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Environmental Regulation and Firms' Extensive Margin Decisions

An Evaluation of Environmental Regulation in China

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Keywords: Environmental Regulation, Firm Entry, Firm Exit, Equity Investment, Spatial Spillover, Inter-city Investment

JEL Codes: L51, O44, Q52, Q58, R38

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1. Introduction

Environmental regulations are generally spatially differentiated.[1] As a result, firms may be deterred from entering or induced to leave pollution-intensive industries in areas with more stringent environmental regulations.[2] Such extensive margin decisions, i.e., firm entry and firm exit, have marked effects on both aggregate pollutant emissions (Najjar and Cherniwchan, 2021) and aggregate productivity growth (Foster et al., 2008; Brandt et al., 2012). Therefore understanding how environmental regulation affects firms' extensive margin decisions is vital.

The literature provides strong evidence that environmental regulations reduce firm entry (see Henderson, 1996; Becker and Henderson, 2000; List et al., 2003 a b, 2004 for example) and increase firm exit (Greenstone et al., 2012; Martin et al., 2014; Cui and Moschini, 2020) in pollution-intensive industries. However, limited attention has been given to the influence of firm characteristics, such as size, survival time, and form of ownership, on how environmental regulation differentially affects the entry or exit of firms. Further, since few studies examine the impacts of environmental regulation simultaneously on firm entry and exit, an overall assessment of how the regulated industry evolves at the extensive margin is difficult. Understanding these effects is important, because they show who bears more of the burden of regulation, but also because these effects may change the market structure and the long-run growth of regulated industries.

Several studies have relied on quasi-experimental approaches, such as county attainment/non-attainment designations under the Clean Air Act in the United States, and difference-in-differences methods to study the effects of environmental policies on firm entry (see Henderson (1996) and Becker and Henderson (2000) for example). However, economic activity in non-regulated areas may be an inappropriate counterfactual for activity in regulated areas because economic activity in non-regulated areas could also be affected by environmental regulation through spatial spillover effects (Currie and Walker, 2019; Karplus et al., 2021). The literature offers little convincing causal evidence though about whether this spatial spillover

[1] For instance, U.S. Clean Air Act applies different stringencies of regulation to counties on the basis of their initial pollution levels. Initially more polluted counties are designated as 'non-attainment counties' and are subject to more stringent regulation than less polluted 'attainment' counties.

[2] Besides the extensive margin responses, firms also respond to more stringent environmental regulations by increasing their investment in abatement and re-optimizing input and output decisions, both of which are decisions at the intensive margin. See Greenstone (2002), Levinson (2009), Walker (2013), Shapiro and Walker (2018) and Fan et al. (2019), for example.

really exists and how severe the problem is.

To address the above-mentioned issues, we investigate the effects of environmental regulation on the extensive margin decisions of Chinese firms, i.e., their entry, exit, and inter-city firm-to-firm equity investments in new firm creation. Our analysis leverages the Firm Registration Database, an administration database maintained by the State Administration of Industry and Commerce of China. The dataset provides firm-level information for all firms registered in China since 1949 including location, industry, ownership, registration date, paid-in capital, exit date (if applicable), and shareholders..[3] We begin by aggregating the data at the city-industry-year level. This provides essential data regarding firm entry, firm exit, net entry, and inter-city equity investments in new firm creation, in terms of number and paid-in capital.

We then consider the effects of the Two Control Zone (TCZ) policy in China, the earliest nationwide environmental regulation, which aimed to reduce acid rain and sulfur dioxide (SO_2) emissions. The TCZ policy was introduced in 1998 and was terminated in 2010. The policy designated all Chinese cities as either TCZ cities or non-TCZ cities according to their environmental quality prior to the policy promulgation. The designation of TCZ cities is a common practice in pollution control; examples include non-attainment counties under the United States Clean Air Act (Currie and Walker, 2019) and dirty census metropolitan areas under the Canada-Wide Standards for Particulate Matter and Ozone (Najjar and Cherniwchan, 2021). The TCZ provides a valuable quasi-experimental setting for an empirical examination in the context of developing countries, which have been understudied in the literature.[4]

We rely on difference-in-difference-in-differences (DDD) estimators, comparing a set of firm extensive margin decisions in cities that were targeted by the regulations and those that were not, both before and after 1998. The data includes 35 Chinese two-digit code industries, including 27 manufacturing industries, 3 utility industries, and 5 mining industries. The baseline specification controls for city-year, city-industry, and industry-year fixed effects. It also controls for the cubic function of the city-industry-specific number of incumbent firms in the baseline

[3] Previous studies on environmental regulation and location choice of firms in China mostly use a sample of firms above a certain scale or in specific groups (Dean et al., 2009; Chen et al., 2018 b). Firms covered in these data are usually large and efficient ones. In contrast, the administrative dataset used in this study contains full firm data for the sampled industries. Because all firms registered in China are recorded, there is no sample selection bias.

[4] Hering and Poncet (2014), Tanaka (2015) and Cai et al. (2016) have respectively shown that TCZ regulation has reduced exports, infant mortality, and foreign direct investment in regulated cities. It appeals also to have several merits for our investigation, for example, only one targeted pollutant (SO_2) and an unchanged treatment group.

year 1991 interacted with year dummies to capture potential confounding factors varying across the three dimensions of city, industry, and year, such as the industry agglomeration effect and industry life cycle.

Our results show that firm entry in more pollution-intensive industries in TCZ cities was more likely to be deterred under the TCZ policy. The impact was particularly profound for firms that were larger, long-lived and privately owned. The TCZ policy also increased firm exit rates, with smaller and older firms from more pollution-intensive industries being more likely to exit the market.

Few studies have examined the impacts of environmental regulation on both firm entry and firm exit. Our study does so, and provides an overall assessment of the effects of environmental regulations on firms' extensive margin decisions in the regulated industries. The results suggest that the environmental regulations reduced turnover in pollution-intensive industries, which, as Caves (1998) points out, are often major contributors to industrial growth. We show further that the TCZ policy led to reduced net entry, especially of large, long-lived and privately owned firms, which tend to be the most competitive in the market. These results suggest that, with fewer competitive counterparts in the market, state-owned firms and large surviving incumbents could be potential beneficiaries of environmental regulation in China.

Estimates of the policy's impacts on firm entry could be overestimated if economic activities in regulated areas relocate to unregulated areas, which is known as the spatial spillover effect (Currie and Walker, 2019; Karplus et al., 2021). Using the data on firm shareholders, we investigate how incumbent firms in regulated cities adjusted their inter-city investments in new firm creation. We find that, in response to the TCZ policy, firms in regulated cities were more likely to increase their inter-city investments in creating new entries in pollution-intensive industries in other cities. However, they increase such investments in both non-regulated cities and other regulated cities with a similar effect size. Moreover, the spillover effect is negligible compared with the policy's overall effect on firm entry. This suggests that the spatial spillover effect of environmental regulation on firm entry could be limited. It is also consistent with the literature that environmental regulation plays a less decisive role in the location choice of firms than other local advantages, e.g., low prices of important factors such as energy and labor (Ederington et al., 2005; Kahn and Mansur, 2013).

This paper contributes to the literature in three respects. First, it supplements the large body of literature examining the effects of environmental regulations on firm entry and exit by providing more evidence of distributional effects. In the literature, Becker and Henderson (2000) examine the nonuniform effects of the Clean Air Act on firm entry by firm size and age, and List et al. (2004) test how domestic and foreign firms respond differently to the Clean Air Act in terms of location choice. However, the evidence of heterogeneous regulatory effects on firm exit is more elusive. Moreover, most results in the literature are based on the setting of the Clean Air Act in the U.S., and their external validity in developing countries is unproven. Our results generate further insight on asymmetric regulatory impacts on firms of different ownership in pollution-intensive industries, and may have external validity for recent environmental regulations in China and in other developing countries that have large state sectors and similar institutions.[5]

Second, this paper, to the best of our knowledge, is the first to simultaneously investigate firm entry and exit in all industries.[6] We uncover the asymmetrical impacts of environmental regulation on the two extensive responses of firms, which has not been discussed much in the literature. On the one hand, both the economic magnitude and the statistical significance of regulatory impacts are more profound for firm entry than for firm exit. On the other hand, more stringent enforcement of environmental regulation does not amplify the impact on firm exit but further depresses firm entry.[7] Our results suggest that, during the policy's implementation, the new entrants from pollution-intensive industries were more likely than incumbent firms to be the focus of regulatory targets.[8] This evidence deepens our understanding of government behaviors in environmental governance.

Finally, our study is one of the few that examines the inter-regional investments within a

[5] For instance, our findings may partly explain the expansion of China's state-owned sectors in the last decade, when environmental regulations became more stringent after the expiration of TCZ policies. Policy-induced changes in market structure may shed further light on the long-run growth of these industries.

[6] Ryan (2012) carefully models firm entry and exit under the Clean Air Act but focuses only on the Portland cement industry.

[7] There are two essential features of TCZ policy, i.e., the policy was more stringently enforced after 2006 when an additional initiative was added to TCZ policy, and the regulations concerning acid rain control zones were more stringently enforced than those related to SO_2 pollution control zones. To explore the effects of different intensities of policy enforcement, we run the regression with our DDD term interacted with a dummy for whether the observation is the post-2006 period as well as a dummy for whether the observation is designated as an acid rain control zone.

