Journal of Development Economics 123 (2016) 73–85

Contents lists available at ScienceDirect

Journal of Development Economics

journal homepage: www.elsevier.com/locate/jdeveco

Does environmental regulation drive away inbound foreign direct investment? Evidence from a quasi-natural experiment in China ☆

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ARTICLE INFO

Article history:
Received 27 April 2015
Received in revised form
17 August 2016
Accepted 20 August 2016
Available online 23 August 2016

JEL classification:
R11
L25
D22

Keywords:
Environmental regulation
Foreign direct investment
Pollution haven effect
Difference-in-difference-in-differences estimation
Two control zones

ABSTRACT

This paper investigates whether environmental regulation affects inbound foreign direct investment. The identification uses the Two Control Zones (TCZ) policy implemented by the Chinese government in 1998, in which tougher environmental regulations were imposed in TCZ cities but not others. Our difference-in-difference-in-differences estimation explores three-dimension variations; specifically, city (i.e., TCZ versus non-TCZ cities), industry (i.e., more polluting industries relative to less polluting ones), and year (i.e., before and after the TCZ policy). We find that tougher environmental regulation leads to less foreign direct investment. Meanwhile, we find that foreign multinationals from countries with better environmental protections than China are insensitive to the toughening environmental regulation, while those from countries with worse environmental protections than China show strong negative responses.

1. Introduction

Governments across the world, concerned about further deterioration of the environment, are toughening their regulations on pollution with the hope that firms will develop greener technologies and produce more environmentally responsible goods. An unintended consequence, however, is that firms may respond by relocating their production to places with less stringent environmental regulations, a phenomenon known as the pollution haven hypothesis. This may not only counteract the effects of environmental policies, but may also worsen the overall scenario. For example, developing countries may manipulate their environmental policies to attract more foreign direct investment (FDI), which could lead to an increase in overall pollution levels.

Despite much anecdotal evidence, however, empirical studies fail to provide conclusive results on the effects of environmental regulation, with some finding no such effects[1] and others documenting significant effects.[2] As a result, the investigation of the pollution haven hypothesis is considered to be "one of the most contentious issues in the debate regarding international trade, foreign investment, and the environment" (Kellenberg, 2009).

An inherent empirical challenge in identifying an effect of environmental regulation on firms' location choice is how to deal with the potential endogeneity of environmental regulation.[3]

☆We would like to thank the co-editor, anonymous referees, Arik Levinson, John List, Daniel L. Millimet, and participants in conferences and workshops for their insightful comments and suggestions, which have significantly improved the paper. Cai acknowledges the financial support from the Fundamental Research Funds for the Central Universities (grant no. 0140ZK1110). Lu acknowledges the financial support from the National University of Singapore (the Ministry of Education AcRF Tier 1 FY2014-FRC2-001). Wu acknowledges the financial support from the Guangdong Provincial Department of Science and Technology (project code 2015A070704047). Yu acknowledges the financial support from the National Natural Science Foundation of China (project code 71402162).

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[1] For example, Friedman et al. (1992), Levinson (1996), Eskeland and Harrison (2003), and Javorcik and Wei (2004). In a related study, List (1999) shows that air pollution emissions in the U.S. converged during 1929–1994, suggesting that states in the U.S. did not compete for industries by loosening their environmental regulations.

[2] For example, Henderson (1996), Becker and Henderson (2000), List and Co (2000), Keller and Levinson (2002), List et al. (2003), and Kellenberg (2009). For literature reviews, see Dean (1992), Levinson (2008), Brunnermeier and Levinson (2004), Copeland and Taylor (2004), and Erdogan (2014).

[3] Jeppesen et al. (2002) conduct a meta-analysis and conclude that differences in methodological considerations explain much of the variation in the findings on the effects of environmental regulation.

http://dx.doi.org/10.1016/j.jdeveco.2016.08.003
0304-3878/

Recent studies have started to tackle the potential endogeneity of environmental regulations, for example by using either the instrumental variable approach (see Millimet and Roy, 2016, for a survey) or the difference-in-differences (DD) method (List et al., 2003, 2004; Millimet and List, 2004; Hanna, 2011; Chung, 2014; Broner et al., 2015).

This paper contributes to the literature on the pollution haven hypothesis on three grounds. First, while recent studies heavily use data from developed countries such as the U.S. (e.g., Hanna, 2011; Millimet and Roy, 2016) and South Korea (Chung, 2014), we examine whether environmental regulation affects inbound FDI in China, the largest developing country in the world. Detecting whether the pollution haven hypothesis exists in developing countries helps in understanding whether the laxity of environmental regulations could be used as a source of comparative advantage to attract FDI and ultimately induce economic growth in developing countries. These findings can also shed light on concerns about whether tough environmental protection in developed countries can achieve the goals of environmental protection in the presence of possible relocation of dirty production to developing countries. In addition, China provides a good setting for investigating the pollution haven hypothesis. On the one hand, Chinese governments have been attracting FDI aggressively since 1978 when China adopted its opening up and reforming policy, and this has made China the second largest FDI (stock) recipient country in the world.[4] On the other hand, China's fast economic growth in recent decades has been accompanied by severe environmental degeneration, including over-exploitation and mass industrial pollution, which are typical problems in developing countries. China is also a large country with substantial differences in the distribution of FDI and environmental quality, which provides us with enough variation to identify the effects of environmental regulation.

Second, our analyses use the most comprehensive firm data in China; specifically, two censuses data sets covering all establishments in 1996 and 2001, and survey data on foreign invested enterprises (FIEs) covering more than three-fourths of total FIEs in 2001. These data allow us to uncover the whole pattern of FDI flows in China, and provide an advantage over previous studies using small or truncated samples of firms in China (for example, a sample of 2886 manufacturing equity joint ventures used by Dean et al., 2009 and a sample of firms with annual sales above 5 million Chinese currency used by Hering and Poncet, 2014). The FIE survey data contain information on the FIEs' sourcing countries, which allows us to investigate whether the deterrent effect of environmental regulation varies across countries with different degrees of environmental protection. Understanding such differential effects can further shed light on concerns about whether strengthening environmental regulations would force firms to relocate production to developing countries with lax environmental regulations.

Third, one concern in the literature regarding the identification of the pollution haven hypothesis is that environmental regulations could be measured with errors, and this endogeneity problem may contaminate the estimates. Our study circumvents this measurement problem by using a change in environmental policy in China, specifically, the implementation of the Two Control Zones (TCZ) policy. The TCZ policy was initiated and the designation for each city regarding the policy status was conducted by the central government with little influence from local governments. To enforce the policy, the National Environmental Protection Bureau (NEPB) was established, and the targets for environmental controls were clearly posited by the State Council (China's cabinet) for the short run and the long run. This context alleviates the concern that government policies are often poorly carried out in developing countries, which leads to the weak findings. For details about environmental regulations in China, see Section 2.

To identify the effects of environmental regulation, we conduct a difference-in-difference-in-differences (DDD) estimation. Specifically, the first difference comes from the comparison of FDI flows in TCZ and non-TCZ cities (with the former adopting tougher environmental regulations); the second difference compares the FDI flows in more polluting and less polluting industries (with the former having stronger deterrent effects); and the last difference is due to the policy implementation in 1998, which divides the sample into pre- and post-treatment periods. The triple difference allows us to control for full sets of country-industry fixed effects, country-year fixed effects, and industry–year fixed effects, in which all potential omitted variables varying at the city level (time varying and time invariant) and at the industry level (time varying and time invariant) have been properly dealt with. For further validity checks, we check the potential bias from the Asian financial crisis in 1997–1998, investigate the expectation and lagged effects, conduct a placebo test with random assignment of TCZ reform, and use an instrumental variable strategy.

We present two sets of results. First, we find stronger deterrent effects of environmental regulation on FDI flows in more polluting industries relative to less polluting ones, confirming the pollution haven hypothesis. A one-standard-deviation increase in pollution intensity causes the negative effect of environmental regulation on FDI flows to be 8 percentage points lower.

Second, we detect significant heterogeneous effects across FDI sourcing countries. Specifically, we examine whether foreign multinationals from countries with more stringent environmental regulations than China behave differently from those from countries with less stringent regulations than China, as the former goes to a country with weaker regulations than those in their home countries while the latter has the opposite. To this end, we divide countries into two groups, based on whether they joined the international treaties (i.e., the *United Nations Framework Convention on Climate Change* and the *Kyoto Protocol*) on environmental protection before or after China. We find that foreign multinationals from countries with better environmental protections than China are insensitive to the toughening environmental regulation, while those from countries with worse environmental protections than China show strong negative responses. These findings may help relieve the concern that toughening environmental protection in developed countries would cause a shift of dirty manufacturing production to countries with laxer environmental regulations.

