学术笔记　第11篇

论文信息: Xiqian Cai, Yi Lu, Mingqin Wu, Linhui Yu. Does environmental regulation drive away inbound foreign direct investment? Evidence from a quasi-natural experiment in China, Journal of Development Economics,2016(123):73-85（**环境规制赶走了外商直接投资吗？来自中国准自然实验的证据)**

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日期：2017年7月21日

*这是我们推送有关双重差分方法（DID）的第二篇论文。
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◆　1 分钟速读

自 2016 年 11 月份以来，我国实际利用外商直接投资金额连续 6 个月出现年初到该月累计额同比负增长。一个自然而然的问题：是什么因素导致 FDI 的下降？日益严格的环境保护政策是否影响了 FDI？“污染避难所假说”在中国是否成立？

该文基于中国 1998 年设立两控区这一环境政策自然实验，利用三重差分估计方法研究了环境规制是否会影响入境外商直接投资这一问题。包含了三个维度变化：城市（两控区城市相对于非两控区城市）、行业（高污染行业相对于低污染行业）、年份（两控区政策实施前后）。研究结果表明：

1. 严格地环境规制导致了更少的外商直接投资。行业污染强度一个标准误的上升会导致环境规制对 FDI 流量下降 8 个百分点。

2. 来自于环境保护严于中国的国家的外国跨国公司对严格的环境规制不敏感。

3. 而来自于环境保护比中国差的国家的外国跨国公司则表现出强烈的负向反应。

此外，该文巧妙之处：利用一个年份的外商投资企业调查数据构建了 DID。把企业成立年份时的合同资本额变量作为成立年份新进入的 FDI，加总得到城市行业层面的新进入 FDI 被解释变量。

◆　重要知识点

污染避难所假说（Pollution Haven Hypothesis）**：**也称“污染天堂假说”或“产业区位重置假说”，主要指污染密集产业的企业倾向于建立在环境标准相对较低的国家或地区。

※END※

环境规制赶走了入境外商直接投资吗？来自中国准自然实验的证据

XiqianCai, Yi Lu, Mingqin Wu, Linhui Yu

摘要：本文研究了环境规制是否会影响入境外商直接投资。1998 年中国政府实施了两控区政策，对两控区城市采取了更为严格的环境规制，而非两控区城市则无要求。据此，本文的三重差分估计方法包含了三个维度变化：城市（两控区城市相对于非两控区城市）、行业（高污染行业相对于低污染行业）、年份（两控区政策实施前后）。本文的研究发现，严格地环境规制导致了更少的外商直接投资。同时，我们也发现，来自于环境保护严于中国的国家的外国跨国公司对严格的环境规制不敏感，而来自于环境保护比中国差的国家的外国跨国公司则表现出强烈的负向反应。

关键词：环境规制；外商直接投资；污染避难所效应；三重差分估计；两控区

1. 引言

世界各国政府日益关注环境恶化问题并加强了对环境污染的规制力度，并要求企业开发和使用绿色技术，生产更环保的产品。但出乎意料的是，企业会将生产转移到环境规制要求较低的地方，这种现象被称为污染避难所假说（污染天堂假说）。这不仅会抵消环境政策作用，还会恶化整体环境。例如，发展中国家可能会操纵环境政策以来吸引更多 FDI，这也导致了整体污染水平的上升。

虽然有许多传闻的证据，但是环境规制效应的实证研究却未能提供一致的结果，一些研究认为没有影响[1]，而另一些研究则认为有重大影响[2]。因此，污染避难所假说被认为是国际贸易、FDI 和环境领域中最具争议性的问题之一"（Kellenberg，2009）。

识别环境规制对企业选址的影响的实证难题是，如何处理环境规制潜在的内生性。最新的研究已经着手处理环境规制潜在的内生性[3]，例如采用工具变量法（Millimet andRoy,2016）或 DID 方法（List et al.,2003, 2004; Millimet andList,2004; Hanna, 2011; Chung, 2014;Broner etal.,2015）。

本文对污染避难所假说的文献有三个方面的贡献。第一，当最新的文献大量使用发达国家的数据如美国（Hanna,2011; Millimet andRoy,2016）和韩国（Chung, 2014）时，本文聚焦于世界上最大的发展中国家中国，和检验了中国环境规制是否会影响入境 FDI。检验发展中国家是否存在污染避难所假说，有助于我们理解放松环境规制强度是否成为发展中国家吸引 FDI 的竞争手段，以此来推动经济增长。这些研究结果也可以论证，发达国家通过把污染产业转移到发展中国，以实现本国严格的环境保护目标。此外，中国为检验污染天堂假说提供了一个很好的样本。一方面，自 1978 年改革开放以来，中国政府不断吸引外资，这也让中国成为世界上第二大 FDI 流入国[4]。另一方面，近几十年来，伴随中国经济的快速增长，环境污染日益恶化，包括过度开发和大量工业污染物排放，这也是发展中国家普遍存在的问题。

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[1]例如，Friedman et al.(1992), Levinson(1996), Eskeland and Harrison(2003), and Javorik and Wei(2004). 在相关的研究中，List(1999)表明美国 1929-2994 年空气污染排放趋同，说明美国各州没有因为产业竞争而放松环境规制。

[2]例如，Henderson(1996), Becker and Henderson(2000), List and Go(2000), Keller and Levinson(2002), List et al.(2003), and Kellenberg(2009).关于文献综述，见 Dean(1992), Levinson(2008), Brunnermeier and Levinson (2004), Copeland and Taylor(2004), and Erdogan(2014)。

[3]Jeppesen et al.(2002) 利用 meta 分析，得出结论方法上的不同解释了环境规制效应的大部分差异。

[4]数据来自于 CIA World Factbook（2013 年 8 月 15 日收录）。

中国也是一个在 FDI 分布和环境质量方面存在很大差异的国家，这为我们识别环境规制的效果提供了足够的差异性。

第二，本文的分析采用了更为可信的中国企业数据。特别地，1996 和 2001 年两个普查数据集涵盖了中国所有企业，2001 年外商投资企业（FIEs）调查数据涵盖了超过四分之三的外商投资企业。这些数据能揭示出中国 FDI 流的整体模式，比以往的研究采用较小或截取样本的中国企业数据更有优势（例如，Dean etal.（2009）采用 2886 个制造业合资股份制企业的样本；Hering and Poncet（2014）利用年销售额大于 500 万元的企业样本）。本文的外商投资企业调查数据还包含了外商投资企业来源国的信息，这让我们能研究环境规制的阻遏效应是否在不同环境保护程度的国家而不同。这种不同的影响效果可以进一步揭示，环境规制较严格的国家的企业是否会将生产转移到环境规制较为宽松的发展中国家。

第三，文献中关于确定污染避难所假说的一个问题：环境规制存在测量误差。这种内生性问题可能会影响估计结果。本文利用中国环境政策的变化即两控区政策，很好地规避了这一问题。两控区政策的启动和设计以及是否成为两控区城市是由中央政府决定的，地方政府一般难以影响该政策制订和实施。为了推行这一政策，中国成立了国家环境保护总局，国务院明确提出了环境控制的短期和长期目标。这种情况太太减轻了发展中国家的环境政策存在执行不力的可能性。环境政策执行不力容易得到环境规则效应较弱的的研究结果。更多关于中国环境规制的细节，详见第二部分。

