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Environmental policy and exports: Evidence from Chinese cities

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ABSTRACT

We study environmental regulation and its role for trade in China. Specifically, we assess the effectiveness of an environmental policy in China that introduced stricter regulations on sulfur dioxide (SO_2) emissions in targeted cities. To identify the causal effect of this policy on exports, we use sectoral export data for a panel of Chinese cities and exploit variations in exports between cities and sectors, over time, and, in a second step, between firm types. We find a relative fall in sectoral exports in targeted cities after the implementation of the policy, which is sharper the more polluting the industry. Further, we find that the observed effect is mainly driven by privately owned firms, whereas exports of state-owned firms seem to be unaffected by the new policy. This finding is consistent with the preferential political treatment of state-owned firms in China.

Introduction

In recent years, air pollution has become a major concern in China, with wide-reaching negative effects on not only health and the environment, but also the economy. Air pollution in Beijing achieved international notoriety in January 2013, spiking at unprecedented levels with conventional measures being "beyond index" (The Economist, 2013). The recent negative focus on urban air quality has harmed China, which has long been criticized internationally for its half-hearted commitment to environmental protection.

However, China has introduced a series of regulatory policies over recent decades, despite its image as a bad student. Concerns that environmental problems may act as a brake on economic growth[1] have produced an ambitious array of environmental-protection laws to reduce firm emissions. There is surprisingly little consensus on the impact of these environmental policies on economic activity, or even the environment. Some now question the effective implementation and enforcement of Chinese environmental laws, which have been argued to largely exist only on paper (OECD, 2006). There are also recurrent doubts over the accuracy of official pollution data (The Economist, 2012). The open question is thus whether Chinese environmental regulations are only green-washing on an epic scale, or whether there have been economic repercussions.

This paper investigates the effectiveness of the so-called Two Control Zones (TCZ) policy in reallocating activity away from polluting sectors. This policy was implemented in 1998 by the Chinese central government with the aim to reduce

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[1] Estimates put the cost of air pollution damage in China between 1.2 and 3.8% of China's annual GDP (World Bank, 2007).

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sulfur dioxide (SO_2) emissions, which are considered to be one of the most important sources of air pollution in China.[2] The TCZ policy targeted locations exceeding the national standards on air pollution. Based on previous years' records, a total of 175 cities across 27 provinces were designated as TCZ and therefore faced the new rules.[3]

The empirical analysis in this paper appeals to a panel data set from 265 Chinese cities for 1997–2003, including 158 TCZ cities. We focus on sectoral exports at the city level to measure the economic effect of the TCZ policy and ask whether the implementation of this policy led to any bias against polluting sectors in TCZ as compared to non-TCZ cities. The TCZ policy effect is identified by comparing the exports of TCZ and non-TCZ cities according to each sector's intrinsic exposure to the regulation, which is proxied by its pollution intensity. In a second step, we further filter the effect via the firm's ownership structure.

The advantage of using export data to assess the effectiveness of environmental regulations in China in reallocating activity away from polluting sectors is three-fold. First, export data, contrary to production data, are disaggregated by sector and city level, and are available both before and after the TCZ policy, which is key to our identification strategy. Second, export data, compared to production data which exclude private firms with revenues below five million yuan, cover the whole universe of exporting firms in China. Moreover, export data allow a much finer sectoral decomposition of activity than the production data where firms only report their main sector of activity. Third, export data, compared to production data or emission data, are less likely to suffer from measurement or misreporting problems, which could severely bias the estimates. In the robustness checks we consider the domestic value-added in exports instead of the value of exports to ensure that the relative fall in exports in more polluting industries signals production shifts.

Our paper contributes to the literature in two ways. We first shed light on the claim that new environmental standards may be at odds with China's export-oriented growth strategy, and hence jeopardize its growth prospects. Proponents of the Porter hypothesis – that regulation brings cost-reducing innovation – have challenged this traditional activity-deterring view and argue that there could be a positive link between regulatory stringency and exports (Porter, 1991; Porter and Van der Linde, 1995).

Second, we add to the abundant literature on what Taylor (2004) calls the "pollution haven effect," whereby tighter environmental rules at the margin affect plant location decisions and activities (Levinson, 1996; Becker and Henderson, 2002; Copeland and Taylor, 2004; Hanna, 2010; Greenstone et al., 2012). Some of this work has looked at Chinese environmental regulations (Dean et al., 2009; Lu et al., 2012) but focuses on the attraction of foreign direct investment.

We further build on recent efforts to address the problem of omitted variables which traditionally hinders the evaluation of environmental policies' impact on trade (Levinson and Taylor, 2008; Millimet and Roy, 2011).[4] It is indeed likely that the way in which environmental policy is designed and enforced in an area is correlated with various broader economic variables, such as GDP per capita or foreign direct investment, where the latter have also been identified in the literature as drivers of export performance.

Our main strategy to counter endogeneity exploits variations in the expected impact of the TCZ policy by sector to isolate the direct regulation-related causal effect. The policy specifically targeted emissions in plants that burn coal, the main source of China's SO_2 emissions. In TCZs, the enforcement of emission standards and the collection of sulfur-emission charges encouraged coal users to adapt their coal-burning processes or use cleaner fuels (State Council, 1998). This increases their production costs, since the adaptation costs (such as that of installing scrubbers or filters) are quite high and the use of cleaner fuel is pricy (Hao et al., 2001). The most cost-effective alternative involves the use of low-sulfur coal or sulfur-fixed briquettes, which is still about 50% more expensive than traditional high-sulfur coal (World Bank, 2003).

As industries vary in terms of their intrinsic dependence on coal, we expect TCZ regulations to have a greater effect on coal-intensive activities and induce a reallocation of resources from higher to lower energy-intensive sectors. This particularity allows us to determine the causal effect of the TCZ policy on exports, even if the selection of TCZs was not exogenous to economic activity. We thus filter the impact of environmental stringency using a sector-level index of energy consumption, which captures its exposure to the new regulations. This strategy is conceptually similar to a triple difference estimate. We compare (i) cities before and after the introduction of the TCZ policy (first difference), (ii) targeted vs. non-targeted cities (second difference), and (iii) sectors with higher vs. lower coal use (third difference).

We appeal to sectoral export data to evaluate the effect of the policy by sector, according to their energy consumption. Our identification strategy partly mitigates the endogeneity issue: by measuring the differential impact of the TCZ policy across sectors, depending on their degree of energy consumption, we reduce the possibility that an omitted variable be driving our results. For an omitted variable to bias our estimates it should also have a differential impact across sectors ordered by energy consumption. The validity of our estimation hinges on the condition that the treated cities would have followed in all sectors the export trend of the control cities if they had not implemented the new environmental policy.

In a second step, our work also addresses concerns about the inadequate enforcement and unsanctioned non-compliance of Chinese environmental regulations (Liu and Diamond, 2005). One common issue is that it is hard for some governmental

[2] Other major air pollutants in China include particulate matter (PM), ozone (O_3) and nitrogen dioxide (NO_2). These were however not specifically targeted by the TCZ policy.

[3] China is divided into 4 municipalities (Beijing, Tianjin, Shanghai and Chongqing) and 27 provinces which are further divided into prefectures. As is common in the literature, we use the terms city and prefecture interchangeably, even though prefectures include both an urban and a rural part.

[4] For a survey of the literature on pollution havens, see Levinson (2008). See Brunel and Levinson (2013) for a recent review of the challenges associated with measuring the repercussions of environmental regulations.

officials who have interests in companies that damage the environment to enforce pollution restrictions.[5] Along the same lines, some firms may be in a better position to avoid compliance and escape the associated sanctions. The institutionally grounded political pecking order of Chinese firms likely implies heterogeneous policy responses by firms according to their ownership. Dollar and Wei (2007) find that state-owned firms are systematically favored by local authorities in terms of access to external funding, property-rights protection, taxation, and market opportunities. State-owned firms will then probably be less affected by the TCZ policy due to their greater bargaining power with the regulator and capacity to absorb the additional costs from the policy (Huang, 2003a). There are thus reasons to consider heterogeneity in the TCZ policy response by ownership type.

Our data allow us to differentiate between the exports of state-owned and private firms. In this second step, we refine our identification strategy by interacting our variable of interest, the triple interaction term, with a dummy for state ownership. Adding this dimension to the analysis filters the impact of stricter environmental rules not only by the sector's pollution intensity but also by firm ownership. We thus improve the identification of the policy impact with respect to possible endogeneity concerns. The analysis at the ownership level further uncovers a potential obstacle to policy effectiveness, which is important for China if it is serious about improving air quality.

Our main findings are a relative fall in exports following the TCZ policy, which is sharper in sectors with greater coal use. To verify the validity of this identification assumption, we conduct a series of sensitivity analyses, including checking any differential pre-treatment time trends, verifying the consistency of the policy impact over time and including proxies for time-varying differences between the targeted and non-targeted cities. We also check that our results are robust to the instrumental variable strategy proposed by Broner et al. (2012), exploiting the exogenous meteorological determinants of the speed of air pollution dispersion. As the relative decline of pollution-intensive activities may reflect both scaling down and relocation away from TCZ cities, our results are consistent with the pollution-haven hypothesis (Javorcik and Wei, 2005; and in the specific context of China, Dean et al., 2009; Lu et al., 2012). It is possible that our findings then simply reflect the relocation of firms from TCZ regulated to non-TCZ regulated cities, in which case total pollution in China may well have remained constant. We unfortunately cannot identify the global effect on pollution. Our results are nevertheless in line with Dean and Lovely (2010)'s conclusion that the pollution intensity of Chinese exports fell dramatically from 1995 to 2004.

Despite the concerns about poorly enforced environmental regulations in China, our results suggest that the TCZ policy was effective. They are coherent with studies measuring significant repercussions on health and mortality (Tanaka, 2014) and on industrial efficiency (Jefferson et al., 2013). This latter study uses firm-level data to investigate the repercussions of TCZ regulations on various proxies of efficiency such as profitability or costs. Jefferson et al. (2013) measure positive effects on the profitability of pollution-intensive firms which they attribute to improved productivity. By contrast they find negative externality effects for non-polluting energy intensive firms which they argue to be due to energy shortage. Our focus is however different as we look at exports as a proxy for the activity scale to determine whether stricter environmental policy reallocates activity away from polluting sectors. Further, compared to their empirical approach the availability of pre-policy observations and the use of the instrumental variable estimator allow us to carefully address endogeneity issues.