[8] There are two possible explanations for the results. One could be that limiting the entry of new pollution sources brings less resistance from the industry and places less political pressure on local governments than regulating existing firms. The alternative explanation is that since the environmental regulations deter firm entry in pollution-intensive industries, incumbents in these industries gain more market power and are thus less likely to exit the market.

country that are induced by environmental regulation. Most existing studies focus on regulatory impacts on inter-country investments, i.e., foreign direct investment flow (Keller and Levinson, 2002; List et al., 2004; Henderson and Millimet, 2007) or multinational firms' foreign production decisions (Hanna, 2010). By testing the inter-city investments caused by environmental regulations, this paper verifies the magnitude of spatial spillover effects of place-based environmental regulation and alleviates the concern about the validity of the reduced-form method for such topics. Moreover, our results address a longstanding concern: whether place-based environmental policies can reduce the entry of polluting firms, or simply bring about a spatial redistribution.

The rest of this paper is organized as follows. Section 2 reviews the background of TCZ policy. Section 3 describes data sources and the sampled industries. Section 4 introduces the econometric models. Section 5 reports the results, and Section 6 concludes.

2. Policy Background

China's acid rain and SO_2 pollution were very severe in the 1990s, and dominated Chinese air pollution policy between 1995 and 2015, after which reducing $PM_{2.5}$ air pollution became the priority. TCZ was the primary policy targeting SO_2 pollution in the period 1998-2010, and its design makes it attractive for investigations into the effects of environmental regulations in China.

The TCZ policy was enacted in 1998 and terminated in 2010.[9] Like the U.S. federal designation of counties as "attainment" or "non-attainment" areas on the basis of local air quality in terms of various pollutants, China's TCZ policy designated cities with SO_2 pollution above a certain level as SO_2 pollution control zones. Similarly, cities with acid rain above a certain level were designated as acid rain control zones.[10] Of China's 337 cities, 170 were designated as TCZ cities, of which 61 were designated as SO_2 pollution control zones and 109

[9] In January 1998, the National Environmental Protection Agency issued its "Designation of Acid Rain Control Zones and SO_2 Pollution Control Zones", promulgating the TCZ policy.

[10] The designation of acid rain control zones was based on three criteria: (a) current monitoring precipitation pH ≤ 4.5; (b) sulfur deposition exceeding the critical load, and (c) areas with large SO_2 emissions. The designation of SO_2 pollution control zones was based on three criteria: (a) the annual average concentration of SO_2 exceeded the national Level 2 standard; (b) the daily average concentration exceeded the national Level 3 standard; (c) SO_2 emissions were high.

Cities meeting all six criteria were designated as being in acid rain control zones. In this study we also investigate the potential difference in the rigor of enforcement between acid rain control zones and SO_2 pollution control zones.

as acid rain control zones. Figure 1 illustrates the spatial distribution of the TCZ cities. The list of TCZ cities was unchanged during our sample period 1991-2010, avoiding the potential endogeneity that the treatment status was self-determined by local time-varying environmental performance.[11]

[Figure 1 About Here]

The TCZ policy set common targets for SO_2 emission reduction in the short run (2000) and long run (2010) to be achieved by each TCZ city in China.[12] The TCZ policy also gave local governments detailed guidance on how to regulate firms in SO_2 emission-intensive industries to meet these standards.[13] As a result, firms in SO_2 emission-intensive industries in TCZ cities were subject to more stringent environmental regulations than firms in less SO_2 emission-intensive industries in the same jurisdiction.

One common caveat when evaluating programs is that confounding policies, which are not explicitly incorporated in the regression, may contaminate the results. Since 2006, another important new initiative has been added to the TCZ policy. China's central government formulates a National Five-Year Plan (FYP) every five years, setting specific development goals to be achieved in the next five years. The FYP released in 2006 was the first to set mandatory emission reduction targets for all provincial governments, obliging all cities, including non-TCZ cities, to reduce emissions. The mandatory nature of the reduction targets meant that, in localities that failed to meet the targets, heads of local government and other

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[11] The TCZ cities accounted for 11.4% of the land in China and nearly 60% of SO_2 emissions in 1995. The designation of TCZ is strongly correlated with polluting activity and thus with economic development. The TCZ cities were generally more developed, with roughly two-fifths of the population and two-thirds of the GDP of the whole country in 1998. We will use event studies to test for parallel trends between TCZ cities and non-TCZ cities and among industries with different pollution intensities.

[12] The targets for the year 2000 included: (a) industrial pollution sources emitting SO_2 meeting the emission standards; (b) SO_2 emissions falling below the emission quota set by the central government; (c) the concentration of SO_2 in key cities meeting national air quality standards; (d) alleviation of the deterioration caused by acid rain. The targets for the year 2010 included: (a) total emission of SO_2 falling below the 2000 level; (b) concentration of ambient SO_2 meeting national air quality standards; (c) significant reduction of areas with pH value of precipitation greater than 4.5.

[13] First, the local government was required to formulate a comprehensive prevention and control plan and implement corresponding projects and pollution treatment funds by imposing a liability on polluters. Second, the TCZ cities were directed to restrict the mining, production, transportation and use of high-sulfur coal, promote the construction of washing facilities for high-sulfur coal mines, and ensure priority-of-use of low-sulfur coal and washed thermal coal. Third, the construction of new coal-fired thermal power plants was prohibited in urban areas, and thermal power plants were directed to install desulfurization systems. Fourth, manufacturers of chemicals, metallurgy, building materials, and non-ferrous metals were required to control SO_2 emitted during the production process. Other policy components included R&D in SO_2 pollution prevention technology and equipment, SO_2 pollution fees, and strengthening environmental supervision and management.

responsible officials would not be rewarded or promoted. SO_2 was the only air pollutant targeted by the new mandatory reduction policy in the five-year period 2006-2010.

When promulgating the original TCZ policy, the National Environmental Protection Agency explicitly mentioned that, to achieve the 2000 and 2010 TCZ pollution control targets, future regulations should be formulated based on TCZ designations. That is, if any new nationwide environmental regulation were to be introduced after 1998, TCZ cities would still be subject to more stringent regulations than non-TCZ cities. To achieve the mandatory emission reduction targets set in 2006, the provincial governments required all cities in their jurisdictions to reduce SO_2 emissions, and TCZ cities remained more heavily regulated than non-TCZ cities with respect to SO_2 emissions. Specifically, the mandatory emission reduction targets set for TCZ cities and non-TCZ cities were 13.55% and 4.04%, respectively (Chen et al., 2018 a). Moreover, the achievement rate at the end of 2010 was 97.53% in TCZ cities and 83.87% in non-TCZ cities, suggesting differences in enforcement between the zones. Thus, during 1998-2010, TCZ worked as a crucial geographic concept for air pollution regulation in China beyond a single policy. Therefore, as in Chen et al. (2018 a), in our study the TCZ policy could be considered as the aggregation of the original TCZ and later mandatory pollution reduction policies that continued to differentially affect TCZ cities. Our estimation refers to the aggregate air pollution control policy effects in TCZ cities compared with their non-TCZ counterparts during 1998-2010.

3. Data

The Firm Registration Database is a population dataset providing details of all Chinese firms including their entry and exit therefore, as noted, there is no sample selection bias. According to the database, nearly 4.3 million new firms were registered, and 2.3 million firms exited our 35 sample industries between 1991 and 2010.[14]

Using each firm's location, industry sector code, registration date, and, where relevant,

[14] The database contained erroneous registration information for some firms and these are dropped in our study. Firms were dropped if (1) the registration date is equal to or later than the cancellation and revocation date; (2) the year of cancellation and revocation is later than 2021; (3) the industrial classification is missing; (4) the ownership information is missing; (5) the registered address is missing or cannot be identified at the prefecture-city level; (6) the industry is not commercial, e.g., it is a governmental or international organization. Eventually, around 3.6% of new firms registered during 1991-2010 were dropped.

cancellation and revocation date, we begin by aggregating firm-level data at the city-industry-year level to obtain firm entry and firm exit data measured by number and paid-in capital during 1991-2010.[15] We then use the shareholder information to calculate the number and paid-in capital of firms' inter-city firm-to-firm equity investments in new firm creation. If the firm buys shares in another newly registered firm up to one month after the registration date of the invested firm, we treat the purchase as a firm-to-firm equity investment in new firm creation and use its share of the total paid-in capital to calculate the scale of its investment.[16] Notice that if a newly registered firm has more than one shareholderit may correspond to multiple counts of firm-to-firm equity investments. Among the nearly 330,000 counts of firm-to-firm equity investments in newly registered firms in our 35 sample industries in 1991-2010, only around 41,000 are inter-city investments, which match up around 35,000 newly registered firms. Finally, we have a balanced city-industry-year data panel of firm entries, firm exits, and inter-city firm-to-firm equity investments with 35 two-digit code industries in 337 cities covering 1991 to 2010.[17]

Our DDD setting requires a measurement of policy stringency at the industry level. In the literature, the initial level of pollution intensity is widely used to proxy each industry's intrinsic exposure to the environmental regulation (see Hering and Poncet (2014), Cai et al., (2016) and

[15] We believe that the paid-in capital is a good proxy for firms' scale. Firstly, during our sample period, the Company Law of the People's Republic of China required that paid-in capital should be proportional to the scale of a firm's total assets (Shi et al., 2021). Secondly, Bai et al. (2020) show that, for firms covered in both the Chinese Annual Industrial Survey (SAIF) and the Firm Registration Database, the correlation between total assets or sales of firms in the SAIF and their paid-in capital is sufficiently high, suggesting that paid-in capital is a good proxy for a firm's size. Finally, since the outcome variables are transformed into either inverse hyperbolic sine or rate, we believe that our results are robust to systematic differences between the paid-in capital and the total asset of firms.