为了识别环境规制的效应，本文采用三重差分估计方法。特别地，第一重差分来自于两控区和非两控区城市的 FDI 流的对比（前者有着更高的环境规制强度）；第二重差分比较了高污染行业和低污染行业的 FDI 流（前者有着更强的阻遏效应）；最后一重差分是由于 1998 年政策的实施，它将样本分成实施前和实施后。三重差分允许我们控制城市-产业固定效应、城市-年份固定效应以及产业-年份固定效应，其中在城市层面（时变和时不变）、行业层面（时变和时不变）潜在的遗漏变量都被适当地处理。在有效性检验中，我们检验了 1997-1998 年亚洲金融危机可能产生的偏误，考察了预期和滞后效应，进行 TCZ 政策随机分配的安慰剂检验，也采用了工具变量策略。

研究结果表明，（1）相对于低污染行业而言，环境规制对高污染行业的 FDI 流入具有强烈的阻遏效应，验证了污染天堂假说。行业污染强度一个标准差的上升导致环境规制对 FDI 流的负面影响降低 8 个百分点。

（2）我们发现 FDI 来源国之间存在显著的异质性效应。特别地，我们检验了环境规制水平比中国高的国家的跨国公司是否与那些环境规制水平比中国差的国家的跨国公司有显著的差别，前者可能倾向于去到一个比母国环境规制更宽松的国家投资，而后者则相反。我们根据是否先于中国加入环境保护国际条约（例如，联合国气候变化框架公约和京都议定书），将国家划分为两组。我们发现从环境保护好于中国的国家来的外国跨国公司对严格的环境规制不敏感，而从环境保护比中国差的国家来的外国跨国公司则表现出强烈的负面反应。这些发现减轻了我们关注污染避难所假设的担心，即发达国家严格的环境规制政策会促使污染较高的制造业生产转转移到环境规制水平较低的国家。

本文的研究与最近污染避难所假说的文献密切相关。Hanna（2011）采用 DD 方法分析了美国清洁空气法修正案如何影响其对外直接投资，研究发现该法案的实施使得跨国公司的海外资产提高了 5.3 个百分点，海外产出提高了 9 个百分点。Chung（2014）也利用 DD 方法研究了外国环境规制水平的变化对韩国对外投资的影响，发现高污染行业的韩国跨国公司在环境规制较为宽松的国家投资更多。对 1977 - 1994 年间相邻 48 个州的美国制造业入境外商直接投资采用两种新颖的识别策略，Millimet and Roy（2016）发现环境规制对高污染行业的入境 FDI 具有显著的负面影响。利用污染扩散的气象条件作为全国环境规制的工具变量，Broner et al.（2015）发现宽松的环境规制环境被视为国际贸易中比较优势的一种来源，

其作用大小可与物质和人力资本的作用可比。

本文的结构安排如下：第二部分是中国环境规制的政策背景，第三部分讨论了数据、变量和估计策略，第四部分是实证分析结果，第五部分是结论。

2. 中国的环境规制

时间线：伴随着中国经济的快速发展，由煤炭燃烧产生的二氧化硫排放也相应地增加[5]。考虑到中国经济的长远发展，中国政府在20世纪80年代中期开始实施一系列环境规制政策。特别地，中国空气污染防治法（APPCL）于 1987 年颁布，并于 1988 年实施。1995 年，APPCL 被重新修订，包括关于空气污染和二氧化硫排放监管的部分。更为重要的是，在 1998 年 1 月，国务院通过了成立两控区的文件《国务院关于酸雨控制区和二氧化硫污染控制区有关问题的答复》，并开始正式实施。

在 380 个地级市中，175 个地级市被选为两控区城市（Hao et al., 2001），他们占全国领土的 11.4%、人口的 40.6%、GDP 的 62.4%以及 1995 年二氧化硫排放的 58.9%。图 1 描绘了中国两控区城市的地理分布；特别地，深灰色区域代表两控区，浅灰色区域代表非两控区，黑色的圆圈大小表示城市规模，城市规模大小是以 1996 年普查数据中企业的数量来衡量。一般而言，二氧化硫控制区位于中国北方，因为这里依赖热能供暖，而酸雨控制区位于中国南方，因为那里的气候潮湿。

划分标准：两控区包括二氧化硫污染控制区和酸雨控制区。国家环境保护总局从 1995 年底开始使用几个标准指定两控区城市，特别地，一个城市被划定为二氧化硫污染控制区的标准是：（1）近年来环境空气二氧化硫年平均浓度超过国家二级标准；（2）日平均浓度超过国家三级标准（即 250ug/m^3）；（3）二氧化硫排放量较大。一个城市被划定为酸雨控制区的标准是：（1）现状监测降水 PH≤4.5；（2）硫沉降超过临界负荷；（3）二氧化硫排放量较大的区域。

新政策：一旦一个城市被划分为两控区城市，更严格的环境规制将会实施。第一，含硫量超过 3%及以上的新煤矿被禁止，现有的高硫煤矿必须逐渐减少生产或停产。第二，在“两控区”大中城市市区内（城区和近郊区），禁止新的燃煤火力发电厂，除了那些原本用来供暖的废热发电厂。此外，新建或更新的燃煤火力发电厂使用含硫量高于 1.5%及以上时必须安装脱硫设备，而已有的使用相同品质煤的火力发电厂在 2000 年以前也必须采取降低二氧化硫排放措施。第三，在高污染行业，如化工、冶金、有色、建材等行业，产生严重污染的生产技术和设备必须淘汰。最后，地方政府必须认真做好二氧化硫排污费的征收、管理和使用工作。

实施：在 1998 年的回复中，国务院也制定了两控区城市环境监管的短期（到 2000 年）和长期（到 2010 年）目标[6]。这些环境规制在空气污染治理方面取得了显著的成效。到 2000 年，102 个两控区城市实现空气二氧化硫年平均浓度达到国家二级标准，84.3%的高污染企业的二氧化硫排放达到目标水平（中国环境年鉴，2001）。到 2010 年，94.9%的两控区城市实现空气二氧化硫年平均浓度达到国家二级标准，也没有城市的报告值超过国家三级及以上标准（中国环境状况公报，2011）。

[5]例如，1993 年，中国 62.3%的城市年均二氧化硫浓度都超过国家二级标准（即 60ug/m^3）。

[6]特别地，到 2000 年底，“工业二氧化硫污染源毕业达到国家排放标准，二氧化硫排放总量控制在国家规定的排放总量指标内，“两控区”内重点城市环境空气二氧化硫浓度都达到国家环境质量标准，酸雨控制区的酸雨得到缓解”。到 2010 年底，“两控区内二氧化硫排放量控制在 2000 年排放水平之内；两控区”内所有城市环境空气二氧化硫浓度都达到国家环境质量标准；酸雨控制区降水 pH≤4．5 地区的面积明显减少。”

