38	8447.86	43068.37	102.95	107.78	3612
Tianjin	0.95	0.0027	60.59	5529.74	70195.12	103.27	106.46	3413.94
Hebei	1.18	0.0014	25.24	13134.90	19538.44	103.59	107.56	18338.63
Shanxi	1.17	0.0067	8.44	5510.26	20956.94	104.22	107.99	14644
Inner Mongolia	0.72	0.0027	17.18	6439.32	21470.75	102.95	107.78	14239.15
Liaoning	1.16	0.0045	104.03	11603.42	22196.44	103.40	106.96	17176.50
Jilin	0.91	0.0007	7.93	5365.50	19747.06	103.93	107.13	9141.69
Heilongjiang	1.11	0.0008	16.92	7052.93	19543.44	104.02	107.16	9547.063
Shanghai	1.23	0.0005	80.08	10933.41	43296.63	103.28	107.44	3009.06
Jiangsu	1.19	0.0011	180.22	25356.60	25786.00	102.42	105.79	35071.75
Zhejiang	1.17	0.0015	73.16	17267.18	27173.44	102.30	106.09	12175.63
Anhui	0.82	0.0007	28.62	7883.28	21102.75	102.49	105.86	11097.44
Fujian	0.94	0.0021	43.92	9454.93	22030.13	103.40	106.72	8240.88
Jiangxi	1.19	0.0012	29.78	5848.44	18353.44	103.23	106.50	10256
Shandong	1.20	0.0032	77.06	24502.62	20908.69	103.14	106.56	30688.25
Henan	1.10	0.0017	37.75	14344.10	18929.81	102.60	107.98	22515.06
Hubei	1.04	0.0014	27.70	10208.16	19058.81	103.09	105.86	16938.31
Hunan	1.14	0.0017	31.37	9916.68	19800.75	102.88	107.23	8578.44
Guangdong	1.17	0.0011	155.83	28213.01	27928.25	102.43	106.35	27613.75
Guangxi	0.84	0.0014	6.53	5946.42	19768.75	102.45	106.97	8714.75
Hainan	0.91	0.0016	9.01	1305.77	20075.75	103.21	105.80	2033
Chongqing	1.16	0.0007	16.55	4840.61	21765.44	103.80	105.57	6431.56
Sichuan	1.15	0.0019	30.58	10833.938	20340.75	102.83	106.56	14059.63
Guizhou	0.78	0.0034	1.73	2961.08	19978.19	103.23	107.43	3616.06
Yunnan	0.82	0.0019	6.97	4848.44	25278.94	103.52	106.67	14059.63
Tibet	0.50	0.00004	0.08	334.63	33490.63	103.30	104.56	952
Shannxi	0.86	0.0012	11.52	5978.40	21108.94	103.24	1-6.08	8138.50
Gansu	0.70	0.0051	0.69	2651.16	19024.63	103.83	106.89	6519.57
Ningxia	0.75	0.0041	0.76	972.75	23187.12	103.30	108.58	3264.60
Qinghai	0.65	0.0010	1.45	815.57	22686.12	105.55	107.27	5033
Xinjiang	0.60	0.0013	1.44	3523.58	21814.87	104.19	106.23	9768.81

Notes: FDI is denoted in 0.1× billion US dollars. GSP and tax revenue are denoted in 0.1× billion RMB. Wage is denoted in RMB. Land prices and energy prices are price index. Road mileage is measured as kilometers. Population is denoted in 10× thousand. Unemployment and unionization is denoted in percentage.

Table 2.2: Summary Statistics: Averages 1998-2013, Continued

Province	Market Proximity (8)	Population (9)	Tax Revenue (10)	Unemployment (11)	Unionization (12)
Beijing	356.08	1625.44	1382.25	1.36	36.33
Tianjin	408.98	1133.69	464.24	3.44	60.62
Hebei	357.89	6919.38	644.47	3.55	60.62
Shanxi	364.93	3391.06	423.71	3.04	33.08
Inner Mongolia	272.79	2410.56	409.46	3.88	37.20
Liaoning	228.97	4271.94	915.53	4.4	43.51
Jilin	191.41	2717.06	289.68	3.78	33.38
Heilongjiang	142.43	3810.25	375.53	4.07	34.76
Shanghai	518.62	186931	1694.23	4.03	64.92
Jiangsu	429.14	7567.94	1914.06	3.34	27.38
Zhejiang	371.15	4961.94	1443.39	3.50	29.25
Anhui	537.69	6156.31	500.77	3.80	13.80
Fujian	315.18	3551.94	610.58	3.58	25.38
Jiangxi	369.97	4332.25	354.39	3.23	19.88
Shandong	333.10	9292.62	1309.10	3.36	25.42
Henan	363.87	9448.12	630.56	3.14	16.67
Hubei	342.48	5840.69	514.63	3.97	21.18
Hunan	322.23	6522.81	447.62	4.11	20.44
Guangdong	215.19	9016.95	2337.44	2.59	28.03
Guangxi	259.03	4731.75	320.68	3.64	13.96
Hainan	196.53	830.31	125.93	3.11	20.03
Chongqing	316.37	2970	225.52	3.81	21.32
Sichuan	248.71	8326.19	702.09	4.22	20.76
Guizhou	277.77	3692.31	253.52	3.86	14.82
Yunnan	164.44	4448.44	433.43	3.78	11.70
Tibet	105.31	280.44	19.55	3.71	11.48
Shannxi	299.62	3704.94	416.27	3.51	23.25
Gansu	189.06	2598.62	148.32	3.10	17.66
Ningxia	250.70	598.25	75.26	4.41	24.89
Qinghai	148.15	543.25	54.28	3.48	23.49
Xinjiang	86.62	2028.75	265.27	3.64	33.71

Notes: FDI is denoted in 0.1× billion US dollars. GSP and tax revenue are denoted in 0.1× billion RMB. Wage is denoted in RMB. Land prices and energy prices are price index. Road mileage is measured as kilometers. Population is denoted in 10× thousand. Unemployment and unionization is denoted in percentage.

The estimating equation is:

$$ln(FDI_{pt}) = \beta ln(RAC_{pt}) + \gamma X_{pt} + \delta_t + d_p + \epsilon_{pt} \tag{2.2}$$

where FDI_{pt} is the measure of inward foreign direct investment flows to province p and year t. RAC_{pt} is the measure of relative abatement cost in province p and year t as defined in Eq. 2.1. The coefficient of interest β captures the impact of relative abatement cost on FDI inflows to the provinces in China. To isolate the effect of relative environmental stringency, I employ province-level characteristics that will impact the investment as in the [33] including production wages, land prices, energy prices, road mileage, market proximity, population, tax capacity, unemployment, and unionization rate. The specification controls time fixed effect δ_t and province fixed effect d_p. I cluster the standard errors at the province level.

To highlight the importance of market size, [33] split their sample into small states and large states. They find the impact of relative abatement cost on FDI is negative in the small states but positive for the large states. Their results show that the region's size is essential to determine the impact of environmental stringency on FDI inflows. I follow the same strategy as in [33] by dividing 31 provinces and province-equivalent municipal cities from China into large regions and small regions.[7] Table 2.3 shows the estimation results.

[7] The size of provinces is ranked by the gross state product in 1998.

Table 2.3: The effect of environmental stringency on FDI

	All	Small Provinces	Big Provinces	Big-Small Indicator
	(1)	(2)	(3)	(4)
ln(RAC)	-0.513***	-0.634***	-0.474***	-0.635**
	(0.060)	(0.084)	(0.059)	(0.078)
Big× ln(RAC)				0.163*
				(0.100)
ln(production wage)	0.334	-0.157	0.782	0.328
	(0.344)	(0.324)	(0.621)	(0.342)
ln(land price)	-0.790	1.132	-0.310	-0.795
	(0.798)	(1.310)	(0.798)	(0.785)
ln(energy price)	0.906	1.502	0.268	0.913
	(0.861)	(0.980)	(1.122)	(0.873)
ln(road mileage)	0.677*	1.303***	0.355	0.683*
	(0.333)	(0.190)	(0.311)	(0.341)
ln(market proximity)	5.221***	4.460*	3.526	5.213***
	(1.353)	(2.002)	(2.756)	(1.320)
ln(population)	-2.141**	0.398	-2.290	-2.141****
	(0.842)	(1.034)	(1.578)	(0.844)
ln(tax capacity)	0.068**	0.092**	0.353	0.068**
	(0.027)	(0.033)	(0.705)	(0.028)
unemployment	-0.041	-0.155	-0.033	-0.039
	(0.062)	(0.086)	(0.079)	(0.066)
unionization	-0.008*	0.004	-0.011*	-0.008*
	(0.004)	(0.006)	(0.006)	(0.004)
Province fixed effect	Yes	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes	Yes
R-squared	0.956	0.952	0.933	0.956
Observations	362	140	222	362

Note: Dependent variable is log level of FDI inflows. Standard errors are in parentheses. All regressions include province and year fixed effect. Standard errors are clustered by province. ***Significant at the 1 percent level; **Significant at the 5 percent level; *Significant at the 10 percent level.

Column (1) reports the results of all 31 provinces in China. The result indicates that relative environmental stringency significantly decreases foreign direct investment flows. Results in column (2) and (3) imply the relative abatement cost decreases FDI inflows in both small and large provinces, which is contrary to the results in [33]. Specifically, a 10% increase in RAC results in a 6.34% decrease in FDI in small provinces and a 4.74% decrease in large provinces. In column (4), I interact main regressor $ln(RAC_{pt})$ with a size dummy that equals to one if the region is large, the coefficients of the estimate is -0.635 for small provinces and -0.472 for large provinces.

2.3 Model

In this section, I develop a spatial economy model closely following [61] and introduce emissions as a negative externality.

