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Alecia Cassidy Fan Wu Yiyuan Zhang

Pollution Liability Insurance and Corporate Environmental Compliance in China



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Alecia Cassidy, Fan Wu, and Yiyuan Zhang

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Pollution Liability Insurance and Corporate Environmental Compliance in China

Abstract

This study examines the effect of a pollution liability insurance mandate on corporate environmental compliance in Shenzhen, China. We employ a triple differences design, comparing electroplating and circuit board manufacturing firms, mandated to purchase insurance, to industries and a neighboring city without the mandate. Results show a 0.48 reduction in annual environmental violations per firm (a 72% decrease). Only about half of firms comply. Within the Shenzhen electroplating and circuit board industry, we find that insured firms violate more than uninsured firms (an increase of about 0.09 annual violations). We find suggestive evidence that this increase is driven by moral hazard rather than adverse selection. Taken as a whole, our findings demonstrate that premium-based incentives effectively counteract market failures due to asymmetric information, increasing environmental compliance on net.

JEL-Codes: Q52, Q53, Q58, K32, G22

Keywords: Environmental compliance; liability insurance; moral hazard; adverse selection

September 2024

^{*} Alecia Cassidy, University of Alabama and RWI Research Network; Fan Wu, China Europe International Business School; Yiyuan Zhang, Instacart. - The authors thank: Maggie Brehm, Paul Brehm, Dylan Brewer, Yipei Cao, Traviss Cassidy, Lucas Davis, Cameron Ellis, Ying Fan, Timo Greve, Tong Guo, Xing Guo, Kookyong Han, Catie Hausman, Harlan Holt, Julian Hsu, Paan Jindapon, Ryan Kellogg, Harim Kim, Andreas Lange, Shaun McRae, David A. Miller, Michael Moore, Thomas Lyon, Michael K. Price, Matthew Van Essen, Michael Waite, Kenny Wunder, Carrie Xu, and Xiaoqing Guo. This manuscript also benefited from feedback from seminar and conference participants at the University of Michigan and AERE Summer Conference. A predecessor version appeared in Zhang's 2017 University of Michigan dissertation ("Three Essays on the Impacts of Energy and Environmental Policies"). The chapter was entitled "Pollution Liability Insurance and Corporate Environmental Compliance: A Case Study of Shenzhen," and was co-authored by Cassidy and Zhang. The statements in this paper are the opinions of the authors alone (and not of Instacart). Declarations: none. – All correspondence to: Alecia Cassidy, RWI Research Network, e-mail: awcassidy1@ua.edu

1 Introduction

The effectiveness of environmental regulation often hinges on the ability to align corporate incentives with environmental goals.¹ One approach is through mandatory pollution liability insurance,² which aims to make firms internalize the costs of environmental damage and incentivize them to reduce their pollution levels. In this paper, we examine whether the introduction of a pollution liability insurance mandate in China improves firms' environmental performance. Theoretically, the insurance mandate could have two countervailing effects. On the one hand, the insurance protects firms from liability for accidents, which raises concerns for moral hazard. On the other hand, insurance companies set premiums with the goal of deterring risky firm behavior.³ Rubinstein and Yaari (1983) and Rogerson (1985) have shown that when premiums can depend on past records in a repeated game between insurer and insured and the insured pay their own premiums, incentives to reduce future premiums can counteract the perverse effects of moral hazard, a hypothesis we test in this paper.

We estimate treatment effects for one of the pioneers in promoting pollution liability insurance in China—the city of Shenzhen. We focus on electroplating and circuit board manufacturing firms, which account for 75 percent of the firms mandated to purchase the insurance in Shenzhen. We also include two non-required industries— the paperproduct industry and the textile and dyeing industry—as a comparison group, and an adjacent city not subject to the mandate (Dongguan). We use a novel firm-level dataset on corporate environmental performance, which allows us to measure annual environmental violations. We employ a triple-differences design, comparing (i) Shenzhen and Dongguan (first difference), (ii) before and after the introduction of the liability insurance (second difference), and (iii) industries covered by the mandate and not covered (third difference).

¹For recent examples, see, e.g., Fowlie (2010); Fowlie, Reguant, and Ryan (2016); Shapiro and Walker (2018); Jacobsen, Sallee, Shapiro, and Van Benthem (2023).

²When accidents occur, liability insurance provides compensation for personal injury and property loss, and covers other related costs such as contamination clean-up charges.

³Premiums are based on characteristics including firm location, production scale, industry, evaluation of risk management capability, and past violations (Ministry of Environmental Protection (MEP) and China Insurance Regulatory Commission (CIRC), 2013).

We find that the insurance requirement reduces violations by about 0.48 (~ 72%). The results are robust to a number of specification checks, including exponential mean models. Furthermore, the results are stable across different sample selection criteria, and the treated and control firms exhibit similar trends prior to treatment.

We also examine compliance with the mandate, and find discrepancies between policy objectives and actual uptake. Only about 49% of required firms obtained insurance by the time they were required to comply, and firms not required to comply purchased insurance, suggesting that compliance was in effect voluntary. Furthermore, data inspection reveals the possibility that a "required firms list" distributed by the Shenzhen government is largely perfunctory, serving more to make the government appear successful in enforcing compliance than to convey information about which firms are required to comply.

Using a difference-in-differences strategy and limiting to the sample of Shenzhen ECB firms, we provide additional suggestive evidence that insured firms do violate more than uninsured firms, by about 0.09 violations- less than a quarter of the magnitude of the overall impact. Moreover, we examine which firms tend to be insured, and find violations do not differ by insurance status, but risk ratings from external auditors (which are used to determine premiums) do, with the least risky firms more likely to be insured. This suggests that moral hazard is more likely than adverse selection to explain the propensity of insured firms to violate more.

We contribute to four strands of literature. First, we contribute to the general literature informing on how policy interventions might be designed to counteract market failures due to asymmetric information in a range of contexts- recent applications include lending markets (Crawford, Pavanini, and Schivardi, 2018; Cuesta and Sepúlveda, 2021; Ioannidou, Pavanini, and Peng, 2022), rental markets (Brewer, 2022), automobile insurance Dionne, Michaud, and Dahchour (2013), and health insurance (Tebaldi, 2024).

Second, we contribute to a growing body of work suggesting that liability and mandatory liability insurance policies can be used as a beneficial form of environmental regulation (Boomhower, 2019; Laffont, 1995; Katzman, 1998; Kolstad, Ulen, and Johnson, 1990; Farber, 1991; Zweifel and Tyran, 1993; Alberini and Austin, 2002; Yin, Pfaff, and Kunreuther, 2011; Ben-Shahar and Logue, 2012).