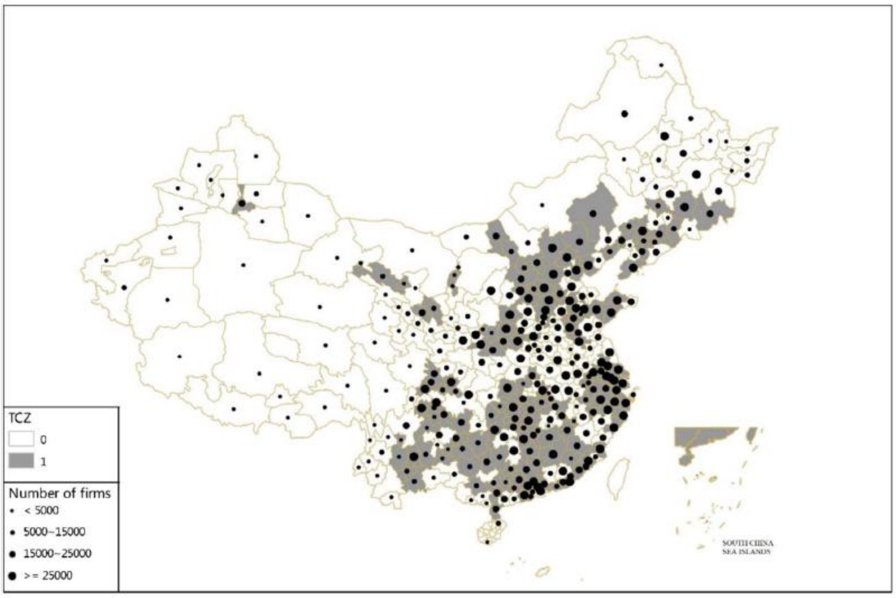

Fig. 1. Geographic distribution of TCZ cities. *Data source*: The national Environmental Protection Bureau, "The Proposal of Designation for Acid Rain Control Areas and SO_2 Pollution Control Areas"; Chinese First National Census of Basic Units.

3. 数据，变量和估计策略

3.1.数据和变量

我们从《国务院关于酸雨控制区和二氧化硫污染控制区有关问题的答复》中获得了两控区城市的详细名单。在样本期间，名单上的城市保持不变。附录中表 A1 列出了详细的名单。

表 1 比较了 1998 年以前，两控区和非两控区城市的一系列城市层面的特征。我们发现对于大多数特征而言，两控区和非两控区城市在均值方面的差异较小。例如，在 1998 年以前，两控区城市比非两控区城市吸引更多 FDI，两组的均值差异大约在 15%-18%。显著的差异：两控区城市普遍是外贸导向型经济，分布在中国南方，且主要是大城市（如直辖市和省会城市）。在下一小节，我们将讨论在识别环境规制效应时如何控制处理组和对照组之间的异质性。

为了度量中国入境 FDI，我们使用两个企业层面的大型数据集，这两个数据集各有利弊。第一个数据集来自于 1996 年全国第一次基本单位普查和 2001 年全国第二次基本单位普查。中国有两个业务单位，分别是法人单位和基本单位，前者由后者组成，后者由前者管理和控制。法人单位的定义原则上与联合国“国民账户体系”（SNA）中的组织单位一致，而基本单位的定义与 SNA 的基本组织（establishment）是一致的。在这两个普查数据中分别有 635 万和 708 万家基本单位，涵盖了所有的行业，包括农业、制造业、建筑业和服务业等。普查数据包含企业的所有基本信息，如每个企业的成立日期、地址、区位代码、隶属行业、所有制以及雇佣人数和销售类别。因此，我们用新建 FDI 的雇佣人数的对数值来衡量 FDI。

虽然普查数据覆盖范围较广，但是在我们的研究设定中具有两个潜在的缺点：（1）处理前后分别只有一年的数据可得；（2）FDI 来源国的信息不可得，使得分析不同来源国的异质性效应不可行。因此，我们采用了 2001 年外商企业调查数据（FIEs）来补充我们的分析。这个数据集共有 150000 个观测值，包括 2001 年 75%的外商投资企业。除了企业的基本信息以及常见的会计信息以外（如就业人数、销售额等），数据还包括了企业合同资本额和来源国的信息。

对于本文的研究，我们需要城市、产业和年份层面的 FDI 流。虽然只有 2001 年 FIEs

的数据，但是它包含了企业成立时的合同投资额，这使得我们可以构建每年城市和产业层面新建 FDI 的合同额，本文用这一数值衡量 FDI 流入。由于只有一年的调查数据，因而我们需要外推企业在进入时的区位信息以进行面板分析。因此，我们认为企业现在的区位即为企业成立时的区位，从而生成一个 1992-2001 年的面板数据。这样做的负面影响是，如果由于两控区政策引起企业改变其区位或者退出，则由于投资转移将导致我们的估计是有偏的。由于我们的原假设是环境规制对企业的选址没有影响，重新选址或退出将不会影响我们对原假设和污染避难所效应的检验。然而，如果拒绝原假设，那么重新选址或退出行为将影响我们估计系数的大小。当我们展示我们估计值大小时，我们将进一步讨论这一问题。

2004 年行业层面的二氧化硫排放量的信息来自于由国家统计局和国家环境保护局出版的《中国环境统计年鉴（2005）》[7]。

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.

3.2. 识别

利用两控区政策进行双重差分法（DD）可以控制时间和地区的变化。特别地，分别有两组样本，处理组是在 1998 年被选为两控区的城市，对照组是非两控区城市。我们可以比较在 1998 年实施两控区政策前后两控区城市与非两控区城市在同一时期 FDI 的变化。

DD 的模型设定如下：

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

Y_{ct} 是城市 c 在 t 年的 FDI 流入；TCZ_c 是城市 c 在 1998 年是否为 TCZ 的状态，即如果 TCZ_c=1 则城市 c 为两控区城市，TCZ_c=0 则为非两控区城市；$Post_t$ 表示处理期，即当 $t\geq$1998 时，$Post_t$=1，否则为 0。α_c 是城市固定效应，捕获城市层面不随时间变化的特征，如地理特征、气候、自然禀赋等；δ_t 是年份固定效应，捕获了不随城市变化的年份因素，如商业周期、货币政策、宏观冲击等；ε_{ct} 是误差项。

然而，关于 DD 分析一个普遍关心的问题是可能存在随时间变化的城市特征与回归元相关，从而使我们的估计有偏。一个例子是集聚效应，它被认为是工业区位选择的重要影响因素（see, e.g., Arauzo-Carodet al.,2010, forareview）。文献中消除集聚经济效应的办法是加入 FDI 的历史存量（e.g., WagnerandTimmins,2009）。然而，Lechner（2009）指出包含滞后被解

[7]采用 2004 年二氧化硫排放水平的一个可能的担忧是这个值可能受到两控区政策的影响，如高污染行业会进行调整。然而，问题是两控区政策实施前二氧化硫排放的数据只有 20 个行业，而 2004 年有 37 个行业，这会导致行业层面的差异减少。尽管如此，我们发现在公共的 15 个行业里，1996-1998 年二氧化硫的排放水平与 2004 的二氧化硫排放水平高度相关；特别地，1996 年与 2004 年二氧化硫排放的相关系数高达 0.8917。这些结果表明行业二氧化硫排放水平在我们的研究期间内相当一致。

释变量 DD 模型存在以下问题：如果 DID 假设在预处理中无条件成立，那么包含滞后变量很可能会在预先处理中破坏假设成立条件。（if the DiD assumptions hould unconditionally on the pre-treatment outcome, they are likely to be violated conditional on pre-treatment outcomes）与此同时，在面板估计中，包含被解释变量滞后项导致误差项与被解释变量滞后项的内生相关性，结果使得式（1）不是一致估计。（see Nickell,1981; Angristand Pischke,2009）。