This study is related to the recent renaissance in the study of the pollution haven hypothesis. Hanna (2011) uses a DD analysis to investigate how the Clean Air Act Amendments (CAAA) in the U.S. have affected its outflow FDI, and finds that the CAAA increased regulated multinationals' foreign assets by 5.3 percent and foreign output by 9 percent. Chung (2014) also conducts a DD analysis to study how the change in environmental laxity in foreign countries affects foreign investment by Korean multinationals, and finds that Korean multinationals in more polluting industries invest more in countries with less stringent environmental regulations. Applying two novel identification strategies to inbound U.S. manufacturing FDI across 48 contiguous states over 1977–1994, Millimet and Roy (2016) find significant negative effects of environmental stringency on inbound FDI in pollution-intensive industries. Using the

[4] Based on statistics from the CIA World Factbook (accessed on August 15, 2013).

meteorological determinants of pollution dispersion as an instrument for environmental regulation at the country level, Broner et al. (2015) find that lax environmental regulations constitute a source of comparative advantage for international trade and the magnitude is comparable to the role of physical and human capital.

The remainder of this paper is organized as follows. The institutional background of environmental regulations in China is described in Section 2. Section 3 discusses the data, variables, and estimation strategy. Empirical findings are presented in Section 4. The paper concludes with Section 5.

2. Environmental regulations in China

Timeline: Sulfur dioxide (SO_2) emissions generated by coal combustion have substantially increased alongside the fast economic growth in China in recent decades.[5] Concerned about China's long-term sustainable economic development, Chinese governments started to implement a series of regulatory policies since the mid-1980s. Specifically, the Air Pollution Prevention and Control Law of the People's Republic of China (APPCL) was enacted in 1987 and came into force in 1988. In 1995, the APPCL was amended, and a section about the regulation of air pollution and SO_2 emissions was included. More important, in January 1998, the State Council approved the setup of two control zones (TCZ) in its document "The Official Reply of the State Council Concerning Acid Rain Control Areas and SO_2 Pollution Control Areas" (the 1998 Reply hereafter), which was then put into effect.

From a total of 380 prefecture-cities, 175 cities, accounting for 11.4% of the nation's territory, 40.6% of the population, 62.4% of GDP, and 58.9% of total SO_2 emissions in 1995, were designated as TCZ cities (Hao et al., 2001). Fig. 1 shows the geographic distribution of TCZ cities in China; specifically, dark grey areas represent two control zones, light grey areas are non-TCZ cities, and black circles show the size of each city in 1996 in terms of the number of firms from our census data (to be introduced in the next section). In general, SO_2 pollution control zones are located in Northern China because of the reliance there on thermal energy for heating, whereas acid rain control zones are located in southern China where the climate is relatively more humid.

Criteria: The two control zones comprise SO_2 pollution control zones and acid rain control zones. The NEPB began designating cities as TCZ cities in late 1995, using several criteria. Specifically, a city was designated as an SO_2 pollution control zone if (1) its average annual ambient SO_2 concentration had been larger than the national Class II standard in recent years; (2) its daily average ambient SO_2 concentrations exceeded the national Class III standard (i.e., 250 $\mu g/m^3$); or (3) its SO_2 emissions were significant. A city was designated as an acid rain control zone if (1) the average pH value of its precipitation was equal to or less than 4.5; (2) its sulfate deposition was above the critical load; or (3) its SO_2 emissions were large.

New Policies: Once a city was designated as a TCZ city, tougher regulatory policies were implemented. First, new collieries based on coal with a sulfur content of 3% and above were prohibited, and existing collieries using a similar quality of coal had to reduce the production gradually or be shut down. Second, new coal-burning thermal power plants were prohibited in city propers and in suburbs of large or medium cities, except for cogeneration plants whose primary purpose was to supply heat. Furthermore, newly constructed or renovated coal-burning thermal power plants using coal with a sulfur content of 1.5% and above had to install sulfur-scrubbers, while existing power plants using similar quality coal had to adopt SO_2 emission-reduction measures by 2000. Third, in polluting industries such as the chemical engineering, metallurgy, nonferrous metals and building materials industries, production technologies and equipment generating severe air pollution had to be phased out. Finally, local governments had to strengthen the collection, administration, and use of SO_2 emission fees.

Enforcement: In the 1998 Reply, the State Council also laid out the targets for environmental controls in the TCZ cities for the short run (by 2000) and for the long run (by 2010).[6] These new environmental regulations have generated a significant improvement in air pollution control. In 2000, 102 TCZ cities achieved the national Class II standard for average ambient SO_2 concentrations and 84.3% of severely polluting firms achieved the target level for SO_2 emissions (China Environment Yearbook, 2001). In 2010, 94.9% of TCZ cities had achieved the national Class II standard for average ambient SO_2 concentrations, with no city reporting values above the national Class III standard (Report of the Ministry of Environmental Protection of the People's Republic of China, 2011).

3. Data, variables, and estimation strategy

3.1. Data and variables

We obtained a detailed list of the names of the cities designated as TCZ cities from the official State Council document, "The Official Reply of the State Council Concerning Acid Rain Control Areas and SO_2 Pollution Control Areas." During the sample period, the composition of this list remained unchanged. Appendix Table A1 contains the list.

Table 1 compares a variety of city characteristics between TCZ and non-TCZ cities before the treatment in 1998. We find that for most of these characteristics, the differences between TCZ and non-TCZ cities are small relative to the two group mean values. For example, while TCZ cities attracted more FDI than non-TCZ cities before 1998, the difference is about 15–18 percent of the two group means. Significant differences lie in TCZ cities being more trade oriented, more likely to be located in Southern China, and more likely to be big cities (such as municipality cities and provincial capital cities). In the next subsection, we will discuss how to control for heterogeneity across treatment and control cities in identifying the effects of environmental regulation.

To measure FDI activities in China, we use two large-scale firm level data sets, in which both have pros and cons. The first data set comes from the Chinese First National Census of Basic Units and the Chinese Second National Census of Basic Units, conduced at the end of 1996 and 2001, respectively. Two business units are available in China, legal unit and basic unit, where the former is made up of the latter and the latter is under the management and

[5] For example, in 1993, 62.3% of cities in China had annual average ambient SO_2 concentration values above the national Class II standard (i.e., 60 $\mu g/m^3$).

[6] Specifically, by the end of 2000, "the sources of industrial SO_2 pollution should achieve the national standard of SO_2 emission. The total amount of SO_2 emission should be within the required amount. Ambient SO_2 concentrations in important cities should achieve the national standards. The acid rain in the acid rain control zones should be alleviated." By the end of 2010, "the total amount of SO_2 emission should be lower than that in 2000. Ambient SO_2 concentrations in all cities should achieve the national standards. The number of acid rain areas with average pH value of precipitation equal to or less than 4.5 should be reduced significantly."