Finally, our results are also consistent with Lu et al. (2012) which show that cities with tougher environmental regulations attract less foreign direct investment (FDI). In contrast to this latter study, our analysis considers the activity of all firms. More importantly, we show that the effect of environmental regulations depends on the firm's sector and its political status. Environmental regulations are shown to produce an export growth bias against polluting sectors in TCZ cities only for non-state firms. The impact of environmental policy appears to be mitigated by state ownership, suggesting that, thanks to reduced obligations to comply with regulations, better access to finance or softer budget constraints that allow for a faster adaptation of the polluting production process, state ownership protects from the negative consequences of pollution regulations on production. It would thus seem important to address the gap between state and non-state firms, even if more work is needed to understand what is behind this effect: corruption, greater bargaining power or a greater ability to absorb a given cost shock due to softer financial constraints.

The remainder of the paper is organized as follows. Section "Air pollution and environmental policies in China" discusses air pollution in China and presents the Two Control Zones policy. Section "Data and stylized facts" presents the data. Section "Empirical methodology and results for aggregate export flows" discusses the empirical approach and our results using the aggregated data set. Section "The role of firm ownership" sets out the role of firm ownership in the Chinese economy and presents the empirical approach and results on this specification. The last section concludes.

Air pollution and environmental policies in China

Coal consumption and air pollution

Air pollution is becoming China's greatest health threat. The country is home to 16 of the world's 20 most-polluted cities (Pandey et al., 2006). The World Bank (2007) estimates that air pollution in China leads to 350,000–400,000 premature

[5] Weak enforcement may also result from a lack of funding, insufficient manpower and the political authority of the supervising authority, the State Environmental Protection Administration (Naughton, 2007).

deaths per annum. SO_2 emissions have long been a major source of ambient air pollution in Chinese cities.[6] They are also the primary source of acid rain, defined as precipitation with a pH value under 5.6, which causes the acidification of soils and water and deteriorates human health.[7] Today, China is the world's largest emitter of SO_2 and most of its emissions originate from burning of coal, much of it highly polluting high-sulphur coal. China's particular high emissions arise because the country obtains 80 percent of its electricity and 70 percent of its total energy from coal, which generally pollutes more than other fossil fuels. China having the third largest coal reserves in the world, and coal being the largest locally exploitable fossil resource leads to a considerable dependence on this resource (IEA, 2013).

The growing concern over the economic costs of SO_2 and acid rain led the Chinese authorities to take more stringent measures to reduce coal-related pollution. Two strategies were followed: the first seeks to improve the efficiency of energy-conversion; the second, which is more long-term, aims for more efficient energy consumption. The ambitious Two Control Zones policy which we analyze here was introduced to achieve these objectives.

Two control zones policy

The Two Control Zones policy was implemented by the central government in 1998 with the objective of reducing SO_2 emissions in cities and areas with particularly high air pollution (State Council, 1998).[8] Cities exceeding certain standards were designated as either acid rain or SO_2 pollution control zones, according to their records in preceding years.[9]

The original list of TCZ cities comes from the official document of the State Council (1998). In total, 175 cities across 27 provinces were designated as TCZ. Together, these cities account for 11.4% of the Chinese territory, 40.6% of national population, 62.4% of China's GDP, and around 60% of total SO_2 emissions in 1995 (Hao et al., 2001).

The National 10th Five-Year (2001–2005) Plan for Environmental Protection required that annual sulfur emissions in the Two Control Zones be reduced by 20% by 2005, from their 2000 levels. As SO_2 emissions were previously unregulated in China, this is an ambitious target.

The three main policy measures embodied in the TCZ plan were the closing of the biggest polluters, reducing the sulfur-content of coal, and cleaner coal-burning. First, the construction of new collieries based on coal with a sulfur content of 3% and above was prohibited, and existing collieries mining similar coal faced production restrictions or were gradually phased out. The World Bank (2003) estimates low-sulfur coal increases firms' total operating costs as it is 40% to 50% more expensive than local high-sulfur coal.[10]

Second, overall emissions from coal-fired power plants and other polluting industries were set to be reduced. The construction of coal-fired power plants in the center or close suburbs of medium and large cities was prohibited, except for co-generation plants whose primary purpose is to supply heat. Moreover, newly constructed or renovated plants using coal with a sulfur content of over 1% had to install sulfur-scrubbers. Existing power plants using this high-sulfur coal were required to adopt SO_2 emission-reduction measures. All green-field coal-fired power plants with capacity over 300 megawatt electrical (MWe) were compelled to put in place flue-gas desulfurization (FGD) facilities.[11]

Polluting manufacturing industries were also targeted directly by the new policy: industrial polluters were required to install control equipment or adopt other mitigation measures in order to reduce emissions (switch to low-sulfur coal, modify their boilers and kilns, and treat effluent gas). Finally, one of the main measures was the implementation of SO_2 emission fees collected from the major sulfur emitters. These implemented measures led to either an increase in the price of energy or induced additional costs related to the purchase of new equipment or the adaptation of the production process. The more dependent a firm is on coal, the more its production costs are likely to rise under the new rules. Exports in the TCZ cities are expected to decline because these additional costs reduce the capacity of firms to expand their export business or force firms to exit the export market or close down entirely.[12]

Indeed, these measures seem to have led many small factories in polluting industries with inefficient technologies causing serious pollution to shut down. By the end of 1999, collieries producing over 50 million tons of high-sulfur coal had

[6] WHO guidelines set the maximum value at 50 μg per cubic meter (μg/m^3). In the 90 Chinese cities that reported data, the median annual SO_2 concentration level was 60 μg/m^3, with the highest being 418 μg/m^3.

[7] Acid rain has expanded from a few pockets in southwestern China in the mid-1980s, to around 30% of the country's land area, affecting mainly the South of China (Guttikunda et al., 2004).

[8] China had a pre-existing system of air-pollution levies prior to the TCZ reform (He et al., 2002). This levy system introduced in 1992 imposed fees on plants according to their emissions. The limited evidence on this system suggests that the levies (which were identical across locations and industries) were too low to be effective (World Bank, 2003). The effect, if any, of this earlier policy should be captured in our regressions by industry-year and city-industry fixed effects.

[9] Based on the records in preceding years, cities are designated as SO_2 pollution control zones if (1) average annual ambient SO_2 concentrations exceed 20 μg/m^3 (Class II standard), (2) daily average concentrations exceed 60 μg/m^3 (Class III standard), or (3) high SO_2 emissions are recorded. Cities are designated as Acid Rain control zones if (1) the average annual pH value for precipitation is less than 4.5, (2) sulphate depositions are greater than the critical load, or (3) high SO_2 emissions are recorded (Tanaka, 2014).

[10] These estimates are based on prices of high-sulfur coal of about 190–250 yuan per ton. Industrial boiler operators are expected to pay an additional 100–150 yuan per ton for low-sulfur coal, compared to local high-sulfur coal. This higher price reflects higher transportation costs as well as better quality (better heating value).

[11] In a typical coal-fired power station, FGD removes at least 95% or more of the SO_2 in the flue gases.

[12] Due to the lack of more detailed data on input prices and adaptation costs, we cannot identify which of the implemented measures are behind the global effect of the policy on exports that we observe in our empirical findings.

been shut (Hao et al., 2001), and by May 2001, 4492 high-sulfur coal mines had ceased production in the TCZ area. Further, 338 small power units, 784 product lines in small cement and glass plants, 404 lines in iron and steel plants, and 1422 additional pollution sources had closed (He et al., 2002).

A number of contributions have suggested the effectiveness of these comprehensive measures in reducing acid rain and air pollution in the Two Control Zones (He et al., 2002; Xu et al., 2004). Among the 175 TCZ cities, the number meeting the national ambient air SO_2 concentration standards increased from 81 in 1997 to 98 in 1999 (He et al., 2002). SO_2 emissions in the TCZ cities fell by about 3 million tons, and about 71% of factories with initial emissions of over 100 tons per year reduced their SO_2 emissions to the standard by 2000 (Tanaka, 2014). The goal of reducing China's total emissions by 10% between 2000 and 2005 was however not achieved (Lu et al., 2010). This was to be expected given the very fast economic growth during this period, which resulted in a rapidly growing demand for coal (World Bank, 2007).

Data and stylized facts

Data

Trade data

The trade data come from the Chinese Customs and provide export flows aggregated by location, year, product, and destination country over the 1997–2003 period. Our dependent variable is annual exports by city and sector. We reaggregate the original eight-digit-level data to the 2-digit ISIC (Rev.3) industry classification for which indicators of pollution intensity are available. We are limiting our sample to exports from the four province-level municipalities and 261 prefecture-level cities that we can identify in the trade data set. Together, these 265 cities are responsible for 90% of China's total export flows for the sectors we analyze. Our final sample consists thus of 46,375 observations (265 cities, 25 sectors, 7 years).

We also have information on the ownership structure of exporting firms, and can distinguish between the exports of state-owned enterprises (SOEs) and privately owned firms.[13] This information on firm ownership is exploited in Section "Empirical results by firm ownership", where we differentiate between SOEs (which also include collectively owned firms) and privately owned firms (private firms, fully foreign-owned firms and joint ventures). The final dataset distinguishing between SOEs and non-SOEs contains 92,750 observations (46,375 city-sector-year observations for each firm-ownership type).

We also consider a specification in which the domestic value-added in exports is considered instead of the value of exports. We borrow the sector-level ratios of domestic value added from Koopman et al. (2012) for the year 1997 and use the concordance table between sectors and HS6 products from Upward et al. (2013).

Industry-level variables: energy intensity and controls

Our main measure of intrinsic exposure to stricter environmental regulations at the sector level is the sector's ratio of coal consumption to value-added ($coal\ int_k$) in logs. Coal intensity is computed for 25 sectors[14] in 1997, the year before the TCZ policy was implemented. This captures the technological characteristics of each sector which are supposed exogenous to firms' regulatory environment.[15]

To ensure that our results are not dependent on a specific definition of exposure, we perform several robustness checks in which alternative measures of sectoral energy intensity are used: the ratio of total energy use over value-added, the ratio of electricity use over value-added, the ratio of SO_2 emissions over value added[16] and the full coal intensity of both direct and indirect inputs.[17] This latter measure uses the input output table of 1997 to compute the coal intensity of a sector as the average of its own use of coal and that of its upstream activities.