2.3.1 The closed economy

There are M engineers and L workers in the economy, each type of labor supplying one unit of its labor inelastically. According to [61], engineers are the type of labor with high-skill, and workers are the type of labor with low-skill.

2.3.2 Preferences

All individuals have the same utility function over a continuum of differentiated goods indexed by ω and homogeneous good indexed by q_0^c. The consumer suffers the disutility from local emissions. The utility function is defined as:

$$U_i^c = q_0^c + \alpha \int_0^N q^c(\omega)d\omega - \frac{\gamma}{2}\int_0^N (q^c(\omega))^2 d\omega - \frac{\eta}{2}\left(\int_0^N q^c(\omega)d\omega\right)^2 - \theta E(Z_i) \tag{2.3}$$

where q_0^c represents a representative's preference for homogeneous goods. $q^c(\omega)$ represents preference for variety ω. The parameter α and η denote the substitution between homogeneous goods and differentiated varieties. The degree of differentiation between varieties is captured by γ. When $\gamma = 0$, varieties are perfect substitutes. $E(Z_i)$ represents the aggregate local emissions. Representative's preference on environment quality is reflected by θ. A higher degree of θ implies a preference for better environmental quality.

2.3.3 Technology

There are two sectors. The agricultural sector produces homogeneous goods. It is subject to the perfect competition hiring workers as the only input. One worker produces one unit of homogeneous goods, which gives a unit wage rate. The manufacturing sector produces a continuum of varieties indexed by $\omega \in [0, N]$ with monopolistic competition hiring both engineers and workers. Specifically, firms will enter the market by employing f_E number of engineers to design blueprints. The subsequent production process requires the employment of workers according to the production scale. Emissions will be generated during the production process, and emissions will affect local welfare.

In terms of production efficiency, the corresponding productions have unknown outcomes. The unit labor requirement in firms' production process is determined by the random selections from certain distribution. The timeline for how firms enter the market is shown below. First, the firm must decide whether to enter the market by hiring f_E number of engineers to design the blueprint. Second, the firm has to bid for a given supply of engineers if it decides to enter. Third, the firm who enters the market will be assigned its unit labor requirement c as soon as the engineers have been allocated to $N_E = M/f_E$ number of bidders. At last, based on the random draws, the firm decide if it will start to produce or not. The number of firms that decide to produce is denoted as $N = \rho N_E$, where ρ is the endogenous share of firms that choose to produce. Following [58] and [61], the productivity $\varphi = 1/c$ is assumed to follow a Pareto distribution. The distribution supports $[1/c_M, \infty]$. The c.d.f of the unit labor requirement is

$$G(c) = (\frac{c}{c_M})^k \tag{2.4}$$

As in [60] and [61], k and c_M regulate the heterogeneity of productivity draws. The 'evenness' dimension is captured by the parameter k, which measures the similarity between the probabilities of different unit labor requirement draws. Smaller k leads to more evenness by causing more low unit labor requirements draws. Accordingly, when k is small, the average unit labor requirement is low. The 'richness' dimension is captured by the parameter c_M, which is the number of alternative unit labor requirements draws. Larger c_M causes more richness and accompanies with a larger chance of high unit labor requirement draws. Accordingly, the average unit labor requirement is high when c_M is large.

2.3.4 Consumption

An engineer or a worker maximizes its utility with respect to each budget constraint.[8] Inverse demand function can be derived as:[9]

$$p(\omega) = \alpha - \gamma q^c(\omega) - \eta Q^c \tag{2.5}$$

where Q^c is the aggregate quantity of differentiated goods, and $Q^c = \int_0^N q^c(\omega)d\omega$. Integrating the demand function, I solve $Q^c = \frac{N\alpha - P}{\gamma + N}$. Next, I substitute Q^c into the inverse demand Eq. 2.5 and derive the demand as:

$$q^c(\omega) = \frac{1}{\gamma}(p^* - p(\omega)) \tag{2.6}$$

where $p^* = \frac{\alpha\gamma + \eta N\tilde{p}}{\gamma + \eta N}$, and it was called as choke price. The choke price ensures the demand is nonnegative. The demand of the economy depends on the number of local consumers. From Eq. 2.6, I derive the total inverse demand and total demand as:

$$p(\omega) = p^* - \frac{\gamma}{L + M} q(\omega) \tag{2.7}$$

$$q(\omega) = \frac{L + M}{\gamma}(p^* - p(\omega)) \tag{2.8}$$

[8] Engineer's budget constraint is $q_0^c + \int_0^N p(\omega)q^c(\omega)d\omega = \rho\tilde{\pi}/f_E + \bar{q_0}^c + \frac{tiEi}{L_i + M_i}$, where ρ is the probability of successfully enter the market, and $\tilde{\pi}$ represents the average producer profit. Worker's budget constraint is $q_0^c + \int_0^N p(\omega)q^c(\omega)d\omega = 1 + \bar{q_0}^c + \frac{tiEi}{L_i + M_i}$.

[9] More details on derivations are shown in Appendix A.1.

2.3.5 Production

Following [72], I introduce production-generated emissions. A firm uses its labor stock l in both abatement and production processes. The technology is given as:

$$q(\varphi) = \varphi\theta \tag{2.9}$$

where φ is firms' exogenous productivity level, and $\varphi = 1/c$. Firms' abatement activity is modeled as diverting a share of labor $(1-\theta)$ away from production to abatement. Emissions are linked to labor l and θ, denoting as $z = \theta^{1/\beta} l$. I substitute emission function into the production technology, which yields a production function as:

$$q(\varphi) = \varphi z^{\beta} l^{1-\beta}$$

The parameter β determines the cost-share of emissions. A firm has to pay its emissions at the unit price τ. In a competitive market, firms minimize their cost of production. Then, I derive the demand of labor, emissions, and emission intensity as:

$$l = \frac{q}{\varphi}(\frac{(1-\beta)\tau}{\beta})^{\beta} \tag{2.10}$$

$$z = \frac{q}{\varphi}(\frac{(1-\beta)\tau}{\beta})^{\beta-1} \tag{2.11}$$

$$\frac{z}{q} = \frac{1}{\varphi}(\frac{(1-\beta)\tau}{\beta})^{\beta-1} \tag{2.12}$$

Eq. 2.12 implies the emission intensity decreases in productivity and emission tax. The firm with a higher productivity level yields a lower emission intensity. The firm-level production cost is derived as:

$$C = \frac{q}{\varphi}\frac{(1-\beta)^{\beta-1}}{\beta^{\beta}}\tau^{\beta} \tag{2.13}$$

I use Θ to denote the term $\frac{(1-\beta)^{\beta-1}}{\beta^{\beta}}$ and write the cost function as $C = \frac{q}{\varphi}\Theta\tau^{\beta}$. Production cost decreases in productivity and increases in emission tax. The distribution of φ follows Pareto distribution with shape parameter k and supports $[1/c_M, \infty]$ as discussed above.

A firm maximizes its profits characterized by monopolistic competition. Profit of a firm is known as $\pi = pq(p) - q(p)c\Theta\tau^{\beta}$. Maximization of the profit leads to a pricing rule and firm-level output as:[10]

$$p(c) = \frac{1}{2}(p^* + c\Theta\tau^{\beta}) \tag{2.14}$$

$$q(c) = \frac{L_i + M_i}{2\gamma}(p^* - c\Theta\tau^{\beta}) \tag{2.15}$$

The cutoff unit labor requirement is $c^* = \frac{p^*}{\Theta\tau^{\beta}}$. It drives demand to zero and only firms whose unit labor requirement satisfies $c \leqslant c^*$ will end up producing. The unit labor requirement distribution is $G^*(c) = \frac{G(c)}{G(c^*)} = (\frac{c}{c^*})^k$. Accordingly, price, output, emissions, revenue, and profit in the form of c^* yield as:

$$p(c) = \frac{1}{2}(c^* + c)\Theta\tau^{\beta}$$

$$q(c) = \frac{L_i + M_i}{2\gamma}(c^* - c)\Theta\tau^{\beta}$$

$$z(c) = \frac{L_i + M_i}{2\gamma}(c^*c - c^2)\Theta^2\beta\tau^{2\beta-1}$$

$$r(c) = \frac{L_i + M_i}{4\gamma}((c^*)^2 - c^2)\Theta^2\tau^{2\beta}$$

$$\pi(c) = \frac{L_i + M_i}{2}((c^*) - c)^2\Theta^2\tau^{2\beta}$$

The probability of a firm to successfully produce after entering is $\rho = (\frac{c^*}{c_M})^k$. The average unit labor requirement can be calculated by the conditional distribution $G^*(c)$, so that $\tilde{c} = \frac{k}{k+1}c^*$. The average price, output, emission, and profit are evaluated to:

$$\tilde{p} = \frac{2k+1}{2(k+1)}c^*\Theta\tau^{\beta}$$

$$\tilde{q} = \frac{L_i + M_i}{2\gamma(k+1)}c^*\Theta\tau^{\beta}$$

[10]More details on derivations are shown in Appendix A.2.

$$\tilde{\pi} = \frac{(L_i + M_i)\Theta^2 \tau^{2\beta}}{2\gamma(k+2)(k+1)}(c^*)^2$$

$$\tilde{z} = \frac{(L_i + M_i)\Theta^2 \tau^{2\beta-1}\beta k}{2\gamma(k+2)(k+1)}(c^*)^2$$

Since the model simply introduces emissions into [61]'s setting. It is a partial equilibrium model taking environmental regulation as exogenous.