[16] In the Firm Registration Database, once a firm has been registered, if a shareholder increases or reduces her own shares in the firm in subsequent years, the original information of the shareholder's investment time and scale will be overwritten (Lin et al, 2020). That is, a shareholder's equity investment time could differ from the birth time of the firm if the shareholder alters her equity investment in later years. Therefore, when calculating firm-to-firm equity investments in newly registered firms, we restrict the sample to those with an investment date within one month of the firm's registration date. Around 25% of all inter-city equity investments were dropped from our sample.

Due to ethical concerns around individual privacy protection, we cannot access information about shareholders who are natural persons. Such equity investments are therefore not included in the data sample. Another difference between the data on firm-to-firm equity investment in newly registered firms and the data on firm entry is that a firm may have many shareholders. Therefore, the count of firm-to-firm equity investment in newly registered firms could be larger than the number of newly-established firms with legal person shareholders.

[17] The data also facilitates this paper's contributions to the growing literature on China's environmental policy by avoiding two drawbacks of previous studies that mainly relied on the dataset of the Annual Survey of Industrial Firms (ASIF) from the National Bureau of Statistics. Since the ASIF is only available after 1998 (the first year of TCZ's implementation) and only covers firms above a certain scale, it was difficult for previous studies relying on ASIF data to study TCZ policy to verify parallel trends and provide a complete picture of regulatory impacts on firms, as the policy impact on larger firms could differ from that on smaller firms (Karplus et al., 2021).

Shi and Xu (2018) for example), because industries with greater initial pollution intensity are more likely to be targeted by the government and therefore bear larger compliance costs. Since the TCZ policy aimed to reduce SO_2 emissions, it is natural to use SO_2 emissions per unit of industrial value-added, i.e., pollution intensity, to measure industry-level policy stringency. We also use aggregate industrial emissions as a measure of industry-specific regulatory stringency in robustness checks. The values of the two measures in 2001 are used in our study.[18]

[Table 1 About Here]

Table 1 reports descriptive statistics of our key variables and reveals an uneven distribution of industrial extensive margin activities. For example, the average city-industry-year observation has 17.79 firm entries, but the minimum and maximum are 0 and 5811 respectively, providing substantial variations for our regressions.

4. Econometric Model

We use the following DDD regression to identify the extensive margin effects of TCZ regulation on firms:

$$Y_{cit} = \beta_0 + \beta_1 \cdot TCZ_c \times Post_t \times SO_{2,i} + \eta_{ct} + \lambda_{ci} + \varphi_{it} + \theta f(stock_{ci}) \times Year_t + \varepsilon_{cit} \quad (1)$$

where Y_{cit} denotes the outcome variables of interest, including firm entry, firm exit, net entry of firms and inter-city firm-to-firm equity investments in newly registered firms. When measuring firm entry (net entry of firms), Y_{cit} is the aggregate number or paid-in capital of all newly registered firms (the difference between the aggregate number or paid-in capital of all newly registered firms and that of all firms exiting in the market) in city c, industry i and year t. For the measurement of firm exits, we follow Greenstone et al. (2012) and use the firm exit rate, the proportion of firms that closed down (or the proportion of the paid-in capital of such

[18] Since industrial pollution intensity in 2001 could be affected by the TCZ policy, ideally, we should use the values of these measurements before 1998. Unfortunately, the official statistics in 1997 only released national SO_2 emission information on 18 industries, the industrial classification standard of which substantially differed from the present one. In contrast, 2001 was the first year that official statistics were released on SO_2 emissions information for 35 industries, with the industry classification standard the same as the current one. Hence, using the 2001 industrial emission data not only allows more cross-industry variations, but also is consistent with the Firm Registration Database. In fact, the correlation coefficient between SO_2 intensities in 1997 and 2001 is around 98.99%, suggesting that the industrial pollution intensities were fairly persistent during the period. In the same setting, Cai et al. (2016) use industrial SO_2 emissions in 2004 to proxy the industry-level stringency of the TCZ policy. The detailed industrial SO_2 emission information can be found in Appendix Table 1.

firms) in the same industry and city and year in city c, industry i and year t.[19] In the inter-city investment regressions, Y_{cit} refers to the aggregate inter-city firm-to-firm equity investments from city c to newly registered firms in industry i in destination areas in year t. Two separate subsample regressions will be conducted based on different specifications of the destination areas: all TCZ cities outside of city c and all non-TCZ cities outside of city c. We will discuss the inter-city investment regressions in detail in subsection 5.6.

Since both the aggregate number of firms and their paid-in capital may have extreme values, zero values and even negative values (for net entry), we follow recent studies such as Bellemare and Wichman (2020), Barreca et al. (2021), and Chari et al. (2021) in using the inverse hyperbolic sine (IHS) transformation, $\text{IHS}\,(y) = \log\,(y + \sqrt{1 + y^2})$, to transform outcome variables that are measured in levels, i.e., firm entry, net entry of firms and inter-city firm-to-firm equity investment in newly registered firms. The interpretation of the IHS function is like that of a logarithmic transformation, but it is well defined for zero and negative values and can reduce the effect of extreme values. After IHS transformation, the parameter of interest, β_1, is the elasticity of policy impact, measuring that on average a 1% increase in the initial level of pollution intensity of an industry (i.e., $SO_{2,i}$) would cause a β_1% change in the number of and paid-in capital of firm entry, net entry of firms and inter-city firm-to-firm equity investments in newly registered firms in TCZ cities. As for the regression on firm exit, β_1 measures that on average a 1% increase in the initial pollution intensity of an industry (i.e., $SO_{2,i}$) would cause a $\beta_1/100$ percentage point change in firm exit rate in TCZ cities.

In the DDD term, $SO_{2,i}$ is the logarithm of the initial pollution intensity of industry i measured in tons of SO_2/100 million Chinese yuan (CNY), proxying the policy exposure of industry i. TCZ_c takes the value of 1 if city c is in the treatment group and otherwise 0. $Post_t$ is a binary variable indicating whether year t falls in the post-1998 period. Since the TCZ policy started in 1998 and expired in 2010, the years from 1991 to 1997 are the pre-policy

[19] Because the number or paid-in capital of firms exiting the market is restricted to less than that of all firms active in the market, the size of which substantially differ across cities, industries and years, the rate measurement allows the variable of firm exits to be comparable across these three dimensions. More importantly, since, as shown, the TCZ regulation significantly reduces firm entry, the regulation also reduces the number and paid-in capital of all incumbents in the market. Hence, owing to the reduced pool, the total number and paid-in capital of firms exiting the market may not necessarily increase, even if firms under the regulation are more likely to exit the market, i.e., the exit rate increases. We also test the impact of TCZ regulation on the total number and paid-in capital of firms exiting the market. Both results turn out to be statistically insignificant.

period with $Post_t$ equal to 0.

To operationalize the DDD estimator, the specification of (1) includes the full set of two-way fixed effects (Deschênes et al., 2017). The city-year fixed effects, η_{ct}, account for all time-invariant and time-varying city characteristics (e.g., geographic location, business environment, and economic growth). The city-industry fixed effects, λ_{ci}, allow for permanent differences in outcomes across industry-by-cities, for example, the time-invariant local comparative advantages and competitiveness of each industry in each city. The industry-year fixed effects control for all factors common to each industry within a year, such as technological advances and national industrial policy. The full set of high-dimensional fixed effects rules out most confounding factors, leaving only the variations at a city-industry-year level.

In addition, we incorporate the term $f(stock_{ci}) \times Year_t$ in equation (1) to alleviate potential omitted variable problems, such as the industrial agglomeration effect or the industry life cycle, that vary across city-industry-year levels. $stock_{ci}$ is the cumulative number of firms in city c, industry i at the beginning of 1991 (the baseline year); $f(*)$ is a cubic function to control the possible non-linear relationship between outcome variables and $stock_{ci}$; $Year_t$ is a set of year dummies; and $f(stock_{ci}) \times Year_t$ flexibly deals with initial heterogeneous agglomeration effects or industry life cycle among cities and industries, allowing them to vary over years. The standard errors are clustered at the city level because the policy implementation unit is the city and the error terms ε_{cit} of different industries within a city may be correlated.

5. Results

In the following, we firstly present the results of the impacts of TCZ regulations on firm entry, firm exit, and net entry of firms, including baseline results, event study, robustness checks, heterogeneous effects and other results. Then, we discuss the potential spatial spillover effect of TCZ regulations on firm entry by focusing on inter-city firm-to-firm equity investments in newly registered firms.

5.1. Baseline results on firm entry, firm exit, and net entry of firms

We examine the impacts of TCZ regulation on firm entry, firm exit, and net entry of firms from three perspectives: those of entrants, existing operators, and the whole industry. First, firms potentially entering pollution-intensive industries face higher entry barriers under the environmental regulation, such as being required to purchase expensive pollutant abatement equipment and adopt best practice technology. They would, therefore, be less likely to enter the market. Second, there exist two opposing effects for the impact of TCZ regulation on firm exit. On the one hand, established firms in pollution-intensive industries generally bear larger compliance costs than those in other industries, leading to depressed productivity and market competitiveness (Greenstone, 2002; He et al., 2020). They are, therefore, more likely to exit the market. On the other hand, if fewer entrants enter the market, established firms in pollution-intensive industries facing regulation could face less competition and gain more market power (Ryan, 2012). Thus, the aggregate impacts of the environmental regulation on firm exit are not obvious. Third, taking firm entry and exit together, the industry-level net entry of firms determines whether the industry shrinks or expands.