We also consider a specification in which we include controls for sectoral capital intensity as pollution intensity is found in the literature to be a positive function of physical capital intensity (Cole et al., 2005, 2008). All industry variables come from the China Statistical yearbooks. The correlation between the different industry indicators appears in Table A1.

In Appendix Table A2, sectors are ranked by their coal intensity measured in 1997. The ranking of sectors is identical to that in Dean and Lovely (2010) who use similar data sources for 1995 and 2004. The manufacture of coke and coal-mining have the greatest energy reliance, followed by the manufacturing of non-metallic mineral products (which includes cement)

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[13] The firm-ownership categories in the original data set are: state-owned, collectively owned, private including fully foreign-owned and joint ventures (with foreign ownership less than 100%), and others. The negligible number of trade flows for the "others" category are excluded from the analysis in Section "The role of firm ownership", which differentiates between state-owned and non-state owned firms.

[14] Sectors are defined according to the 2-digit ISIC (Rev.3) industry classification. Data on pollution and energy intensity come from the China Statistical yearbooks and follow the Chinese industrial classification system. The aggregation up to the ISIC classification is undertaken separately for data in 1997 and 2003 using the appropriate official correspondence tables, which take into account any changes in the Chinese industrial classification system.

[15] Our coal-intensity indicator is measured at the national level prior to TCZ implementation so as to capture sector-level intrinsic characteristics in terms of energy use and pollution intensity which are exogenous to location-specific features pertaining to the availability of energy sources or economic performance. The potential repercussions of these latter dimensions on exports are accounted for in our empirical analysis by city-year fixed effects and city-industry fixed effects.

[16] This sectoral measure is computed for 2003, as this is the first year in which they appear in the Chinese Environmental Yearbooks.

[17] In the unreported results (available upon request), we check that our main findings are robust when measuring coal, energy, electricity and SO_2 intensity based on production instead of value added.

and basic metals. The sector with the lowest coal and energy intensity is the manufacture of tobacco products. In the empirical analysis, we verify that our results are not driven by a particular sector.

City-level variables

The customs data include exports for four province-level municipalities and 261 prefecture-level cities. Of the 265 cities in our export data set, 158 are designated as TCZ.[18] The geographical distribution of the TCZs is displayed in Appendix Fig. B1.[19]

Table A3 provides some summary statistics separately for TCZ and non-TCZ cities, while Table A4 shows the correlation between the main city-level indicators. All location-specific variables are measured at the prefecture level so as to be consistent with the export data, and at the beginning of the sample period in order to ensure their exogeneity with respect to the city's TCZ status.

Table A3 shows that TCZs differ significantly from non-TCZs in a number of dimensions. Notably, TCZ cities are bigger, richer[20] and export more. Our empirical analysis therefore takes into account these differences in location characteristics, since they may lead to a greater demand for a cleaner environment in TCZ cities, irrespective of the TCZ policy. We show in Table 4 that our result of an export-deterring effect of the TCZ policy is not driven by any failure to account for the differences between TCZ and non-TCZ cities in terms of GDP per capita, coastal location and presence of special policy zones. The information on the location of special policy zones comes from Wang and Wei (2010).[21] GDP per capita is calculated using population data at the prefecture level from the census in 2000, which yields the most reliable estimates for the period. To be consistent, we use prefecture-level GDP for 2000 provided by China Data Online at the University of Michigan.[22]

Finally, data for the construction of the instrument we propose in Section "Instrumental variable approach" (wind speed at 10 m height and mixing height) come from the European Centre for Medium-Term Weather Forecasting (ECMWF) ERA-Interim data set.[23]

Stylized facts regarding export patterns and coal intensity

There are large systematic variations in sectoral exports by coal intensity and TCZ status. These differences changed over time in a way which bodes well for the empirical analysis below.

Fig. B2 ranks sectors by coal intensity (horizontal axis), and plots on the vertical axis the export value of TCZs (top panel) and non-TCZs (middle panel) as well as the difference in export value between the two city types for the two extreme years of the trade data (1997 and 2003). The data points correspond to the sectors listed in Table A2. The dashed lines show the fitted linear relations. Between 1997 and 2003, total exports increased substantially in both TCZ and non-TCZ cities.[24] In the former, exports increased more slowly in coal-intensive sectors; no such pattern appears for non-TCZ cities. The bottom panel shows a rising export premium for low-pollution sectors in TCZs relative to non-TCZs. This is consistent with environmental regulations deterring exports mainly in coal-intensive sectors. Overall, the data suggest a relative reallocation of exports from high to low energy-intensive sectors, but only for TCZs.

Empirical methodology and results for aggregate export flows

Our empirical analysis is carried out in two steps. We first look at the sectoral export patterns by energy intensity following the introduction of the TCZ policy; in Section "The role of firm ownership" we then see whether there are in addition any differences in export performance according to firm ownership.

Empirical methodology

We identify the effect of stricter environmental policies from the differential effect of the TCZ policy across sectors, where the effect depends on the sector's intrinsic exposure to the new regulations.

We estimate the following equation on our panel of sectoral export data for 265 cities over 1997–2003.

$$Exports_{ikt} = \alpha TCZ_i \times Exposure_k \times post + \nu_{it} + \lambda_{kt} + \theta_{ik} + \varepsilon_{ikt} \quad (1)$$

[18] The official list of 175 targeted cities includes 158 prefecture-level cities and the 4 municipalities (Beijing, Tianjin, Shanghai and Chongqing). After dropping four prefecture-level cities that do not report exports over the period, our final sample covers 158 TCZ locations.

[19] Table B1 lists all of the cities in our sample.

[20] This is in line with Cole et al. (2011) who measure in the context of China a positive relationship between income and air and water emissions.

[21] These zones were created by the government starting in 1979 in Guangdong, to promote industrial activity, innovation and exports. They offer low-tax regimes and faster administrative procedures to favor industrial clustering.

[22] Consistent GDP per capita information is only available for 243 cities in our sample. Regressions using this indicator thus have a slightly lower number of observations.

[23] We use the monthly average of daily means. Mixing height refers to boundary layer height in the ERA-Interim data set we use. See Section "Instrumental variable approach" for the construction and more details of the instrument.

[24] Overall in the 158 TCZ cities, total exports increased every year by 16% on average. In the 107 non-TCZ cities the average growth rate was 13.5%.

where $Exports_{ikt}$ are the free-on-board export sales in industry k at year t for city i, TCZ is a dummy for the city having been targeted by the policy, and *post* is a dummy for the years post 1998, the year the TCZ policy was implemented. It takes the value 0 in 1997 and 1998 and 1 for the years 1999–2003. The variable $Exposure_k$ reflects exposure to stricter environmental regulations and varies across sectors. As explained in Section "Industry-level variables: energy intensity and controls" our main proxy of exposure at the sector level is the sector's ratio of coal consumption to value-added (in logs). In Eq. (1) ν_{it}, λ_{kt} and θ_{ik} correspond to city-year, sector-year and city-sector fixed effects, and ε_{ikt} is an idiosyncratic error term. We run regressions with exports in levels instead of logs, as we can then include the zero export flows, which represent about 32% of our final sample.[25]

With the fixed effects, our estimates appeal to within changes that are different between TCZ and non-TCZ cities. The effect of stricter regulatory constraints is identified by comparing export performance across sectors. Our main coefficient of interest is hence that on the triple interaction term α. If environmental regulations do affect a city's exports negatively, we expect a relative decline of exports in targeted cities with respect to non-targeted cities. However, this effect should be smaller in low coal-intensity sectors where the rise in production costs is muted. In all regressions, we cluster standard errors at the city level since regressions with aggregated right-hand side variables can produce downward bias in the estimated standard errors (Moulton, 1990). Also Bertrand et al. (2004) argue that difference in difference estimations, as we have here, often yield inconsistent standard errors due to the serial correlation of the error term within the treated units (here the cities) and therefore recommend clustering at this level.

Main results for aggregate export flows

In columns 1 and 2 of Table 1 we estimate Eq. (1) without the dyadic (city-year, sector-year, sector-city) fixed effects, including only year, city and sector dummies. In these columns, the TCZ dummy is picked up in the city fixed effects, while sectoral coal intensity is captured by the sector dummies and the *post* dummy in the year fixed effects. Theoretically, the TCZ export impact is captured by the double interaction $TCZ_i \times post$. In column 1, the coefficient on this interaction term is positive and significant, suggesting a relative rise in sectoral exports in TCZ cities. This positive coefficient likely reflects other changes in TCZ cities at that time which affected exports: for example, the general privatization and opening of trade that occurred in these cities in preparation for China's WTO entry in 2001. In column 2, we triple interact the TCZ and post dummies with sectoral coal intensity, on top of the double interactions between sectoral coal intensity and both the post and TCZ dummies. This triple interaction term, $TCZ_i \times coal\ int_k \times post$, shows whether there is a differential effect by coal intensity in treated cities.

Column 3 shows our benchmark specification in Eq. (1). Since we include fixed effects at the city-year, sector-year and city-sectoral levels, the double interaction terms drop out, which however does not affect the size and significance of α. As in column 2, α is negative and highly significant, suggesting that stricter environmental regulations did indeed induce a relative reduction of exports as a function of sectoral coal intensity. A 10% difference in coal intensity in a TCZ city is estimated to lead to a relative fall in annual exports of 1.14 million US dollars. Compared to mean exports of around 51 million US dollars in TCZ cities, this amounts to a 2.2% reduction. This is an economically significant change. We can nonetheless put this in perspective by comparing it to the substantial average annual figure for export growth of 16% over this period.

Relatively lower exports in polluting sectors in TCZ cities can result from different sources. It can either come from a relative fall in the export volume of existing exporters (the intensive margin), or it can result from a change in the number of firms in the different locations (the extensive margin). This second margin could be driven by a relative higher number of firms setting up in non-targeted locations, or a stronger movement of firm closure in targeted cities and eventual relocation to a less stringent environment. However, we cannot disentangle these different channels. Ederington et al. (2005) argue that relocation will likely only be limited as the industries with the greatest pollution abatement costs are also the least mobile geographically. In any case, given that our data set is a quasi exhaustive list of China's export flows, finding a negative α indicates that the policy has been effective, inducing a relative decline of pollution-intensive sectors in the targeted cities relative to the non-targeted cities.