2.3.6 Free entry, ZCP, and equilibrium

Free entry condition ensures firms' profits equal to zero. The equilibrium free entry condition is when the expected profit equals the cost to design blueprints, which can be stated as:

$$\rho\tilde{\pi} = w f_e \tag{2.16}$$

where f_e represents the number of engineers required to design the blueprint. w is engineers' wage rate. The following equations $p^* = \frac{\alpha\gamma+\eta N\tilde{p}}{\gamma+\eta N}$, $c^* = \frac{p^*}{\Theta\tau^\beta}$, $\tilde{p} = \frac{2k+1}{2(k+1)}c^*\Theta\tau^\beta$ yield the zero cutoff profit (ZCP) condition as:

$$N = \frac{2(k+1)\gamma(\alpha - c^*\Theta\tau^\beta)}{\eta c^*\Theta\tau^\beta} \tag{2.17}$$

Next, I characterize the equilibrium of this model with five unknowns: c^*, N, w, $\tilde{\pi}$, ρ, and five equations,[11] reducing the cutoff unit labor requirement for an existing firm as:

$$c^* = \left(\frac{(c_M)^k f_e 2\gamma(k+2)(k+1)}{(L+M)\Theta^2\tau^{2\beta}}\right)^{\frac{1}{k+2}} \tag{2.18}$$

The cutoff unit labor requirement c^* decreases in the number of local consumers and emission tax, which implies a tougher competition among firms:

$$\frac{\partial c^*}{\partial \tau} < 0, \frac{\partial c^*}{\partial M} < 0$$

[11] The five equations are: $\rho = G(c^*)$, $N = \rho M/f_e$, $\tilde{\pi} = \frac{(L_i+M_i)\Theta^2\tau^{2\beta}}{2\gamma(k+2)(k+1)}(c^*)^2$, Eq. 2.16, Eq. 2.17.

As in [61], it's important to consider how heterogeneity affects the negative relationship between cutoff unit labor requirement and market size. The differentiation yields:

$$\frac{\partial^2 c^*}{\partial M \partial c_M} > 0, \frac{\partial^2 c^*}{\partial M \partial k} > 0$$

The above equations imply that heterogeneity impacts the effect of market size on the intensity of competition. More heterogeneity along the richness dimension (larger C_M) and less heterogeneity along the evenness dimension (larger k) weakens the competition in the large market.

According to those results, I find heterogeneity plays an essential role in determining the competition intensity. The key part of this paper that is different from [33] is that the extended model developed from [61] considers firm heterogeneity. Accordingly, the role of the market size will be impacted by productivity distribution, which cannot be recovered in a homogeneous setting.

2.3.7 The open economy

In this section, I consider an open economy with two regions: H (home) and F (foreign). Each region has a certain share of workers. The total number of workers is L. The share of workers in H is μ, and the share of workers in F is $1-\mu$, with $\mu \in [0,1]$. Workers are geographically immobile between regions. The total stock of engineers is M. The share of engineers located in H and F are λ and $1-\lambda$, with $\lambda \in [0,1]$. Engineers are mobile between regions and will decide to relocate in a region that gives them higher utility.

Preferences and technology

All individuals have the same preferences in both regions defined by Eq. 2.3. The homogenous goods are produced with perfect competition and constant return to scale. They are traded freely between two regions. Differentiated varieties are produced with monopolistic competition and increasing return to scale. Their trading between two regions incurs the iceberg trade cost t, and $t > 1$.

The timeline for how firms enter the market and start to produce is shown below. First, the firm has to choose whether and where to hire high-skill engineers. Second, if the firm decides the region, it has to bid for the local engineers for designing blueprints. Third, the firm that enters the local market will be assigned its unit labor requirement as long as engineers have been allocated to these entrants. The unit labor requirement is drawn from the distribution $G(c)$ over $[0, c_M]$. Next, based on the draws of the unit labor requirement, the firm will choose whether to start to produce or not. Firms' production is restricted to the region they enter.

Consumption and production

The choke price p^* under the closed economy implies that the maximum price to ensure a positive demand in the region H is:

$$P^H = \frac{\alpha\gamma + \eta N_s^H \tilde{p}^H}{\gamma + \eta N_s^H} \tag{2.19}$$

where N_s^H is the number of varieties selling to H. Firms located in H maximize their profits earned from domestic and foreign markets separately with cutoff unit labor requirement: c_D^H, c_D^F, $c_X^H = \frac{P^F}{\Theta\tau_H^\beta t}$, and $c_X^F = \frac{P^H}{\Theta\tau_F^\beta t}$. The average profit-maximizing price, output, emission, and profit on the domestic market and foreign market can be derived as:

$$\tilde{p}_D^H = \frac{2k+1}{2(k+1)}\Theta\tau_H^\beta c_D^H, \quad \tilde{p}_X^H = \frac{2k+1}{2(k+1)}\Theta\tau_F^\beta c_D^F \tag{2.20}$$

$$\tilde{q}_D^H = \frac{\mu L + s^H M}{2\gamma(k+1)}\Theta\tau_H^\beta c_D^H, \quad \tilde{q}_X^H = \frac{(1-\mu)L + s^F M}{2\gamma(k+1)}\Theta\tau_F^\beta c_D^F \tag{2.21}$$

$$\tilde{z}_D^H = \frac{(\mu L + s^H M)\Theta^2\tau_H^{2\beta-1}\beta k}{2\gamma(k+1)(k+2)}(c_D^H)^2, \quad \tilde{z}_X^H = \frac{((1-\mu)L + s^F M)\Theta^2\beta k}{2\gamma(k+1)(k+2)t}\frac{\tau_F^{2\beta}}{\tau_H}(c_D^F)^2 \tag{2.22}$$

$$\tilde{\pi}_D^H = \frac{(\mu L + s^H M)\Theta^2\tau_H^{2\beta}}{2\gamma(k+1)(k+2)}(c_D^H)^2, \quad \tilde{\pi}_X^H = \frac{((1-\mu)L + s^F M)\Theta^2\tau_F^{2\beta}}{2\gamma(k+1)(k+2)}(c_D^F)^2 \tag{2.23}$$

Since the firm is indifferent between entering the market or not due to the free entry condition, the wage of engineers equals the firm's profits:

$$w^H f_E = \frac{(\mu L + s^H M)\Theta^2 \tau_H^{2\beta} (c_D^H)^{k+2} + ((1-\mu)L + s^F M)\Theta^2 \tau_F^{2\beta} (c_D^F)^{k+2} (tT^\beta)^{-k}}{2\gamma(k+1)(k+2)c_M^k} \tag{2.24}$$

$$w^F f_E = \frac{((1-\mu)L + s^F M)\Theta^2 \tau_F^{2\beta} (c_D^F)^{k+2} + (\mu L + s^H M)\Theta^2 \tau_H^{2\beta} (c_D^H)^{k+2} (t/T^\beta)^{-k}}{2\gamma(k+1)(k+2)c_M^k} \tag{2.25}$$

Using Eq. 2.19 and analogous expressions for region F, I derive the number of firms selling to region H and F as:

$$N_s^H = \frac{2\gamma(k+1)}{\eta} \frac{\alpha - c_D^H \Theta \tau_H^\beta}{c_D^H \Theta \tau_H^\beta} \tag{2.26}$$

$$N_s^F = \frac{2\gamma(k+1)}{\eta} \frac{\alpha - c_D^F \Theta \tau_F^\beta}{c_D^F \Theta \tau_F^\beta} \tag{2.27}$$

N_s^H consists of the number of domestic firms in H and exporters from F. Following [61], I can write N_s^H as the following functions, which gives an equilibrium of labor market:

$$N_s^H = (\frac{c_D^H}{c_M})^k \frac{s^H M}{f_E} + (\frac{c_D^H T^\beta}{t c_M})^k \frac{s^F M}{f_E} \tag{2.28}$$

$$N_s^F = (\frac{c_D^F}{c_M})^k \frac{s^F M}{f_E} + (\frac{c_D^F}{t T^\beta c_M})^k \frac{s^H M}{f_E} \tag{2.29}$$

where $s^H = \lambda$ is the share of engineers in region H, and $s^F = 1 - \lambda$ is the share of engineers in F. For any given spatial allocation range $\lambda \in [0, 1]$, I can solve for unknown c_D^H, c_X^H, c_D^F, and c_X^F numerically. The corresponding indirect utilities for engineer located in region H and F are evaluated to:

$$V^H = w^H + \frac{\alpha - c_D^H \Theta \tau_H^\beta}{2\gamma}(\alpha - \frac{k+1}{k+2} c_D^H \Theta \tau_H^\beta) - \theta Z^H \tag{2.30}$$

$$V^F = w^F + \frac{\alpha - c_D^F \Theta \tau_F^\beta}{2\gamma}(\alpha - \frac{k+1}{k+2} c_D^F \Theta \tau_F^\beta) - \theta Z^F \tag{2.31}$$

2.4 Simulation

The indirect utility difference between region H and region F is:[12]

$$\begin{aligned}\Delta V(\lambda) &= V^H(\lambda) - V^F(\lambda) \\ &= \Delta W(\lambda) + \Delta CS(\lambda) - \theta \Delta Z(\lambda)\end{aligned} \tag{2.32}$$

The utility difference depends on the three channels: wage, consumer surplus, and emissions. The three channels jointly determine the spatial equilibrium. The driving force of the engineer's relocation decision is the current indirect utility difference:

$$\dot{\lambda} = d\lambda/dt = \begin{cases} max\{0, \Delta V(\lambda)\} & if\, \lambda = 0 \\ \Delta V(\lambda) & if\, 0 < \lambda < 1 \\ min\{0, \Delta V(\lambda)\} & if\, \lambda = 1 \end{cases}$$

Four forces govern the stability of the equilibrium. Two of them favor agglomeration: market-access effect and cost-of-living effect. Starting with the symmetric market case, if a small migration happens from F to H, engineers will spend their income locally, which makes H a larger market. A larger number of firms will be located in H and the number of jobs will shrink in F. This effect attracts engineers to relocate to H continuously. The mechanism is called as demand-linked circular causality. Second, I consider the cost-of-living effect. The small migration will increase the share of varieties produced in H. Hence, the average price and markup in H are lower. This effect is called self-reinforcing since the lower price will foster more migration in the future.