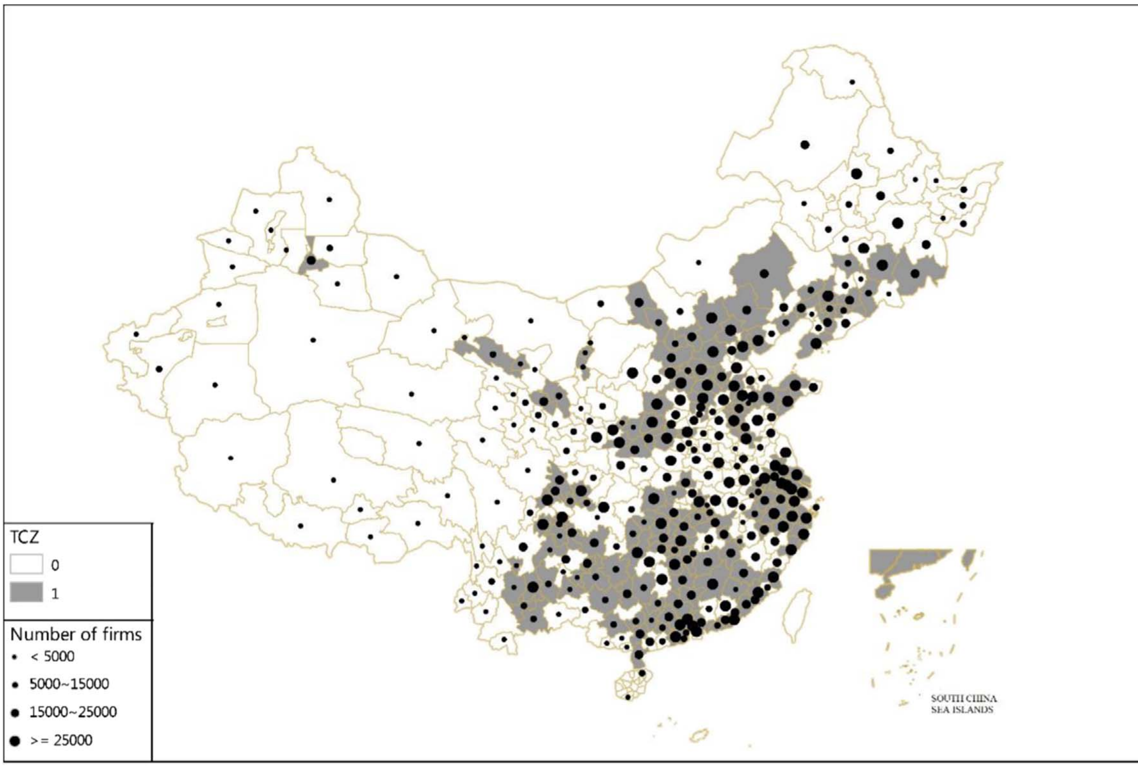

Fig. 1. Geographic distribution of TCZ cities. *Data source*: The national Environmental Protection Bureau, "The Proposal of Designation for Acid Rain Control Areas and SO_2 Pollution Control Areas"; Chinese First National Census of Basic Units.

Table 1
Summary statistics and description of variables before 1998.

Variable name	TCZ		non-TCZ		Description
	Mean	S.D.	Mean	S.D.	
FDI (log)	8.40	2.05	7.06	1.70	Amount of real FDI received (10,000 USD)
Domestic output (log)	14.35	1.31	13.33	1.32	Output of the industrial sector (10,000 CNY)
Retail consumption (log)	13.11	1.16	12.27	0.98	Total retail sales of social consumption goods (10,000 CNY)
Tax revenue (log)	11.14	1.1	10.17	1.19	Fiscal revenue and tax collected by government
GDP per capita (log)	8.72	0.62	8.37	0.54	Per capita GDP
College students (log)	8.77	1.4	7.96	1.11	Number of college students
Telephones (log)	2.91	1.15	2.13	0.99	Number of telephones owned by every 10,000 households
Total road area (log)	5.57	0.86	5.16	0.81	Total paved road area (square meters)
High school students (log)	11.88	0.92	11.38	1.07	Number of high school students (10,000)
Electricity consumption	11.85	1.11	10.93	1.07	Total electricity consumption (10,000 kW.h)
Trade exposure	0.07	0.21	0.03	0.09	Ratio of trade value (import and export) in GDP
SOEs presence	0.19	0.07	0.23	0.09	Share of SOEs in all firms (in number)
Northern	0.37	0.48	0.61	0.49	Northern cities of China
Coastal	0.15	0.36	0.16	0.36	Coastal cities of China
Mountains	0.39	0.49	0.28	0.45	City surrounded by mountains
Municipality	0.03	0.16	0.00	0.00	Four municipalities of China (Beijing, Shanghai, Tianjin, Chongqing)
Provincial capital city	0.13	0.34	0.05	0.21	Provincial capital cities in China (27 cities)
Old industrial cities	0.14	0.34	0.09	0.29	City with large number of old plants (former industry basis)
Total employment (log)	3.69	0.89	3.15	0.87	Total number of employed persons (10,000)
Number of firms (log)	7.06	1.08	6.27	0.96	Total number of industrial firms
Share of air-polluted industries	0.3	0.16	0.23	0.13	Output share of air polluted industries in total output of the city

Data source: Chinese City Statistical Yearbook, 1992–1997.

control of the former. The definition of a legal unit is consistent in principle with that of the organization unit in the System of National Accounts (SNA) of the United Nations, whereas the definition of a basic unit is in accord with that of an establishment in the SNA. There are, respectively, 6.35 million and 7.08 million basic units in the two censuses, covering all industries including agriculture, manufacturing, construction, service, etc. The census data contain firms' full basic information, such as date of establishment, address, location code, industry affiliation, and ownership, but only report the amount of employment and sales category for each firm. As a result, we focus on the logarithm of employment for newly established FDI as the measurement of FDI flows.

Despite their intensive coverage, the census data have two potential drawbacks in our research setting: (1) only one year before and one year after the treatment are available, preventing the investigation of common pre-treatment trends; and (2) no information on the origin country of the FDI is available, making analysis of heterogeneous effects across origin countries infeasible. Hence, we complement our analysis by using a second firm level data set, the survey of FIEs in 2001. This is the most comprehensive survey of foreign firms in China, and the data have around 150,000 observations, accounting for more than 75% of total foreign firms in China in 2001. In addition to firms' full basic information and common accounting measures (such as employment, sales, etc.), the data contain information on the contractual investment capital at the establishment and origin countries of the firm.

For our analysis, we need the information of FDI inflow at the city, industry and year level. While the FIE data are only available in 2001, they contain the information of the contractual investment capital at the time of firm establishment. This enables us to construct for each year the total contractual investment capital of new FDI entries in a city and an industry. We use this value as the measure of FDI inflow from the FDI data. With access to only one year survey, however, we need to extrapolate firms' location information at the time of entry so as to conduct a long panel analysis. To this end, we consider firms' current location as their location of establishment, resulting in a panel from 1992 to 2001. The downside of this practice is that if firms changed their location or exited in response to the TCZ policy, then our estimates would be biased because of the investment deflection. As our null hypothesis is that environmental regulations have no effects on firm location choice, relocation or exiting should not affect the test on the null hypothesis or the findings of the pollution haven hypothesis. However, in the case of rejection of the null hypothesis, such relocation and/or exiting behavior would affect the magnitude of coefficients. We will discuss this issue further when we present the magnitude of our estimates.

The industry level SO_2 emission information in 2004 is obtained from the *China Environment Statistical Yearbook 2005*, published by the National Bureau of Statistics of China and the NEPB.[7]

3.2. Specification

The time and regional variations in the adoption of the TCZ policy provide an opportunity for a difference-in-differences (DD) analysis. Specifically, there are two groups of cities, the treatment group comprising cities designated as TCZ cities in 1998, and the control group comprising non-TCZ cities. We can then compare FDI in TCZ cities before and after the adoption of the TCZ policy in 1998 with the corresponding change in non-TCZ cities during the same period.

The DD estimation specification is as follows:

$$Y_{ct} = \alpha_c + \gamma \cdot TCZ_c \times Post_t + \delta_t + \varepsilon_{ct}, \quad (1)$$

where Y_{ct} is the measurement of FDI flows in city c at year t; TCZ_c indicates city c's TCZ status in 1998, i.e., $TCZ_c = 1$ if city c is a TCZ city and =0 if city c is a non-TCZ city; $Post_t$ indicates the post-treatment period, i.e., $Post_t = 1 \; \forall \; t \geq 1998$ and =0 otherwise; α_c are city fixed effects, capturing city c's all time-invariant characteristics such as geographic features, climate, natural endowment, etc.; δ_t are year fixed effects, capturing all yearly factors common to all cities such as business cycle, monetary policy, macro shocks, etc.; and ε_{ct} is the error term.

However, a concern about the DD analysis is that there could be some time-varying city characteristics that correlate with our regressor of interest and hence bias the estimate. One example is the agglomeration effect, which is found to be an important determinant of industrial location choice (see, e.g., Arauzo-Carod et al., 2010, for a review). One way to capture agglomeration economies in the literature is to include the historical stock of FDI (e.g., Wagner and Timmins, 2009). However, as discussed by Lechner (2010), the problem with the inclusion of the lagged dependent variable in the DD setting is that "if the DiD assumptions hold unconditionally on the pre-treatment outcome, they are likely to be violated conditional on pre-treatment outcomes." Meanwhile, the inclusion of the lagged dependent variable causes a mechanical correlation between the error term and the lagged dependent variable in the panel estimation, consequently generating inconsistent estimates in Eq. (1) (see Nickell, 1981; Angrist and Pischke, 2009).