[Table 2 About Here]

The main results of TCZ policy on firm entry, firm exit and net entry of firms can be seen in Table 2.

Firstly, as shown in columns (1) and (2), as the initial pollution intensity of an industry $SO_{2,i}$ increases by 1%, the number of firms entering and the total paid-in capital of new entrants in the industry under TCZ regulation statistically significantly decrease by 0.04% and 0.13%, respectively. The results are consistent with the literature. However, unlike previous studies that focus on the impacts of environmental policy on firm entry measured in number of firms (see Henderson, 1996; Becker and Henderson, 2000; List et al., 2003 a, b, 2004, for example), we estimate its impacts on both the number and size (i.e., paid-in capital) of new entrants. Since the effect of TCZ regulations on firm paid-in capital is much greater than on the number of firms entering, the results may suggest that potential large entrants into pollution-intensive industries in TCZ areas are more likely to be deterred by the environmental regulation, which will be confirmed in the following heterogeneity analysis.

Secondly, columns (3) and (4) of Table 2 report the baseline estimates of equation (1) for firm exit rates in terms of number and capital. It is shown that, as the initial pollution intensity of an industry increases by 1%, the exit rate of firms by number and by paid-in capital in the industry increases by 0.0010 and 0.0011 percentage points respectively (albeit only at a significance level of 0.1). In contrast to the results shown in columns (1) and (2), the TCZ regulation has almost the same effect on the number and paid-in capital of firms exiting the market.

Thirdly, columns (5) and (6) of Table 2 present the policy's impact on the net entry of firms, i.e., its overall impact on the industry. As the initial pollution intensity of an industry increases by 1%, the number and the total paid-in capital of the net entry of firms decrease by 0.07% and 0.19%, respectively. Evidently, under environmental regulations, pollution-intensive industries are more likely to shrink. As emphasized in the literature on industry dynamics (see Foster et al., 2008 and Brandt et al., 2012 for examples), the net entry of firms plays an important role in the creative destruction process and therefore contributes to aggregate productivity growth in the industry. Hence, the reduction of net entry of firms induced by the environmental regulation may imply lower aggregate productivity in the regulated industries.

In sum, our results show that the TCZ policy statistically significantly reduces firm entry, increases firm exit, and reduces the net entry of firms in pollution-intensive industries. But how large are these magnitudes? To help interpret these economic magnitudes, a 'back-of-envelope' calculation can be used to show that the TCZ policy, in total, has reduced the number and paid-in capital of entrants by 16% and 49% and increased the number and paid-in capital of firms exiting the market by 6.5% and 33%.[20]

When compared with the magnitudes discussed in the existing literature, these regulatory

[20] We first calculate the policy-induced changes of firm entry and firm exit for each industry in the treated cities in the post-treatment period 1998-2010 and then aggregate the calculated changes over all industries to get the aggregate impacts of the TCZ policy. Since the outcome variables of firm entry are the total number or paid-in capital, some algebra can show that, for any industry i, the policy-induced changes in these outcome variables over the whole post-treatment period are:

$$\Delta Y_{i,TCZ,1998-2010} = Y_{i,TCZ,1998-2010} - Y_{i,TCZ,1998-2010}/\exp(\hat{\beta}_1 \cdot SO2_i),$$

where $Y_{i,TCZ,1998-2010}$ is the sum of the number or paid-in capital of all newly registered firms in industry i in all TCZ cities in all years in the period 1998-2010, and $SO2_i$ is the logarithm of the pollution intensity of industry i. As for the total number and paid-in capital of firms exiting the market, it can be shown that, for any industry i, the policy-induced changes over the whole post-treatment period are:

$$\Delta Y_{i,TCZ,1998-2010} = \hat{\beta}_1 \cdot SO2_i \cdot Stock_{i,TCZ,1998-2010}/100,$$

where $Stock_{i,TCZ,1998-2010}$ is the sum of the number or paid-in capital of yearly existing incumbents in industry i in all TCZ cities in all years in the period 1998-2010.

Finally, we use the above two equations to calculate the change in the number or paid-in capital of entrants and firms exiting the market in each industry in TCZ cities in the period 1998-2010. We then reach the overall effect of TCZ regulation on firms in TCZ cities in percentage changes, $\Delta Y_{TCZ,1998-2010}/(Y_{TCZ,1998-2010} - \Delta Y_{TCZ,1998-2010}) * 100\%$, where $\Delta Y_{TCZ,1998-2010} = \sum_{i=1}^{35} \Delta Y_{i,TCZ,1998-2010}$ and $Y_{TCZ,1998-2010} = \sum_{i=1}^{35} Y_{i,TCZ,1998-2010}$. In the 35 industries in TCZ cities in 1998-2010, the total number and paid-in capital of entrants are around 2.49 million and 18.6 trillion CNY, and the total number and paid-in capital of firms exiting the market are around 1.64 million and 4.1 trillion CNY. The TCZ policy in total reduces the number and paid-in capital of entrants by 16% and 49% and increases the number and paid-in capital of firms exiting the market by 6.5% and 33%.

impacts on firm entry, firm exit, and net entry fall into an intermediate range. For instance, using a quasi-experimental policy design, Henderson (1996) shows that in counties in the U.S. switching from attainment status to non-attainment status there was a 7-10 percentage point reduction in the number of new firm entries in polluting industries. Becker and Henderson (2000) show that a switch in attainment status reduced the number of new firm entries in polluting industries by 26-45 percent. As for the regulatory impact on firm exit, Greenstone et al. (2012) find that the non-attainment status increased the number of firms exiting in heavy-emitting industries by 0.4 percentage points, nearly 10% of the mean annual exit rate of the sample. In terms of regulatory impact on net entry at the industry level, Najjar and Cherniwchan (2021) find that the net exit of polluters induced by $PM_{2.5}$ regulation in Canada accounted for roughly 25% of net exit in the average regulated industry in the census metropolitan areas.

Moreover, since we use the same context to test the effects of environmental regulation on firm entry and firm exit, the statistical significance levels and sizes of the two effects are directly comparable. Our results, including the results that will be shown below, indicate that potential entrants have shouldered more regulatory burden than incumbent firms. This suggests the asymmetric impacts of environmental regulation on firm entry and firm exit.

5.2. Event study

Since our empirical models rely on triple difference estimators, the parallel trend assumption needs to be satisfied – i.e., that there was no systematic difference in the outcome variables between the TCZ cities and non-TCZ cities before the policy treatment. We test the assumption using the following event study:

$$Y_{cit} = \beta_0 + \sum_{k=1991}^{2010} \beta_{1,k} \cdot SO2_i \times TCZ_c \times Year_k + \eta_{ct} + \lambda_{ci} + \varphi_{it} + \theta f(stock_{ci}) \times Year_t + \varepsilon_{cit}, \quad (2)$$

where $Year_k$ is a dummy variable equal to one if it is in year *k* and zero otherwise.

We use equation (2) to estimate a vector of coefficients $\beta_{1,k}$ which tests whether the outcome variables among industries with differing pollution intensities varied significantly between TCZ cities and non-TCZ cities in year *k*. If all the coefficients $\{\beta_{1,k}\}_{k=1991}^{1997}$ cannot reject the null hypothesis of no statistically significant differences in outcomes between the treatment and the control group in the pre-treatment periods, then the parallel trend assumption of the triple difference design is valid. In the regression, $\beta_{1,1997}$ is omitted as the reference group to avoid multicollinearity.

[Figure 2 About Here]

Figure 2 presents the event study results for the six outcome variables studied above, i.e., the number and paid-in capital of firm entry, firm exit, and net entry of firms. The outcome variables in all six regression estimates of $\{\beta_{1,k}\}_{k=1991}^{1997}$ are close to zero and insignificant, implying no systematic differences between TCZ cities and non-TCZ cities before the TCZ policy.

5.3. Robustness checks

Figure 3 presents the results of the following robustness checks.

[Figure 3 About Here]

(a) Clustering of the standard errors. The results are statistically significant and robust with standard errors clustered at the city-industry level.

(b) Measures of industry-specific exposure to TCZ. The hypothesis underpinning our triple difference design is that dirtier industries are more likely to be targeted and strictly regulated by the local government. In the baseline specification, we use the initial industrial emission intensity to proxy the regulatory stringency imposed on the industry. Figure 3 shows that using initial total industrial SO_2 emissions instead of emission intensity would yield similar results, except that the impact on firm exit rate becomes insignificant. This may suggest that firms are more likely to exit from industries with higher pollution intensity than from those with higher absolute emissions levels.

(c) Choice of control variables. The only control variables besides fixed effects in the baseline estimation are year dummies interacted with the cubic function of the city-industry-specific number of incumbent firms in 1991. The results in Figure 3 indicate that neither dropping the controls nor replacing the cubic functional form with a linear one would change the results.