另一个遗漏的时变变量是相邻位置的特征，这也被认为会影响 FDI 的选址（see, for example, Blonigenet al.,2007; MillimetandRoy,2016）。文献中解决该问题的一个办法是控制 FDI 的空间滞后项（即所有城市 FDI 的逆距离加权平均）。然而，GibbonsandOverman(2012) 指出由于误差项与空间滞后的 FDI 内生相关，该模型可能导致估计不一致。

针对这些问题，本文利用不同行业具有不同污染强度这一事实，构造了 DDD 估计作为本文的主要识别策略。具体来说，我们加入随时间（1998 年两控区政策实施前后）、地区（两控区 versus 非两控区）、产业（高污染与低污染）变化的变量。DDD 估计的模型如下：

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

SO_{2i}表示产业 i 的 SO_2 排放，由于 SO_{2i}的信息只到二位码行业（行业列表详见附录表 A2），我们将变量加总到城市、二位码行业和年份层面。为了解决潜在的异方差和序列相关，我们将 cluster 标准误到城市-行业层面。

与 DD 估计相比，DDD 估计允许我们控制产业-年份固定效应、产业-城市固定效应和城市-年份固定效应。换句话说，我们可以控制随时变和时不变的城市特征，如区域溢出、集聚、腐败、地方政治活动、能源价格等。我们也可以控制时变和时不变的产业特征，如技术变化、进口竞争程度变化、产业政策等。并且我们允许不同城市的产业是不同的，只要这种产业-城市层面的差异在样本期间固定。其余可能的遗漏变量需要同时在时间、城市、产业层面变化。在 DDD 估计的有效性检验中，我们采取了一系列的敏感性分析，包括控制 1997-1998 年亚洲金融危机、检验预期效应和滞后效应、随机分配两控区改革的安慰剂检验、利用 Hering and Poncet（2014）的工具变量法。具体细节见 4.2 节。

4. 实证结果

4.1. 基本结果

DDD 估计结果见表 2，第一栏采用普查数据，第 2 栏采用外商企业调查数据。我们发现三重交互项都是显著为负。结果表明有更严格环境规制的城市（如两控区政策的实施）、在污染行业中吸引了更少的 FDI，这验证了污染避难所假说。

在中国，有两个可能的原因导致严格的环境规制赶走 FDI。第一，两控区政策要求淘汰落后、污染的生产技术和设备，并严格收取 SO_2 排污费，这增加了两控区污染行业的生产成本。第二，两控区政策禁止新建煤矿和新建燃煤热能发电厂采用低质量煤，并且要求现有的发电厂建立除硫设备，这导致了两控区企业电力成本的上升，因为煤仍然是中国主要的发电燃料来源。

经济大小：环境规制效应的经济规模是显著的。表 2 的系数显示了环境规制实施（由于两控区政策实施）在不同 SO2 排放强度的产业对 FDI 流的不同影响，特别地，污染强度一个标准差的提升将导致环境规制对 FDI 流的负面影响下降 8 个百分点。

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.

在解释该效应的大小时，值得注意的是，投资转移的可能性，即当两控区城市存在严格的环境规制时，FDI 可能会流向那些环境规制相对宽松的非两控区城市。换句话说，可能不是实验组受到了负面影响，而是控制组受到了正向影响。只要它是由环境规制变化驱动的，投资转移支持污染避难所假说，但对估计大小应当谨慎解释。特别地，它构成了污染避难所效应的上限。虽然在目前的设定中我们不能确定投资转移有多严重，但是我们提供了一些启发性的证据。特别地，我们从世界投资报告中收集了 1996-2002 年 FDI 流量数据，画出了样本期间流入中国的 FDI 以及占世界总 FDI 份额的时间趋势图，见图 2a。我们发现流入中国的 FDI 从 1992 年开始增长，到 1997 年达到顶峰，在亚洲金融危机期间有所下降。同时，流入中国的 FDI 占世界总 FDI 的份额在 1992-1994 年期间保持增长，然后开始下降，到 2000 年降至最低。图 2b 进一步说明 1992-2009 年中国 FDI 流入两控区城市和非两控区城市的情况，FDI 的数据来源于各年《中国城市统计年鉴》。我们发现两组都保持相同的增长态势，但在亚洲金融危机期间都出现下降。因此，这些数据都表明我们的估计结果应不太受投资转移的影响。

我们估计的大小与以往的文献是可比的[8]。例如，Becker and Henderson（2000）发现美国 1993-2003 年严格的环境使得污染行业新企业成立数减少了 26-45%。Kelenberg（2009）估计了 1999-2003 年期间，一个失败的严格环境政策导致在排名前二十国家中的美国附属公司的生产价值增长约 8.6%，而在前二十百分位数的发展中和转型经济体的美国附属公司的价值增长 32%。Hanna（2011）发现美国在 1966-1999 年期间的美国国家航空管理局增加了美国的跨国外国资产 5.3%，外国产出增加了 9%。利用韩国跨国公司对外投资数据，Chung（2014）发现当外国相对韩国而言减少一个标准偏差的环境规制力度，韩国跨国公司的投资在高于平均污染强度一个标准偏差的产业增加 12.4%。