Another example of omitted time-varying variables is the attributes of the neighboring locations, which are found to influence the location choice of FDI (see, for example, Blonigen et al., 2007; Millimet and Roy, 2016). One way to address this issue in the literature is to control for a spatially lagged FDI measure (i.e., the inverse-distance-weighted average of the FDI received by all other cities) in the regression. However, as pointed out by Gibbons and Overman (2012), estimating such a model produces inconsistent parameter estimates because of a mechanical correlation between the error term and the spatially lagged FDI measure.

In light of these concerns, we exploit the fact that industries having different intrinsic polluting intensity are affected differently, and conduct a DDD estimation as our main identification. Specifically, we use the time variation (e.g., before and after the TCZ policy in 1998), regional variable (e.g., TCZ versus non-TCZ cities), and industry variable (e.g., more polluting industries relative to less polluting ones). The DDD estimation specification is as follows

$$Y_{ict} = \gamma \cdot TCZ_c \times Post_t \times SO_{2i} + \eta_{ct} + \lambda_{ic} + \varphi_{it} + \varepsilon_{ict}, \quad (2)$$

where SO_{2i} is the degree of SO_2 emission by industry i. Given that the information of SO_{2i} is only available at the 2-digit industry level (a list of industries is contained in Appendix Table A2), we aggregate the variables and conduct the analyses at the city, 2-digit industry and year level. To deal with potential heteroskedasticity and serial correlation, we cluster the standard errors at the city–industry level.

Compared with the DD estimation, the DDD specification allows us to control for a whole set of industry–year fixed effects, industry–city fixed effects, and city–year fixed effects. In other words, we are able to control for all time-varying and time-invariant city characteristics, such as regional spillovers, agglomeration, corruption, local political activism, energy prices, etc. We also control for all time-varying and time-invariant industry characteristics, such as changes in technology, changes in import competition degrees, industry policies, etc. And we allow for industries to be different in different cities, as long as

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[7] One concern of using the SO_2 emission level in 2004 is that the value may be affected by the TCZ policy, e.g., the adjustment by polluting industries. However, a problem of using the SO_2 emission information before the TCZ policy enacted in 1998 is that the data were only available for around 20 industries compared with 37 industries in 2004, which leads to a substantial reduction in the cross-industry variations. Nonetheless, we find high correlations between the SO_2 emission levels in 1996–1998 and that in 2004 for the 15 common industries; specifically, 0.8917 for the correlation between 1996 and 2004, 0.9336 for the correlation between 1997 and 2004, and 0.9340 for the correlation between 1998 and 2004. These results suggest that the industry aggregate SO_2 emission levels were quite persistent during our research period.

Table 2
Main results.

Dependent variable	(1) Employment(log)	(2) FDI(log)
TCZ* Post * SO_2	−0.504**	−0.526***
	(0.196)	(0.137)
City–year fixed effect	X	X
City–industry fixed effect	X	X
Industry–year fixed effect	X	X
Data source	Census	FIE
Observations	21,238	111,930
R^2	0.788	0.676

Note: (1) For data source, census refers to the census data in 1996 and 2001, while FIE refers to the survey of foreign-invested enterprises.
(2) TCZ is a dummy variable indicating whether the city was designated as a two control zone in 1998. Post is a dummy variable taking value 1 if it is after 1997 and 0 otherwise. SO_2 is the SO_2 emission level (in 10,000,000 tons) in the industry.
(3) Standard errors, clustered at the city–industry level, are reported in the parenthesis.

** Statistical significance at the 5% level.
*** Statistical significance at the 1% level.

such industry–city differences remain fixed in our sample period. The remaining possible omitted variables need to vary simultaneously across time, cities, and industries. As further checks on the validity of our DDD estimation, we provide a battery of sensitivity analyses, including controlling for the Asian financial crisis in 1997–1998, checking the expectation and lagged effects, a placebo test with the random assignment of TCZ reform, and an instrumental variable regression following Hering and Poncet (2014). For details, see Section 4.2.

4. Empirical findings

4.1. Main results

The DDD estimation results are presented in Table 2, where data from the censuses are used in column 1 and the survey data on FIEs are used in column 2. We find that the triple interaction term is consistently negative and statistically significant. These results indicate that cities with tougher environmental regulations (i.e., where the TCZ policy has been implemented) attracted less FDI in more polluting industries, confirming the pollution haven hypothesis.

There are two possible reasons why tough environmental regulations drive away FDI in China. First, the TCZ policies require that outdated, dirty production technologies and equipment are phased out, and the collection of SO_2 emission fees is strengthened, which increases production costs particularly for polluting industries in the TCZ cities. Second, the TCZ policies also prohibit the establishment of new collieries and new coal-burning thermal power plants that use low quality coal, and they require the installation of desulfurization equipment in the existing power plants, which leads to an increase in electricity costs faced by firms in the TCZ cities, because coal is still the main fuel source for power in China.

Economic magnitude: The economic magnitude of the effect of environmental regulation is significant. The coefficients in Table 2 capture the differential responses of FDI flows to the tough environmental regulations (caused by the implementation of the TCZ policy) across industries with different SO_2 emissions. Specifically, a one-standard-deviation increase in pollution intensity causes the negative effect of environmental regulation on FDI flows to be 8 percentage points lower.

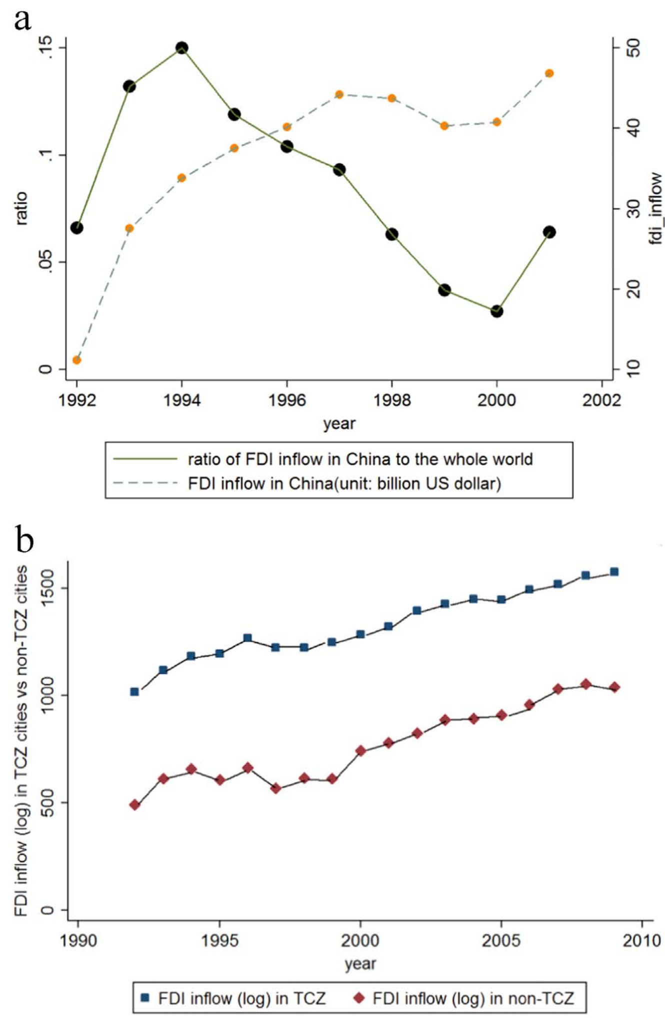

Fig. 2. (a) FDI inflow. *Data resource*: World investment report, 1996 and 2002, United Nations Conference on Trade and Development. (b) Time trends of FDI inflows in TCZ and non-TCZ cities. *Data resource*: Chinese City Statistics Yearbook, various years.

A caveat in interpreting the magnitude of the effect is the possibility of investment deflection. That is, facing the tough environmental regulations in the TCZ cities, FDI may flow into non-TCZ cities where the environmental regulations are less stringent. In other words, it may not be that the treatment group is negatively affected by the treatment, but that the control group is positively affected by the treatment. While the investment deflection is consistent with the evidence on the pollution haven hypothesis so long as it is driven by the changes in environmental regulations, the estimation magnitude needs to be interpreted with caution. Specifically, it constitutes an upper bound of the pollution haven effect. Although there is no affirmative way to detect how seriously the investment deflection is in this setting, we provide some suggestive evidence. Specifically, we collect the FDI inflow data from the World Investment Report in 1996 and 2002, and plot time trends of overall FDI inflows into China and its share in the world's total FDI during the sample period in Fig. 2a. We find that FDI inflows in China started to grow in 1992, reached a peak in 1997, and declined a bit during the Asian Financial Crisis. Meanwhile, FDI in China as share of the world's total FDI grew from 1992 to 1994 and then started to fall until it bottomed out in 2000. Fig. 2b further shows Chinese FDI inflow into TCZ and non-TCZ cities

Table 3
Robustness check.