On the contrary, firms' fear of competition and consumers' preference for environmental quality generate dispersion forces. To break even into a larger market, firms have to pay a lower nominal wage for engineers, which makes the larger region less attractive to relocate. Also, engineers prefer to locate in a region with better environmental quality. A larger share of firms in H generates more emissions compared with F, which discourages relocation.

Figure 2.1 shows how the share of firms at home responds to environmental stringency. I plot figure 2.1 for $\alpha = 10$, $\gamma = 2$, $f_E = 1$, $k = 1$, $\eta = 10$, $L = 50$, $M = 20$, $C_m = 15$,

[12] Aggregate emission functions are presented in Appendix A.3.

$\theta = 0.0425$, $\beta = 0.5$, $\tau_H = 5.7$, $\tau_F = 5.1$, $t = 2.4$, $\mu = 0.7$, and $\lambda = 0.7$.[13] The figure shows that as emission tax increases, the share of firms will decrease in both large and small regions. To investigate the role played by the market size, I plot figure 2.2 to examine how the derivative of the above relationship responds to the emission tax. Figure 2.2 shows, at the beginning, the emission tax has stronger impact on the small region and weaker impact on the large region. As emission tax continues to increase, the impacts on both regions begin to converge. To compare with the results in [33], I plot the same relationship using their model. Interestingly, results from figure 2.3 and figure 2.4 indicate that, although the share of firms decreases in both large and small regions when emission tax increases, the derivative is not depending on the regions' size.

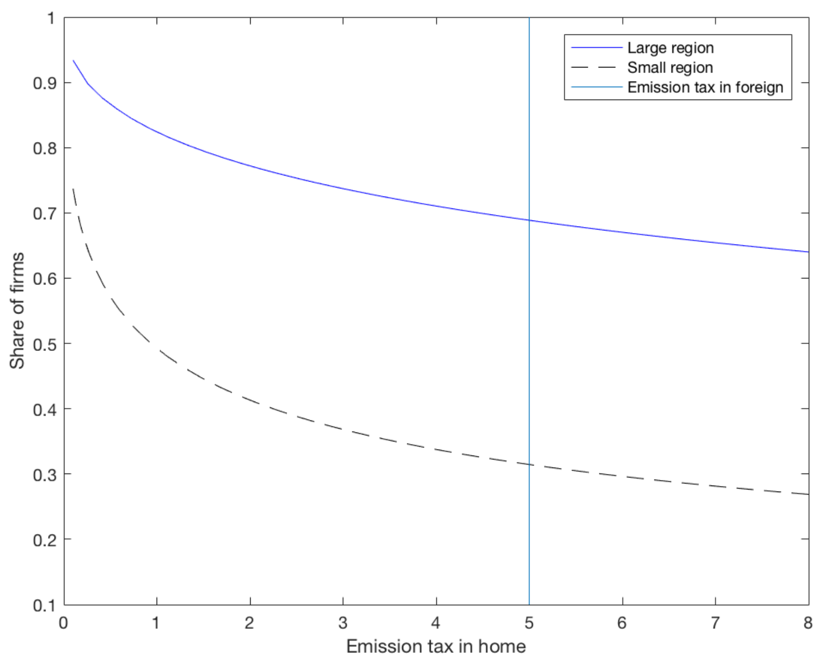

Figure 2.1: The effect of environmental stringency on the share of firms

[13]The value of parameters comes from [61].

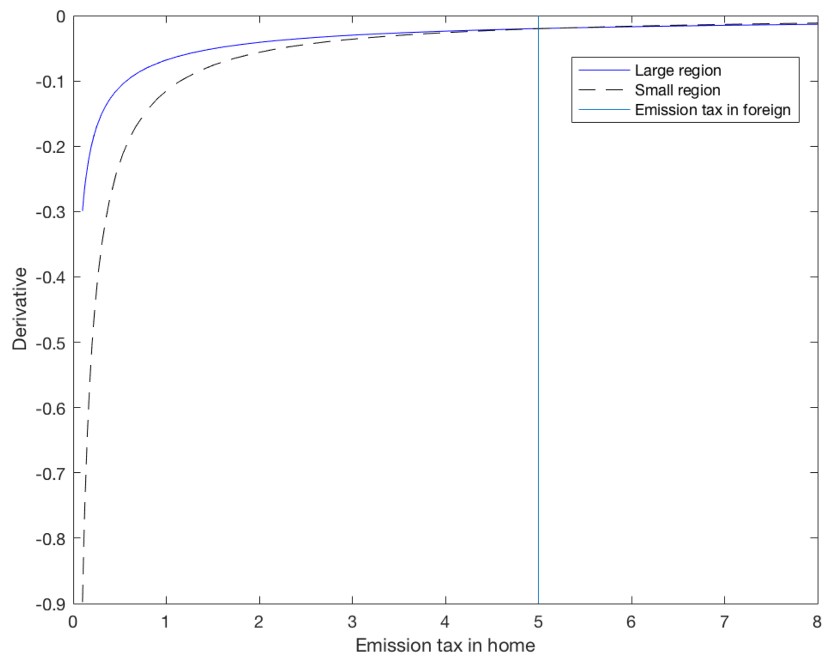

Figure 2.2: Heterogeneous effects

2.5 Conclusion

This paper examines the external validity of the results in [33] using Chinese data from 1998-2013 covering 31 Chinese provinces. The data has all control variables in the same nature used by [33]. Empirical results imply that the relative abatement pollution cost harms FDI inflows to China's provinces regardless of the region's size. Specifically, environmental stringency has a weaker impact on the large region but a stronger impact on the small region. The finding is consistent with the extended spatial economy model. The empirical example of [33] focuses on the states in the US. This study highlights the provinces in China. These results contribute to the public ambivalence toward concern about the pollution haven in the developing country.

To explain the empirical results, the paper develops a spatial economy model closely following [61] with emissions as a negative externality in the light of firm heterogeneity. The simulation shows the effect of environmental regulation on the share of firms depends on the region's size. Specifically, the effects of regulation stringency on the share of firms are

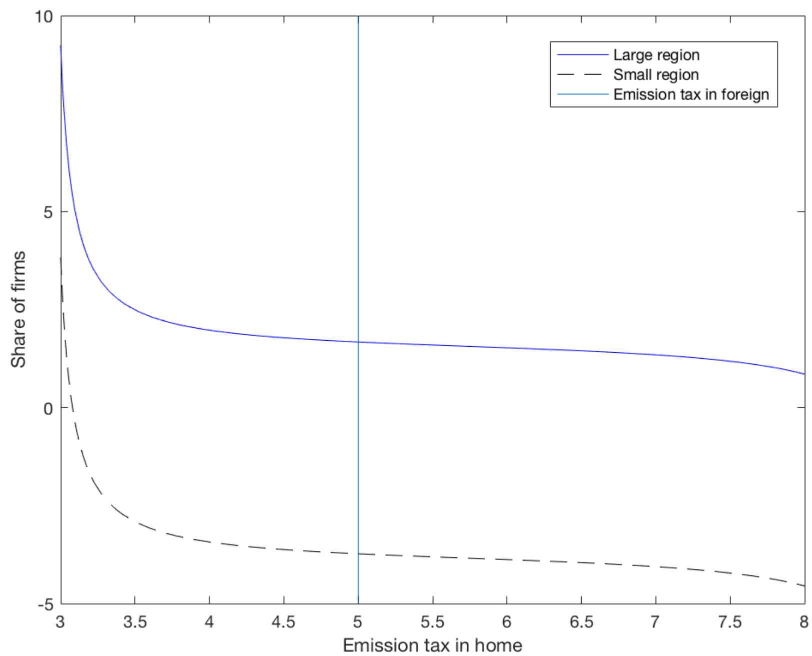

Figure 2.3: The effect of environmental stringency on the share of firms

stronger in the small region compared with the impact in the large region. In a broader sense, this paper contributes to the literature that investigates the impact of environmental regulation on FDI, pollution haven hypothesis, and home market effect by providing new evidence focusing on the size of the economy.

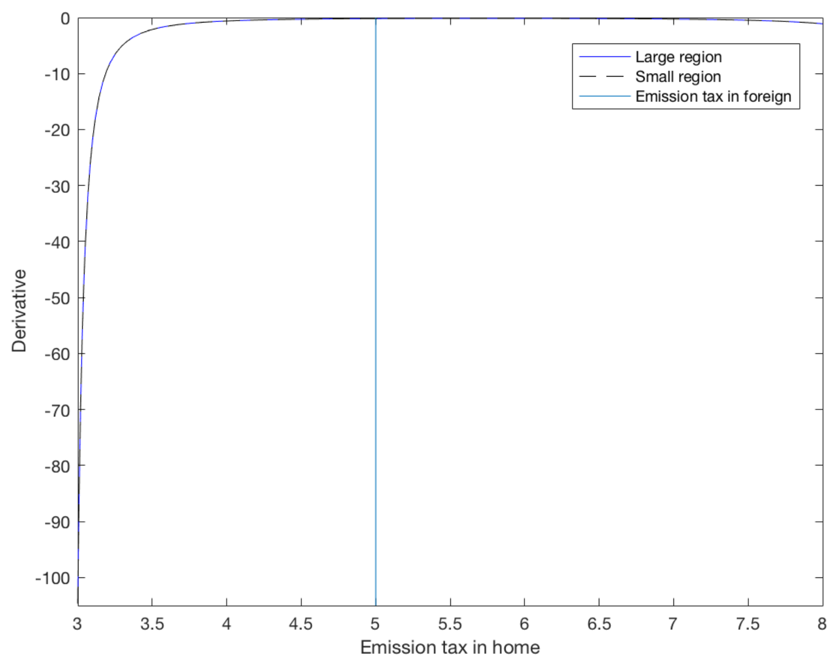

Figure 2.4: Heterogeneous effects

Chapter 3

How Much does Import Competition from China Affect Pollution in the US?