[8]这些研究采用不同的方法、数据和样本期间；因此，大小的比较需要谨慎地解释。

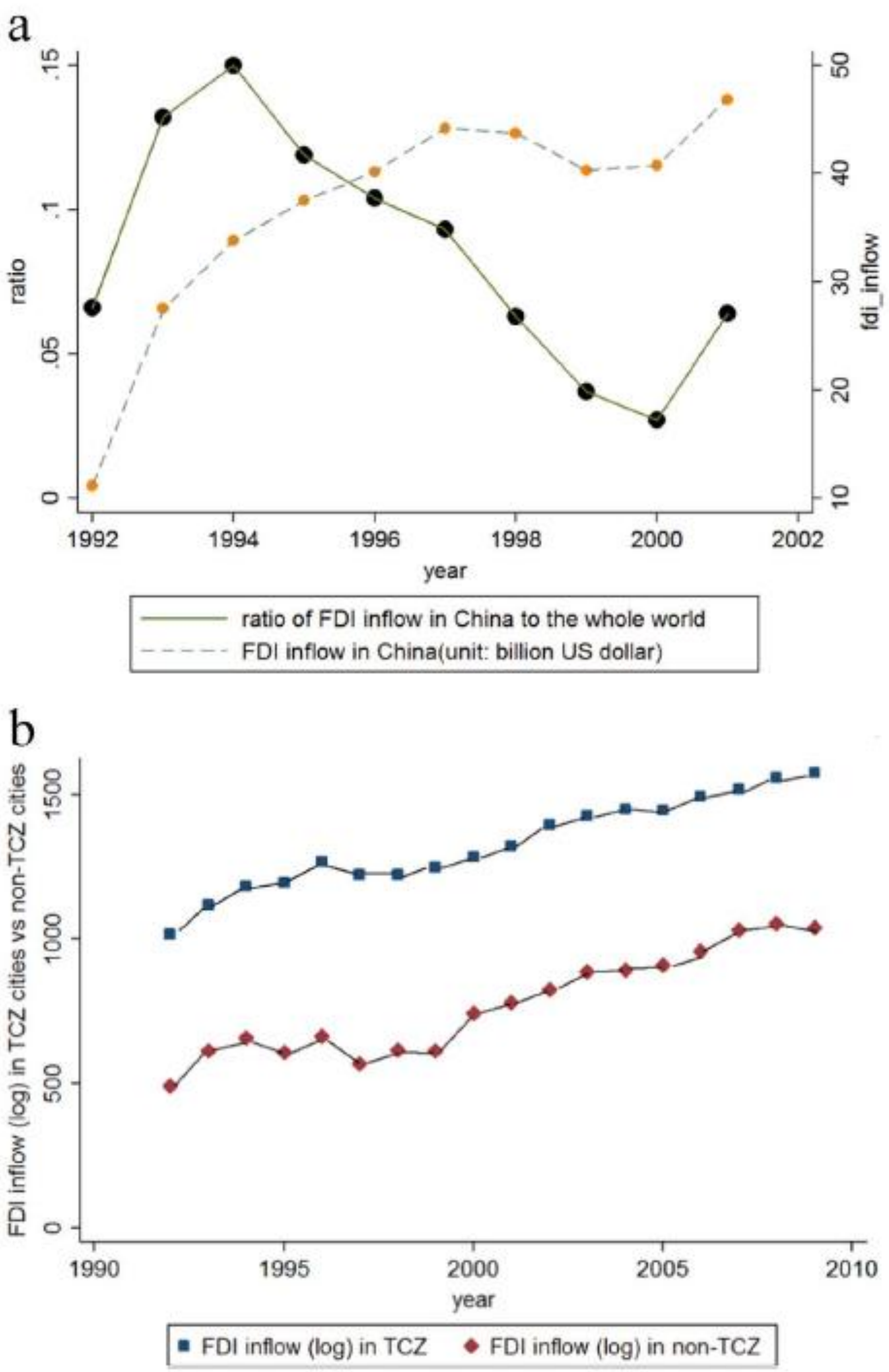

Fig. 2. (a) FDI inflow. *Data resource*: World investment report, 1996 and 2002, United Nations Conference on Trade and Development. (b) Time trends of FDI inflows in TCZ and non-TCZ cities. *Data resource*: Chinese City Statistics Yearbook, various years.

4.2. 稳健性检验

在这一小节，我们对前述结论进行了一系列稳健性检验。

1997-1998 年亚洲金融危机：如果其他影响事件同时发生，任何关于处理效应的发现将不能认为是单纯的环境规制效应。对外商投资而言一个重要的事件是 1997-1998 年亚洲金融危机。如果亚洲金融危机对两控区城市和高污染行业的影响更大，那么我们之前对环境规制

效果的估计将被污染。例如，东亚国家像日本和韩国在 1998 年之前通常会在中国北方投资于高污染行业。在亚洲金融危机期间，如果日本和韩国的跨国公司减少了在中国的投资，那么即便没有环境规制影响，我们也会看到如表 2 所示的负向的估计系数。为了处理该问题，我们利用包含 FDI 母国信息的外商企业调查数据，在分析中排除了日本和韩国的外商投资。回归结果见表 3 中列（1）。在减少样本量的计量分析中我们发现了相同的估计结果，无论是统计显著性还是系数大小，都表明我们的结果不是由于 1997-1998 年亚洲金融危机导致的。

滞后，提前和时间趋势项：另一个潜在的问题是环境政策变化时机问题。特别地，中国环境保护总局于 1995 年底开始编制两控区名单，花了近两年时间，国务院才最终批准，一个可能的问题：是否存在预期效应，即环境规制对 FDI 流量的效应在政策实际颁布实施（1998）前已经产生了。同时，环境规制对 FDI 流量的效应也可能存在滞后效应。为了解决该问题，我们按照 Laporte and Windmeijer（2005）的方法来估计环境规制的效应。具体地说，我们估计以下方程：

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

其中，δ_{1998+j} 是年份 1998+j 的指示变量，默认（省略）年份为 1992 年。因此，γ_j 捕获了环境规制五年的滞后效应和三年的提前效应。由于普查数据只有两年的面板，因此我们利用外商投资企业调查数据。估计结果见图 3。我们发现在政策提前期（1998 年以前），估计结果没有明显的时间趋势。而当 1998 年两控区政策实施后，估计结果呈明显的下降趋势，并且显著为负（尽管在 2000 年有跳跃）。这些结果表明环境规制对 FDI 流的效应是瞬时的，实验组和对照组之间在政策实施前没有显著的差别。

安慰剂检验：在这里，我们仔细观察识别问题。具体地，令 $X_{ict}=TCZ_c\times Post_t\times SO_{2i}$，令 $\varepsilon_{ict}=\beta\omega_{ict}+\tilde{\varepsilon}_{ict}$，这样 $E[X_{ict},\omega_{ict}]\neq 0$、$E[X_{ict},\tilde{\varepsilon}_{ict}]=0$。换句话说，识别问题来自于 ω_{ict}。因此，我们的估计结果 $\hat{\gamma}$ 为

$$p\lim\hat{\gamma}=(X'X)^{-1}(X'Y)=\gamma+\beta(X'X)^{-1}(X'\omega)=\gamma+\beta\delta$$

其中 $p\lim\delta=(X'X)^{-1}(X'\omega)$，如果 $\beta\delta\neq 0$，那么 $\hat{\gamma}\neq\gamma$。

因为我们需要进一步检验是否由于城市-产业-年份层面的遗漏变量 ω_{ict} 导致我们的结果不一致，我们通过随机选取两控区城市进行安慰剂检验（类似的情况见 Chetty et al., 2009; La Ferrara et al., 2012）。具体地说，在我们的回归样本中，287 个城市里有 160 个是两控区城市。我们首先从 287 个城市中随机挑选 160 个城市作为两控区城市，剩下的为非两控区城市；然后我们构造一个临时的处理变量，即 $TCZ_c^{false}\times Post_t\times SO_2$。这种随机过程保证了新构建的回归元对 FDI 流量没有影响（即 $\gamma^{false}=0$）；因此，如果不存在显著的遗漏变量（即 $\beta\delta=0$），那么我们应该有 $\hat{\gamma}^{false}=0$。换句话说，任何显著的结果都表明我们估计的方程存在误设。我们进行 500 次这种随机数据生成过程以避免任何罕见事件的污染。

表 3 的第 2 栏和第 3 栏报告了用普查数据和外商投资企业调查数据进行 500 次随机分配估计的平均值。我们发现均值几乎为 0（普查样本得到的结果为 0.001，外商投资企业数据得到的结果为-0.007），表明 $\hat{\gamma}^{false}=0$。进一步，我们画出了由这两个数据集得到的 500 个估计系数的分布以及他们相应的 p 值，分别见图 4a 和 b。分布集中在 0 附近，而且大部分的 p 值都大于 0.1。同时，我们真实的估计值（见表 2 的第 1、2 栏）是安慰剂检验中明显的异常

值。综合来看，这些结果表明我们的估计不因任何遗漏变量而产生严重的偏误。

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.