Columns 4–10 of Table 1 present some robustness tests.[26] Column 4 excludes the top and bottom four sectors in terms of coal intensity, as identified in Appendix Table A2. The estimated α is higher, so our benchmark findings are not driven by these extreme sectors.[27] In columns 5–8 we check that the results are robust to alternative measures of pollution intensity. Instead of coal over value added we consider in column 5 the ratio of total energy use to value added and in column 6 the

[25] A more standard approach to incorporate the zero trade flows would be to use a generalized linear model with a log link (also called PQML estimator). However, we encounter computation problems when we want to control for time-varying city and sector characteristics at the same time as city-sector fixed effects. Our benchmark estimates are based on exports in levels, but we show that our results are robust to limiting the sample to positive flows (in levels and in logarithm), and to generalized linear model estimates with a reduced number of fixed effects. Ideally, we would also check for robustness using a Heckman two-stage procedure, but we lack a convincing exclusion restriction.

[26] In the unreported results (available upon request), we also verify that our results remain when regressions are estimated excluding one province or one sector at a time.

[27] The coefficient on the triple interaction term in column 4 suggests a fall of about 4.5% in exports (calculated at the mean for the sample of TCZ cities) from a 10% rise in coal intensity.

Table 1
TCZ policy and export values.

Dependent variable:	Exported value (city/sector/year)									Domestic VA
Exposure:	Coal				Energy	Electricity	Full Coal	SO_2	Coal	
				W/o extreme sectors						
	1	2	3	4	5	6	7	8	9	10
TCZ_i × post	0.207[a]	−0.275[b]								
	(0.062)	(0.106)								
$Exposure_k$ × post		−0.000								
		(0.002)								
TCZ_i × $Exposure_k$		−0.106[a]								
		(0.039)								
TCZ_i × $Exposure_k$ × post		−0.114[a]	−0.114[a]	−0.214[a]	−0.102[a]	−0.078[b]	−0.182[b]	−0.119[a]	−0.117[a]	−0.080[b]
		(0.040)	(0.040)	(0.068)	(0.039)	(0.032)	(0.066)	(0.041)	(0.041)	(0.028)
TCZ_i × capital/$labor_k$ × post									0.025	
									(0.029)	
Fixed effects	City, year, sector		City-year, sector-year & sector-city							
Observations	46,375	46,375	46,375	31,535	46,375	46,375	46,375	46,375	46,375	46,375
R^2	0.025	0.029	0.198	0.258	0.197	0.197	0.197	0.199	0.198	0.220
No. of cities	265	265	265	265	265	265	265	265	265	265
No. of TCZ cities	158	158	158	158	158	158	158	158	158	158

Heteroskedasticity-robust standard errors clustered at the city level appear in parentheses. Exposure to stricter regulations at the sector level is computed by the sector's ratio of coal consumption to value-added (in logs) in columns 1–4 and in columns 9 and 10, the logarithm of the sector's total energy use over value added in column 5, the logarithm of the sector's electricity use over value added in column 6, and the logarithm of the sector's SO_2 emissions over value added in column 8. Column 7 uses weighted average of coal intensity of both direct and indirect inputs, with weights coming from the 1997 input–output table. In column 10, the explained variable is the domestic value-added of exports computed using ratios from Koopman et al. (2012).

[a] Indicate significance at the 1% confidence level.

[b] Indicate significance at the 5% confidence level.

[c] Indicate significance at the 10% confidence level.

ratio of electricity to value-added. Since more than 75% of China's energy is generated from coal, industries that are intensive in overall energy or electricity are also likely to be affected by the TCZ policy as they are more likely to face power shortages or higher energy prices.[28] In column 7, we use the full (direct and indirect) coal intensity of sectors computed as the weighted average of their own use of coal and that of their upstream activities. In column 8, the exposure of sectors to the policy is measured by the logarithm of the ratio of SO_2 emissions to value-added. Overall, our results appear to be remarkably robust to the various definitions of exposure and confirm that more energy intensive industries experience a relative fall in exports following the TCZ policy compared to less energy-intensive and thus less polluting sectors. In column 9, we address the concern that polluting industries are in general also capital intensive (as indicated by the correlation between capital and pollution intensity in Table A1). We add the interaction of the $TCZ \times post$ term with the sectoral capital-labor ratio in our benchmark specification of column 3. Our main finding remains.

In the final column of Table 1, we investigate whether the relative fall in exports in more polluting industries leads also to a shift of domestic value-added and production by using the domestic value-added in exports as dependent variable. We use the Koopman et al. (2012) ratios to obtain the dollar value of the domestic value-added embedded in the exports for each city-sector-year. This approach is intended to account for the large share of imported intermediates in Chinese exports. As shown by Koopman et al. (2012), the value added in Chinese exports is low and highly variable across sectors. Our results show a relative decline in coal-intensive sectors also in value added. This suggests that the reallocation of activities away from pollution-intensive sectors is not only in terms of export value but also in terms of value-added and production.

Finally, we undertake some robustness checks related to the role of zero-value export flows. Since we have around 32% of zeros in our data base, a standard approach in the literature is a quasi-maximum likelihood estimator (PQMLE). However, including all of the fixed effects as in the OLS regressions is not feasible. In columns 1 and 2 of Table A5, we present the PQMLE results of our benchmark regression in Table 1, column 3 and the robustness check in column 9, including only city-year and sector-year fixed effects. For comparison, we display in columns 3 and 4 results of OLS regressions with the same fixed effects. The two estimation methods provide rather similar predictions for a 0.1 increase in the triple interaction term. Results in column 1 suggest that yearly exports would reduce by $1-\exp(-0.0119)=1.2\%$ while the corresponding value

[28] Since electricity prices in China are administratively set, we expect a less pronounced effect of the TCZ policy when using this proxy for pollution intensity.

Table 2
Estimations at the provincial level.

Explained variable	$Exports_{pkt}$ (province/sector/year)		
Proxy for TCZs weight (TCZ_p)	Nb cities 1	GDP 2	Exports 3
$TCZ_p \times$ coal $int_k \times$ Trend 1992–1998	−0.095 (0.059)	−0.082 (0.049)	−0.062 (0.042)
$TCZ_p \times$ coal $int_k \times$ Trend 1999–2003	−0.540[b] (0.254)	−0.420[c] (0.205)	−0.308[c] (0.168)
Fixed effects	Province-sector, province-year, year-sector		
Observations	8700	8700	8700
No. of provinces	29	29	29
R^2	0.414	0.412	0.410

Heteroskedasticity-robust standard errors clustered at the province level appear in parentheses.
[a] Indicate significance at the 1% confidence level.
[b] Indicate significance at the 5% confidence level.
[c] Indicate significance at the 10% confidence level.

based on column 3 results and using the average value of yearly city-sector exports for the entire sample of 32 million US dollar is 3.6%=0.1 × 0.114/0.32. Columns 5–8 of Table A5 show the estimates when we limit our analysis to positive trade flows. In columns 5 and 6 we use a log transformation of the dependent variable while the last two columns show the results using the original specification on a sample of positive export flows only. The finding of a relative reallocation of export activities in TCZ cities away from coal-intensive sectors is confirmed throughout the specifications.

In the following sections, we conduct a series of sensitivity analyses to see whether our results are affected by the endogenous selection of TCZs. We first check the validity of the parallel trend assumption in TCZs and non-TCZs. Second, we control for some other city characteristics that are potentially correlated with sectoral exports. Third, we carry out an instrumental variable estimation. Our findings remain robust to all of these checks.

Verifying the parallel trend assumption

This section proposes two complementary approaches to verify that our results of diverging export patterns between TCZs and non-TCZs after the policy implementation do not solely reflect pre-existing different trends.

Ideally, we would like to use pre-treatment data for more years prior to 1998 to verify that the relative decline in coal-intensive industries we observe in TCZs did not exist prior to the new environmental policy. As highlighted in Section "Stylized facts regarding export patterns and coal intensity", the cities targeted by the TCZ policy had very polluted air. This high level of pollution may have induced authorities to limit emissive activities even before the policy was implemented. However, sectoral export flows at the city-level are unfortunately not available for the years before 1997. The finest level of geographic disaggregation for sectoral export flows before 1997 is provincial. Our first approach to investigate the parallel trend hypothesis consists in testing for diverging export patterns between provinces depending on the extent to which they are targeted by the TCZ policy. We rely on three proxies to capture the weight of to-be TCZ cities at the province-level: the percentage of prefecture-level cities in the province that are designated as TCZs, their share in the province-level GDP (measured in 2000), and their share in the province-level export value (measured in 1997).

We use a panel of sectoral export flows at the provincial level between 1992 and 2003 and test whether we observe a significant reallocation of exports away from coal intensive sectors that reflects the importance of to-be-TCZ cities in the province. While we expect such an evolution after 1998, the common trend assumption would require that no such pattern exists before. The results based on the three different proxies for TCZ at the provincial level are displayed in Table 2. They suggest a reduction of polluting exports that is proportional to the importance of TCZs and that started after 1998. Regardless of the choice of the proxy of the province-level importance of TCZs, we find negative and significant coefficients only for the trend after 1998.[29]

In a second approach, we return to the city level data and take a closer look at the policy impact estimated in Section "Main results for aggregate export flows" by studying how this impact evolves over time. Therefore, in Table 3 we reproduce column 3 of Table 1 but decompose the *post* dummy into various year dummies, keeping 1997 as the benchmark. Column 1 shows negative coefficients on the yearly interaction terms of *TCZ* × *coal int*, which become larger over time. The coefficient for 1998 is negative but insignificant, suggesting that the evolution of export patterns between TCZs and non-TCZs was

[29] As in Table 1, we verify that our results globally hold when using domestic value-added of exports as the dependent variable and when using alternative proxies of exposure. More details on this robustness check are available upon request.

Table 3
Yearly effects.