(d) Sample. We also check whether our results are robust to changes in the sample of industries, time periods, and cities. First, since previous studies tend to focus on manufacturing industries when studying the impacts of environmental regulations on firm entry or exit, “manufacturing” in Figure 3 shows the results of a regression that keeps only the sample of manufacturing firms (recall that our data include all firms from 35 industries, 27 of which are manufacturing industries), in line with the literature. Second, during our sample period, there were two financial crises, the 1997 Asian financial crisis, and the 2008 global financial crisis. These may have affected firms’ extensive margin decisions substantially, and therefore may have affected our results. In Figure 3, we therefore present the results after dropping the years 1997 and 2008. Third, TCZ cities include four municipalities (Beijing, Shanghai, Tianjin, and Chongqing) which are province-level cities, placing them higher in the political hierarchy than the other (prefecture-level) cities in China. In case the observations of these four municipalities are outliers driving our results, we re-estimate the model by dropping these observations from the “Municipality” in Figure 3. As shown in Figure 3, the results of all three sample changes remain nearly the same as the baseline results.

[Figure 4 About Here]

Finally, we concluded our robustness checks with a placebo test, in which we randomly designated TCZ status to 170 cities out of the 337 sample cities. If our baseline results were driven only by the actual TCZ policy, we would not expect any statistically significant results from the fake policy treatment. We conduct the process of random designation and coefficient estimation 500 times. The distribution of the 500 estimated coefficients is plotted in Figure 4, in which the dots are coefficients estimated by fake policy treatment and the vertical red line is our baseline result based on the true policy treatment. The distribution of placebo estimates in Figure 4 is not only narrowly centered around zero but also far away from our baseline result. This further endorses the claim that the changes in firms’ extensive margin decisions in pollution-intensive industries in TCZ cities are driven by TCZ regulations.

5.4. Heterogeneous effects

To further explore the distributional impacts of TCZ policy on firm entry, firm exit and net entry of firms, we conduct multiple subsample regressions, splitting the entire sample according to firm characteristics, including size, survival time, and type of ownership.[21] Table 3 presents the results of these subsample regressions.

[Table 3 About Here]

Panel A of Table 3 reports the heterogeneous effects of the TCZ policy on firms of different sizes. Our baseline results have shown that the TCZ policy has asymmetrical impacts on the number and paid-in capital of firm entry. Although these suggest that large potential entrants are more likely to be deterred by the regulation, we do not yet provide direct proof. We separate firms into two groups, large and small, in terms of their paid-in capital. This is used to detect which group is more likely to be affected by the policy. To make the firm size comparable across industries and years, we first calculate, for each industry, in each year, the national newly registered firms' median paid-in capital. We then define a firm as a large (small) firm if its paid-in capital is larger (smaller) than the national median paid-in capital for its own industry in the year it was registered.

Panel A of Table 3 shows that the impacts of the TCZ regulations on the number and paid-in capital of large entrants are more than twice the impacts on small entrants, supporting our previous conjecture. The results are also consistent with the fact that the TCZ policy itself sets restrictions on new emitters above a certain emission level, and that local governments trying to meet the policy goal have an incentive to reject the entry of new, large emitters. However, it is the small enterprises that are more likely to exit the market. Since all firms in an affected industry must comply with new regulations that may require investment in pollutant abatement, such as installing new equipment, small incumbents face a larger fixed cost than large incumbents. This would then raise the average costs for small incumbent firms by more than those of large incumbent firms. Because large firms are less likely to enter the market and small firms are more likely to leave it, the environmental regulation may affect the market's structure at the margin, i.e., regulated industries may become more concentrated in local markets (Ryan, 2012). As such, large incumbents staying in the market may benefit from less competition in

[21] Since aggregate data are used for estimations, here we test heterogeneous effects by subsample rather than adding interaction terms, to keep the sample size and empirical specification unchanged. If we added interaction terms, the observations would not be at the city-industry-year level but would vary in four dimensions, i.e., city-industry-year-size, city-industry-year-survival time, and city-industry-year-ownership. Thus, it is tricky in our setting to control for covariates that vary at the additional dimension.

the local market. Columns (5) and (6) of Panel A also verify that the environmental regulation has larger impacts on the net entry of large firms.

Panel B of Table 3 presents the heterogeneous effects of the TCZ policy on firms with different lifespans. This is important because the exit of a firm that has only recently entered the market has little impact on the economy, compared to the loss of an established firm, especially if it has accumulated experience and become more efficient over time. We split the sample of firms entering the market (i.e., newly registered firms) into two groups: short-lived entrants that survive four years or less, and long-lived entrants that survive for more than four years. We also split the sample of firms exiting the market into young firms that exited the market within the first four years of their existence, and older firms that have survived for more than four years. The results show that, although the TCZ policy reduces firm entry for both short-lived and long-lived firms, the negative effects on long-lived firms are substantially greater. Moreover, the regulation has no impact on the exit rate of young firms but significantly increases the exit rate of older firms. Overall, the net entry of long-lived firms is more likely to be depressed. The results suggest that, under environmental regulation, the lifespan of firms in pollution-intensive industries tends to be shorter and that they exit the market sooner.

In Panel C of Table 3 we present the heterogeneous effects of the TCZ policy on firms with different types of ownership. As stressed in the literature, because state-owned firms are more likely to be protected by local governments (Shi and Xu, 2018), and because foreign-owned firms generally have cleaner production (List et al., 2004), they are least affected by environmental regulations.[22] To investigate the heterogeneous effects of TCZ regulation on firms with different ownership types, we split the sample into private firms, foreign-owned firms, and state-owned firms. Our results support the above argument. The TCZ regulation does not have any statistically significant impact on state-owned firms for any of the six outcome variables but generates statistically significant impacts on privately owned firms in terms of five outcome variables, i.e., reducing the number and paid-in capital of private entrants and net entry, and increasing the paid-in capital of private firms exiting the market. The impacts of regulation on foreign-owned firms are less marked. Only the paid-in capital of foreign-owned

[22] There is also an argument that, in China, new policy regulations such as the recent de-leveraging policy, de-capacity policy, and anti-trust campaign, tend to hit private firms, but to be neutral, if not beneficial in their effects, on state-owned firms.

firm entry is statistically significantly depressed, with the economic magnitude less than half of the impact on the paid-in capital of private firms. The net entry of foreign-owned firms (by number of firms) even marginally increases under the regulation.

To sum up, the heterogeneity results show that, under the TCZ regulation, large, long-lived and private firms in pollution-intensive industries are less likely to enter the market, small and long-lived firms are more likely to exit the market, and, overall, net entries by large, long-lived and private firms are significantly depressed. Because large, long-lived and private firms are more likely to be competitive in the market, environmental regulation may have unintended consequences on the market structure and competitiveness of regulated industries. Moreover, as mentioned, state-owned firms and large surviving incumbents may benefit from the regulation because it facilitates their expansion in the local market.

5.5. The intensity of policy enforcement

We now discuss two specific elements of TCZ design, i.e., the mandatory reduction of SO_2 emissions after 2006, and acid rain control zones versus SO_2 pollution control zones. The 2006 policy leads to differences across time in the stringency of policy enforcement, and the differences between SO_2 and acid rain control zones lead to differences in policy stringency across regions.

[Table 4 About Here]

As mentioned as a component of the 2006-2010 Five-Year Plan a new mandatory reduction in SO_2 emissions was added to the TCZ policy. Thus, the TCZ policy is expected to have become more stringent after 2006. To assess the impact of this additional policy on firms in TCZ areas, we add the interaction term $SO_{2,i} \times TCZ_c \times Post_t \times 1(t \geq 2006)_t$ in our baseline model, where $1(t \geq 2006)_t$ is a dummy variable indicating whether t is a year after 2006. This new interaction term captures the additional impact imposed by the 2006 FYP mandatory reduction policy. As shown in Panel A of Table 4, the FYP mandatory reduction policy reinforced the environmental regulations more stringently in TCZ areas than in non-TCZ ones. Specifically, the FYP mandatory reduction policy significantly amplified the impacts of TCZ regulation on firm entry in both number and paid-in capital, although it had no additional significant impacts on firm exit. The results support our expectation that the environmental regulation tends to be enforced more strictly on new entrants than on incumbent firms. Moreover, the reinforcement effects of the FYP mandatory reduction policy are consistent with the literature. For instance, in a similar difference-in-difference setting with the interaction term $TCZ_c \times 1(t \geq 2006)_t$, Chen et al. (2018 a) show that the TCZ policy significantly reduced SO_2 emissions but also curtailed economic growth in regulated cities after 2006.

Whilst the TCZ includes both acid rain control zones and SO_2 pollution control zones, the stringency with which the two sets of control zones are applied could differ. Acid rain is generated by sulfur oxides and nitrogen oxides, which react with water molecules in the atmosphere to produce acids. In practice, cities meeting the criteria for both SO_2 pollution control zones and acid rain control zones were only designated as acid rain control zones. This implies that acid rain control zones face more challenges in pollution control than SO_2 pollution control zones. Moreover, of the 170 TCZ cities, the 109 that were designated as acid rain control zones are almost all located in southern China, which is more humid and rainier than northern China. Southern cities differ from northern ones not only in social and economic development, but also in the sources that produce SO_2.[23] These differences in economic and environmental background may affect the intensities with which the regulations are enforced. To assess the impacts of differences in regulation in the two control zones, we add the interaction term $SO_{2,i} \times TCZ_c \times Post_t \times 1(acid\ rain\ control\ zone)_i$ in equation (1) with the dummy $1(acid\ rain\ control\ zone)_i$ indicating whether city i is designated as an acid rain control zone. The results in Panel B of Table 5 confirm that TCZ regulation is more likely to reduce the number and paid-in capital of firms entering pollution-intensive industries in acid rain control zones. Further, the extent of the impact is as large as that of the mandatory FYP reduction policy. Again, no statistically significant impacts of the interaction term are found on firm exit.