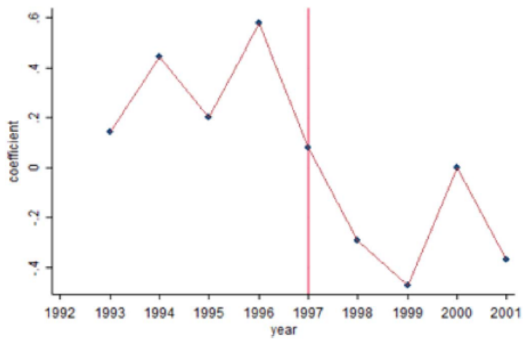

Fig. 3. Estimated coefficients. Note: The coefficients in the figure are the coefficients for TCZ * SO_2 * Year Dummies, and dependent variable is registered capital of foreign capital (in log).

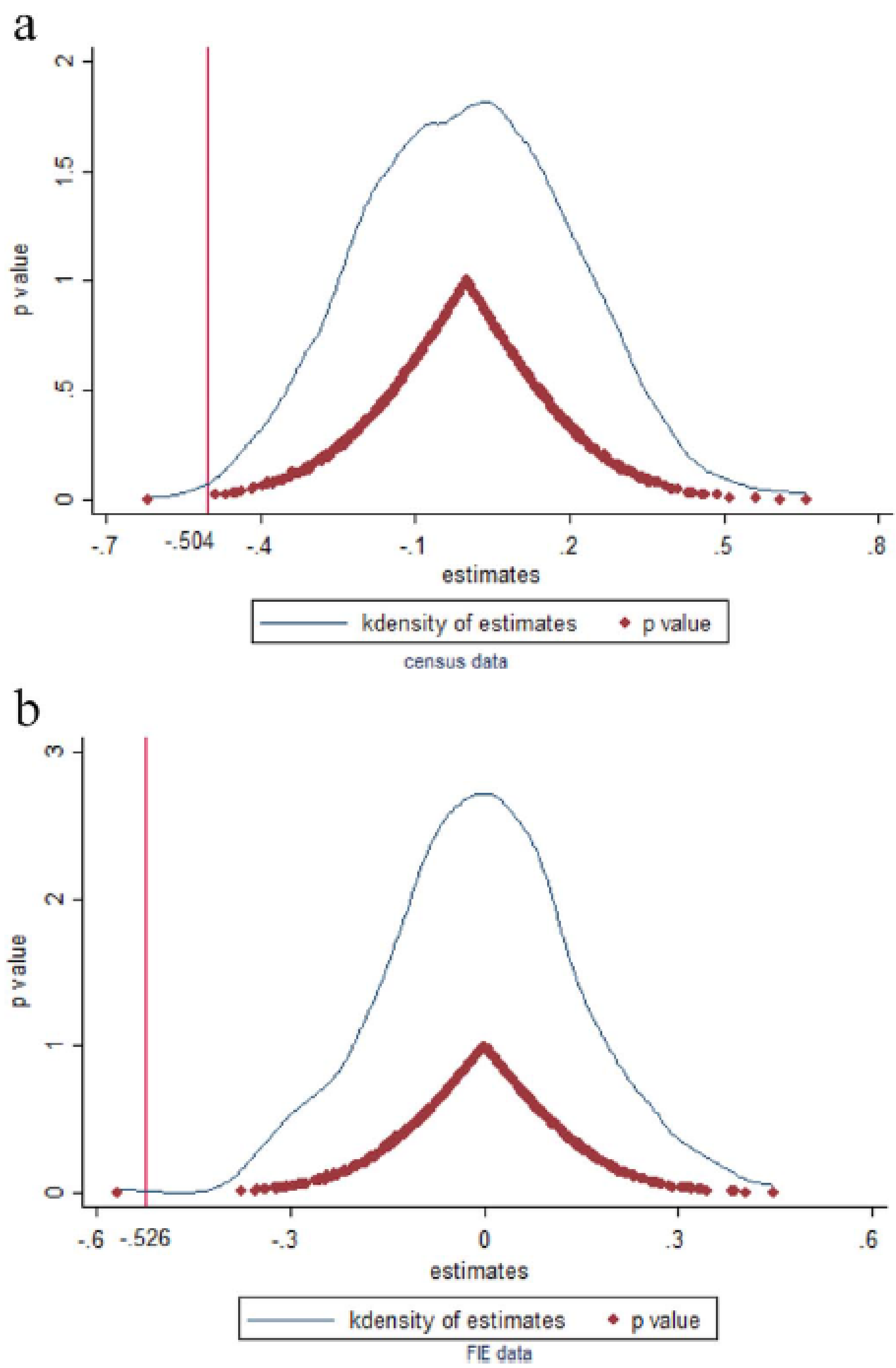

Fig. 4. (a) The Kernel density of 500 estimates using census data. *Note*: *X* axis presents the estimated coefficients of TCZ * Post * SO_2 from the 500 randomized assignment exercises. The blue curve is the kernel density distribution of the estimates, whereas the red dots are associated *p*-values.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

工具变量估计：为了进一步检验我们的估计是否受到城市-产业-年份层面的遗漏变量导致的偏误的影响，我们采用工具变量法，参考 Hering and Poncet（2014）的研究，利用两控

区城市的通风系数作为工具变量。根据 Box 模型（Jacobson，2002），两个气象力量决定了污染的扩散速度。一是风速，风速越大，污染物横向扩散越快；二是混合层高度，这导致污染物垂直扩散。具体地说，通风系数被定义为风速和混合层高度的乘积，值越大污染物扩散越快。

我们根据中国城市的经纬度搜集了在 10 米高度的风速和边界层信息（通常用混合层75*75 的网络单元来衡量），数据来源于欧洲中期天气预报中心 ERA-Interim 数据集，用平均风速乘以边界层高度得到通风系数。回归中我们使用的通风系数是离每个城市最近的单元格1991-1996 年的平均系数。

工具变量估计第二阶段的结果见表 3 第 4、5 栏，第 1 阶段的结果见附录表 A3[9]。我们仍然发现环境规制对 FDI 流量具有显著的负向影响，估计系数变大。这些结果表明我们发现的污染避难所效应并不受遗漏变量和反向因果的影响。

国内生产：鉴于前述的分析针对外资企业样本，我们也检验环境规制是否对国内企业选址的存在影响，我们利用普查数据，重新计量分析了国内企业的样本。估计结果见表 4 第 1 栏。我们发现估计系数较小且不显著，这表明严格的环境规制对国内投资没有影响。在第 2 栏和第 3 栏中，我们进一步把国内企业的样本分为国有企业和私营企业，结果仍然不显著。

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	−0.262	0.338
	(0.308)	(0.369)	(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.