3.1 Introduction

Beginning in the 1990s, the United States' manufacturing imports from developing countries have grown rapidly, with China's share increasing the most ([8]). The landmark year is 2000. China became a member of the World Trade Organization (WTO). In the following year, the United States established the Permanent Normal Trade Relations to China, thereby eliminating the uncertainty of annual tariff renewals ([63]). Both policies have contributed to the rapid growth of Chinese exports to the United States. During 1991-2007, pounds of US emissions from core chemicals in manufacturing sectors fell by 68%, from 1.9 billion to 0.6 billion. The toxicity of released chemicals fell by 55%, from 58 trillion units to 26 trillion units (Figure 3.1).[1]

The debate on the impacts of international trade on the environment has been fruitful. A large amount of literature discusses the impacts of trade liberalization on emissions. While, how emissions respond to the growing trade liberalization is uncertain ([19]). On the one

[1]Information on pounds and toxicity of core released chemicals are collected from the report of Risk-Screening Environmental Indicators (RSEI).

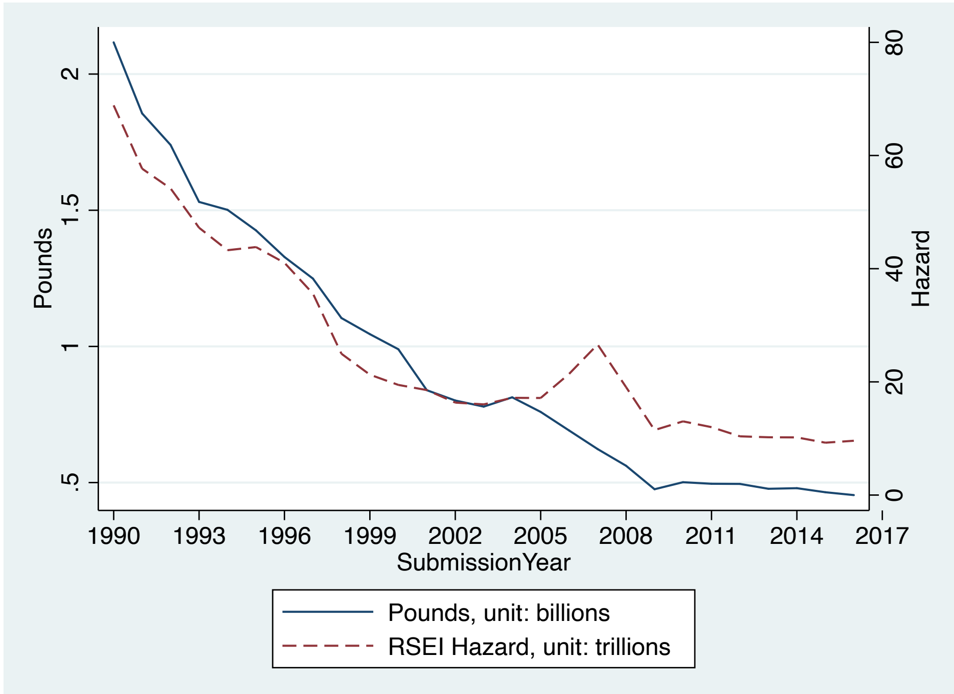

Figure 3.1: Pounds Released and Hazard in the US

hand, firms may innovate and, as a result, produce with cleaner technologies when trade liberalizes. On the other hand, firms may produce with higher emissions to save costs. Two opposite effects have uncertain outcomes on total emissions. One might wonder how much import pollution is caused by imports from China, the largest trade partner of the US. This paper links the changes in the US environmental results from 1991-2007 with changes in Chinese import competition and examines how US emissions respond to Chinese import competition at the industry level and commuting-zone level.

The method of this paper is based on the work of [1] and [32], as well as related papers [8] and [63]. The key identification challenge in examining the effects of import competition from China on the local economy is that import exposure might be driven by unobserved demand effects. I follow the existing literature to account for this potential endogeneity problem. [8] suggests employing China's import competition for the other eight developed countries over the same period (1991-2007) as instrumental variable. It is because the other developed countries are also affected by import competition driven by the increasing competitiveness of China's manufacturing sector. In addition, evidence also shows that most of the expansion in China's imports during 1991-2007 comes from the increasing competitiveness of manufacturing firms and accession to WTO ([13], [57], [12]).

I first analyze the relationship between the United States' import exposure from China and industrial emissions. Empirical findings indicate that the rise in the import exposure results in losses of 35.7 million pounds released in the first period 1991-1999 and 82.9 million pounds released in the second period 1999-2007. I also find the import exposure led to losses of 0.714 trillion units of hazard in the first period and 2.29 trillion units of hazard in the second period. Next, I investigate the impacts of import exposure on other industrial outcomes. Interestingly, empirical results show that stronger import exposure led to increases in pounds released per employment and hazard per employment. To investigate localized emissions losses, I investigate the above relationship at the commuting-zone level. Evidence shows that the commuting-zone level import exposure results in losses of pounds released and hazard per employment, but the estimates are statistically insignificant. At last, following the spirit of [63], I examine the impacts of the conferral of Permanent Normal Trade Relations (PNTR) with China in 2001 on US emissions. Empirical results imply that industries that more exposed to the policy change will suffer more emissions losses.

All in all, the results in this paper contribute to a large amount of research examining the effects of trade liberalization on the environment. Environmental literature has a long tradition of exploring the impact of trade liberalization on emission levels. [6] and [34] find openness to trade results in less pollution. [16] study the effects of NAFTA on SO_2 and PM_10. It finds NAFTA significantly reduced emissions of these pollutants. [69] find environmental regulation can explain 75 percent or more of the observed manufacturing emissions fall. However, few studies examine trade liberalization's effect on the toxicity of emissions. [42] uses establishment-level data to evaluate the relationship between import competition, export status, and environmental performance. Results show that increases in import competition from low environmental regulation countries associate with reduced hazard score. As in [42], I use Risk-Screening Environmental Indicators (RSEI) derived from Toxic Release Inventory (TRI). Since the released chemicals are heterogeneous with respect to their toxicity, RSEI reports the toxicity of released chemicals to provide a better measurement of the damage generated by emissions. In contrast with [42], this paper provides an identification based on instrumental variables to establish causality.

At last, this paper contributes to a large amount of literature exploring the relationship between international trade and local market outcomes by focusing on environmental performance. Most empirical works examine how trade liberalization affects the labor market. [8], [32], and [1] examine the employment responses to the rising Chinese import competition. All literature finds evidence that import exposure from China results in a decrease in US employment. [63] investigate the relationship between the establishment of permanent normal trade relations (PNTR) with China and the fall in manufacturing employment in the US. They find industries with higher NTR gaps experience more employment declines. [7] also find the drop in US employment results from the deaths of establishments. [17] examine how import competition from China impacts the Korean labor market. They find the trade shock results in an increase in temporary jobs during 1992-2013. [32] and [55] investigate the impact of US export expansion on manufacturing employment and find the surge in export rises employment. In contrast, this study is the first to study the effects of Chinese import competition on US emissions.

The paper proceeds as follows. Section 2 discusses the data and the measure of import competition. Section 3 describes the specifications. Section 4 describes the main results. Section 5 concludes.

3.2 Data

I collect the data from multiple sources to examine the effects of Chinese import competition on environmental performance in the US over 1991-2007.

3.2.1 Emissions

I use the Risk-Screening Environmental Indicators (RSEI) derived from Toxic Release Inventory (TRI) to obtain the information on emissions. Since released chemicals are heterogeneous concerning their toxicity and damage, RSEI calculates values that reflect the risk-related impacts on human health of modeled TRI releases and transfers. RSEI is the annual data at the establishment level. The main data used in this study covers the period 1990-2007. To merge with the trade exposure, I aggregate the pounds released and hazard at the 4-digit Standard Industrial Classification (SIC) level and the commuting-zone level.

RSEI provides two measures of emissions: pounds released and hazard. Hazard is an indicator that incorporates both pounds released and the toxicity weights of chemicals. Toxicity weights range from 0.02-1,400,000,000. Hazard includes information on damage generated by pollution, which is a complement measure of pounds released. However, RSEI is subject to several limitations. First, RSEI relies on TRI-reported data, and TRI does not incorporate all toxic chemicals. Second, compliance with TRI reporting has changed over time, which has led to more facilities reporting over the year. Third, facilities may under-reporting their emissions ([26], [50], [42]). Last but not the least, RSEI only reports the measure of emissions for the establishment that exceeds the reporting threshold, potentially making the estimation biased.

3.2.2 Trade data and import exposure

Trade data comes from the UN-Comtrade Database. I follow [1] using the crosswalk in [62] to link 6-digit HS import data to 4-digit SIC system. Additionally, I use the NBER-CES data to derive production measures including capital to value-added, industrial wage, high-tech equipment and computer investment, and the share of production workers in total employment. To examine the impact on other industrial outcomes, I use the information on employment and establishment. Data comes from County Business Patterns. I merge these data with RSEI into 344 manufacturing industries.[2] Table 3.2 provides descriptive statistics for the sample data.

[2]The trade data provided by [1] covers 392 manufacturing industries.