The above results, leveraging variation of stringency of environmental regulation across both time and regions, again reveal that more stringent environmental regulations further deter firm entry but pose no additional impact on firm exit. This echoes our finding that the regulatory impacts on firm entry and exit are asymmetric.

[23] In China, SO_2 is mainly emitted from coal use in power plants, manufacturing firms, and residential heating in winter. Unlike the southern cities, which have higher temperatures in the winter, northern cities have centrally controlled public heating systems, which are coal-based and the main air pollution source in the winter season.

5.6. Results on spatial spillover effects of firm entry

Spillover effects, which could violate the Stable Unit Treatment Values Assumption (SUTVA), a vital precondition of the Rubin Causal Model, are common threats to the empirical design of difference-in-differences or triple difference estimators. In our study, if firms subjected to environmental regulations tend to migrate to unregulated areas, then all regions in the economy could be affected by the policy, leaving no clean counterfactuals for the causal inference. In this case, the regulatory impacts of firm entry could be overestimated because the results may reflect increasing firm entry in unregulated areas, which is driven by inter-regional investments from regulated areas to unregulated areas and would not happen without the policy (Currie and Walker, 2019; Karplus et al., 2021). Although the idea is intuitive, to the best of our knowledge, no study has provided direct evidence on the spatial spillover effects of environmental regulation on firm entry.[24] Taking advantage of the shareholder information in our data, we provide empirical evidence about whether the spillover threat exists and to what extent it affects estimates.

We use equation (1) to explore the spatial spillover effect of firm entry. The outcome variable Y_{cit} is the aggregate of inter-city firm-to-firm equity investments from city c to newly registered firms in industry i in two destination areas, i.e., all TCZ cities outside of city c and all non-TCZ cities outside of city c. Shareholder information on registered firms shows around 270,000 firm-to-firm equity investments in newly registered firms in the 35 sample industries during the period 1991-2010. The number of intra-city and inter-city firm-to-firm investments are respectively around 230,000 and 41,000, accounting for 85% and 15% of all firm-to-firm investments in new firm creation in the 35 industries. Evidently, the scale of inter-regional investments in new firm creation was rather limited in China at that time, and we have a non-negligible fraction of zeros in our outcome variables. Hence, we first estimate a linear probability model with the dummy outcome variable Y_{cit}, which equals one if there is at least one inter-city firm-to-firm investment from city c to newly registered firms in industry i in year t, and equals zero otherwise. We then examine the impact of the regulation on inter-city firm-

[24] Chen et al. (2021) find a policy spillover effect within the firms' production network. They show that, in response to energy efficiency regulation policies in China, regulated firms cut output and shifted production to unregulated firms in the same conglomerate instead of improving their energy efficiency.

to-firm investments measured by the number and paid-in capital.

[Table 5 About Here]

We split the sample into two subsamples based on whether the investment destinations are TCZ cities or non-TCZ cities. The subsample regression results are shown in Panel A and Panel B of Table 5. Our results show that TCZ regulation increases inter-city firm-to-firm equity investments from regulated cities to newly registered firms in pollution-intensive industries in non-regulated cities and in other regulated cities of a similar size. One may conclude that, since both regulated and non-regulated areas appear equivalently impacted, the threat of a spillover effect on the DDD estimator may have been completely offset. However, it is also possible that the results in Panel A of Table 5 could be overestimated. In the subsample regression shown in Panel A, the control group is inter-city investment from non-TCZ cities to new firm creation in pollution-intensive industries in TCZ cities. The counterfactuals could be unsatisfactory because, as the environmental regulations in the investment destinations become more stringent, firms from unregulated cities may reduce their inter-city investment toward pollution-intensive industries in regulated cities.

In contrast, the counterfactuals in the subsample regression of Panel B of Table 5 are inter-city investments from non-regulated cities to other non-regulated cities. Since both the origin city and destination city of the inter-city investments are unregulated, the counterfactuals are rather clean. As shown in Panel B of Table 5, as the initial pollution intensity of an industry increases by 1%, the number and paid-in capital of inter-city firm-to-firm equity investments from TCZ cities to newly registered firms in the industry in non-TCZ cities increase by 0.006% and 0.04%, respectively. The results provide clear evidence for the spatial spillover effect of environmental regulations, confirming the conjecture raised in the literature.

Despite this evidence, the spatial spillover effect appears too small to contaminate the DDD estimator. Firstly, a comparison of the results in Panel B of Table 5 and Table 2 shows that the spillover effects in terms of the number and paid-in capital of entering firms are only 16% and 31%, respectively, of the total regulatory effect on firm entry. (Note that this is only comparing the elasticities of policy effects). Secondly, if we consider the extent of policy effects, the spatial spillover effect becomes negligible compared with the total impact of the regulation on firm entry. The number of firm entries in the 35 sample industries during 1991-2010 is around 4.3 million, which is more than one hundred times the inter-city firm-to-firm equity investments in new firms over the same period. Moreover, any one firm entry may correspond to multiple inter-city firm-to-firm equity investments if the firm has multiple shareholders from other cities. Even if we compare the number of all firm-to-firm equity investments to the number of inter-city firm-to-firm equity investments, the former is approximately seven times larger than the latter. Hence, if we combine the differences in both the elasticities and the level of outcome variables, the spatial spillover effect of TCZ regulation on firm entry appears too small to threaten our estimators. The results are generally consistent with the literature's findings that environmental regulations play a much smaller role than local advantages, such as low prices of important factors in the geographic distribution of economic activities (Ederington et al., 2005; Kahn and Mansur, 2013).

6. Conclusion

This paper investigates the effects of environmental regulations on the extensive margin (entry and exit) decisions of Chinese firms. Using registration information on all firms in China, we employ triple-difference estimators to investigate the effects of TCZ regulation on firm entry, firm exit, net entry of firms, and inter-city firm-to-firm equity investments in new firm creation.

The paper shows that environmental regulation indeed affects the extensive margin decisions of regulated firms in pollution-intensive industries, reducing entry and increasing exits. Even though we detect a spatial spillover effect of environmental regulations on firm entry, i.e., regulated firms may increase inter-regional investments in new firm creation, the size of the effect is too small to contaminate the baseline results.

Moreover, we show that the regulatory impacts on firm entry and exit are asymmetric. On the one hand, the environmental regulation generates larger impacts on firm entry than on firm exit in pollution-intensive industries. On the other hand, additional supporting policies, including the pollution policies in the Five-Year Plan and their more stringent enforcement, reinforce the TCZ's impacts on firm entry but do not amplify the regulatory impacts on firm exit.

Finally, the potential distributional effects of environmental regulation should be noticed.

Targeted by the regulation, large, long-lived and privately owned firms in pollution-intensive industries are less likely to enter the market, and small and long-lived incumbents are more likely to exit, leading to a more concentrated market and a larger state sector in pollution-intensive industries. These results suggest that environmental regulations could be deeply intertwined with other policies. In a country that lacks competitive neutrality, environmental regulations may have unintended consequences for regulated industries.

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Table 1 Summary Statistics

	(1) Number	(2) Mean	(3) S.D.	(4) min	(5) max
Panel A: The regressor of interest					
DDD	235,900	1.656	2.549	0	8.709
Panel B: Firm entry, firm exit, and net exit					
Entry (Number)	235,900	18.28	73.05	0	5,811
Entry (Capital)	235,900	13,185	62,431	0	47,64281
Exit rate (Number)	212,378	5.605	9.688	0	100
Exit rate (Capital)	211,944	2.878	10.12	0	100
Net Entry (Number)	235,900	8.707	51.24	-1,230	4,949
Net Entry (Capital)	235,900	10,879	60,577	-3,307,122	4,296,511
Panel C: Equity investments toward TCZ cities					
Dummy	235,900	0.0666	0.249	0	1
Number	235,900	0.129	0.767	0	42
Capital	235,900	1,624	490,839	0	232,486,880
Panel D: Equity investments toward non-TCZ cities					
Dummy	235,900	0.0310	0.173	0	1
Number	235,900	0.0457	0.342	0	45
Capital	235,900	17,473	5,815,516	0	1,998,793,246

Notes: DDD refers to the regressor of interest, $SO2_i \times TCZ_c \times Post_t$. The variable "Dummy" in panel C (D) equals one if there is at least one inter-city firm-to-firm investment from city *c* to newly registered firms in industry *i* in TCZ cities (non-TCZ cities) in year *t*, and equals zero otherwise. The unit of capital is 10 thousand CNY.

Table 2 Main Results

	(1) Entry (Number)	(2) Entry (Capital)	(3) Exit rate (Number)	(4) Exit rate (Capital)	(5) Net Entry (Number)	(6) Net Entry (Capital)
DDD	-0.0385***	-0.1316***	0.0960*	0.1066*	-0.0665***	-0.1855***
	(0.0091)	(0.0256)	(0.0503)	(0.0582)	(0.0138)	(0.0348)
Obs.	235,900	235,900	212,333	211,895	235,900	235,900

Notes: Each cell reports a separate regression of the DDD term, $SO2_i \times TCZ_c \times Post_t$, on outcomes in city c, industry i and year t. All regressions control for city-industry, industry-year, and city-year fixed effects, and for the cubic function of the cumulative number of incumbents in city c industry i in 1991 interacted with year dummies. The reported standard errors are clustered at the city level. *: p < 0.10; **: p < 0.05; ***: p < 0.01.