Third, we contribute to a growing economic literature on Chinese environmental policy (Greenstone, He, Li, and Zou, 2021; Karplus, Zhang, and Zhao, 2021; Yu and Zhang, 2023; He, Wang, and Zhang, 2020; Ge, Huang, and Shi, 2024; Chen, Kahn, Liu, and Wang, 2018; Zhang, Chen, and Guo, 2018; Lin, 2013).

Fourth, we contribute to a budding literature on environmental liability insurance in China. To our knowledge, our paper is the first to estimate causal impacts of the insurance mandate on firm violations of environmental laws in China. Despite numerous local applications of pollution liability insurance pilots (Feng, Mol, Lu, He, and VanKoppen, 2014a,b), only a handful of studies have characterized the impacts of the insurance in China, and all have focused on outcomes other than firm-level violations.

Yang and Zhang (2022) and Wu, Zhang, Zhu, Jiang, and Jakovljevic (2022) examine the impact of the mandatory insurance policy on financial performance of listed firms (including accounting outcomes, Tobin's q and Corporate Social Responsibility ratings). Chen and Yang (2023) analyze the solvency of the insurance market.

Evidence on whether the insurance policy has the potential to reduce air and water pollution in China is mixed, with Xu and Jiao (2020) finding no impacts, and Zhu, Chen, Sun, and Lyu (2023) finding that air pollution is significantly reduced in cities with pilot programs. Shi, Jiang, Bao, Zhang, and Kang (2023) find reductions in only some of the pollutants they analyze, and document substantial regional heterogeneity in impacts. All of these studies use city or province level variation in implementation of pilot programs, similar to our estimation of the overall effect.

Our paper offers several advances: first, we examine violations, which directly factor into insurance premiums, and are likely to be more impacted by this particular policy than pollution as a whole. Second, our detailed data on which firms were required to buy insurance, which firms bought insurance, and risk ratings by external auditors jointly allow us to understand both compliance with the policy and the extent of market failures due to asymmetric information in this context.

The rest of the paper is organized as follows: Section 2 provides background information regarding environmental accidents and pollution liability insurance in China, and explains our choice to focus on Shenzhen's ECB sector. Section 3 describes the data. Section 4 describes the main specification and results (Section 4.1), investigates compliance with the mandate (Section 4.2), tests for adverse selection or moral hazard among insured firms (Section 4.3), and presents stylized facts on which firms get insurance (Section 4.4). Section 5 discusses and concludes.

2 Policy Background

2.1 Environmental Accidents in China

China's remarkable economic and industrial development has been accompanied by worsening environmental quality and a growing number of environmental accidents (Cao, Yang, Liu, Ma, Wang, and Bi, 2018). According to data from the China Environmental Yearbook, roughly 540 accidents occurred each year between 2006 and 2014, many of which were catastrophic, resulting in water pollution, farmland contamination, poisoning and even death.⁴ These accidents have led to productivity loss in farmland and fisheries, and exposed thousands of Chinese citizens to health risks. The direct financial loss was estimated to be more than tens of millions of dollars (China Environment Yearbook, 2015).

These accidents have also given rise to social unrest, which results in mass demonstration and protests.⁵ For victims, obtaining timely and fair compensation for health and property damages is challenging. This is in part due to the inadequacies of China's legal system when it comes to environmental issues. Litigation is often lengthy, and evidentiary burdens are sometimes unreasonable. When it comes to health issues, compensation is often inadequate, owing to a lack of precedent for quantifying damages. For

⁴Figure A-1 shows the number of environmental accidents that occurred annually from 2006 to 2014. Table A-1 in the appendix presents examples of major environmental accidents from 2000 to 2022.

⁵News coverage on protests can be easily found online, such as this one: http://www.europe-solidaire. org/spip.php?article15399.

example, when a chemical company in Hunan was found to be responsible for blood lead levels in 13 children that exceeded China's national standard, families of 11 of the children were denied compensation on the grounds that their condition did not require medical procedures or drugs and thus the court had no procedure for calculating damages due to lead in the blood. The two children with the highest blood levels were able to obtain only 10,000 CNY, or approximately 1,600 USD, in compensation.⁶

2.2 Environmental Pollution Liability Insurance

To address growing public concern about the environment and ensure fair compensation for environmental damages, the Chinese government promulgated environmental pollution liability insurance with the stated purpose of employing an "economic instrument."

The rollout involved three stages (Feng et al., 2014a). The insurance was first introduced to a few northeastern cities in 1991 (Congjun and BinChik, 2012). However, the enrollment was low, as only 15 firms had purchased coverage between 1991 and 1994 (Born and Chen, 2013). The second phase took place in 2007 when "The Guidelines on Environmental Pollution Liability Insurance" (The Guidelines) was issued jointly by the Ministry of Environmental Protection (MEP) and the China Insurance Regulatory Commission (CIRC). The Guidelines encouraged local governments to experiment with promoting the insurance. Four provinces and four cities were chosen as pilots by the end of 2008.⁷ These places represent different geographic regions of China. By 2012, 14 cities had launched trial applications of the policy. The third phase started in February 2013 when the central government promulgated "The Guiding Opinions on Pilot Scheme for Compulsory Environmental Pollution Liability Insurance" (The Opinions). The Opinions recommended that provinces mandate the insurance to be purchased by all firms dealing with heavy metals. According to The Opinions, three types of expenses are covered by the insurance in case of accidental pollution: (1) third-party liability (personal injury, death and property loss), (2) necessary and reasonable expenses incurred by the insured

⁶See the news report at http://view.news.qq.com/original/intouchtoday/n3448.html.

⁷These are Jiangsu, Hubei, Hunan, Henan, Chongqing, Shenzhen, Ningbo, and Shenyang.

to save a third party's life (including expenses for medical treatment) or to prevent or mitigate the loss of property of any third party, and (3) necessary and reasonable clean-up expenses incurred by the insured in order to control the extent of pollution or to remediate contaminated waters and land in accordance with environmental legislation.

Guided by The Opinions, each province is responsible for developing its own implementation plan based on local conditions. Therefore, there is considerable variation across regions in terms of roll-out pace, enforcement strength and industry coverage. This heterogeneous implementation across China motivates our selection of just one jurisdictional unit as our treatment group.

In this paper, we study whether the mandatory pollution insurance policy improves firms' environmental compliance. Although the effect on environmental accidents is interesting, we do not have enough observations on accidents given that they are rare in nature.⁸ Instead, we focus on how the mandatory pollution insurance affects the relatively more frequent violations of environmental regulations. On one hand, having insurance can lead to moral hazard and cause firms to mitigate risk less in their production process. This will result in more violations. On the other hand, two channels exist to incentivize polluters to improve their operation and increase compliance with environmental legislation. The first channel is through the environmental risk assessment conducted by a third party as required by the government. Third party experts evaluate firm characteristics such as production scale, location, and operational procedures and determine their riskiness. More risky firms will be required to purchase insurance with higher coverage at a higher expense.⁹ They can also provide suggestions on how to reduce their risks. The second channel lies in how the premiums are structured. Insurance companies take into account firms' past environmental compliance records when setting their premiums. Firms with no violation records will be offered discounts. This provides another channel to incentivize firms to comply with environmental regulations. See Appendix Section A-4 for more information on the process by which ratings and

⁸For example, in Shenzhen, the first insurance payout happened in 2015.