Dependent variable:	Exported value (city/sector/year)		
Coefficient for	$TCZ_i \times$ coal $int_k \times$ Year 1	Coal $int_k \times$ Year Non-TCZ cities 2	Coal $int_k \times$ Year TCZ cities 3
1998	−0.013 (0.008)	−0.000 (0.001)	−0.013[c] (0.008)
1999	−0.028[b] (0.013)	−0.001 (0.001)	−0.029[b] (0.013)
2000	−0.066[a] (0.025)	−0.000 (0.001)	−0.066[a] (0.025)
2001	−0.103[b] (0.040)	0.001 (0.002)	−0.103[b] (0.040)
2002	−0.148[a] (0.052)	−0.000 (0.003)	−0.149[a] (0.052)
2003	−0.258[a] (0.091)	−0.001 (0.004)	−0.258[a] (0.091)
City-year fixed effects	Yes	Yes	Yes
City-sector fixed effects	Yes	Yes	Yes
Sector-year fixed effects	Yes	No	No
Observations	46,375	18,725	27,650
R^2	0.199	0.108	0.184
No. of cities	265	107	158

Heteroskedasticity-robust standard errors clustered at the city level appear in parentheses.
[a] Indicate significance at the 1% confidence level.
[b] Indicate significance at the 5% confidence level.
[c] Indicate significance at the 10% confidence level.

similar the year the TCZ policy was launched. TCZ export patterns became increasingly biased against pollution-intensive sectors over time, compared to non-TCZs. This is consistent with the delays inherent to the production and organizational changes required by the policy.[30]

In columns 2 and 3 of Table 3 we check that our main result does not merely reflect a secular trend of a relative decline in coal-intensive industries across China. We split the data up into TCZ and non-TCZ cities. Column 2 shows the results for exports in non-TCZ cities while column 3 reports those for TCZ cities. Our variables of interest here are the interactions between coal intensity and the year dummies, controlling for city-sector and city-year fixed effects. In non-TCZ cities, we see no significant fall in exports related to coal intensity. By contrast, in the sub-sample of TCZ cities, the negative coefficients indicate a relative decline in the exports of more polluting industries that becomes larger in size over time. In this sub-sample, we find a significant impact in 1998, the year the policy was launched. These contrasting results suggest that the reallocation away from polluting sectors, which we interpret as the effect of the TCZ policy, does not reflect a general shift of the exports of Chinese cities towards cleaner industries.

Additional controls

Table 4 provides additional robustness checks to see whether the export-deterring effect of the TCZ policy is driven by omitted variables which match the time-varying differences between TCZ and non-TCZ cities.

The economic convergence process at work in China could be one explanation of the relative export decline in TCZ locations. Over the years, more firms have relocated or have been created in the relatively poorer inland provinces, where labor and land are cheaper. The "Go West" strategy launched in 2000 to develop China's Western hinterlands and improve their infrastructure has further increased their attractiveness. Moreover, polluting firms may find less-developed regions more attractive as there might be less concerns there about environmental damage. In column 1 of Table 4 we consider whether the relocation and growth of firms away from coastal China drives our results. We add the interaction of coal

[30] In the unreported results, which are available upon request, we check that our findings in Table 3 hold when using the alternative specifications of pollution intensity or domestic value-added of exports as dependent variable as in Table 1.

Table 4
TCZ policy and export values: additional controls.

Dependent variable:	Exported value (city/sector/year)				
	1	2	3	4	IV 5
$TCZ_i \times$ coal $int_k \times$ post	−0.088[a] (0.031)	−0.050[b] (0.023)	−0.120[a] (0.043)	−0.043[c] (0.026)	−0.190[c] (0.115)
$Coast_i \times$ coal $int_k \times$ post	−0.148[a] (0.053)	−0.112[a] (0.043)		−0.058[c] (0.035)	−0.048 (0.034)
$SPZ_i \times$ coal $int_k \times$ post		−0.217[a] (0.081)		−0.119[b] (0.054)	−0.096[c] (0.054)
ln(GDP pc_i) × coal $int_k \times$ post				−0.161[b] (0.069)	−0.145[b] (0.061)
Fixed effects	City-year, sector-year & sector-city				
Observations	46,375	46,375	42,525	42,525	42,525
R^2	0.199	0.202	0.200	0.205	0.006
No. of cities	265	265	243	243	243
Partial R^2					0.051
p-value (C-statistics)					0.115
Underidentification					11.685
p-value (Underid.)					0.00
Weak identification F-test					12.932
p-value (Weak id.)					0.000

Heteroskedasticity-robust standard errors clustered at the city level appear in parentheses. The results from the first step of column 5 appear in Table A6. The substantial *p*-value of the C-statistic for the exogeneity of $TCZ_i \times coal\ int_k \times post$ indicates that the IV and OLS results are not significantly different from each other. The underidentification test is reflected in the Kleinbergen–Paap LM statistics, and the weak identification test in the Kleinberg–Paap Wald F-statistics. The values obtained from both tests suggest that our instrument is relevant.

[a] Indicate significance at the 1% confidence level.
[b] Indicate significance at the 5% confidence level.
[c] Indicate significance at the 10% confidence level.

intensity and the post-treatment dummy with *Coast*, a dummy for being located in a coastal province.[31] The negative and significant effect of the TCZ policy is robust to this control.

TCZ and non-TCZ cities may also differ in terms of their outward orientation. In recent decades, the Chinese government has created a number of special policy zones (SPZ) including special economic zones, High-technology Industry Development Areas, Economic and Technological Development Areas and Export Processing Zones, to which preferential fiscal treatment has attracted many exporters and foreign-owned firms (Wang and Wei, 2010). Among the 62 cities with a special policy zone in our sample, 50 were targeted by the TCZ policy. Table A4 shows that the correlation between the TCZ and SPZ cities is around 0.23. Column 2 of Table 4 includes an interaction between a SPZ dummy, sectoral coal intensity, and the post-treatment dummy: the coefficient on our variable of interest ($TCZ_i \times coal\ int_k \times post$) remains negative and significant, so the correlation between TCZ and SPZ cities did not drive the results in Table 1.

We next test whether the relative fall in energy-intensive exports reflects that as cities become wealthier they demand better air quality, and thus push for polluting factories to be closed down. Since TCZ cities are on average richer, the TCZ variable could thus capture a greater demand for health. Also, independently of the demand for cleaner air, the city's industry mix may also change with income. If firms in polluting sectors require more land or other particular inputs, we expect the relocation of polluting industries away from wealthier cities to areas where these inputs are cheaper.

We account for any trend in sectoral composition due to economic development via the interaction of $coal\ int_k \times post$ with the natural logarithm of GDP per capita. As we do not have reliable information on GDP per capita for all cities in our sample, our number of observation drops to 42,525 (243 cities, 7 years, and 25 sectors). Column 3 therefore shows the benchmark specification for this restricted sample, confirming the benchmark results from Table 1. Column 4 introduces the new interaction. This variable attracts a negative coefficient, suggesting a relative shift away from polluting activities as income rises. The coefficient on the variable $TCZ_i \times coal\ int_k \times post$ is smaller but remains negative and significant at the 10% level.[32]

[31] The provinces with direct access to the sea are Tianjin, Hebei, Liaoning, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan and Guangxi.

[32] These results are also found in specifications in which the coast dummy is replaced by a dummy for western provinces and the interaction of $coal\ int_k \times post$ with the share of secondary industry in the city's GDP is added. More details on these robustness checks are available upon request.

In line with our expectations, coal-intensive exports post-1998 all fall more if the city is on the coast, in a special zone, or has greater GDP per capita. In column 4, these newly added variables interacted with coal-intensity do take away much of the impact of the TCZ interaction term, though the latter remains statistically significant. These results confirm the findings in Dean (2002) and Wang and Wheeler (2003) that Chinese provinces with greater GDP per capita, located on the coast, have more stringent environmental regulations in general.

Instrumental variable approach

Our empirical analysis relies on a triple difference estimate to assess the impact of the TCZ environmental policy given that selection into TCZ is not exogenous but reflects initial high pollution levels. However, since pollution may be correlated with other characteristics that in turn affect exports, we may still have endogeneity problems even though we controlled for numerous other factors in the previous section. In this section, we therefore want to complement the triple difference estimates by an instrumental variable. We follow Broner et al. (2012), who study the impact of environmental policy in cross-country data. They instrument environmental policy using the ventilation coefficient, reflecting the meteorological conditions that influence the speed of dispersion of pollutants in the air. The hypothesis is that meteorological conditions which slow the dispersion of pollutants in the air likely lead to the adoption of stricter environmental regulation.[33] Here, cities where pollution is dispersed more slowly are more likely to be targeted by the Two Control Zones policy as, for given local SO_2 emissions, the SO_2 concentration in the air remains higher for longer.

The ventilation coefficient is identified in the standard Box model of atmospheric pollution as the determinant of the dispersion speed of air pollution (Jacobsen, 2002). This coefficient is defined as the product of wind speed, which determines the horizontal dispersion of pollution, and mixing height, which determines the height at which pollutants disperse in the atmosphere. For two locations with the same level of emissions, that with the higher ventilation coefficient suffers less from air pollution. As ventilation coefficients are determined by large-scale weather systems, they can plausibly be considered as exogenous to local economic activity. We use this exogenous source of air pollution differences between cities as our instrument for the TCZ status.

The ERA-Interim data used also by Broner et al. (2012) provides wind speed at 10 m height and mixing height for a global grid of $75^\circ \times 75^\circ$ cells (about 83 square kilometers). The ventilation coefficient for every grid cell is constructed by multiplying average wind speed and boundary layer height. We then average this indicator by cell for 1991 to 1996 (two years prior to the implementation of the policy). The locations in the ERA-Interim database can be matched to our Chinese cities via latitudes and longitudes (obtained from world-gazetteer.com). We define each city's ventilation coefficient as the average of that in its four closest cells in the ERA-Interim grid.

As seen in Table A3, the ventilation coefficient is on average lower for TCZ than for non-TCZ cities. The same holds for the two components, wind speed and boundary layer height. This is as expected: a higher ventilation coefficient reflects the faster dispersion of air pollution. This likely reduces the measured concentration of SO_2 and hence the need for stringent environmental regulations. Appendix Table A4 shows the correlations between the ventilation coefficient, wind speed and boundary layer height and the TCZ variable, as well as with other city variables.

Column 5 of Table 4 applies our instrumental variable approach to the extended specification of column 4, instrumenting $TCZ_i \times coal\ int_k \times post$ by the interaction of the city's ventilation coefficient, coal intensity and the post dummy. It confirms a negative and significant impact of the policy that grows with sectoral coal intensity.[34] Having only a single instrument, we cannot test model overidentification and check the exogeneity of our instrument. However, the bottom of the table shows tests of both underidentification and weak identification. The latter is equal to the F-test on the excluded instrument in the first-step regression. The low p-value indicates that our instrument is relevant. The results of the first-step estimation appear in Appendix Table A6: these reveal a negative and significant correlation between the instrument and the instrumented variable, as expected. We report at the bottom of column 5 of Table 4 the test for the exogeneity of $TCZ_i \times coal\ int_k \times post$. The p-value of the C-statistic (higher than 0.1) indicates that – under the assumption that our instrument is valid - there is no significant difference between the OLS and IV estimates. This suggests that the inclusion of our three categories of fixed effects (city-sector, city-year, year-sector) captures to a large extent why a city was designated as TCZ. We thus cannot reject the null hypothesis that in presence of these fixed effects there is no endogeneity problem with the OLS estimators. For this reason, the OLS specification is maintained as the preferred specification for the remainder of the paper.