Dependent variable	(1) FDI(log)	(2) Random assignment Employment(log)	(3) Random assignment FDI(log)	(4) IV Employment(log)	(5) IV FDI(log)
TCZ * Post * SO_2	−0.545***	0.001	−0.007	−2.243**	−1.582*
	(0.135)	(0.203)	(0.150)	(1.089)	(0.866)
City–year fixed effect	X	X	X	X	X
City–industry fixed effect	X	X	X	X	X
Industry–year fixed effect	X	X	X	X	X
Data source	FIE, Excluding Korea and Japan	census	FIE	census	FIE
Observations	111,930	21,238	111,930	19,388	102,180
R^2	0.663	–	–	0.784	0.674

Note: (1) For data source, census refers to the census data in 1996 and 2001, while FIE refers to the survey of foreign-invested enterprises.
(2) TCZ is a dummy variable indicating whether the city was designated as a two control zone in 1998. Post is a dummy variable taking value 1 if it is after 1997 and 0 otherwise. SO_2 is the SO_2 emission level (in 10,000,000 tons) in the industry.
(3) Standard errors, clustered at the city–industry level, are reported in the parenthesis.
(4) In columns 4 and 5, we further include three controls, GDPPC * Post * SO_2, Coastal * Post * SO_2, and Special Zone * Post * SO_2, following Hering and Poncet (2014).

* Statistical significance at the 10% level.
** Statistical significance at the 5% and level.
*** Statistical significance at the 1% level.

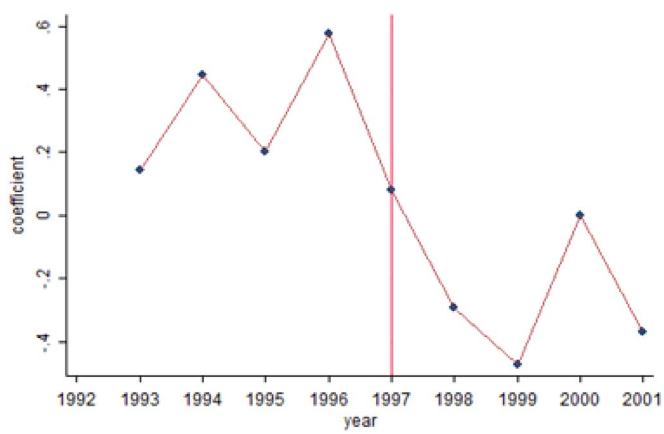

Fig. 3. Estimated coefficients. Note: The coefficients in the figure are the coefficients for TCZ * SO_2 * Year Dummies, and dependent variable is registered capital of foreign capital (in log).

from 1992 to 2009, where the FDI information is obtained from the *Chinese City Statistics Yearbook* at various years. We find increasing trends in both groups, despite some declines during the Asian Financial Crisis. Combined, these results indicate that our findings are not entirely explained by investment deflection.

Our estimated magnitude is comparable to those found in the literature.[8] For example, Becker and Henderson (2000) find that tougher environmental regulations caused the birth rate of firms in polluting industries to drop by 26–45% in the U.S. Kellenberg (2009) estimates that during 1999–2003, a failing environmental policy caused the value added of U.S. affiliates located in the top 20th percentile of countries to grow by approximately 8.6%, while the corresponding number for the top 20th percentile of developing and transition economies was 32%. Hanna (2011) finds that the CAAA in the U.S. between 1966 and 1999 increased U.S. multinationals' foreign assets by 5.3% and foreign output by 9%. Using the data on foreign investment by Korean multinationals, Chung (2014) finds that when a foreign country increases its environmental laxity relative to Korea by one standard deviation from the mean, there is a 12.4% increase in investment by Korean multinationals from an industry one standard deviation above the mean pollution intensity than an industry at the mean pollution intensity.

4.2. Robustness checks

In this subsection, we conduct a battery of further robustness checks on our aforementioned results.

The 1997–1998 Asian Financial Crisis: If other events happened at the same time, any findings about the treatment effect cannot be attributed only to the effect of environmental regulation. One important event regarding foreign investment was the Asian financial crisis in 1997–1998. If the Asian financial crisis hit TCZ cities and more polluting industries more strongly, our aforementioned estimates of the effect of environmental regulation could be contaminated. For example, East Asian countries such as Japan and Korea used to invest more in cities in Northern China that hosted heavy and polluting industries before 1998. If, during the Asian financial crisis, Japanese and Korean multinationals reduced their investment in China, we would find similar negative estimated coefficients in Table 2 even without the effects of environmental regulations. To

[8] These studies are conducted using different methods, data, and time periods; hence, the magnitude comparison should be interpreted with caution.

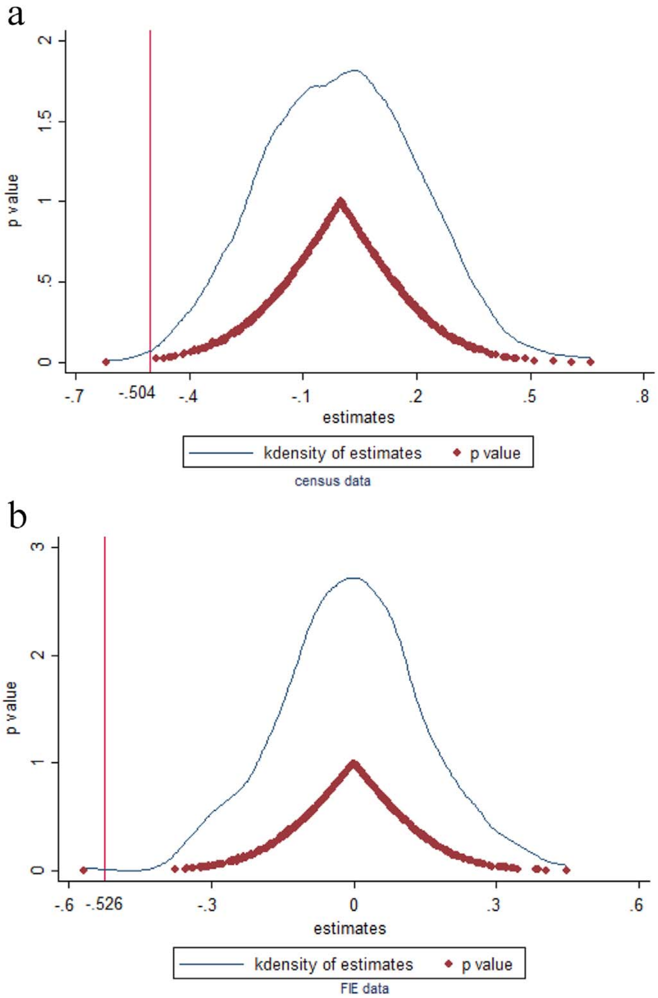

Fig. 4. (a) The Kernel density of 500 estimates using census data. *Note*: X axis presents the estimated coefficients of TCZ * Post * SO_2 from the 500 randomized assignment exercises. The blue curve is the kernel density distribution of the estimates, whereas the red dots are associated *p*-values. The red line is the true estimate from column 1 of Table 2. (b) The Kernel density of 500 estimates using FIE data. *Note*: X axis presents the estimated coefficients of TCZ * Post * SO_2 from the 500 randomized assignment exercises. The blue curve is the kernel density distribution of the estimates, whereas the red dots are associated *p*-values. The red line is the true estimate from column 2 of Table 2.

address this concern, we exploit the advantage of the FIE survey data, which contain the information on the FDI home countries, and exclude FDI from Japan and Korea from the analysis. The regression results are reported in Table 3, column 1. We find a similar estimate in this reduced sample, in terms of statistical significance and magnitude, implying that our findings are not driven by the 1997–1998 Asian financial crisis.