Table 3.1: Summary statistics 1

	N	Mean	S.D.	Median	Min	Max
Period, 1991-1999						
100× annual Δ in US import exposure	344	0.36	1.01	0.05	-0.25	12.14
Instrument for Δ in US import exposure	344	0.24	0.68	0.04	-1.51	6.62
100× annual log Δ in US pounds released	344	-0.97	1.67	-0.88	-10.49	7.43
100× annual log Δ in US hazard	344	-1.07	3.00	-0.88	-13.15	13.90
Period, 1999-2007						
100× annual Δ in US import exposure	344	0.95	1.93	0.30	-0.38	19.70
Instrument for Δ in US import exposure	344	0.70	1.30	0.27	-0.27	14.15
100× annual log Δ in US pounds released	344	-1.08	1.99	-0.77	-14.44	5.54
100× annual log Δ in US hazard	344	-0.89	2.57	-0.70	-12.14	8.79
Period, 1991-2007						
100× annual Δ in US import exposure	344	0.66	1.57	0.30	-0.38	19.70
Instrument for Δ in US import exposure	344	0.47	1.06	0.27	-1.51	14.15
100× annual log Δ in US pounds released	344	-1.02	1.83	-0.77	-14.44	7.43
100× annual log Δ in US hazard	344	-0.99	2.80	-0.70	-13.15	13.90

Notes: The measure of import exposure comes from [32]. The measure of pounds released and hazard is computed by 100× the annualized decrease in the value of pounds and hazard provided by RSEI.

The primary measure of Chinese import competition is the change in US import exposure from China during 1991-2007. I follow [1] and [32] to derive the change in import exposure from China as:

$$\Delta IP_{it}^{US} = \frac{\Delta IM_{i,t}^{US}}{Y_{i,t_0} + IM_{i,t_0} - EX_{i,t_0}} \tag{3.1}$$

where i is 344 industries. $\Delta IM_{i,t}^{US}$ denotes the variation of the United States imports from China during 1991-2007 (t is either 1991-1999 or 1999-2007 as in the [1] and [32]). $Y_{i,t_0} + IM_{i,t_0} - EX_{i,t_0}$ denotes initial domestic absorption (measured as industrial real shipments, Y_{i,t_0}, plus industry imports, IM_{i,t_0}, minus industry exports, EX_{i,t_0}). t_0 is the initial year chosen at 1991. The quantity in Eq. 3.1 implies the change in import exposure to US in industry i and period t.

[13] find China's manufacturing productivity has grown for 8% annually, while the US has an annual growth of 4%. Productivity growth is likely to drive China's export surge. The supply-driven changes will reduce demand and production. One concern by using this measure for the subsequent estimation is the change in import exposure could be associated

with some unobserved demand-side shocks, resulting in a biased estimation for the baseline specification. To identify the supply-driven piece of Chinese import competition on the US manufacturing industries' environmental performance, [8] suggests employing China's import competition changes in the other eight developed countries over the same period:[3]

$$\Delta IP_{it}^{OTH} = \frac{\Delta IM_{i,t}^{OTH}}{Y_{i,t_0} + IM_{i,t_0} - EX_{i,t_0}} \tag{3.2}$$

where $\Delta IM_{i,t}^{OTH}$ is the actual US imports from China to the eight developed countries in industry i during the period t. The denominator is the industrial initial absorption in 1988. This instrument's validity is based on the fact that much of the increase in imports from China comes from the Chinese manufacturing firms' growing competitiveness and accession to WTO, and the import competition to the other high-income countries are also driven by China's productivity growth ([13], [14], [57], [12]).

To explore the geographic differences in trade shocks as in [8], [1], [32], I use Commuting Zones (CZs) to separate economies in the United States. Commuting zones cover all metropolitan and non-metropolitan regions in the US. They are logical geographic units for defining local labor markets ([73], [9]). My analysis includes 600 CZs.[4] The final data consists of 1200 observations, with 600 commuting zones in two periods, 1991-1999 and 1999-2007. Information on gender, education, and age are constructed from the Census Integrated Public Use Micro Samples and the American Community Survey.[5] Table 3.2 provides summary statistics of the sample data.

[3]The eight developed countries are Australia, Denmark, Finland, Germany, Japan, New Zealand, Spain, and Switzerland.

[4]The RSEI data I collected from EPA covers 677 commuting zones. The data have some missing values of pounds released or hazard in certain years. I keep those CZs with full information on pounds and toxicity in both two subperiods, 1991-1999 and 1999-2007. There are 600 CZs left after I merge the emission data with import exposure provided by [32]. The import exposure provided by [32] and [8] covers 722 CZs.

[5]This paper also uses [8]'s public data source for data construction

Table 3.2: Summary statistics 2

	N	Mean	S.D.	Median	Min	Max
Period, 1991-1999						
100× annual Δ in US import exposure	600	0.06	0.09	0.04	-0.002	0.95
Instrument for Δ in US import exposure	600	0.05	0.06	0.03	-0.01	0.53
100× annual log Δ in US pounds released per employment	600	-0.10	1.54	-0.17	-7.82	11.79
100× annual log Δ in US hazard per employment	600	-0.25	2.65	-0.88	-14.09	14.69
Period, 1999-2007						
100× annual Δ in US import exposure	600	0.15	0.13	0.11	3.03e-07	1.02
Instrument for Δ in US import exposure	600	0.14	0.13	0.11	-0.01	1.023
100× annual log Δ in US pounds released per employment	600	-0.63	1.57	-0.47	-16.19	9.23
100× annual log Δ in US hazard per employment	600	-0.44	2.45	-0.38	-11.78	11.84
Period, 1991-2007						
100×annual Δ in US import exposure	600	0.11	0.12	0.07	-0.002	1.02
Instrument for Δ in US import exposure	600	0.10	0.11	0.06	-0.01	1.023
100× annual log Δ in US pounds released per employment	600	-0.37	1.58	-0.33	-16.19	11.79
100× annual log Δ in US hazard per employments	600	-0.35	2.55	-0.38	-14.09	14.69

Note: The measure of import exposure comes from [32]. The measure of pounds released and hazard is computed by 100× the annualized decrease in the value of pounds and hazard provided by RSEI.

I construct the commuting-zone level import exposure as in [1] and [32]:

$$\Delta IP_{ct}^{US} = \sum_i \frac{L_{ci,t_0}}{L_{c,t_0}} \Delta IP_{it} \tag{3.3}$$

where c denotes commuting zone c, and i is SIC industry. L_{ci,t_0} is the employment in commuting zone c and industry i at the start of period. L_{c,t_0} the total employment in commuting zone c at the start of period. ΔIP_{it} is the industry level import exposure derived from Eq. 3.1. ΔIP_{ct}^{US} denotes the increases in import exposure in commuting zone c at period t (t is either 1991-1999, or 1999-2007).

As with the case in the industry measure of import exposure, the estimate of the effect of the Chinese import competition on the US pounds released and toxicity may understate the true impact at the commuting-zone level. To explore the causal impact of increased import exposure on the environmental outcome, I derive the instrument for import exposure in commuting-zone level using the import exposure from China to the other developed countries over the same period ([32]). Non-US exposure variable ΔIP_{ct}^{OTH} was derived as:

$$\Delta IP_{ct}^{OTH} = \sum_i \frac{L_{ci,t_0}}{L_{c,t_0}} \Delta IP_{it}^{OTH} \tag{3.4}$$

At last, I follow [63] to explore the impact of the establishment of permanent normal trade relations (PNTR) on emissions in the US. In October 2000, Congress passed a bill to change China's normal trade relations status with the US to permanent. The granting of PNTR allowed for permanent access for Chinese made goods into the US market and led an end to annual renewals of China's trade status. The establishment of PNTR ended the uncertainty that linked with annual NTR's renewals. This policy increased the incentives of US firms to incur sunk costs by investing in China. Following [63], I begin by quantifying the PNTR's effect on industry i as:

$$NTR\,Gap_i = Non\,NTR\,Rate_i - NTR\,Rate_i \tag{3.5}$$

where $Non\,NTR\,Rate_i$ is the rate of non-NTR to which tariffs would have increased if annual renewal had failed. $NTR\,Rate_i$ is the NTR rate that was imposed by PNTR. Followed by [63], I use 1999 NTR gaps, which is the year before the establishment of PNTR. Data on tariffs, contract intensity, union membership, technology, and change in China import tariff come from [63]'s public dataset. I merge these data with RSEI at 4-dight SIC level. The final dataset contains 5518 observations over 1990-2007 compared with 5700 observations in [63].

In the folowing analysis, I also use the public data source from [62], [8], [1], and [32].

3.3 Empirics

First, I investigate the impact of import exposure on emissions at the industry level over 1991-2007. Second, I follow [8], [1], and [32] to evaluate the the impact of import exposure on emissions at the commuting-zone level. At last, following [63], I study the impact of eliminating potential tariff increases on Chinese imports (PNTR) on US emissions.

3.3.1 The effects of import exposure at the industry

To explore the effect of import exposure on manufacturing industries' emissions, I fit models in the following form used by [1]:

$$\Delta ln(E_{it}) = \gamma_t + \beta_1 \Delta IP_{it} + \beta_2 X_{io} + \epsilon_{it} \tag{3.6}$$

where $\Delta ln(E_{it})$ is 100 times annual log change in pounds released or hazard in industry i at t. ΔIP_{it} is 100 times the annual change in import exposure in industry i over period t.[6] X_{i0} are sectoral controls including the ratio of capital to value-added in 1991, the log of the industrial average wage in 1991, the share of production workers in total employment in 1991, high-tech investment as the share of total investment, and computer investment as the share of total investment. γ_t is the separate time dummies for each period, and ϵ_{it} is an error term. The coefficient of interest β_1 measures the impact of the import exposure on industry emissions. ΔIP_{it} is instrumented by ΔIP_{it}^{OTH} as illustrated in Eq. 3.2. Other than two main outcome variables, I considered other industrial outcomes including employment, pounds per employment, hazard per employment, number of establishment, employment per establishment, pounds per establishment, and hazard per establishment. I cluster the standard errors at the industry level.