The role of firm ownership

The previous section focused on the different impact of the TCZ policy across sectors. We now refine our approach by appealing to the political pecking order of Chinese firms.

[33] See Broner et al. (2012) for more details on the determinants of atmospheric pollution, the ventilation coefficient and its suitability as an environmental-policy instrument.

[34] This result holds when using the domestic value-added of exports as dependent variable, when adding the interaction of $coal\ int_k \times post$ with the share of secondary industry in the city's GDP and when replacing the coast dummy with a dummy for the western provinces.

The enforcement of environmental policies and the role of firm ownership

Reflecting the considerable administrative decentralization in China, local governments are effectively given discretion as to how to interpret and carry out policies. Hence, as in other economic domains, local authorities are legally responsible for enforcing environmental regulations but have only limited resources and power to do so (Wang et al., 2003). The unavoidable consequence is generalized bargaining through which many polluters can effectively avoid paying charges, fines or other penalties. As such, firms are affected very differently by policies in general, and pollution policies in particular, depending on their bargaining power with the regulator and their capacity to absorb the additional costs resulting from the policy. In China, these two dimensions directly relate to firm ownership. Huang (2003b) notes that China's institutional landscape is best described as a political pecking order systematically favoring state-owned enterprises (SOEs), both financially and legally. Local authorities, whose income and promotion prospects are directly tied to the performance of state-owned firms, have vested interests which oppose the dismantling of the inefficient public sector.

This ownership bias has very concrete repercussions in terms of discriminatory and incomplete policy enforcement in China. Local governments tend to resist the rationalization of state-owned firms under their supervision through local protectionism. An entire World Bank report details the various discriminatory measures put in place by local authorities to curb competition and favor politically connected firms (World Bank, 2005). These measures include direct control over the quantity of sales, price limits and local subsidies, discriminatory regulation enforcement, and intervention in the input, labor and finance markets. In line with public firms' greater political power, regional protection is more widespread in industries dominated by SOEs (Poncet, 2005). Dean et al. (2009) consider the enforcement of water-pollution charges in China and show that private-sector firms have less bargaining power than state-owned enterprises: state-owned firms are in a better position to escape sanctions.[35] Also Wang and Wheeler (2005) find in a study at the plant-level that there exists a significant negative correlation between state ownership and the effective levy on air pollution paid by Chinese firms.

These findings suggest that any repercussions of the TCZ policy on economic output may be mitigated for state-owned firms. This first source of difference by firm-ownership type is amplified by a second relating to heterogeneous cost-absorption capacities. A large literature has shown that private firms suffer from greater credit constraints. One well-acknowledged consequence of China's political pecking order of firms is the systematic misallocation of financial resources (Dollar and Wei, 2007). Despite the very large pool of financial capital in the Chinese state-dominated banking sector, the majority of lending goes to less-efficient SOEs, leaving healthy private enterprises without access to external funding. SOEs can furthermore count on huge government subsidies, to the extent that they are often seen as bottomless pits for government-channeled investment funds (Boyreau-Debray and Wei, 2004). Because of easy funding SOEs may also be the first firms to adopt cleaner technology, for example, substitution of electricity for direct use of coal to power industrial process (Roumasset et al., 2008); thus they become less polluting without reducing production or export. We argue that, thanks to reduced obligations to comply with regulations, better access to finance and softer budget constraints, public enterprises may continue their business as usual despite the new environmental regulations, while private enterprises are forced to adjust by cutting their productive and export activities due to increased costs.

Accounting for firm ownership

As argued above, and in line with the political preference for state-owned firms, the TCZ policy should particularly affect private firms. We thus differentiate between state and non-state firms, and estimate the following equation:

$$\begin{aligned} Export^F_{ikt} = {} & \alpha TCZ_i \times coal\ int_k \times post + \beta TCZ_i \times coal\ int_k \times post \times SOE \\ & + \gamma_1 TCZ_i \times post \times SOE + \gamma_2 coal\ int_k \times post \times SOE \\ & + \theta^F_{ik} + \mu^F_t + \nu_{it} + \lambda_{kt} + \varepsilon^F_{ikt} \end{aligned} \tag{2}$$

where $Exports^F_{ikt}$ are the free-on-board export sales of firm type F in industry k in year t for city i.[36] We consider two firm types, state-owned and private (domestic nonstate-owned and foreign firms). The SOE dummy is 1 for exports of state-owned firms and 0 otherwise.

The coefficients of interest here are those on the first two interaction terms, α and β. If environmental regulations do distort exports according to energy intensity, this should especially hold for non-state firms. Compared to private firms, the exports of state-owned firms should be less sensitive to energy intensity after the introduction of the TCZ policy due to their greater bargaining power with the regulator and capacity to absorb the policy's higher costs. Hence, we expect α to be negative and β to be positive.

Our estimates control for all of the triple interactions between the four components TCZ_i, $post$, $coal\ int_k$ and SOE. We therefore include $TCZ_i \times post \times SOE$ as well as $coal\ int_k \times post \times SOE$. The remaining triple interaction, $TCZ_i \times coal\ int_k \times SOE$, is captured by the city-industry-firm type fixed effects, θ^F_{ik}. These latter fixed effects allow us to separate the policy impact from other factors that are common to exports of a given firm type in a specific sector in a given city. As in Eq. (1), we control

[35] Similar findings are found in terms of taxation: private firms experience worse tax and legislative treatment (Huang, 2003a).

[36] In this sample zero export flows account for about 44% of observations.

Table 5
TCZ policy and exports by firm ownership.

Dependent variable:	$Exports^F_{ikt}$ (city/sector/year/firm-type)				Domestic VA	$Exports^F_{ikt}$
	Benchmark 1	W/o extremes 2	Full coal 3	K/L 4	5	6
$TCZ_i \times$ coal $int_k \times$ post	−0.094[a] (0.031)	−0.170[a] (0.055)		−0.098[a] (0.033)	−0.065[b] (0.021)	−0.037[b] (0.018)
$TCZ_i \times$ coal $int_k \times$ post $\times$ SOE	0.073[a] (0.024)	0.127[a] (0.046)		0.079[a] (0.026)	0.050[b] (0.017)	0.031[b] (0.013)
$TCZ_i \times$ full coal $int_k \times$ post			−0.148[b] (0.046)			
$TCZ_i \times$ full coal $int_k \times$ post $\times$ SOE			0.115[b] (0.038)			
$TCZ_i \times$ capital/$labor_k \times$ post				0.037[c] (0.019)		
$TCZ_i \times$ capital/$labor_k \times$ post $\times$ SOE				−0.049 (0.030)		
$Coast_i \times$ coal $int_k \times$ post						−0.050[b] (0.023)
$Coast_i \times$ coal $int_k \times post_t \times$ SOE						0.041[b] (0.019)
$SPZ_i \times$ coal $int_k \times$ post						−0.096[b] (0.039)
$SPZ_i \times$ coal $int_k \times$ post $\times$ SOE						0.073[b] (0.034)
ln(GDP pc_i) $\times$ coal $int_k \times$ post						−0.127[b] (0.055)
ln(GDP pc_i) $\times$ coal $int_k \times$ post $\times$ SOE						0.094[b] (0.043)
Controls	$TCZ_i \times$ SOE $\times$ post, $Exposure_k \times$ SOE $\times$ post					
Fixed effects	city-sector-firm-type, city-year, sector-year, firm-type-year					
Observations	92,750	63,070	92,750	92,750	92,750	85,050
R^2	0.122	0.172	0.121	0.122	0.137	0.128
No. of cities	265	265	265	265	265.000	243
p-value ($\alpha+\beta=0$)	0.096	0.013	0.211	0.079	0.110	0.571

Heteroskedasticity-robust standard errors clustered at the city level appear in parentheses. Additional controls: column 4 does not show the coefficient on capital/$labor_k \times$ SOE $\times$ post. In the last column, the unreported interactions are those of SOE $\times$ post with the four variables $Coast_i$, SPZ_i and $ln(GDP\ pc_i)$.
[a] Indicate significance at the 1% confidence level.
[b] Indicate significance at the 5% confidence level.
[c] Indicate significance at the 10% confidence level.

for unobservables by adding city-year (ν_{it}), and sector-year (λ_{kt}) fixed effects. Finally, we include μ^F_t dummies to account for any systematic time-varying differences in average export performance between firms of different ownership types.

Empirical results by firm ownership

Table 5 presents the empirical results from Eq. (2). The benchmark specification is in column 1 and columns 2–6 show various robustness checks. Column 2 excludes the top and bottom four sectors in terms of coal intensity. Column 3 uses the full coal intensity of the sector, so it takes into account the coal dependence from upstream sectors. Column 4 adds the interaction term with capital intensity, measured as the ratio of capital over labor. Column 5 uses the domestic value-added of exports as dependent variable. Column 6 includes interactions for the impact of income, Special Policy Zones and coastal location, in the same spirit as Table 4.[37]

[37] As in Table 1, we verify that our benchmark results are robust to the use of alternative exposure proxies. Column 6 holds when using the domestic value-added of exports as dependent variable, when adding the interaction of *coal* $int_k \times$ *post* with the share of secondary industry in the city's GDP, when replacing the coast dummy with a dummy for the western provinces and when using the alternative exposure proxies. More details are available upon request.

In all six columns, the coefficients α and β have the expected respective positive and negative signs. The bottom of the table shows the p-value from the test of the impact for state-owned firms being null, i.e. $\alpha+\beta=0$. Once we include the additional controls, this hypothesis cannot be rejected, so state-ownership shelters firms from the negative export-effect of the TCZ policy. The relative export reallocation away from pollution-intensive activities appears to be limited to non-state owned firms. As a consequence, the new environmental policy induces firms of different ownership types to self-select into sectors with different energy-intensities, with private firms becoming relatively less specialized in the more intensive industries. In contrast, any change in the sectoral composition of exports of state-owned firms seems to be much less pronounced.