Lags, Leads, and Time Trends: Another potential concern regards the timing of the change in environmental policy. Specifically, as the NEPB began compiling the TCZ list in late 1995 and took two years to get approval from the State Council, one may be concerned about whether there is any expectation effect, that is, whether the effect of environmental regulation on FDI flows happened before the effective date of the policy (i.e., 1998). Meanwhile, there is also a possibility of the lagged effect of environmental regulation on FDI flows. To address these concerns, we follow Laporte and Windmeijer (2005) by estimating all the lags and leads of the environmental regulation effect. Specifically, we estimate the following equation:

$$Y_{ict} = \sum_{j=-5}^{3} \gamma_j \cdot TCZ_c \times \delta_{1998+j} \times SO_{2i} + \eta_{ct} + \lambda_{ic} + \varphi_{it} + \varepsilon_{ict}, \tag{3}$$

where δ_{1998+j} is the indicator variable for year 1998 + j; and the default (omitted) year category is 1992. Hence, γ_j captures five-year lag and three-year lead effects of environmental regulation. As the census data only are a two-year panel, we conduct this exercise using the FIE survey data. The regression results are plotted in Fig. 3. We find that in the pre-treatment period (i.e., before 1998), there are ups and downs in the estimates without clear time trends. Right after the TCZ policy was implemented in 1998, there is a clear decrease in the estimates and they remain significantly negative (despite a jump in 2000). These results demonstrate that the effect of environmental regulation on FDI flows is immediate, and the treatment and control groups do not exhibit differential time trends before the treatment.

Placebo test: Here, we take a closer look at the identification issues. Specifically, denote $X_{ict} \equiv TCZ_c \times Post_t \times SO_{2i}$ and let $\varepsilon_{ict} = \beta\omega_{ict} + \tilde{\varepsilon}_{ict}$, such that $E[X_{ict}, \omega_{ict}] \neq 0$ and $E[X_{ict}, \tilde{\varepsilon}_{ict}] = 0$. In other words, all the identification issues come from ω_{ict}. Hence, our estimator $\hat{\gamma}$ is

$$plim\ \hat{\gamma} = \left(X'X\right)^{-1}\left(X'Y\right) = \gamma + \beta\left(X'X\right)^{-1}\left(X'\boldsymbol{\omega}\right) = \gamma + \beta\delta \tag{4}$$

where $plim\ \delta \equiv \left(X'X\right)^{-1}\left(X'\boldsymbol{\omega}\right)$. And $\hat{\gamma} \neq \gamma$ if $\beta\delta \neq 0$.

As a further check for whether our results are biased due to the omitted variable at the city–industry–year ω_{ict}, we conduct a placebo test by randomly assigning TCZ status to cities (for similar practices, see, e.g., Chetty et al., 2009; La Ferrara et al., 2012). Specifically, in our regression sample, there are 160 TCZ cities of 287 cities. We first randomly select 160 cities from the total 287 cities and assign them as TCZ cities, with the remaining being non-TCZ cities; then we construct a *false* treatment variable, i.e., $TCZ_c^{false} \times Post_t \times SO_{2i}$. The randomization ensures that this newly constructed regressor of interest should have no effect on FDI inflow (i.e., $\gamma^{false} = 0$); hence, if no significant omitted variables exist (i.e., $\beta\delta = 0$), we should have $\hat{\gamma}^{false} = 0$. In other words, any significant findings would indicate the misspecification of our estimation equation. We conduct this random data generating process 500 times to avoid contamination by any rare events.

Table 3, columns 2 and 3, reports the mean values of the estimates from the 500 random assignments for the census data and FIE survey data, respectively. We find that the mean values are almost zero (i.e., 0.001 for the census sample and −0.007 for the FIE survey data), suggesting that $\hat{\gamma}^{false} = 0$. We further plot the distribution of 500 estimated coefficients and their associated *p*-values for the two data sets in Figs. 4a and b, respectively. The distributions center around zero and most of estimates' *p*-values are larger than 0.1. Meanwhile, our true estimates (from columns 1 and 2 of Table 2, respectively) are clear outliers in the placebo tests. Combined, these results suggest that our estimates are not severely biased due to any omitted variables.

Instrumental variable estimation: To further check whether our estimates are biased to omitted variables at the city–industry–year level or not, we adopt an instrumental variable strategy following Hering and Poncet (2014), who use the ventilation coefficient as the instrument for the TCZ status. According to the Box model (e.g., Jacobson, 2002), two meteorological forces determine the pollution dispersion. The first one is wind speed, in which faster wind speed is helpful for

Table 4
Domestic firms results.

Dependent variable: Employment (log)	(1) All domestic firms	(2) Domestic SOEs	(3) Domestic nonSOEs
TCZ * Post * SO_2	−0.022 (0.308)	−0.262 (0.369)	0.338 (0.292)
City–year fixed effect	X	X	X
City–industry fixed effect	X	X	X
Industry–year fixed effect	X	X	X
Data source	Census	Census	Census
Observations	21,812	21,812	21,812
R^2	0.884	0.680	0.888

Note: (1) Census refers to the census data in 1996 and 2001.
(2) TCZ is a dummy variable indicating whether the city was designated as a two control zone in 1998. Post is a dummy variable taking value 1 if it is after 1997 and 0 otherwise. SO_2 is the SO_2 emission level (in 10,000,000 tons) in the industry.
(3) Standard errors, clustered at the city–industry level, are reported in the parenthesis.
(4) SOE refer to state owned enterprises, and nonSOE refer to domestic firms that are belong to SOEs.

Table 5
Heterogeneous effects.

Dependent variable: FDI(log)	(1) Early participant countries (UNFCCC)	(2) Late participant countries (UNFCCC)	(3) Early participant countries (RKP) (RKP)	(4) Late participant countries (RKP)
TCZ * Post * SO_2	−0.094 (0.084)	−0.435*** (0.116)	−0.071 (0.071)	−0.414*** (0.123)
City–year fixed effect	X	X	X	X
City–industry fixed effect	X	X	X	X
Industry–year fixed effect	X	X	X	X
Data source	FIE	FIE	FIE	FIE
Observations	111,930	111,930	106,190	111,930
R^2	0.587	0.645	0.554	0.659

Note: (1) The data is the survey of foreign-invested enterprises (FIE).
(2) TCZ is a dummy variable indicating whether the city was designated as a two control zone in 1998. Post is a dummy variable taking value 1 if it is after 1997 and 0 otherwise. SO_2 is the SO_2 emission level (in 10,000 tons) in the industry.
(3) The UNFCCC refers to the United Nations Framework Convention on Climate Change, in which China joined in 1994. Early participant countries (UNFCCC) refer to countries that joined the UNFCCC in 1994, whereas late participant countries (UNFCCC) refer to countries that joined the UNFCCCafter 1994.There are 67 countries which belongs to former group (see Table A2 for the list).
(4) The RKP refers to the Ratification of Kyoto Protocol, which China approved in 2002. Early participant countries (RKP) refer to countries that signed the RKP before 2002, while late participant countries (PKP) refer to countries that joined the RKP after 2002. There are 61 countries which belong to the former group (see Table A3 for the list).
(5) Standard errors, clustered at the city–industry level, are reported in the parenthesis.
*** Statistical significance at the 1% level.

pollutants to disperse horizontally. The second one is mixing height, which causes pollutants to disperse vertically. Specifically, ventilation coefficient is defined as the product of wind speed and mixing height, with the higher values meaning the faster dispersion of pollutants.

We collect the information on wind speed at 10 m height and boundary layer height (which is used to measure mixing height for the grid of 75 * 75 cells) from the European Centre for Medium-Term Weather Forecasting (ECMWF) ERA-Interim dataset. We first match the EAR-interim database with our Chinese cities according to their latitudes and longitudes, and then multiply wind speed and boundary layer height at each cell to obtain the ventilation coefficient. The ventilation coefficient we use in the regression is the average coefficient from 1991 to 1996 for the nearest cell of each city.

The second-stage results of the instrumental variable estimations are reported in columns 4 and 5 of Table 3, with the first-stage results being reported in Appendix Table A3.[9] We continue to find a negative and statistically significant effect of environmental regulations on FDI inflow, with the magnitude being even larger. These results indicate that our findings on the pollution haven effect is not driven by the omitted variables or reverse causality.

Domestic production: While our aforementioned analyses focus on the sample of foreign firms, it is interesting to examine whether the effect of environmental regulation on location choice also exists for Chinese domestic firms. To this end, we use the census data, and re-do the analysis by using the sample of domestic firms. Estimation results are reported in Table 4, column 1. We find a small and statistically insignificant estimated coefficient, suggesting that toughening environmental regulation has no effect on domestic investment. In columns 2 and 3, we further decompose the sample of domestic firms into state-owned enterprises (SOEs) and non-SOEs, and continue to find insignificant effects of environmental regulation.

These results can be explained by the institutional features in China. First, SOEs are highly controlled by the governments, specifically, by the State-owned Assets Supervision and Administration Commission (SASAC) of the State Council.