3.3.2 The effects of import exposure at the commuting-zone

The above specification compares the changes in emissions across industries with different exposure to the Chinese import competition at the industry level. While this approach cannot identify the effects at the regional level. [8], [1], and [32] examine the effects of China's import exposure on commuting-zone level employment. In this section, I follow [8], [1], and [32] to explore the geographic differences in US import exposure from China based on 600 commuting zones.

I estimate the specification with the following form:

$$\Delta E_{ct} = \gamma_t + \beta_1 \Delta IP_{ct} + X_{ct}^{'} \beta_2 + \epsilon_{ct} \tag{3.7}$$

[6] Variables in decade changes are annualized.

where ΔE_{ct} equals 100 times the annual log change in the pounds released per employment or hazard per employment in commuting c over period t. The key explanatory variable ΔIP_{ct} is the import exposure at period t and commuting zone c. The coefficient of interest β_1 measures the effect of import exposure on pounds per employment or hazard per employment. γ_t is the separate time dummies for each decade to control for different time trends. I also include a set of census division dummies to control regional-specific trends. X_{ct} contains a set of controls that might affect environmental performance including percentage of foreign-born population, percentage of college-educated population, percentage of employment in manufacturing, percentage of employment in routine occupation,[7] percentage of employment among women, and average offshorability index of occupation.[8] I cluster the standard errors at the commuting-zone level.

3.3.3 PNTR and environmental performance

At last, I follow [63] to explore the impact of the US establishing the permanent normal trade relations on industrial emissions. The specification for the estimation is:

$$ln(E_{it}) = \beta PostPNTR_t \times NTRGap_i + PostPNTR_t \times X_i^{'}\gamma + X_{it}^{'}\gamma + \delta_t + \delta_i + \epsilon_{it} \quad (3.8)$$

where $ln(E_{it})$ is the log level of pounds released or hazard in industry i and year t. $PostPNTR_t$ is time dummy for the year PNTR was imposed ($PostPNTR_t$ equals to 0 before 2001 and 1 after 2001). $NTRGap_i$ is the quantified PNTR's impact. X_i is time-invariant industry characteristics including contract intensity, change of China import tariff, and the degree to which industries incorporate high-technology products. X_{it} is time-variant variable including union membership. The regression function controls for year fixed effect δ_t and industry fixed effect δ_i. I cluster standard errors at the industry level.

[7]Routine intensive occupation is the occupation that the major activities follow precisely prescribed procedures, [8].

[8]The offshorability index is the degree to which a job needs neither face-to-face contact nor proximity to a specific worksite in a commuting zone, [8].

3.4 Results

3.4.1 Benchmark industry estimation

In the benchmark industry-level estimation, I include ten one-digit manufacturing sector dummies. Regression with sector controls could identify the sector-level impacts of import exposure. Table 3.3 presents the results of benchmark estimation with sector controls.

Table 3.3: Main Results

	(1) Pounds	(2) Pounds	(3) Hazard	(4) Hazard
100× annual Δ in US exposure to Chinese imports	-0.315***	-0.246*	-0.199*	-0.144*
	(0.050)	(0.136)	(0.108)	(0.221)
t1{1991-1999}	-0.937***		-1.269***	
	(0.113)		(0.179)	
t2{1999-2007}	-0.714***	0.160	-0.524***	0.656**
	(0.124)	(0.180)	(0.181)	(0.268)
Log of industrial average wage in 1991 (in 2007 $)	-0.438		-0.343	
	(0.391)		(0.737)	
The share of production workers (1991)	-0.007		0.005	
	(0.009)		(0.017)	
Capital/value added (1991)	0.323***		0.132	
	(0.121)		(0.207)	
High-tech investment as share of total (1990) investment	0.054		0.070	
	(0.043)		(0.065)	
Computer investment as share of total (1990) investment	-0.041**		-0.004	
	(0.018)		(0.030)	
Sector controls	Yes	No	Yes	No
Industry fixed effect	No	Yes	No	Yes
First Stage Results				
Dep. var: Δ Imports				
ΔIP^{OTH}	1.208***	1.230***	1.208***	1.230***
	(0.143)	(0.164)	(0.143)	(0.164)
N	688	688	688	688
R^2	0.374	0.104	0.180	0.207

Notes: Dependent variable: 100 × annualized log change in industrial pounds released. Robust standard errors are in parentheses. ***Significant at the 1 percent level, **Significant at the 5 percent level, *Significant at the 10 percent level.

Results in columns (1) and (3) indicate that a higher level of Chinese import competition results in less industrial pounds released and hazard. Explicitly, one percentage point increase in industry import competition decreases the industrial pounds released and hazard by 0.315 and 0.199 percentage points respectively during 1991-2007. As a further check, I include a set of dummies for 344 manufacturing industries in the stacked first difference identification. The coefficient in columns (2) and (4) are still significant, but the magnitudes are modestly reduced.

Based on the coefficients from columns (1) and (3), I construct the difference between actual and counterfactual pollution in pounds released and hazard by following [1] to evaluate the economic magnitude of 2SLS estimates. I derive the following expression using Eq. 3.6:

$$\Delta E_t = \sum_i \left(E_{it}(1 - e^{\hat{\beta}_1 \Delta I\hat{P}_{it}}) \right) \tag{3.9}$$

where $\hat{\beta}_1$ is the estimated coefficient in Eq. 3.6. $\Delta I\hat{P}_{it}$ was derived from multiplying the first stage regression's partial R-squared from Eq. 3.6 and the measure of import exposure ΔIP_{it}. I employ the industry's end-of-period pounds released and hazard to convert estimates from logs into levels. Results suggest that the rise in the import exposure resulted in losses of 35.7 million pounds released in the first period 1991-1999 and 82.9 million pounds released in the second period 1999-2007. Results also imply that the import exposure led to losses of 0.714 trillion units of hazard in the first period and 2.29 trillion units of hazard in the second period.

Other than focusing on the impact of import exposure on two main measures of emissions, I explore the impact of import exposure on the other industrial outcomes. The results provide a broader perspective on the adjustment of industry. Following [1] and [32], I use information on employment and establishments from CBP. Table 3.4 presents the result of the effect of import exposure on various industrial outcomes. Column (1) implies stronger import exposure significantly reduces employment, which is consistent with the finding in [8], [63], [1], and [32]. Interestingly, columns (2) and (3) imply that import exposure increases pounds released per employment and hazard per employment in the industry. Results in columns (4) and (5) show that the growth in trade exposure results in a less count of establishment and employment per establishment. I also evaluate the impact of import exposure on pounds per establishment and hazard per establishment, the coefficients are still negative but became statistically insignificant.

Table 3.4: Other Market Outcomes

	(1) Emp	(2) Pounds per Emp	(3) Hazard per Emp	(4) Num Estabs	(5) Emp per Estab	(6) Pounds per Estab	(7) Hazard per Estab
100× annual Δ in imports	-0.945***	0.408*	0.547**	-0.353**	-0.593**	-0.834	0.056
	(0.296)	(0.231)	(0.262)	(0.114)	(0.233)	(0.126)	(0.153)
t1 {1991-1999}	0.151	-1.138***	-1.268***	0.555***	-0.404	-1.150***	-1.834***
	(0.350)	(0.322)	(0.372)	(0.203)	(0.289)	(0.209)	(0.272)
t2 {1999-2007}	-2.624***	1.753***	1.940***	-0.829***	-1.794**	0.803	0.269
	(0.349)	(0.327)	(0.289)	(0.236)	(0.272)	(0.235)	(0.250)
Production controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	688	688	688	688	688	688	688
R^2	0.329	0.210	0.232	0.175	0.244	0.136	0.136

Notes: Dependent variable: 100 × annualized log change in industrial outcomes. Robust standard errors are in parentheses. The sample includes 344 SIC sectors during 1991-1999 and 1999-2007. ***Significant at the 1 percent level, **Significant at the 5 percent level, *Significant at the 10 percent level.

3.4.2 Commuting-zone estimation

Table 3.5 shows the results of the environmental performance over 1991-2007 in commuting-zone level. Column (1) focuses on the effects of Chinese import competition on pounds released per employment. The result indicates that an increase in US import exposure from China is associated with fewer pounds released per employment. Column (2) includes several labor force control variables. The impact of import exposure is found to be insignificant. I further examine the effect of Chinese import competition on toxicity per employment. The coefficients of estimates are not significant in both column (3) and column (4). Estimates in column (2) and (4) also imply that the commuting zones with more routine-intensive occupations result in lower pounds released per employment and hazard per employment.

Table 3.5: Import Exposure and Commuting-Zone Pollution

	Pounds	Pounds	Hazard	Hazard
100×annual Δ in US import exposure	-2.103**	-0.559	-1.093	1.867
	(0.555)	(0.873)	(0.382)	(1.993)
Percentage of employment in routine occupations		-0.081***		-0.060*
		(0.024)		(0.031)
Percentage of employment among women		0.003		0.074**
		(0.013)		(0.029)
percentage of foreign-born population		-0.011**		0.018
		(0.005)		(0.013)
Percentage of college-educated population		-0.002		-0.035**
		(0.005)		(0.014)
Percentage of employment in manufacturing		-0.952		-4.151**
		(0.916)		(1.857)
Occupation's average offshorability index		0.239		-0.519*
		(0.156)		(0.268)
Census division dummies	No	Yes	No	Yes
First Stage Results				
Dep. var: Δ Imports				
ΔIP^{OTH}	0.826***	0.665***	0.826***	0.665***
	(0.036)	(0.052)	(0.036)	(0.052)
Observations	1200	1200	1200	1200
R^2	0.211	0.146	0.230	0.832

Notes: Dependent variables: 100 × annualized log change in industrial pounds released and Hazard per employment. Robust standard errors are in parentheses. The sample includes 600 commuting zones over 1991-1999 and 1999-2007. ***Significant at the 1 percent level, **Significant at the 5 percent level, *Significant at the 10 percent level.