⁹The coverage requirement can range from 150k to 1.5 million dollars.

premiums are determined.

2.3 The Shenzhen ECB Industry

Shenzhen was the first pilot city in South China, and one of the first to implement the insurance policy on a large scale.^{10,11} Shenzhen is a suitable case for the empirical analysis for two reasons. First, being a pilot city, Shenzhen has a large number of insured firms and a relatively long history of implementing the policy. The mandatory insurance requirement was first introduced in 2008 for firms producing hazardous waste, and then extended to other industries such as hazardous chemical and lead battery producers, sewage and garbage disposal plants, and electroplating and circuit board factories in 2012. The coverage reflects Shenzhen's industrial structure and includes firms that pose the highest environmental risks to the public. As of 2015, a total of 747 firms were subject to the insurance mandate in Shenzhen. Second, Shenzhen is one of the few regions that publicly list the names of required and insured firms and continuously update the lists from year to year. This allows us to keep track of each firm's status (e.g. whether a firm was required to purchase insurance and whether it actually purchased it in each year). Furthermore, Shenzhen releases publicly available firm level environmental risk ratings and re-ratings, which are used to determine premiums, and which we use to examine potential adverse selection and moral hazard.

We focus on the electroplating and circuit board manufacturing industry (hereafter referred to as ECB). ECB firms account for about 75 percent of all required firms. The ECB sector is relatively homogeneous in terms of products, production processes, and the amount of waste produced.¹²

¹⁰It is located in the relatively developed Pearl River Delta, bordering Hong Kong to the south.

¹¹Shenzhen was selected as a pilot largely due to its status as an experimental field for both economic reform and environmental protection. Shenzhen was singled out to be the first special economic zone of China in 1980, and has proven to be one of the most robust and fastest growing cities in the country since then. Shenzhen is also regarded as a "green" city. It was named the nation's first model city for environmental protection in 1997, and thereafter won other awards such as "model city for protection of ozone layer" and "national greenery model city." It has been a test field for a number of environmental policies. For example, in 2013, Shenzhen became one of seven cities to pilot China's regional carbon emission trading system.

¹²By contrast, although hazardous chemical producers are also required to purchase the insurance, depending on which chemicals they produce, the production process can be very different, making direct

We use the city of Dongguan as a control group. Dongguan is adjacent to Shenzhen¹³ and has a similar industrial structure. Dongguan did not impose any insurance requirement over the course of our sample.¹⁴ We exploit this difference in implementation timing in our design. We also include the paper-product industry and the textile & dyeing industry as controls.¹⁵ These two industries are also regular polluters but are not required to buy the insurance due to their relatively low risk of causing environmental disasters.

3 Data

To measure firms' environmental performance, we use violations data from the Institute of Public & Environmental Affairs (IPE).¹⁶ IPE is a non-profit environmental research organization registered and based in Beijing, China. Since its establishment in June 2006, IPE has dedicated itself to collecting, collating, and analyzing government and corporate environmental information. The IPE database provides records of environmental violations committed by companies and factories drawn from various sources, including reports from news articles and local environmental protection agencies. Each record identifies the name of the polluter, describes the violation, and documents the date, the supervision agency and the record source.

We use the number of violations a firm commits in a year to measure its environmental

comparison across firms less viable.

¹³A map is presented in Appendix Figure A-2. The distance between the two cities is approximately 62 km.

¹⁴Our sample covers the years 2006–2014. Dongguan announced a voluntary pollution liability insurance pilot in June of 2015, but only 14 firms had insurance by the end of 2015 (https://ta.sun0769.com/tacontent/?id=1837). The voluntary pilot encouraged insurance for both ECB and paper and textiles (whereas in Shenzhen, the ECB industry was required to insure and paper and textiles was not). Therefore, we anticipate any forward-looking behavior among firms in Dongguan to be both a small effect (since the policy is not announced until 2015, so firms would have had to acquire insider knowledge) and to be similar between ECB and paper and textiles industries, and thus netted out by our fixed effects.

¹⁵We compile the list of firms in those industries by selecting firms which pay pollution discharge fees (indicating they are polluters) and have certain relevant characters in their names. For example, we will pick out polluting firms that contain "paper" in their names and put them under the "paper-product industry" category. This is not perfect as not all paper-product companies have "paper" in their names. But if whether containing "paper" or not in the name is uncorrelated with the other characteristics of the firm, this process gives us a random sample of firms in this industry.

¹⁶http://www.ipe.org.cn/

performance. Violations range from exceeding pollution limits to operating pollution treatment devices inappropriately or failing to obtain environmental permits for new projects. Some violations are detected through onsite inspection, while others are found using automatic monitoring devices. We remove two types of records. First, we remove entries related to firms' annual environmental credit rating grades, as they reflect firms' overall environmental performance in a given year and hence double count any violations firms have already committed. Second, we remove any records that result from special enforcement actions. These happen when local environmental protection agencies temporarily intensify the inspection effort, targeting clusters of firms or particular industries. This leaves us with 1,933 violation records for 1,064 firms in the sample from 2006 to 2014.¹⁷ We use these records to construct a balanced panel of annual firm violations.¹⁸

Table 1: Summary Statistics

City	Industry	Number of Firms	Average Number of Violations
Shenzhen	ECB industry	557	0.10
	paper-product industry	14	0.06
	textile & dyeing industry	29	0.07
Dongguan	ECB industry	165	0.13
	paper-product industry	128	0.09
	textile & dyeing industry	171	0.06

Notes: This table reports the number of firms and the average number of violations per firm per year for each industry in each city in our dataset (which spans years 2006–2014)

Table 1 presents summary statistics for the three industries in Shenzhen and Dongguan, including counts of firms. On average, for every 100 ECB firms, 10 violations are committed per year in Shenzhen, while 13 violations are committed per year in Dongguan.

To motivate the empirical analysis, we plot the average number of violations over time across cities and industries (Figure 1). In general, the movements in Shenzhen and Dongguan track each other closely before 2012. The number of violations was low before

¹⁷We inquired about data from more recent years, but the IPE was unable to provide it.

¹⁸It is possible that firms closed or changed industry over this time period, leaving our sample to under-count violations for these firms. We address this possibility using information from external risk audits, which took place in 2014 and in which closures and industry changes are flagged. See also footnote 22.



Figure 1: Average Number of Violations by Industry and City over Time

Notes: This figure depicts average yearly per-firm violations over time for Dongguan and Shenzhen, broken out by ECB and non-ECB firms.