[9] We also follow Hering and Poncet (2014) in adding three additional controls; that is, $GDPPC_c \times Post_t \times SO2_i$, $Coastal_c \times Post_t \times SO2_i$, and $Special\ Zone_c \times Post_t \times SO2_i$.

Important decisions such as the opening or closing of SOEs and adjustment of investment are not generally made by the general managers, but strongly influenced by administrative orders from the governments. For example, during the financial crisis in 2008–2009, China's President Hu Jintao announced publicly that SOEs could not lay off their employees and should instead try to expand labor employment. Similarly, in the summer of 2013, because of the slowdown in China's economic growth, less than half of the university graduates in China found a job. The Chinese government again ordered SOEs to hire as many college graduates as possible. On the other hand, because of the poor economic institutions in China, non-SOEs are often local firms, which have connections and networks. For example, a major source of startup capital comes from informal financing, such as family wealth and borrowings from relatives and friends, as non-SOEs are discriminated against bank loans due to the financial repression system (e.g., Allen et al., 2005; Ayyagari et al., 2008). Meanwhile, poor protection of property rights and weak contract enforcement make non-local transactions risky, and trade expansion over regions is significantly influenced by the political connections of the entrepreneurs (e.g., Lu, 2009). Combined, these institutional imperfections make Chinese domestic firms less foot-loose compared with their foreign counterparts, which explains the insignificant effects of environmental regulation on domestic investment.

4.3. Heterogeneous effects

Thus far, we have estimated the average effect of environmental regulation on FDI flows from all origin countries. With the information on FDI source country in the FIE survey data, we are able to investigate the possible heterogeneous effects across FDI home countries. Specifically, we examine whether foreign multinationals from countries with more stringent environmental regulations behave differently from those from countries with less stringent regulations. To this end, we categorize foreign countries into two groups depending on their regulations relative to China's. Hence, for countries with more stringent environmental regulations than China, their multinationals go to a country with weaker regulations compared with the levels in their home countries. Meanwhile, multinationals from countries with less stringent environmental regulations than China invest in a country with stronger protection of environments.

We use two methods to rank countries in terms of their environmental regulations. First, we check when each country joined the *United Nations Framework Convention on Climate Change* (UNFCCC), an international environmental treaty put into effect in 1994. The objective of the UNFCCC is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." We then divide the sample into two groups, based on whether the country joined the UNFCCC before or after China did in 1994. We conceptualize that the later participant countries may have lower recognition and less stringency of environmental protection than earlier participant countries (the list of countries in the two groups is provided in Appendix Table A4). The regression results for the two groups are presented in Table 5, columns 1 and 2. Interestingly, we find that the effect of environmental regulation on FDI flows is small and statistically insignificant for the group of countries that joined the UNFCCC at the same time as China, but the effect remains economically and statistically significant for the later participant countries.

However, a problem with the UNFCCC is that "The framework set no binding limits on greenhouse gas emissions for individual countries and contains no enforcement mechanisms." These issues were addressed in the *Kyoto Protocol* in 1997, which "established legally binding obligations for developed countries to reduce their greenhouse gas emissions in the period 2008–2012." Hence, in a second approach, we collect the year when each country signed the *Kyoto Protocol*, and divide the sample into two groups, based on whether the county signed the ratification of the *Kyoto Protocol* before or after China did. Given the binding obligations in the *Protocol*, we hypothesize that countries signed the treaty earlier (later) than China have more (less) stringent environmental regulations than China. The list of countries in the two groups is presented in Appendix Table A5. The estimation results are reported in Table 5, columns 3 and 4. Consistently, we find that the stringent environmental regulation has a sizable and statistically significant effect only on FDI flows from countries that joined the *Protocol* later.

Combined, these results indicate that foreign multinationals from countries with good environmental protection are insensitive to the change in environmental regulation in China. Their investment in China is possibly to exploit other benefits of the country, instead of the lax environmental regulation. However, environmental regulation seems to be an important factor determining investment in China by foreign multinationals from countries that joined international treaties on environmental protection later than China. These findings may help relieve the concern that toughening environmental protection in developed countries would cause a shift of dirty manufacturing production to countries with laxer environmental regulations, which then may not combat the environmental deterioration and would have significant distributional implications on employment and industry structures.

5. Conclusion

In this paper, we investigated whether foreign multinationals respond to environmental regulations by reallocating their production to places with less stringent regulations. To control for the potential endogeneity of environmental regulations, we use a change in environmental policy, namely China's 1998 TCZ policy. Our identification of the effect of environmental regulation comes from a comparison of the outcome variable for TCZ cities in pollution intensive industries versus clean industries with that for non-TCZ cities before and after the policy change, or the DDD estimation.

By using two comprehensive firm data sets in China (i.e., the 1996 and 2001 censuses on basic units and the 2001 survey of FIEs), we find that a one-standard-deviation increase in pollution intensity causes the negative effect of environmental regulation on FDI flows to be 8 percentage points lower, confirming the pollution haven hypothesis. The results are robust to a series of robustness checks on the identifying assumption, and to checks on other econometric concerns. Moreover, we find that foreign multinationals from countries with better environmental protections than China are insensitive to the toughening environmental regulation, while those from countries with worse environmental protections than China show strong negative responses.

This paper contributes to the literature on the pollution haven hypothesis by carefully addressing the endogeneity problem associated with environmental regulations. Meanwhile, our use of data from a developing country complements existing studies that focus more on developed countries, particularly the U.S.

Table A1
TCZ cities in China.
Source: "The Official Reply of the State Council Concerning Acid Rain Control Areas and SO_2 Pollution Control Areas".

Province	TCZ city	Province	TCZ city	Province	TCZ city	Province	TCZ city	Province	TCZ city
Beijing	Beijing		Tonghua	Jiangxi	Nanchang		Yueyang	Chongqing	Chongqing
Tianjin	Tianjin	Shanghai	Shanghai		Pingxiang		Changde	Sichuan	Chengdu
Hebei	Shijiangzhuang	Jiangsu	Nanjing		Jiujiang		Zhangjiajie		Zigong
	Tangshan		Wuxi		Yingtan		Yiyang		Panzhihua
	Handan		Xuzhou		Ganzhou		Chenzhou		Luzhou
	Xingtai		Changzhou		Ji'an		Huaihua		Deyang
	Baoding		Suzhou	Shandong	Jinan		Loudi		Mianyang
	Zhangjiakou		Nantong		Qingdao	Guangdong	Guangzhou		Suining
	Chengde		Yangzhou		Zibo		Shaoguan		Neijiang
	Hengshui		Zhenjiang		Zaozhuang		Shenzhen		Leshan
Shanxi	Taiyuan		Taizhou		Yantai		Zhuhai		Nanchong
	Datong	Zhejiang	Hangzhou		Weifang		Shantou		Yibin
	Yangquan		Ningbo		Jining		Foshan		Guang'an
	Shuozhou		Wenzhou		Taian		Jiangmen		Meishan
	Yuncheng		Jiaxing		Laiwu		Zhanjiang	Guizhou	Guiyang
	Xinzhou		Huzhou		Dezhou		Zhaoqing		Zunyi
	Linfen		Shaoxing	Henan	Zhengzhou		Huizhou		Anshun
Inner Mongolia	Huhhot		Jinhua		Luoyang		Shanwei	Yunnan	Kunming
	Baotou		Quzhou		Anyang		Qingyuan		Qujing
	Wuhai		Taizhou		Jiaozuo		Dongguan		Yuxi
	Chifeng	Anhui	Wuhu		Sanmenxia		Zhongshan		Zhaotong
Liaoning	Shenyang		Maanshan	Hubei	Wuhan		Chaozhou	Shaanxi	Xian
	Dalian		Tongling		Huangshi		Jieyang		Tongchuan
	Anshan		Huangshan		Yichang		Yunfu		Weinan
	Fushun		Xuancheng		Ezhou	Guangxi	Nanning		Shangluo
	Benxi		Chaohu		Jingmeng		Liuzhou	Gansu	Lanzhou
	Jinzhou	Fujian	Fuzhou		Jingzhou		Guilin		Jinchang
	Fuxin		Xiamen		Xianning		Wuzhou		Baiyin
	Liaoyang		Sanming	Hunan	Changsha		Guigang		Zhangye
	Huludao		Quanzhou		Zhuzhou		Yulin	Ningxia	Yinchuan
Jinlin	Jilin		Zhangzhou		Xiangtan		Hezhou		Shizuishan
	Siping		Longyan		Hengyang		Hechi	Xinjiang	Urumqi

Table A2
2-digit industry list.
Source: China's environmental yearbook, 2005.