这些结果可以被解释为中国的制度性特征。首先，国有企业被政府高度控制，由国务院下的国有资产管理委员会管理。重大决策如国有企业的成立和关闭、资产重组通常不是由总经理决定，而是受到政府的行政命令影响。例如，在 2008-2009 年金融危机期间，国家主席胡锦涛宣布国有企业不能让工人下岗，反而要扩大就业。同样地，2013 年夏季，由于中国经济增长下滑，近半数中国大学生找不到工作，中国政府再一次命令国有企业尽可能多地招聘大学生。其次，由于中国制度环境较差，非国有企业大都是拥有关系网的地方性企业。例如，注册资本的一个主要来源是非正式的融资，如家庭财富和亲友间借贷，因为非国有企业因金融约束而受到银行贷款的歧视（Allen et al.,2005; Ayyagari et al., 2008）。与此同时，财产权保护不力和合同执行不力导致非本地交易风险高，跨地区的贸易受到地方保护主义的显著影响（Lu,2009）。综上所述，这些制度的不完善导致与外资企业相比中国国内企业更少迁移，这也解释了环境规制对国内投资的影响不显著。

4.3. 异质性效应

到目前为止，我们估计了环境规制对所有来源国 FDI 流量的平均效应。外国投资企业调查数据中包含 FDI 来源国的信息，使得我们能够研究不同 FDI 来源国的异质性效应。具体地，我们检验了来自于严格环境规制国家的跨国公司与那些来自于宽松环境规制国家的跨国公司的 FDI 投资行为是否不同。为此，我们根据它们相对于中国的环境宽松度分为两组。对于那些比中国环境规制严格的国家来说，它们的跨国公司去到一个比母国环境规制更为宽

[9]我们按照 Hering and Poncet(2014)的研究，加入三个控制：$GDPPC_c \times Post_t \times SO_{2i}$, $Coastal_c \times Post_t \times SO_{2i}$, 和 $Special\ Zone_c \times Post_t \times SO_{2i}$。

松的国家进行投资。同时，对于那些比中国环境规制宽松的国家来说，它们的跨国公司在一个比母国环境规制更严格的国家投资。

我们采用两种方法划分这些国家。第一，我们检查每个国家加入《联合国气候变化框架公约》这一于 1994 年生效的国际环境条约的时间，《联合国气候变化框架公约》的目标是“将大气中温室气体的浓度稳定在防止气候系统受到危险的人为干扰的水平上”。我们根据是否先于中国加入 UNFCCC 将其划分样本划分为两个组别。我们定义后加入国家的环境规制水平比先加入国家的环境规制水平更宽松（两组国家划分名单见附录表 A4）。两组的回归结果见表 5 第 1、2 栏。有趣的是，我们发现在与中国同期加入 UNFCCC 的组别中，环境规制对 FDI 流量的影响较小而且不显著。但是对后加入的国家来说，这一效应在经济和统计意义上显著。

然而，《联合国气候变化框架公约》“没有对个别缔约方规定具体需承担的义务，也未规定实施机制”。这些问题在 1997 年《京都议定书》中得到解决，“它要求发达国家在 2008-2012 年期间强制减少温室气体的排放”。因此，在第二种方法中，我们根据每个国家签署《京都议定书》的年份，将样本划分为先于和后于中国签订两组。由于《京都议定书》有强制的减排义务，因此我们假设先于中国签订的国家比后于中国签订的国家具有更严格的环境规制水平。两组国家名单见附录表 A5。估计结果见表 5 第 3、4 栏。同样地，我们发现严格的环境规制对 FDI 流的效应在后签订《京都议定书》的国家中显著。

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	−0.435***	−0.071	−0.414***
	(0.084)	(0.116)	(0.071)	(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.

综上所述，这些结果表明从环境保护良好的国家来的外国跨国公司对中国环境规制的变化不敏感，它们对中国的投资可能是受到中国其他利益的影响，而不是宽松的环境规制。然而，对于那些比中国更晚加入国际环境条约的国家的跨国公司来说，环境规制可能是决定其对华投资的一个重要因素。这些发现也有助于我们消除疑虑：发达国家严格的环境规制将会导致其污染的生产转移到环境规制相对宽松的国家。这可能没有加剧 FDI 流入国的环境污染，而对就业和产业结构的分布将有重大影响。

5. 结论

本文研究了跨国公司面对环境规制是否会将生产转移到环境规制更为宽松的国家。我们控制环境规制潜在的内生性问题，本文利用中国 1998 年设立两控区这一环境政策，我们对环境规制效应的识别来自于两控区高污染行业和非两控区低污染行业在政策变化之前和之后的结果，即 DDD 估计。

通过利用中国两个可信的数据集（即 1996 和 2001 年基本单位的普查数据和 2001 年外商投资企业调查数据），本文发现污染强度一个标准单位的上升会导致环境规制对 FDI 流量的负面影响下降 8 个百分点，验证了污染避难所假说。本文研究结果对于识别假设的一系列

稳健性检验和其他计量经济学关注点的检验是稳健的。此外，我们发现环境保护好于中国的外国跨国公司对严格的环境规制不敏感，而环境保护比中国差的外国跨国公司则表现出强烈的负面反应。

本文的研究对目前污染避难所假说研究的贡献是，较好地解决了环境规制的内生性问题。同时，相比于以往的文献多研究发达国家，特别是美国，本文采用发展中国家的数据研究了这一问题。

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	Shijiazhuang	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.

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	
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Journal of Development Economics 123 (2016) 73–85

Contents lists available at ScienceDirect

Journal of Development Economics

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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."

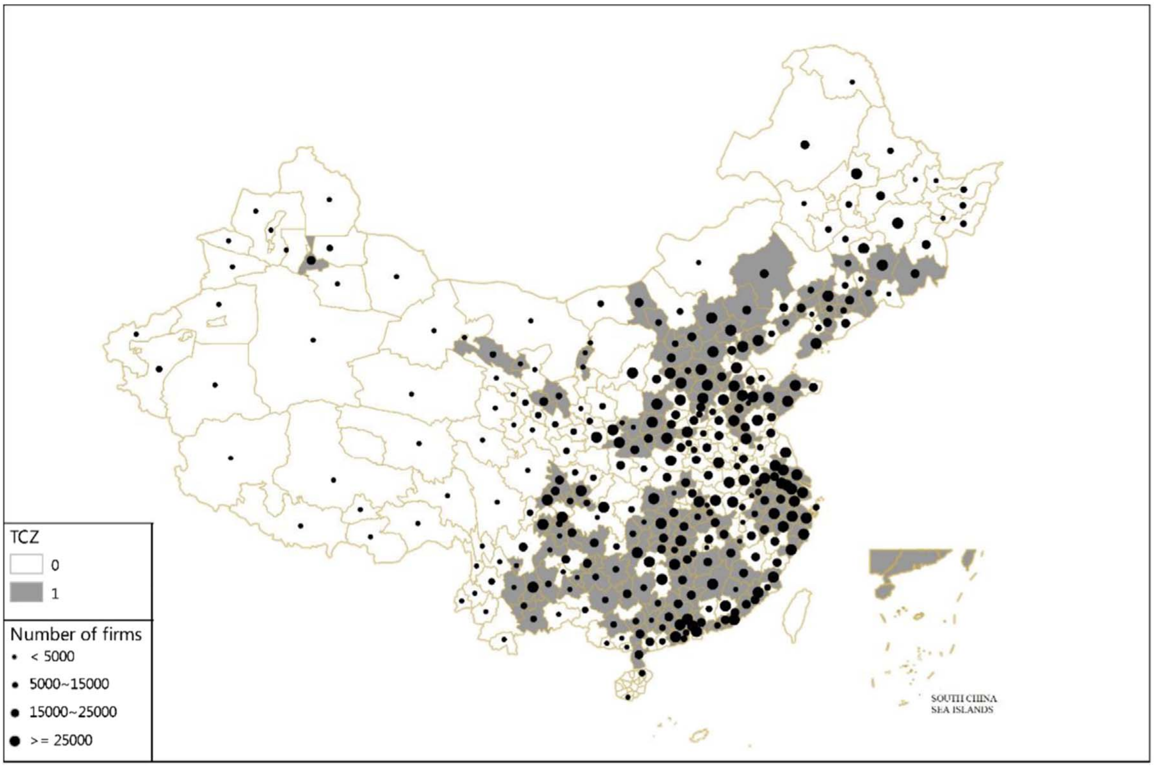

Fig. 1. Geographic distribution of TCZ cities. *Data source*: The national Environmental Protection Bureau, "The Proposal of Designation for Acid Rain Control Areas and SO_2 Pollution Control Areas"; Chinese First National Census of Basic Units.