2012 and increased substantially after 2012. This sudden increase can be attributed to several factors. The most likely factor contributing to the increase is the delegation of supervision power to lower levels. Before 2013, only the environmental supervision branch directly under the municipal environmental protection agency had the punitive power, but afterwards this power was delegated to all protection bureaus at the district and town-level. This change increased the number of supervisory personnel, and thus led to a sudden increase in the number of violation records.¹⁹ Other factors that may have contributed to the increase include greater scrutiny on polluters and the increasing usage of automatic monitoring devices.^{20,21} Because of these changes, a direct before-after comparison will be problematic and therefore we focus on the difference across cities. For ECB firms, the gap became larger after 2012, which suggests that the policy might have an impact. However, the change in the gap could have been driven by an idiosyncratic shock to one city but not the other around the same time as the policy was implemented. This motivates us to look at a third difference – the difference between required and non-required industries. This will ensure that city-level shocks that affect the number of violations in all three industries do not bias our estimates.

4 Empirical Specifications and Results

4.1 Main Effect of Insurance on Shenzhen ECB Sector

4.1.1 Main Empirical Framework

We use the following linear specification for our main estimation:

$$Viol_{icst} = \alpha Shenzhen_c ECB_s Post_t + \theta_{cs} + \tau_{tc} + \delta_{ts} + \epsilon_{icst}$$
(1)

¹⁹A principal at the policy and regulation division of Dongguan's environmental protection agency confirmed this in an interview with Dongguan Daily. See: http://news.sun0769.com/dg/headnews/201311/t20131106_2985615.shtml.

²⁰In 2006, none of the violations was detected by automatic monitoring devices, while in 2014, about 10% were. Automatic monitoring devices make detection of violations easier.

²¹Karplus et al. (2021) points out that 2006–2015 was characterized by increased enforcement of environmental laws in China.

We use subscript *i* to index firms, *s* to index the three sectors, *c* to index the two cities, and *t* to index years (2006–2014). *Viol*_{*icst*} is the number of violations firm *i* committed in year *t*. *Shenzhen*_{*c*} is a dummy indicating whether the firm is in Shenzhen. *ECB*_{*s*} is a dummy indicating whether the firm is in the ECB sector. θ_{cs} is a set of city by sector fixed effects, τ_{tc} is a set of year by city fixed effects, and δ_{ts} is a set of year by sector fixed effects. We cluster standard errors at the firm level.

Note that the treatment effect we recover (α) is an industry-level effect. This is suitable to measure the overall impact for two reasons. First, we expect spillovers between firms of the same industry, violating SUTVA if we attempt to compare nearby firms. Therefore, it makes sense to use a geographically distinct control group for our main analysis. Further, any enhanced media attention could be applied to the entire industry (e.g. Bai, Gazze, and Wang, 2022). Second, all firms in Shenzhen's ECB industry were eventually required to obtain insurance due to this policy. Even if firms did not purchase insurance in a specific period, they might alter their behavior in anticipation of future requirements. Behavior driven by the expectation of lower future premiums is forward-looking and may begin before obtaining insurance.

4.1.2 Main Results

Our main estimates are presented in Table 2. In the first column, we show the estimate for the entire sample. In the second column, we exclude situations where firms closed or changed industry.²² In the third column, we exclude the year 2012. The mandatory insurance requirement for ECB firms was introduced on May 30, 2012, with firms expected to comply by the end of 2012. Therefore, firms would only have had a chance to

²²Note that we do not have complete information on which firms closed or changed industry and when. The information we do have comes from risk re-ratings within the Shenzhen ECB sector, but only some firms were re-rated, and we do not have information on why firms were re-rated. Firms that close would mechanically have 0 violations in our dataset, so we think that taking these out is prudent. We acknowledge that, because some non-Shenzhen ECB firms also close, taking them out in the treatment group but not the control group should bias our estimates towards 0. The point estimates are not significantly different when excluding these problematic observations. See the appendix for more on the re-rating data (Section A-4) . We additionally check in the appendix (Table A-4, discussed in Section A-3.2) that the results are robust to the sample restriction that all Shenzhen ECB firms have non-missing re-rating data- in this sample, it would be impossible for the reduction in violations that we find to be driven by firms in the treatment group closing down or changing industries, because re-ratings occurred in 2014.

adjust their behavior in the second half of 2012, and may not have acquired the insurance until the end of that year. This is our preferred specification. As a percent of the average violations in Dongguan's ECB sector in the post period, the estimate represents a 72% reduction in violations. In the fourth column, we show robustness to including firm fixed effects. The impacts are similar and highly statistically significant across all columns of the table.

	(1)	(2)	(3)	(4)
Shenzhen \times ECB \times Post	-0.485***	-0.482***	-0.476***	-0.476***
	(0.127)	(0.127)	(0.128)	(0.128)
Sample Selection:				
Exclude Closed or Chngd		Y	Y	Y
Exclude 2012			Y	Y
Fixed Effects:				
Sector \times Yr	Y	Y	Y	Y
$City \times Yr$	Y	Y	Y	Y
City imes Sector	Y	Y	Y	
Firm				Y
DG ECB Mean	0.463	0.463	0.658	0.658
Firms	1,064	1,054	1,054	1,054
Observations	10,640	10,540	9,486	9,486

Table 2: Main Estimates

Notes: This table presents estimates corresponding to specification (1). The first column includes sector by year, city by year, and city by sector fixed effects. In the second column, we restrict the sample by excluding firms observations where a firm closed or changed industry. In the third column, we additionally drop the year 2012. In the fourth column, we replace city by sector FE with firm FE. Standard errors are clustered at the firm level.

Figure 2 presents the event study analogue of column 2 in Table 2. The event study version replaces $Post_t$ in (2) with a set of year dummies, excluding a dummy for base year 2012. The figure shows large negative impacts following the introduction of the policy, with no evidence of differential pre-trends.

Our primary specification is linear, but we are sympathetic to the view that a nonlinear model could be more suitable. Therefore, we present estimates from two exponential mean models (Poisson QMLE and negative binomial MLE) as well as an inverse hyperbolic sine transformation of the dependent variable in the appendix (Section A-3.1 and Table A-3). The table shows that implied percentage changes are similar across models. We additionally show that results are robust to various alternative sample



Figure 2: Event study

Notes: This figure depicts event time coefficients from the main regression specification. The shaded region represents 95% confidence intervals. Standard errors are clustered at the firm level.

selection criteria (Appendix Table A-4, discussed in Section A-3.2).

4.2 Compliance

Up to this point, our analysis has operated under the assumption that every firm in Shenzhen's ECB industry purchased insurance. This could be conceptualized as an intentto-treat. However, in reality, the government created lists of firms that were required to comply with the insurance mandate by specific years, and compliance was only partial. In this sub-section, we investigate compliance.