3.4.3 PNTR and environmental performance

The industry level results relate changes in environmental performance across industries with changes in import exposure from China. The commuting-zone level results explore the geographic differences in trade shocks. In this section, I follow [63] to explore the link between industry level emissions and the conferral of PNTR. [63] uses a difference-in-difference specification to examine the effect of the US granting PNTR to China on domestic employment.

Table 3.6 shows the baseline results for Eq. 3.8. Columns (1) and (3) include only the difference-in-difference term and the fixed effects. Columns (2) and (4) add time-invariant and time-variant industry characteristics. Estimates in the second and fourth columns are statistically significant and negative in pounds released and hazard, implying the establishment of PNTR is associated with fewer pounds released and hazard. The remaining rows of columns (2) and (4) display a negative and significant relationship between emissions and contract intensity, indicating that industries with higher ability to enforce written contracts have fewer pounds released and hazard after the imposition of PNTR. Results also show that pounds released decrease in industries in which Chinese import tariffs increase. Hazard decreases in industries that encompass high-technology products. The positive coefficient on US union membership implies that US emissions of pounds released and hazard rise in industries in which union membership rate is high.

Table 3.6: Robustness checks: PNTR and Industrial Pollution

	Pounds	Pounds	Hazard	Hazard
Post$\times$ NTR $\text{Gap}_{1999,i}$	-3.467***	-1.047**	-3.371***	-0.923*
	(0.269)	(0.456)	(0.382)	(0.679)
Post $\times$ Contract Intensity_i		-1.742***		-1.500***
		(0.424)		(0.479)
Post$\times\Delta$ China Import Tariffs_i		-1.348*		-1.137
		(0.737)		(1.081)
Post $\times$ Technology Adopted_i		0.134		-0.717**
		(0.242)		(0.352)
US Union Membership_{it}		0.024***		0.018**
		(0.006)		(0.009)
NTR_{it}		7.365**		9.226**
		(3.103)		(4.262)
Industry fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes
Observations	5518	5518	5518	5518
R^2	0.818	0.826	0.826	0.832

Notes: Dependent variables are log of industrial pounds released and hazard. Robust standard errors are in parentheses, clustered at the industry level. ***Significant at the 1 percent level, **Significant at the 5 percent level, *Significant at the 10 percent level.

3.5 Conclusion

Many researchers have investigated the relationship between trade liberalization and emissions measured by emissions' quantity. In this paper, I use Risk-Screening Environmental Indicators (RSEI) derived from the Toxic Release Inventory to recover the toxicity of released chemicals. I relate changes in the environmental outcomes of the US from 1991-2007 to changes in the import competition from China and examines how the US emissions respond to the Chinese import competition at the industry level and commuting-zone level. I further follow [63] to examine the effect of the conferral of Permanent Normal Trade Relations with China in 2001 on emissions of the US.

The methodology follows the spirit of [8], [1], and [32]. Since the change in import exposure could be caused by some unobserved industry demand-side shocks, which will cause an endogeneity issue. [8] uses the increased Chinese import competition in the other developed countries over the same period (1991-2007). I first analyze this relationship at the industry level. Empirical results show that the rise in the import exposure resulted in losses of 35.7 million pounds released in the first period 1991-1999 and 82.9 million in the second period 1999-2007. I also find the import exposure led to losses of 0.714 trillion units of hazard in the first period and 2.29 trillion units of hazard in the second period. Empirical results also show that stronger import exposure led to an increase in pounds released per employment and hazard per employment. To investigate localized emissions losses, I explore the effects of Chinese import competition at the commuting-zone level. Evidence indicates that the import exposure resulted in fewer pounds released and hazard per employment, but the estimates are statistically insignificant. At last, following [63], I analyze the relationship between emissions and the US granting Permanent Normal Trade Relations to China. Empirical results show that industries more exposed to the import exposure incur more emissions drop.

The findings have significant implications for trade liberalization's impact on emissions. Since the research on how the toxicity of discharged pollutant responses to trade liberalization is limited, the analysis in this paper provides a broader picture on the damage caused by emissions. Results show that rising Chinese import competition between 1991-2007 reduces not only the quantity but also the toxicity of emissions. This study highlights the health outcome of the trade, which contributes to the public ambivalence toward concern about increasing Chinese import competition and the trade war.

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Appendices

A Solving the model

This section provides details on how to solving model in section 2.3.

A.1 Solving the demand fuction

Maximization engineers or workers preferences of Eq. 2.3 subject to the budget constriants yields an inverse demand function:

$$\begin{aligned}\mathscr{L} = q_0^c + \alpha \int_0^N q^c(\omega)d\omega - \frac{\gamma}{2}\int_0^N (q^c(\omega))^2 d\omega - \frac{\eta}{2}\Big(\int_0^N q^c(\omega)d\omega\Big)^2 - \theta E(Z_i) \\ +\lambda\Big(\rho\tilde{\pi}/f_E + \bar{q_0}^c + \frac{tiEi}{L_i + M_i} - q_0^c - \int_0^N p(\omega)q^c(\omega)d\omega\Big)\end{aligned} \tag{A.1}$$

Deriving the FOC with respect to $q^c(\omega)$:

$$\alpha - \gamma q^c(\omega) - \eta\int_0^N q^c(\omega)d\omega = \lambda p(\omega) \tag{A.2}$$

$$\lambda p(\omega) = \alpha - \gamma q^c(\omega) - \eta Q^c$$

$$\lambda p(\omega) = \alpha - \gamma\bar{q}^c - \eta N\bar{q}^c$$

$$\bar{q}^c = \frac{\alpha - \lambda\bar{p}}{\gamma + \eta N}$$

Multiplying N on both sides of the function yields to:

$$Q = \frac{N\alpha - \lambda P}{\gamma + \eta N} \tag{A.3}$$

Insert Eq. (A.3) into Eq. (A.2), I can solve for demand function as:

$$q^c(\omega) = \frac{1}{\gamma}\Big(\frac{\alpha\gamma + \eta N\lambda\bar{p}}{\alpha + \eta N} - \lambda p(\omega)\Big) \tag{A.4}$$

where $\frac{\alpha\gamma+\eta N\lambda\bar{p}}{\alpha+\eta N}$ is the choke price.

A.2 Solving the price and output

Firms minimize their cost given production function (2.9):

$$\mathscr{L} = l + \tau Z + \lambda(q - q(z, l))$$

Taking the FOC with respect to z and l and deriving the demand of two inputs as:

$$l = \frac{q}{\varphi}(\frac{(1-\beta)\tau}{\beta})^{\beta}$$

$$z = \frac{q}{\varphi}(\frac{(1-\beta)\tau}{\beta})^{\beta-1}$$

Next, I derive cost function as follows:

$$C = \frac{q}{\varphi}\Theta\tau^{\beta}$$

where $\Theta = \frac{(1-\beta)^{\beta-1}}{\beta^{\beta}}$.

Maximization firms profit and taking derivative of p yields:

$$q(p) + p\frac{\partial q}{\partial p} - \frac{1}{\varphi}\Theta\tau^{\beta}\frac{\partial q}{\partial p} = 0 \tag{A.5}$$

Solving the price p as:

$$p = -\frac{q}{\frac{\partial q}{\partial p}} + \frac{1}{\varphi}\Theta\tau^{\beta}$$

Next, I solve for $\frac{\partial q}{\partial p}$ and $-\frac{q}{\frac{\partial q}{\partial p}}$ as:

$$\frac{\partial q}{\partial p} = \frac{1}{\gamma}(L_i + M_i)$$

$$-\frac{q}{\frac{\partial q}{\partial p}} = p^* - p$$

The price and output can be derived as:

$$p(c) = \frac{1}{2}(p^* + c\Theta\tau^\beta) \tag{A.6}$$

$$q(c) = \frac{L_i + M_i}{2\gamma}(p^* - c\Theta\tau^\beta) \tag{A.7}$$

A.3 Aggregate emissions

Aggregate emissions in two regions are Z^H and Z^F. Z^H consists of emissions from goods that are domestically consumed and that are exported, which implies to $Z^H = N_D^H z_D^H + N_X^H z_X^H$. The emission in region H and F are derived as:

$$Z^H = \frac{s^H M D^2 \beta k}{2\gamma(k+1)(k+2)(c_M)^k f_E \tau_H}\left((\mu L + s^H M)\tau_H^{2\beta}(c_D^H)^{k+2} + ((1-\mu)L + s^F M)\tau_F^{2\beta} t^{-(k+1)}(T^\beta)^{-k}(c_D^F)^{k+2}\right) \tag{A.8}$$

$$Z^F = \frac{s^F M D^2 \beta k}{2\gamma(k+1)(k+2)(c_M)^k f_E \tau_F}\left(((1-\mu)L + s^F M)\tau_F^{2\beta}(c_D^F)^{k+2} + (\mu L + s^H M)\tau_H^{2\beta} t^{-(k+1)}(T^\beta)^{k}(c_D^H)^{k+2}\right) \tag{A.9}$$

Vita

Tingsi Wang received her bachelor's degree in Accounting at Communication University of China. After getting her bachelor's degree, she went to Syracuse University to pursue a master's degree in Economics. She joined the economics department at the University of Tennessee after she graduated from Syracuse University. Her primary research focused on Environmental Economics and International Trade. After graduating in 2020, Tingsi Wang started her career in the private sector.