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:

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

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

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

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

[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.

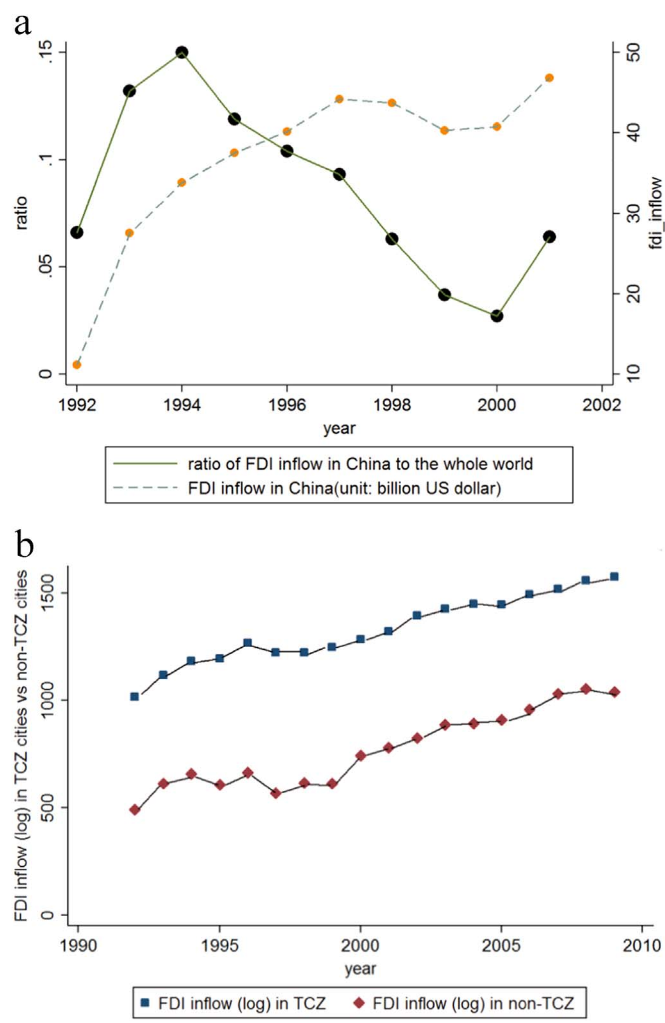

Fig. 2. (a) FDI inflow. *Data resource*: World investment report, 1996 and 2002, United Nations Conference on Trade and Development. (b) Time trends of FDI inflows in TCZ and non-TCZ cities. *Data resource*: Chinese City Statistics Yearbook, various years.

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.

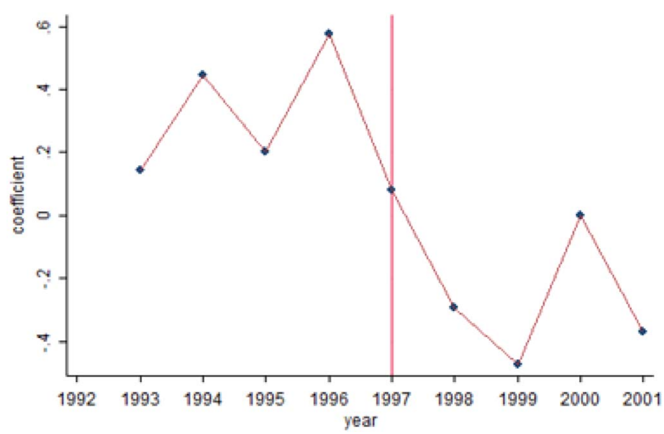

Fig. 3. Estimated coefficients. Note: The coefficients in the figure are the coefficients for TCZ * SO_2 * Year Dummies, and dependent variable is registered capital of foreign capital (in log).

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.

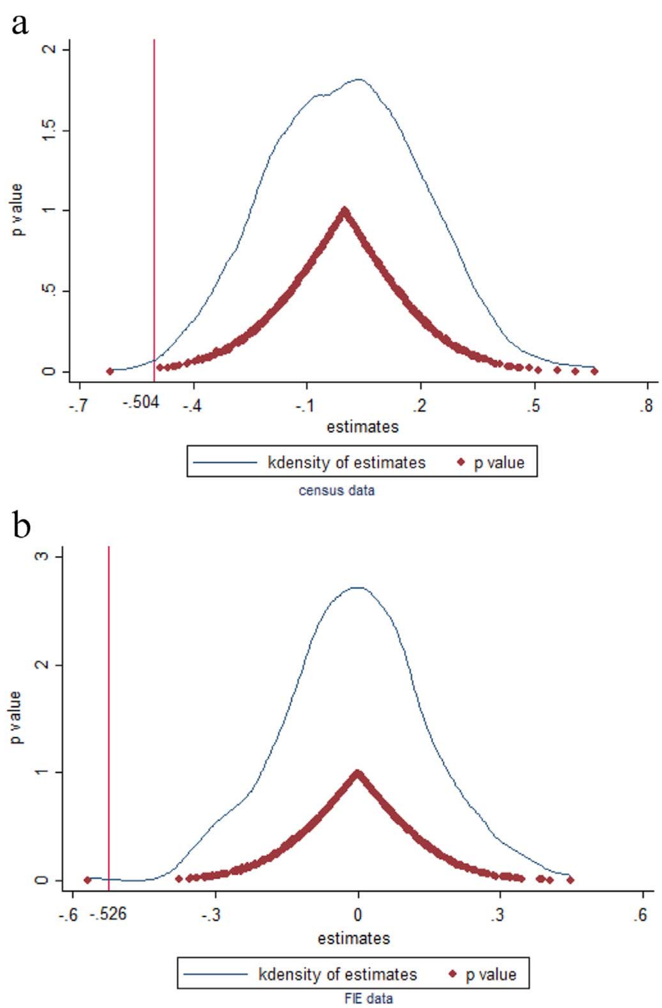

Fig. 4. (a) The Kernel density of 500 estimates using census data. *Note*: X axis presents the estimated coefficients of TCZ * Post * SO_2 from the 500 randomized assignment exercises. The blue curve is the kernel density distribution of the estimates, whereas the red dots are associated *p*-values. 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 $E\left[X_{ict}, \omega_{ict}\right] \neq 0$ and $E\left[X_{ict}, \tilde{\varepsilon}_{ict}\right] = 0$. 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	−0.262	0.338
	(0.308)	(0.369)	(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	−0.435***	−0.071	−0.414***
	(0.084)	(0.116)	(0.071)	(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, $GDPPC_c \times Post_t \times SO_{2i}$, $Coastal_c \times Post_t \times SO_{2i}$, and $Special\ Zone_c \times Post_t \times SO_{2i}$.

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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