The largest batch of firms was required to comply by 2012, with additional firms required to comply in 2013 and 2014. In Figure 3a, we show the compliance rates of ECB firms in Shenzhen over time. The figure indicates the total number of firms that were required to obtain insurance (transparent regions) versus those that actually obtained it (solid regions). The colors indicate the cohorts, defined by when a firm was first "required" to obtain insurance. Only about 49% of required firms obtain insurance in a given year, a fact that calls into question whether insurance was required in practice.

Figure 3b presents complementary information on compliance. For each required cohort, we plotted the percent of firms obtaining insurance by the end of each of 2012, 2013, and 2014. The figure shows that firms from the 2013 required cohort were more



Figure 3: Compliance

Notes: Panel (a) is an area that plot describes insurance requirement and uptake among ECB firms in Shenzhen. The transparent region indicates the total number of required firms and solid areas indicate the number of firms that have obtained insurance by cohort and year. Panel (b) presents the percent of firms insured by time the firm was first put on a required firms list. Marker size denotes number of firms.

likely to purchase insurance by the end of 2012 than those in the 2012 required cohort. Figures 3a and 3b show that only about half of required firms purchase insurance, and firms purchase insurance when not required, calling into question whether the cohorts of required firms actually convey information about which firms are required to comply.

We suspect that the government may be manipulating these lists to artificially enhance their compliance statistics. Specifically, firms that did not comply with the insurance mandate were removed from the required lists, thereby giving the false impression of higher compliance rates. This is demonstrated by the dip in Figure 3a (transparent region dipping in 2013), which we believe reflects the removal of non-compliant firms from the required list rather than a genuine reduction in requirements. Data inspection revealed that 122 firms were on a required list but were later removed at some point. Of these, at least one firm closed or changed industry,²³ 18 had insurance in the past, but none bought insurance after being taken off the required list. Notably, 115 firms were removed in 2013, with none having bought insurance in 2012 despite being required, and 67 of these firms were re-added in 2014, with 11 buying insurance in that year. This all suggests that the "required firms list" is largely perfunctory, serving more to make the government appear successful in enforcing compliance rather than reflecting the actual enforcement of the mandate.

This investigation into the actual implementation of the policy indicates that the compliance achieved is largely influenced by market mechanisms rather than strict regulatory enforcement. Consequently, this context allows for the possibility of adverse selection, which would be convenient to ignore in a study of mandatory pollution liability insurance. This is unfortunate from the standpoint of pinning down mechanisms since moral hazard and adverse selection can be empirically indistinguishable.²⁴

That said, the finding that insurance was not driven by regulatory compulsion may enhance the external validity of our conclusions. First, the Chinese government's stated

²³This information is gleaned from re-rating data, which is not comprehensive. See the appendix for more on re-rating data (Section A-4).

²⁴We discuss this further in Section 4.3, and show suggestive evidence that adverse selection is unlikely in this context.

objective was to establish a market-based system for pollution liability insurance, and our findings suggest that this policy operated with a greater reliance on market forces than previously assumed. Second, the insights gained from this analysis may be more applicable to other developing countries where command-and-control approaches are less feasible.

4.3 Adverse Selection and Moral Hazard

To explore the potential for adverse selection and moral hazard, we restrict the sample to only Shenzhen ECB firms and compare insured and non-insured firms. Because we found in Section 4.2 that the required lists do not provide useful information about which firms are expected to comply, we proceed with our analysis as if they are irrelevant to firm decisions.

Figure 4 shows the average number of violations broken out by whether firms were ever insured or not. Pre-trends appear to be roughly parallel, which points against adverse selection.²⁵

Figure 4: Average number of violations for insured and non-insured firms over time.



Notes: The figure shows the average number of violations over time, by whether the firm ever obtained insurance in our sample, calculated from raw data.

Most of our variation is from pre-to-post 2012 and between firms that obtained

²⁵However, it is still possible that unobserved aspects of a production process could influence firms' decision to become insured. Firms are more informed about future expected pollution risk than regulators, insurance companies, or the authors of this paper.

insurance vs. those that did not. The main estimating equation to test whether there was a differential impact on violations by whether a firm was insured is thus:

$$Viol_{it} = \beta EverInsured_i Post_t + \eta_i + \sigma_t + \epsilon_{it}$$
⁽²⁾

We also present estimates replacing *EverInsured*_i*Post*_t in equation (2) with a timevarying insurance measure, *Insured*_{it}. This measure indicates that the firm had obtained insurance by the start of the current year (for example, we set *Insured*_{it} to 1 in 2013 when a firm had obtained insurance by the end of 2012).²⁶ The interpretation is slightly less straightforward because there are 55 instances where a firm stops the insurance during the same year. Therefore, we produce a robustness check in which we exclude these 55 observations.

One concern raised by our exploration of risk levels in the next sub-section is that the insured and not insured groups are not directly comparable- in particular, the higher risk firms are less likely to obtain insurance. Therefore, we undertake a linear regression adjustment specification:

$$Viol_{it} = \gamma_1 Insured_{it} + \gamma_2 Insured_{it} R\ddot{is}k_i + \eta_i + \sigma_t + \sum_s \mathbb{1}[s=t]R\ddot{is}k_i + \epsilon_{it}$$
(3)

In the above, the variable $Risk_i$ is the risk rating re-centered about its mean in the ever insured group. That is, $Risk_i = Risk_i - \frac{\sum_{i:EverInsured_i=1}Risk_i}{\sum_i EverInsured_i}$. We interact re-centered risk with both the dummy for being insured and the year dummies.

This regression adjustment specification accounts for treatment effect heterogeneity, following Heckman, Ichimura, Smith, and Todd (1997) and Heckman, Ichimura, Smith, and Todd (1998). Intuitively, this accomplishes two objectives. First, it allows for the relationship between $Risk_i$ and potential outcomes to vary in a linear fashion (so the intercept and slope are allowed to differ for the insured and not insured groups). Second,

²⁶Recall that a firm is defined as having complied in 2013 if they bought insurance by the *end* of 2013.

it re-centers the treatment effect, so that γ_1 represents the effect of insurance at the average risk level for firms in the insured group, which strengthens our argument for having found an average treatment effect on the treated.

In (3), the parameter γ_1 is our main effect of interest (regression-adjusted average treatment effect on the treated), comparable to β in (2) and its variations. γ_2 is the interaction effect between insurance and risk rating– a positive value would indicate that higher risk firms violate more when they are insured.

The estimates comparing insured and uninsured firms are presented in Table 3. The overall impact of insurance is stable across columns, indicating robustness to which measure of insurance is chosen (ever insured vs. currently insured), whether we drop firms that subsequently stopped insurance, and regression adjustment to account for differential risk levels between insured and uninsured. However, the estimates are only statistically significant at the 5-10% level.