Table 3 Heterogeneous Effects

	(1) Entry (Number)	(2) Entry (Capital)	(3) Exit rate (Number)	(4) Exit rate (Capital)	(5) Net Entry (Number)	(6) Net Entry (Capital)
Panel A: Scale						
Large	-0.0426***	-0.1443***	0.0162	0.0599	-0.0779***	-0.2005***
	(0.0089)	(0.0278)	(0.0292)	(0.0509)	(0.0121)	(0.0354)
Small	-0.0181**	-0.0473***	0.0798**	0.0467**	-0.0131	-0.0090
	(0.0086)	(0.0130)	(0.0392)	(0.0214)	(0.0116)	(0.0152)
Panel B: Survival time						
Short-lived	-0.0168**	-0.0479**	-0.0228	-0.0165	-0.0091*	-0.0311*
	(0.0080)	(0.0199)	(0.0302)	(0.0349)	(0.0053)	(0.0176)
Long-lived	-0.0349***	-0.1283***	0.1188***	0.1231***	-0.0625***	-0.2029***
	(0.0086)	(0.0264)	(0.0396)	(0.0429)	(0.0135)	(0.0338)
Panel C: Ownership						
Private	-0.0358***	-0.1284***	0.0125	0.0455*	-0.0486***	-0.1564***
	(0.0118)	(0.0309)	(0.0250)	(0.0253)	(0.0122)	(0.0318)
Foreign	-0.0045	-0.0500***	-0.0032	0.0156	0.0124*	-0.0374
	(0.0046)	(0.0186)	(0.0192)	(0.0353)	(0.0071)	(0.0256)
State-owned	0.0067	-0.0134	0.0298	0.0223	0.0073	-0.0241
	(0.0044)	(0.0145)	(0.0245)	(0.0231)	(0.0068)	(0.0229)
Obs.	235,900	235,900	212,333	211,895	235,900	235,900

Notes: Panels A, B, and C report results from subsample regressions of firms with different scales, survival time, and ownership types. Each cell reports a separate regression of the DDD term, $SO2_i \times TCZ_c \times Post_t$, on outcomes in city c, industry i and year t. All regressions control for the city-industry, industry-year, and city-year fixed effects, and for the cubic function of the cumulative number of incumbents in city c industry i in 1991 interacted with year dummies. The reported standard errors are clustered at the city level. *: p < 0.10; **: p < 0.05; ***: p < 0.01.

Table 4 Results on Intensity of Policy Enforcement

	(1)	(2)	(3)	(4)	(5)	(6)
	Entry (Number)	Entry (Capital)	Exit rate (Number)	Exit rate (Capital)	Net Entry (Number)	Net Entry (Capital)
Panel A: FYP obligatory reduction policy since 2006						
DDD	-0.0253***	-0.1012***	0.0912*	0.1176*	-0.0512***	-0.1694***
	(0.0079)	(0.0238)	(0.0543)	(0.0672)	(0.0137)	(0.0361)
DDD×	-0.0345***	-0.0790***	0.0127	-0.0286	-0.0398**	-0.0418
$1(t \geq 2006)_t$	(0.0081)	(0.0238)	(0.0675)	(0.0771)	(0.0172)	(0.0456)
Panel B: More stringent enforcement in acid rain control zones zone						
DDD	-0.0178	-0.0652**	0.0507	0.1345*	-0.0222	-0.1297***
	(0.0111)	(0.0325)	(0.0628)	(0.0695)	(0.0173)	(0.0487)
DDD×	-0.0325**	-0.1040***	0.0709	-0.0436	-0.0694***	-0.0873*
$1(ARCZ)_i$	(0.0130)	(0.0327)	(0.0590)	(0.0666)	(0.0232)	(0.0525)
Obs.	235,900	235,900	212,333	211,895	235,900	235,900

Notes: Each cell reports a separate regression of the DDD term, $SO2_i \times TCZ_c \times Post_t$, and its interaction term on outcomes in city c, industry i and year t. All regressions controlled for city-industry, industry-year, and city-year fixed effects, and for the cubic function of the cumulative number of incumbents in city c industry i in 1991 interacted with year dummies. The reported standard errors are clustered at the city level. *: p < 0.10; **: p < 0.05; ***: p < 0.01.

Table 5 Relocation Results

	(1) Dummy	(2) Number	(3) Capital
Panel A: TCZ as destination			
DDD	0.0044***	0.0069***	0.0263***
	(0.0015)	(0.0022)	(0.0100)
Panel B: Non-TCZ as destination			
DDD	0.0040***	0.0060***	0.0410***
	(0.0012)	(0.0016)	(0.0093)
Obs.	235,900	235,900	235,900

Notes: Each cell reports a separate regression of the DDD term, $SO2_i \times TCZ_c \times Post_t$, on inter-city firm-to-firm equity investments in new firms from city c to industry i in TCZ cities (Panel A) or non-TCZ cities (Panel B) in year t. All the regressions control for the city-industry, industry-year and city-year fixed effects, and for the cubic function of the cumulative number of incumbents in city c industry i in 1991 interacted with year dummies. The reported standard errors are clustered at the city level. *: p < 0.10; **: p < 0.05; ***: p < 0.01.

Figure 1 The spatial distribution of TCZ cities

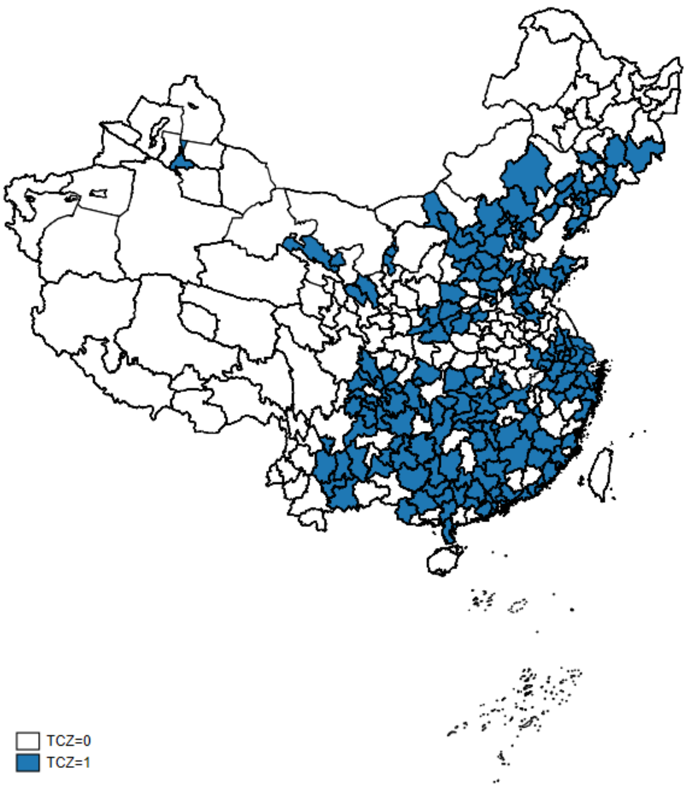
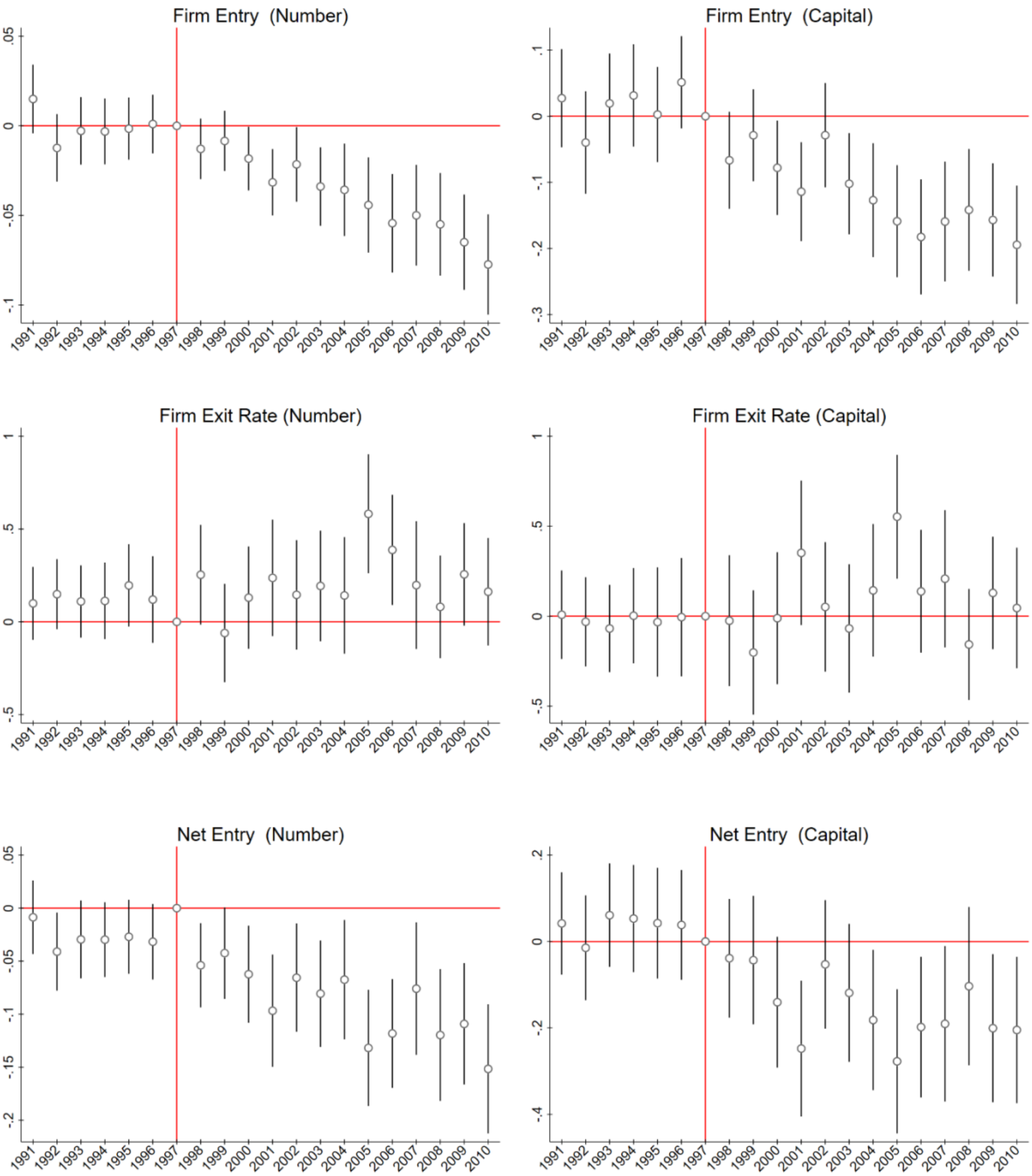