Conclusion

This paper has considered the impact of stricter environmental regulations from the Two Control Zones (TCZ) policy on the export activity of firms in China. We use a data set of 265 Chinese cities (of which 158 were targeted by the policy), and exploit variations across time, sector and firm type to extract the causal effect of the policy on firms' export performance. We find evidence that the TCZ policy has greater negative repercussions on exports the larger the pollution content of the activity, suggesting that the TCZ policy was effective. Targeted cities experienced a relative reallocation of export activities away from pollution-intensive sectors. Our results are robust to a variety of checks that control for potential remaining endogeneity such as accounting for the differences between TCZ and non-TCZ cities in terms of GDP per capita, coastal location and presence of special policy zones. The estimated impact also resists an instrumental variable approach that uses the exogenous meteorological determinants of the speed of air pollution dispersion as an instrument for the city TCZ status.

More work is required to allow us to distinguish between scaling down and the relocation from TCZ regulated to non-TCZ regulated cities, in which latter case total pollution in China would remain constant. Poor data quality and the limited availability of pollution statistics have to date precluded the direct assessment of the extent to which TCZ regulations reduced emissions of firms or led to lower SO_2-intensity in production.

The results by firm-type reflect the political pecking order of Chinese firms. The impact of environmental policy appears to be mitigated by state ownership suggesting that, thanks to weaker obligations to comply with regulations or softer budget constraints that allow for a faster adaptation of the polluting production process, state ownership protects from the negative consequences of pollution regulations on production. Public enterprises may continue their business more or less as usual despite the new environmental regulations, while non-state firms are forced to adjust by cutting their productive and export activities as a consequence of the associated higher costs. More work is needed to understand the mechanisms behind the gap between state and non-state firms. Potential explanations include corruption, greater bargaining power or a greater ability to absorb a given cost shock due to softer financial constraints or better access to finance. In general, heterogeneity in the effect of environmental regulations by ownership type would seem to be an interesting subject for further research.

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Appendix A

Table A1
Correlation of industry indicators.

Variables	Coal	Energy	Electricity	SO_2	Full Coal	K/L
Coal/value added	1					
Energy/value added	0.938	1				
Electricity/value added	0.769	0.924	1			
SO_2 emissions/value added	0.862	0.792	0.655	1		
Full coal/value added (direct+ indirect)	0.809	0.855	0.781	0.668	1	
Capital/labor	0.303	0.285	0.070	0.273	0.309	1
Observations	25					

Table A2
List of sectors.

Sector name	Energy intensity				Export Share			
	Coal	Energy	Elec.	Full coal	1997		2003	
	over value added in 1997				TCZ	no TCZ	TCZ	no TCZ
Manuf. of coke, refined petr. & nucl. fuel	0.141	0.106	0.003	0.060	0.014	0.031	0.014	0.025
Mining of coal & lignite; extr. of peat	0.135	0.081	0.005	0.104	0.007	0.018	0.006	0.032
Manuf. of other non-metal. mineral prod.	0.116	0.111	0.005	0.080	0.023	0.027	0.016	0.030
Manufacture of basic metals	0.105	0.159	0.011	0.090	0.044	0.055	0.024	0.048
Manuf. of chemicals & chemical products	0.060	0.097	0.007	0.065	0.062	0.080	0.046	0.078
Manufacture of paper & paper products	0.051	0.061	0.005	0.050	0.004	0.002	0.003	0.002
Publishing and printing	0.038	0.040	0.004	0.046	0.002	0.000	0.002	0.000
Other mining and quarrying	0.026	0.032	0.003	0.044	0.004	0.019	0.002	0.013
Manufacture of food & beverages	0.021	0.021	0.002	0.025	0.037	0.118	0.021	0.108
Manufacture of textiles	0.018	0.028	0.003	0.026	0.100	0.119	0.069	0.103
Manuf. of wood; prod. of wood & cork	0.018	0.020	0.002	0.026	0.010	0.035	0.009	0.041
Manuf. of furniture; manufacturing n.e.c.	0.015	0.033	0.004	0.025	0.086	0.066	0.068	0.089
Manuf. of rubber and plastics products	0.012	0.023	0.003	0.051	0.033	0.023	0.028	0.031
Mining of metal ores	0.011	0.043	0.007	0.044	0.001	0.003	0.001	0.000
Manuf. of medical, precision & optical	0.009	0.015	0.001	0.026	0.026	0.011	0.028	0.012
Manuf. of other transport equipment	0.008	0.015	0.002	0.021	0.009	0.005	0.016	0.009
Manuf. of motor vehicles, trailers	0.008	0.015	0.002	0.021	0.020	0.008	0.020	0.016
Manuf. of fabricated metal products	0.008	0.020	0.003	0.059	0.036	0.052	0.034	0.050
Manuf. of machinery & equipment n.e.c.	0.007	0.014	0.001	0.029	0.038	0.025	0.055	0.038
Manufacture of radio, TV and com.	0.004	0.016	0.002	0.041	0.053	0.024	0.058	0.027
Manuf. of electrical machinery	0.004	0.016	0.002	0.018	0.093	0.036	0.169	0.051
Manuf. of office machinery	0.003	0.008	0.001	0.028	0.062	0.023	0.167	0.015
Tanning and dressing of leather	0.003	0.005	0.001	0.014	0.069	0.096	0.045	0.062
Manuf. of wearing apparel	0.003	0.006	0.001	0.014	0.165	0.125	0.101	0.118
Manuf. of tobacco products	0.002	0.003	0.001	0.017	0.003	0.001	0.001	0.000

Coal is expressed in 10,000 tons, total energy consumption is expressed in 10,000 tons of SCE, electricity is expressed in 1000 million kWh. The industry's value added is measured in 100 million yuans. Export shares for the TCZ cities are defined as the sector's share in total exports coming from TCZ cities. Export shares for the non-TCZ cities are defined as the sector's export share in total exports of non-TCZ cities. Source: China Statistical Yearbooks.

Table A3
Summary statistics by city.

Variables	Total Obs	TCZ=0		TCZ=1		Proba diff
		Mean	S.D.	Mean	S.D.	
$Exports_{ikt}$ (100 million USD), 1997–2003	46,375	0.044	0.209	0.510	3.061	0.000
$Exports_{it}$ (100 million USD), 1997–2003	1855	1.11	2.03	12.76	40.37	0.000
Domestic VA content of $Exports_{ikt}$ (100 million USD), 1997–2003	46,375	0.035	0.167	0.398	2.212	0.000
Special Policy Zone dummy (SPZ)	265	0.112	0.317	0.316	0.467	0.000
Coastal province	265	0.299	0.460	0.481	0.501	0.003
GDP per capita (2000) (yuan per person)	243	7596	7169	9376	5321	0.028
GDP, 2000 (100 million yuans)	243	220.20	186.89	464.75	549.17	0.000
Population, 2000 (10,000 persons)	243	349.4	240.8	453.6	335.9	0.010
Ventilation coefficient (IV)	265	2930.5	548.7	2727.7	462.1	0.001
Boundary layer height (IV), (m)	265	538.27	78.94	513.32	69.16	0.007
Wind speed at 10 m (IV), (m/s)	265	5.49	0.35	5.34	0.29	0.000
Number of cities		107		158		

$Exports_{ikt}$ refers to the exports of city *i* in sector *k* for year *t*. $Exports_{it}$ refers to the total exports of city *i* for year *t*.

Table A4
Correlation of city indicators.

Variables	TCZ	ln(GDP pc)	SPZ	Coast	VC (IV)	Height (IV)
TCZ	1.000					
ln(GDP pc)	0.234	1.000				
SPZ	0.228	0.558	1.000			
Coastal province	0.153	0.428	0.203	1.000		
ln(Ventilation coefficient) (IV)	−0.174	0.211	0.033	0.104	1.000	
Boundary layer height (IV)	−0.137	0.187	−0.002	0.062	0.954	1.000
Wind speed (IV)	−0.216	0.127	0.011	−0.049	0.820	0.651
Observations	243					

Table A5
Alternative specifications: TCZ policy and exports.

Dependent variable:	$Exports_{ikt}$				$ln(Exports_{ikt})$		$Exports_{ikt}$	
	PQML all export flows		OLS		OLS positive export flows			
	1	2	3	4	5	6	7	8
$TCZ_i \times$ coal $int_k \times$ post	−0.119[a] (0.045)	−0.165[a] (0.047)	−0.114[b] (0.040)	−0.117[b] (0.040)	−0.076[c] (0.043)	−0.104[b] (0.050)	−0.163[a] (0.057)	−0.213[a] (0.071)
$TCZ_i \times$ coal int_k	−0.262[a] (0.094)	−0.332[a] (0.096)	−0.106[b] (0.039)	−0.084[b] (0.034)				
$TCZ_i \times$ capital/$labor_k \times$ post		0.288[b] (0.126)		0.025 (0.029)		0.132 (0.126)		0.227[b] (0.094)
$TCZ_i \times$ capital/$labor_k$		0.304[c] (0.163)		−0.185[a] (0.051)				
City-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City-sector fixed effects	No	No	No	No	Yes	Yes	Yes	Yes
Observations	46,375	46,375	46,375	46,375	31,391	31,391	31,391	31,391
R^2			0.032	0.033	0.185	0.185	0.226	0.226
No. of cities	265	265	265	265	265	265	265	265

$Exports_{ikt}$ refers to the exports of city i in sector k for year t. Heteroskedasticity-robust standard errors clustered at the city level appear in parentheses.
[a] Indicate significance at the 1% confidence level.
[b] Indicate significance at the 5% confidence level.
[c] Indicate significance at the 10% confidence level.

Table A6
IV estimations, first step.

Dependent variable:	$TCZ_i \times Coal_k \times post_t$ 1
ln $(VC_i) \times Coal_k \times$ post	−0.635[a] (0.177)
$Coast_i \times Coal_k \times$ post	0.071 (0.070)
$SPZ_i \times Coal_k \times$ post	0.131 (0.084)
ln(GDP $pc_i) \times Coal_k \times$ post	0.161[c] (0.082)
City-year fixed effects	Yes
Sector-year fixed effects	Yes
City-sector fixed effects	Yes
Observations	42,525
R^2	0.124
Partial R^2	0.051
No. of cities	243
F-test excluded instrument	12.932
p-value	0.000

Heteroskedasticity-robust standard errors clustered at the city level appear in parentheses. The results of the second step appear in column 5 of Table 4. The F-test on the excluded instrument is equal to the Weak identification test.
[a] Indicate significance at the 1% confidence level.
[b] Indicate significance at the 5% confidence level.
[c] Indicate significance at the 10% confidence level.