The regression adjustment specification in the fourth column of Table 3 additionally allows us to test whether firms evaluated as higher risk violate more or less after obtaining insurance. The interaction effect shows that, conditional on getting insurance, higher risk firms violate more. This constitutes evidence of moral hazard.

Because it is conceptually most straightforward, we present the event study analogue of column 1 in Table 3 to check that pre-trends appear to be parallel. The event study version replaces $Post_t$ in (2) with a set of year dummies, excluding a dummy for base year 2012 (Figure 5). The pre-period coefficients are not statistically different from 0, but 95% confidence intervals mostly include the post-period estimates (the one exception is the coefficient on year 2011). In the post-period, we can reject the null hypothesis that the effect equals 0 in 2013 but not in 2014- this finding is congruent with the relatively weak significance levels depicted for the impact of insurance in Table 3.

One might be concerned that our identification strategies in equations (1) and (2) appear to be very different. In particular, we do not use other industries and sectors to

	(1)	(2)	(3)	(4)
Ever Insured × Post	0.090^{*}			
	(0.048)			
Insured		0.119**	0.102^{*}	0.096*
		(0.051)	(0.053)	(0.055)
Insured $ imes$ Risk				0.211^{**}
				(0.106)
Sample Selection:				
Exclude Closed or Chngd	Y	Y	Y	Y
Exclude 2012	Y	Y	Y	Y
Exclude Stopped Ins			Y	Y
Fixed Effects and Slopes:				
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
$Yr \times Risk Slopes$				Y
Uninsured Mean	0.239	0.246	0.246	0.260
Firms	547	547	547	459
Observations	4,923	4,376	4,323	3,631

Table 3: Estimates Comparing Insured and Uninsured Firms

Notes: In column 1, we present the estimates corresponding to (2). In column 2, we replace Ever Insured with a dummy for the firm obtaining insurance by the beginning of the year. In column 3, we exclude those situations where a firm stopped the insurance during that same year. In column 4, we undertake a linear regression adjustment by re-centering the risk level by its mean among insured firms, and then interacting it with our insured dummy as well as year dummies. At the bottom of the table, "uninsured mean" is the mean number of violations in the post-period for the uninsured group of Shenzhen ECB firms. In column 1, the uninsured group is defined as the never-insured, whereas in the remaining columns, the group is all firms not insured by the beginning of the year. Standard errors are clustered at the firm level.

Figure 5: Event Study, by Insurance



Notes: The figure shows the event study corresponding to the event study analogue of equation (2). The shaded area represents 95% confidence intervals computed from standard errors clustered at the firm level.

net out potential confounders in our estimation of (2).²⁷ In light of this, our appendix presents an additional robustness check that adds continuity between our two empirical designs (Table A-2). In the table, we show the results from separate regressions of (1), each using either the ever insured or never insured as the treated group of Shenzhen ECB firms, and comparing the two treated groups to controls in Dongguan and paper and textiles as in our main estimation. The difference in the coefficients between these two separate regressions is very similar in both magnitude and statistical significance to that in column 1 of Table 3.²⁸

4.4 Which firms end up obtaining insurance?

This section explores whether insured firms differed from uninsured firms along two dimensions: pre-period violations (Section 4.4.1) and risk ratings (Section 4.4.2).

4.4.1 **Pre-period Violations**

We first check whether the distribution of baseline violations is similar for ever and never insured firms by presenting the density of baseline violations (Figure 6a). The density is similar across the two groups, though the tail is longer for the never insured group. We do not find evidence that ever insured and never insured firms had different pre-period violations (means are 0.09 and 0.10, p=.23).²⁹

4.4.2 Risk Ratings

Environmental risk ratings were produced by independent auditing firms and are used to determine insurance premiums. Appendix Section A-4 describes the ratings. These ratings are positively correlated with baseline violations. Figure 6b presents the average number of insured firms by environmental risk rating. The figure demonstrates that, for a given level of baseline violations, the never insured have higher risk ratings. Additionally,

²⁷Year by sector fixed effects would be the exact same as year fixed effects since there is only one sector, and city by sector fixed effects would be the same as year fixed effects since there is only one city. City by sector fixed effects would be absorbed by firm fixed effects.

²⁸The difference is calculated using stacked regression and estimated to be 0.090. The *p*-value associated with the null hypothesis that the coefficients are the same is p = 0.059.

²⁹This t-test is calculated from the sample of all firms in the Shenzhen electroplating industry, with each firm as one observation.

Figure 6: Insurance, Violations, and Risk Ratings

(a) Density of Baseline Violations, Ever Insured vs. Never Insured



Notes: Panel (a) depicts the kernel density of violations in the pre-period for ever and never insured firms. Panel (b) presents the relationship between violations and risk ratings (see Appendix Section A-4 for more). Panel (c) plots the fraction of insured firms over time by risk rating.

the figure illustrates that firms with lower risk ratings are more likely to have insurance, suggesting that higher premiums for high-risk firms may discourage them from obtaining insurance. Appendix Figure A-3 presents complementary evidence that firms classified as medium or high risk tend to have higher levels of baseline violations.

Figure 6c additionally depicts the fraction of insured firms over time by risk rating. The lowest risk firms are most likely to have insurance in every year. This further strengthens the argument for moral hazard driving the increase in violations for insured firms that we see in Section 4.3, instead of adverse selection.

We speculate that these stylized facts are driven by premiums which are differentiated enough by risk levels to deter adverse selection. However, we cannot rule out a separating equilibrium with partial unraveling. Without loss of generality, suppose two insurance products serve "safe" and "risky" firms, respectively. Firms at intermediate risk levels are pooled with higher risk firms, leading to premiums being too high in expectation for the majority of firms in this group, and resulting in under-insurance among the risky firms. Adverse selection could still be at play *among* the risky firms.

5 Discussion and Conclusion

The substantial reduction in environmental violations that we document following the introduction of the insurance mandate suggests that pollution liability insurance can increase corporate environmental compliance. By tying insurance premiums to environmental performance, firms are incentivized to adopt better practices to reduce environmental risk.

Our main finding is a reduction of 0.48 violations per year for firms in the Shenzhen ECB sector. This should be seen as an overall net effect of the insurance mandate. The effect is highly statistically significant and robust across various sample selection criteria and model specifications, including linear, Poisson, negative binomial, and inverse hyperbolic sine models. An event study analysis shows no evidence of differential pre-trends. We also investigate compliance with the mandate, and find lists of firms required to comply contain no information on actual enforcement or encouragement of insurance uptake, and mainly serve to make the government appear successful in implementing the policy. This is in line with prior findings that Chinese local governments tend to manipulate data on environmental policy (Ghanem and Zhang, 2014; Ghanem, Shen, and Zhang, 2020; Karplus et al., 2021). It also parallels the finding in Feng et al. (2014b) that compulsory environmental pollution liability insurance is in effect voluntary in China. Firms purchase insurance even when not required, which means our setting admits the possibility of adverse selection.