Figure 2 Event Study

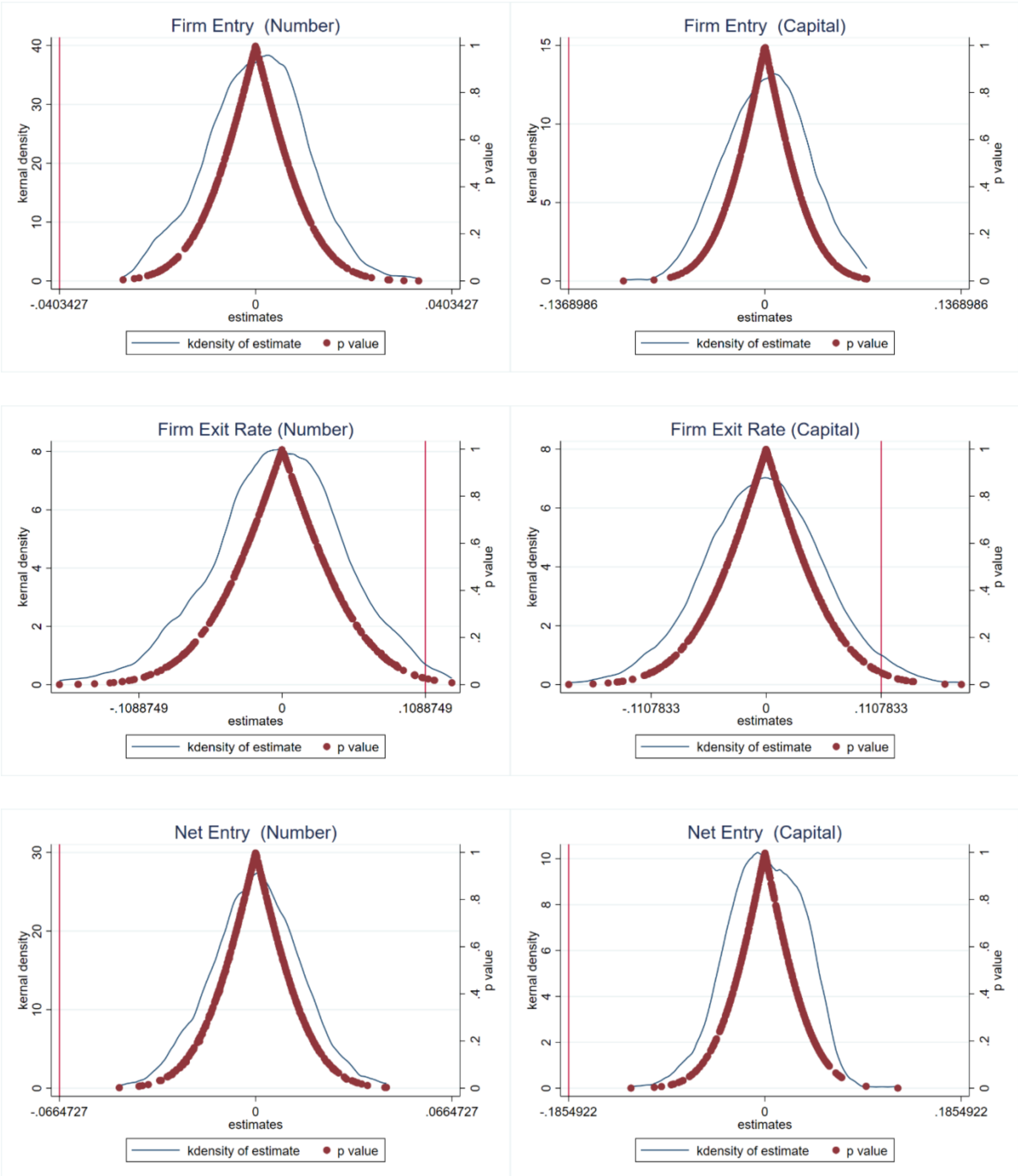


Notes: The figures show estimates of event study estimation of the effects of $SO2_i \times TCZ_c \times Post_t$ on outcomes. The points indicate changes in outcomes compared with 1997 (the period immediately before the TCZ treatment) conditional on the cubic function of the cumulative number of incumbents in city c in 1991 interacted with year dummies and a full set of city-industry, industry-year, and city-year fixed effects. The vertical line at each point indicates the 95% confidence intervals where standard errors are clustered at the city level.

Figure 3 Robustness checks

Notes: The dot presents the estimated coefficients of the effects of $SO2_i \times TCZ_c \times Post_t$ on outcomes. Each horizontal indicates the 95% confidence intervals where standard errors are clustered at the city level. "Baseline" reports the estimations of the baseline results. "Cluster" demonstrates the result with standard errors clustered at the city-industry level. "Emission Level" reports the results using the total SO_2 generated rather than SO_2 intensity to estimate the regressions. "No Controls" and "Linear Controls" are the results of dropping or using the linear function at the level of the cumulative number of incumbents in 1991 interacted with year dummies. "Manufacturing", "Financial crisis" and "Municipalities," respectively, report the results of only keeping the sample of manufacturing industries, dropping the years 1997 and 2008, and dropping the four municipalities.

Figure 4 Placebo test



Notes: The X-axis presents the estimated coefficients of $SO2_i \times TCZ_c \times Post_t$ from the 500 randomized assignment exercises. The blue curve is the kernel density distribution of the estimates, whereas the red dots are associated with p-values. The vertical line is the true estimate.

Appendix Table 1: 2-digit code industry list

code	Industry	Intensity (2001)	SO2 generated (2001)	Value-added (2001)
C32	smelting and rolling of nonferrous metals	6060	3582320	591
D44	electricity, heat production and supply industry	3005	8102301	2696
C30	products made from non-metallic mineral resources	1436	1739836	1212
C22	papermaking and paper products	1052	499556	475
B08	ferrous metal mining and selection	998	72150	72
C26	making of chemical raw materials and products	805	1289173	1601
D45	gas production and supply industry	764	35255	46
C28	chemical fiber production	761	169042	222
C25	oil, coking and nuclear fuel processing	757	668592	883
C31	smelting and rolling of ferrous metals	577	882827	1530
B10	non-metallic ores mining and selection	522	65452	125
B09	nonferrous metal mining and selection	476	67533	142
C15	liquor, beverage, and tea production	352	226445	643
B06	coal mining, washing, and selection	313	218335	699
C17	textile industry	232	322592	1388
C14	food production	196	88696	452
C20	wood processing and products made of wood, bamboo, rattan, coir, and grass	183	35267	193
C13	processing of agricultural byproducts	161	152013	945
C27	pharmaceutical industry	128	92182	722
C29	rubber and plastic products manufacturing	104	82807	793

C35	manufacturing of special machinery and equipment	59	37352	637
B07	petroleum and natural gas extraction	56	112230	2019
C34	manufacturing of general machinery and equipment	51	49562	972
C33	metal products manufacturing	48	34545	713
C19	leather, fur, feather products and footwear business	47	18350	392
C36,37	transportation equipment	41	67131	1634
C21	furniture making	38	4421	118
C23	printing and recording media replication industry	30	7333	244
D46	water production and supply industry	29	4636	162
C38	electrical machinery and equipment manufacturing	28	38601	1378
C16	tobacco product manufacturing	24	26066	1093
C24	production of articles for education, culture, sports, and entertainment purposes	19	3498	180
C18	clothes and accessories	18	12330	688
C40	instrument and meter manufacturing industry	17	3973	238
C39	computer, communication, and other electronic equipment	11	22091	2035

Notes: The unit of SO_2 generated is tons, while the unit of value-added is 100 million CNY. The unit of intensity is tons/100 million CNY. In 2001, the industry "transportation equipment" with the code of "C36, 37" is comprised of two two-digit code industries, i.e., "automobile manufacturing" and "railroad, water, and aerospace transportation equipment manufacturing".