2-digit Industry name	2-digit Industry name
Coal mining and washing industry	Pharmaceuticals
Petroleum and natural gas mining industry	Chemical Fiber
Ferrous metals mining industry	Rubber Products
Non-ferrous metals mining industry	Plastics Products
Non metallic mining industry	Non-metallic Mineral Products
Other mining industry	Ferrous metal smelting and processing industry
Agricultural and sideline food processing industry	Non-ferrous Metal Smelting and Processing
Food manufacturing industry	Metal Products
Beverage Manufacturing	General Machinery Manufacturing
Tobacco Processing	Special Equipment Manufacturing
Textile	Transport Equipment
Textile and garment, shoes, cap manufacturing industry	Electrical Machinery and Apparatus
Leather, Fur, and Coat Products	Communication equipment, computer and other electronic equipment manufacturing industry
Wood processing and bamboo products industry	Instruments and Meters and Office Machines
Furniture	Handicrafts and other manufacturing
Paper Making and Paper Products	Waste resources and recycling of waste materials
Printing and Recording Media Reproducing	Electricity, heat production and supply industry
Stationery and Sporting Goods	Gas production and supply industry
Petroleum Processing and Coking	Water production and supply industry

Table A3
IV estimation, first stage.

Dependent variable	(1) TCZ * Post * SO_2	(2) TCZ * Post * SO_2
Ln(VC) * Post * SO_2	−0.285***	−0.284***
	(0.083)	(0.083)
City–year fixed effect	X	X
City–industry fixed effect	X	X
Industry–year fixed effect	X	X
Data source	FIE	census
Observations	102,180	19,388
F-test excluded instrument	11.804	11.812
Weak identification	11.805	11.799

Note: (1) For data source, census refers to the census data in 1996 and 2001, while FIE refers to the survey of foreign-invested enterprises.
(2) TCZ is a dummy variable indicating whether the city was designated as a two control zone in 1998. Post is a dummy variable taking value 1 if it is after 1997 and 0 otherwise. SO_2 is the SO_2 emission level (in 10,000,000 tons) in the industry.
(3) Standard errors, clustered at the city–industry level, are reported in the parenthesis.
(4) We further include three controls, GDPPC * Post * SO_2, Coastal * Post * SO_2, and Special Zone * Post * SO_2, following Hering and Poncet (2014).
*** Statistical significance at the 1% level.

Appendix A

See Tables A1–A5

Table A4
Country list for UNFCCC.
Source: World Development Indicators, 2007, issued by World Bank.

Early participation group	Early participation group	Late participation group	Late participation group	Late participation group	Late participation group
Algeria	Mongolia	Afghanistan	Gabon	Namibia	The Principality of Monaco
Argentina	Nepal	Albania	Gibraltar	Nauru	The State of Palestine
Australia	Netherlands	American Samoa	Guatemala	Nicaragua	The United Arab Emirates
Austria	New Zealand	Barbados	Haiti	Niger	The United States of Virgin Islands
Bangladesh	Nigeria	Belarus	Honduras	Oman	Togo
Benin	Norway	Belgium	Hong Kong	Panama	Tonga
Botswana	Pakistan	Belize	Hungary	Puerto Rico	Tuamotu Archipelago
Brazil	Papua New Guinea	Bermuda	Iran, Islamic Republic	Republic of Cape Verde	Turkey
Burkina Faso	Paraguay	Bolivia	Iraq	Republic of Cyprus	Turks and caicos islands
Canada	Peru	Bonaire	Israel	Republic of Iceland	Tuvalu
Costa Rica	Philippines	Brunei Darussalam	Jamaica	Republic of Malta	Ukraine
Cuba	Poland	Bulgaria	Kazakhstan	Republic of Marshall Island	Venezuela
Czech Republic	Portugal	Burundi	Kiribati	Republic of Pala	Vietnam
Denmark	Republic of Korea	Côte d'Ivoire	Korea, Dem Republic	Republic of San Marino	Yemen, Republic.
Ecuador	Romania	Cambodia	Kuwait	Republic of Seychelles	Yugoslavia
Estonia	Slovak Republic	Cameroon	Kyrgyz Republic	Russian Federation	Zaire
Finland	Spain	Canary Islands	Lao PDR	Saibutai	Other countries
France	Sri Lanka	Cayman Islands	Latvia	Saint Vincent	
Germany	Sudan	Chile	Lebanon	Saudi Arabia	
Greece	Sweden	Colombia	Lesotho	Sierra Leone	
Guinea	Switzerland	Commonwealth of the Bahamas	Liberia	Singapore	
India	Trinidad and Tobago	Congo ,Dem.Republic	Libya	South Africa	
Indonesia	Tunisia	Cook Islands	Luxembourg	Syrian Arab Republic	
Ireland	Uganda	Croatia	Macau	Taiwan	
Italy	United Kingdom	Curacao	Macedonia	Tajikistan	
Japan	United States	Dominican Republic	Madagascar	Tanzania	
Jordan	Uruguay	Egypt, Arab Republic	Maldives	Thailand	
Kenya	Uzbekistan	El Salvador	Mali	The Federation of Saint Kitts and Nevis	
Malaysia	Zambia	Equatorial Guinea	Moldova	The Independent State of Samoa	
Mauritius	Zimbabwe	Eritrea	Morocco	The Kingdom of Bahrain	
Mexico		Fiji	Myanmar	The Principality of Liechtenstein	

Table A5
Country list for RKP.
Source: World Development Indicators, 2007, issued by World Bank.

Early participation group	Early participation group	Late participation group	Late participation group	Late participation group	Late participation group
Argentina	Italy	Afghanistan	Jordan	Republic of Malta	Ukraine
Austria	Jamaica	Albania	Kazakhstan	Republic of Marshall Island	United States
Bangladesh	Japan	Algeria	Kenya	Republic of Pala	Venezuela
Belgium	Latvia	American Samoa	Kiribati	Republic of San Marino	Vietnam
Benin	Lesotho	Australia	Korea, Dem Republic	Republic of Seychelles	Yemen, Republic
Bolivia	Liberia	Barbados	Kuwait	Russian Federation	Yugoslavia
Brazil	Mauritius	Belarus	Kyrgyz Republic	Saibutai	Zaire
Bulgaria	Mexico	Belize	Lao PDR	Saint Vincent	Zambia
Burundi	Mongolia	Bermuda	Lebanon	Saudi Arabia	Zimbabwe
Cambodia	Morocco	Bonaire	Libya	Sierra Leone	Other countries
Cameroon	Netherlands	Botswana	Luxembourg	Singapore	
Canada	New Zealand	Brunei Darussalam	Macau	Sudan	
Chile	Nicaragua	Burkina Faso	Macedonia	Sweden	
Colombia	Panama	Canary Islands	Madagascar	Switzerland	
Costa Rica	Papua New Guinea	Cayman Islands	Malaysia	Syrian Arab Republic	
Cuba	Paraguay	Commonwealth of the Bahamas	Maldives	Taiwan	
Czech Republic	Peru	Congo, Dem.Republic	Mali	Tajikistan	
Denmark	Poland	Cook Islands	Moldova	The Federation of Saint Kitts and Nevis	
Dominican Republic	Portugal	Croatia	Myanmar	The Independent State of Samoa	
Ecuador	Republic of Korea	Curacao	Namibia	The Kingdom of Bahrain	
El Salvador	Romania	Egypt, Arab Republic	Nauru	The Principality of Liechtenstein	
Estonia	Slovak Republic	Equatorial Guinea	Nepal	The Principality of Monaco	
Finland	South Africa	Eritrea	Niger	The State of Palestine	
France	Spain	Fiji	Nigeria	The United Arab Emirates	
Germany	Sri Lanka	Gabon	Norway	The United States of Virgin Islands	
Greece	Tanzania	Gibraltar	Oman	Togo	
Guatemala	Thailand	Haiti	Pakistan	Tonga	
Guinea	Trinidad and Tobago	Hong Kong	Philippines	Tuamotu Archipelago	
Honduras	Uganda	Indonesia	Puerto Rico	Tunisia	
Hungary	United Kingdom	Iran, Islamic Republic	Republic of Cape Verde	Turkey	
India	Uruguay	Iraq	Republic of Cyprus	Turks and caicos islands	
Ireland	Uzbekistan	Israel	Republic of Iceland	Tuvalu	

Appendix B. Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jdeveco.2016.08.003.

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