To quantify the extent of market failures due to asymmetric information, we use variation in insurance uptake within firms subject to the mandate. Insured firms exhibit an increase in violations compared to uninsured firms (~ 0.09 additional violations). Several findings suggest that the increase is driven by moral hazard rather than adverse selection. First, baseline violations are similar between insured and uninsured firms. Second, conditional on obtaining insurance, higher risk firms tend to violate more. Third, insured firms tend to be those with the lowest risk ratings.

Our finding that the increase in violations among insured firms is only about a quarter of the overall negative impact on violations indicates that market failures due to asymmetric information are effectively mitigated by premium-based incentives. This can be attributed to forward looking behavior on the part of firms- firms reduce violations because they expect to obtain insurance in the future. The findings support Rubinstein and Yaari (1983) and Rogerson (1985), who suggest that appropriate premium structures can counteract moral hazard by linking premiums to past performance. Furthermore, at least in the short run, the findings suggest partial compliance with the mandate did not undermine policy effectiveness, and that "treatment" should be considered at the industry level given forward-looking behavior of firms.

Several caveats apply. First, the results may not directly apply to other regions and industries. Although we find the insurance reduces violations in Shenzhen, to the extent

that other regions may adopt a different premium formula, firms' compliance behavior may be different in those places.

Second, for the analysis, we assume away any shock that affects only one industry in only one of the cities. We consider such a case to be unlikely, given that the cities are next to each other and firms in those cities serve a much larger national and even global market. However, this is a possibility that we cannot completely rule out.

Third, the number of violations is subject to enforcement strength and inspection effort. Although we have removed special inspections, we cannot observe the enforcement effort directly. If enforcement effort changes in different ways for different industries and those changes are city-specific, this may invalidate our approach. Enforcement could depend on local political incentives (e.g. He et al., 2020; Chen et al., 2018; Greenstone and Hanna, 2014) or central government oversight (Zhang et al., 2018). The impact of enforcement and inspection can be complicated and paradoxical in the Chinese context (Lin, 2013).

Concerning this policy in particular, three questions remain unanswered in our analysis. First, does the initial reduction in violations that we document persist over time? Second, do firms engage in riskier behaviors in other areas not covered by the insurance (Hernández-Cortés, 2022)? Third, what role do insurance companies play in monitoring and enforcing compliance with environmental laws?

We end with two suggestions for future work on pollution liability insurance policies more broadly. First, randomized control trials (RCTs) or natural experiments that introduce variations in insurance terms, such as premium adjustments based on past compliance, could be used to fully understand the mechanisms behind the firm-level behavior we document. Second, further investigation into the political economy considerations associated with these mandates in developing vs. developed countries could better contextualize our findings.

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Appendix

A-1 Appendix Figures

Figure A-1: Number of Environmental Accidents: 2006-2014



Notes: This figure presents the number of environmental accidents in China over the sample period.



Figure A-2: Location of Shenzhen and Dongguan

Notes: This map of China indicates the location of Shenzhen and Dongguan. Source: Google Maps.

Figure A-3: Density of baseline violations by Risk Category



Notes: This figure shows the density of baseline violations by risk rating.

A-2 Appendix Tables

Environmental Accident	Date	Polluting Firms	Province	Consequence
Duyun dam collapse	09/11/2002	Lead and Zinc Mining Firms	Guizhou	Water and land contamina- tion
Aniline explosion and leakage	11/13/2005	Jilin Petrochemical Company	Jilin	6 killed; 70 injured; River contamination
Lead poisoning	08/02/2009	Dongling Group	Shaanxi	851 children poisoned
Cadmium pollution	08/06/2009	Xianghe Chemical Plant	Hunan	26 killed; Many poisoned; Farmland contamination
Copper acid water leakage	07/03/2010	Zijin Mining Group	Fujian	River contamination; Finan- cial loss of \$4.6 million from
Xingang oil spill	07/16/2010	Dalian New Port	Liaoning	fisheries Marine and land contamina- tion
Tianjin chemical explosion	08/12/2015	Tianjin Port	Tianjin	165 killed; 798 injured; Ma- rine contamination
Xiangshui chemical explosion	03/21/2019	Jiangsu Tianjiayi Chemical	Jiangsu	78 killed; 617 injured; River contamination
Yichun molybdenum mine leakage	03/28/2020	Luming Mining	Heilongjiang	River contamination
Panzhou oil leakage	02/07/2022	Hongsheng Coal Coking Company	Guizhou	River and soil contamination

 Table A-1: Major Environmental Accidents in China: 2000-2022

Notes: This table contains a list of prominent accidents that the authors compiled from news reports.

	(1) Ever Insured:	(2) Never Insured:	(3) Diff:
Shenzhen × ECB × Post	-0.443***	-0.533***	0.090*
	(0.062)	(0.058)	(0.048)
Test Statistics:			
χ^2 , diff=0			3.557
p -val, diff=0			0.059
Sample Selection:			
Exclude Closed or Chngd	Y	Y	
Exclude 2012	Y	Y	
Fixed Effects:			
Sector \times Yr	Y	Y	
$City \times Yr$	Y	Y	
City × Sector	Y	Y	
Firms	855	706	
Observations	7,695	6,354	

Table A-2: Separate Main Effects by Insurance

Notes: This table presents estimates from the linear specification in equation (1), breaking the treatment group out into ever and never insured firms and separately comparing each to controls. In column 1, we include only ever insured firms within Shenzhen's ECB sector (but still include all Dongguan and non-ECB firms as controls). In column 2, we include only never insured firms within Shenzhen's ECB sector (again including all Dongguan and non-ECB firms as controls). Each specification includes sector-by-year, city-by-year, and city-by-sector fixed effects. In column 3, we present the difference between the coefficients in the first two columns. The standard error on the difference is calculated from the stacked regression that combines columns 1 and 2. We also present test statistics from a test that the coefficients are the same from the stacked regression. Standard errors are clustered at the firm level. Throughout, we exclude observations where firms were closed or changed industry as well as the year 2012.

A-3 Robustness Checks

A-3.1 Nonlinear Models

In this standalone appendix section, we show robustness to alternative specifications of our main model. In Table A-3, we compare our linear specification to two exponential mean models (Poisson quasi-MLE and Negative Binomial MLE), as well as an IHS transformation of our dependent variable.

To compare the magnitude in the OLS specification with the magnitude in the count specifications, we also present the percentage change in the expected number of violations attributable to the policy in the post-period. For the OLS specification, the

	(1) Linear	(2) Poisson	(3) Neg Binomial	(4) IHS
Shenzhen \times ECB \times Post	-0.476 ^{***} (0.128)	-4.002*** (1.218)	-3.990*** (1.216)	-0.326*** (0.074)
% Change	-60.771*** (7.052)	-98.173*** (2.226)	-98.151*** (2.248)	-59.887*** (6.391)
Sample Selection:				
Exclude Closed or Chngd	Y	Y	Y	Y
Exclude 2012	Y	Y	Y	Y
Fixed Effects:				
Sector \times Yr	Y	Y	Y	Y
$City \times Yr$	Y	Y	Y	Y
City × Sector	Y	Y	Y	Y
Firms	1,054	1,054	1,054	1,054
Observations	2,108	2,108	2,108	2,108

Table A-3: Comparison with Nonlinear Models

Notes: This table presents estimates comparing the linear model to various nonlinear models discussed in Section A-3.1, including Poisson quasi-maximum likelihood estimation (QMLE), negative binomial maximum likelihood estimation (MLE), and the inverse hyperbolic sine (IHS) transformation of the dependent variable. Column (1) shows the results from the linear specification, while columns (2) and (3) present results from the Poisson QMLE and negative binomial MLE models, respectively. Column (4) displays the results using the IHS transformation. Standard errors are clustered at the firm level and presented below main estimates. The percentage changes in the second line provide comparable interpretations across different model specifications. For these, the standard errors are computed using the delta method. Throughout, we exclude observations where firms were closed or changed industry as well as the year 2012. Each specification includes sector-by-year, city-by-year, and city-by-sector fixed effects. percentage change in the expected number of violations can be expressed in terms of potential outcomes as: $\frac{\alpha}{E(Viol_{it}(0)|Shenzhen=1,ECB=1,Year\geq 2013)} \times 100$, where $Viol_{it}(0)$ is the potential outcome in which the policy was not introduced. We estimate this target parameter by predicting $\widehat{Viol}(0)$ for each post-2013 observation, setting *Shenzhen* = 1, *ECB* = 1 and α *Shenzhen_i* · *ECB_i* · *Post_t* = 0. For the exponential mean models, the percentage change in the expected number of counts is equal to $(exp(\alpha) - 1) \times 100$. Standard errors for percentage changes are computed using the delta method.

A-3.2 Sample Selection

In this appendix section, we check that our results are robust to alternative sample selection criteria. As discussed in Section 4.2, the lists of firms that are required to comply in a given year do not appear to contain information on actual policy implementation.

In column 1, we exclude observations where the firm was not required to have insurance. In column 2, we limit to only the firms on the initial (2012) required list. This alleviates concerns that the government required additional firms to comply because those firms had already bought insurance. In column 3, we exclude firms that were required to purchase the insurance but did not.

In column 4, we exclude Shenzhen firms that were missing re-rating data. Our re-rating data is the only definitive source of information we have on whether firms closed or changed industry. A non-missing re-rating indicates that the firm was still in operation in the same industry, but without re-rating data, we cannot be 100% sure that a firm did not close or change industry.³⁰ Ensuring that all firms in the treatment group were still in operation rules out the possibility that the reduction in violations we find is driven by closures of treated firms.

The results are robust to all of these exclusions, though point estimates are slightly reduced across all four columns when comparing to Table 2. We note that concomitantly excluding each of these groups of potentially problematic observations is probably too stringent. Our overall conclusion is that the results presented in Table 2 are unlikely to

³⁰See footnote at the bottom of page 13.

be entirely driven by governmental selection into the required lists, non-compliance, or firm closings.

	(1)	(2)	(3)	(4)
Shenzhen × ECB × Post	-0.422***	-0.426***	-0.428***	-0.410***
	(0.088)	(0.088)	(0.096)	(0.098)
Sample Selection:				
Exclude Closed or Chngd	Y	Y	Y	Y
Exclude 2012	Y	Y	Y	Y
Exclude Non-required	Y	Y	Y	Y
Exclude 2013-2014 Cohorts		Y	Y	Y
Exclude Non-compliers			Y	Y
Exclude Missing Re-rating				Y
Fixed Effects:				
Sector \times Yr	Y	Y	Y	Y
$City \times Yr$	Y	Y	Y	Y
City × Sector	Y	Y	Y	Y
Firms	1,006	976	735	710
Observations	5,471	5,424	4,989	4,951

Table A-4: Alternative Sample Selection

Notes: This table presents estimates from the linear specification in equation (1), with additional sample limitations (on top of those in column 3 of Table 2). In column 1, we exclude cases where a Shenzhen ECB firm was not required to have insurance. In column 2, we exclude cases where a Shenzhen ECB firm was not in the 2012 cohort. In column 3, we exclude cases where a Shenzhen ECB firm was required to purchase the insurance but did not obtain it. In column 4, we exclude cases where a Shenzhen ECB firm has missing re-rating data. Standard errors are clustered at the firm level. Throughout, we exclude observations where firms were closed or changed industry as well as the year 2012. Each specification includes sector-by-year, city-by-year, and city-by-sector fixed effects.

A-4 Risk Ratings and Re-ratings

Risk ratings were conducted by external auditors. They are determined by the following

criteria:

- Pollutant Emission: Includes the quantity and toxicity of pollutants emitted by the enterprise.
- Wastewater Management: Effectiveness of wastewater treatment and compliance with discharge standards.
- Waste Management: Handling and disposal of solid waste, including hazardous waste.

- Air Pollution Control: Measures in place to control air pollutant emissions.
- Environmental Compliance: Adherence to environmental regulations and standards.
- Proximity to Sensitive Areas: Location relative to environmentally sensitive areas such as water bodies, residential zones, and protected areas.
- Frequency and Severity of Environmental Incidents: Record of past environmental accidents and incidents.
- Operational Practices: Implementation of best practices in environmental management and sustainability.

Ratings are used by insurance companies to determine premiums. The scale of the ratings in our database spans 3-6, though technically a score of 1 or 2 is possible- see an explanation of risk categorizations at: http://amr.sz.gov.cn/attachment/1/1195/1195401/9772235.pdf. Scores 1-2 are described as "Serious Risk", scores 3-4 are described as "Relatively High Risk", and scores 1-2 are described as "Ordinary Risk." We re-order the risks so that a higher value in our scale is riskier. We designate risk levels 3 and 4 as "high"-risk, 5 as "medium", and 6 as "low". Levels 3 and 4 are grouped because level three describes relatively few firms in our sample (N = 10). To construct our re-ordered numeric scale, we use values Low=1, Medium=2 and High= 3.

Whereas 471 of the required firms had an initial rating, 413 had a re-rating. Re-ratings were conducted by third party auditors just like original ratings. Ratings do not appear to change much (Figure A-4).



Figure A-4: Rating Changes

Notes: This figure presents the number of firms in each re-rating class by original rating category.