Appendix B

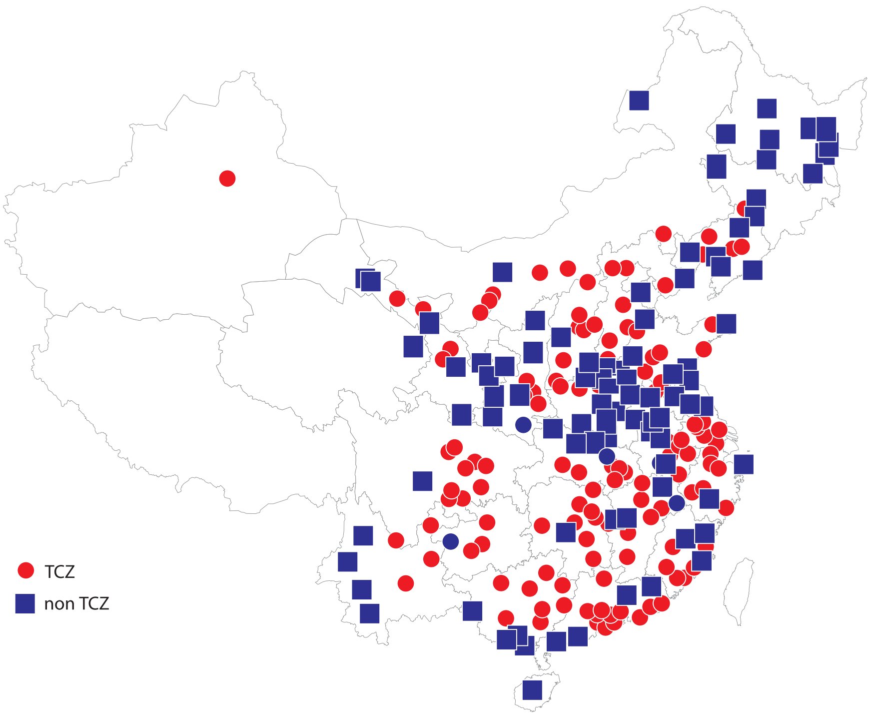

Fig. B1. Location of two control zones cities.

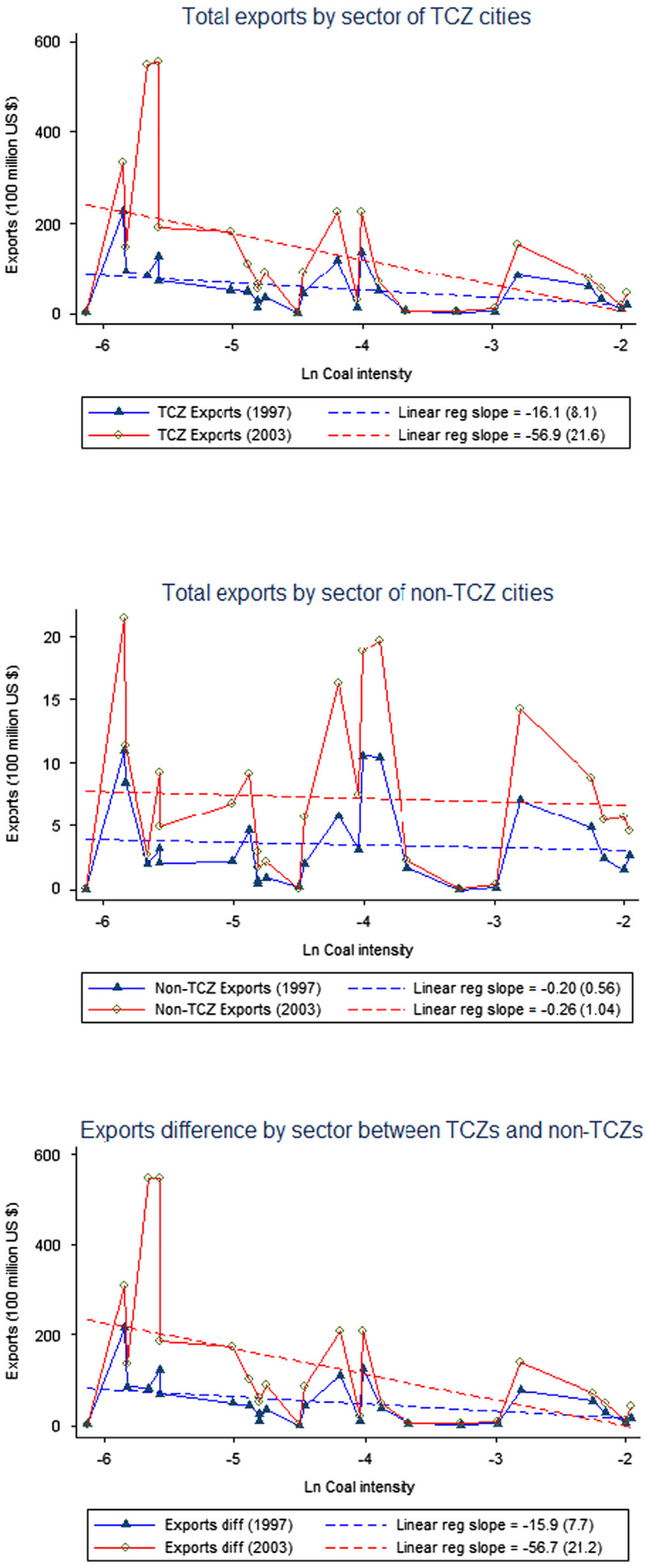

Fig. B2. Variations in sectoral exports by coal intensity and TCZ status (100 million US $) in 1997 and 2003.

Table B1
List of cities.

Province	City	Code	TCZ	SPZ	Province	City	Code	TCZ	SPZ
Beijing	Beijing	1101	1	1	Shandong	Liaocheng	3714	0	0
Tianjin	Tianjin	1201	1	1	Shandong	Linyi	3715	0	0
Hebei	Shijiazhuang	1301	1	1	Shandong	Heze	3716	0	0
Hebei	Tangshan	1302	1	0	Shandong	Laiwu	3720	1	0
Hebei	Qinhuangdao	1303	0	1	Henan	Zhengzhou	4101	1	1
Hebei	Handan	1304	1	0	Henan	Kaifeng	4102	0	0
Hebei	Xingtai	1305	1	0	Henan	Luoyang	4103	1	1
Hebei	Baoding	1306	1	1	Henan	Pingdingshan	4104	0	0
Hebei	Zhangjiakou	1307	1	0	Henan	Anyang	4105	1	0
Hebei	Chengde	1308	1	0	Henan	Hebi	4106	0	0
Hebei	Cangzhou	1309	0	0	Henan	Xinxiang	4107	0	0
Hebei	Langfang	1310	0	0	Henan	Jiaozuo	4108	1	0
Hebei	Hengshui	1311	1	0	Henan	Puyang	4109	0	0
Shanxi	Taiyuan	1401	1	1	Henan	Xuchang	4110	0	0
Shanxi	Datong	1402	1	0	Henan	Luohe	4111	0	0
Shanxi	Yangquan	1403	1	0	Henan	Sanmenxia	4112	1	0
Shanxi	Changzhi	1404	0	0	Henan	Shangqiu	4113	0	0
Shanxi	Jincheng	1405	0	0	Henan	Zhoukou	4114	0	0
Shanxi	Shuozhou	1406	1	0	Henan	Zhumadian	4115	0	0
Shanxi	Xinzhou	1408	1	0	Henan	Nanyang	4116	0	0
Shanxi	Luliang*	1409	0	0	Henan	Xinyang*	4117	0	0
Shanxi	Jinzhong*	1410	1	0	Hubei	Wuhan	4201	1	1
Shanxi	Linfen	1411	1	0	Hubei	Huangshi	4202	1	0
Shanxi	Yuncheng	1412	1	0	Hubei	Shiyan	4203	0	0
Inner Mongolia	Hohhot	1501	1	0	Hubei	Yichang	4205	1	0
Inner Mongolia	Baotou	1502	1	1	Hubei	Xiangfan	4206	0	1
Inner Mongolia	Wuhai	1503	1	0	Hubei	Ezhou	4207	1	0
Inner Mongolia	Chifeng	1504	1	0	Hubei	Jingmen	4208	1	0
Inner Mongolia	Hulunbeir*	1507	0	0	Hubei	Huanggang	4209	0	0
Inner Mongolia	Ulanqab*	1510	0	0	Hubei	Xiaogan	4210	0	0
Inner Mongolia	Bayannaoer*	1511	0	0	Hubei	Xianning	4211	1	0
Liaoning	Shenyang	2101	1	1	Hubei	Jingzhou	4212	1	0
Liaoning	Dalian	2102	1	1	Hubei	Suizhou	4215	0	0
Liaoning	Anshan	2103	1	1	Hunan	Changsha	4301	1	1
Liaoning	Fushun	2104	1	0	Hunan	Zhuzhou	4302	1	0
Liaoning	Benxi	2105	1	0	Hunan	Xiangtan	4303	1	0
Liaoning	Dandong	2106	0	0	Hunan	Hengyang	4304	1	0
Liaoning	Jinzhou	2107	1	0	Hunan	Shaoyang	4305	0	0
Liaoning	Yingkou	2108	0	0	Hunan	Yueyang	4306	1	0
Liaoning	Fuxin	2109	1	0	Hunan	Changde	4307	1	0
Liaoning	Liaoyang	2110	1	0	Hunan	Yiyang	4309	1	0
Liaoning	Panjin	2111	0	0	Hunan	Loudi*	4310	1	0
Liaoning	Tieling	2112	0	0	Hunan	Chenzhou	4311	1	0
Liaoning	Chaoyang	2113	0	0	Hunan	Huaihua	4313	1	0
Jilin	Changchun	2201	0	1	Guangdong	Guangzhou	4401	1	1
Jilin	Jilin	2202	1	1	Guangdong	Shaoguan	4402	1	0
Jilin	Siping	2203	1	0	Guangdong	Shenzhen	4403	1	1
Jilin	Liaoyuan	2204	0	0	Guangdong	Zhuhai	4404	1	1
Jilin	Tonghua	2205	1	0	Guangdong	Shantou	4405	1	1

Table B1 (*continued*)

Province	City	Code	TCZ	SPZ	Province	City	Code	TCZ	SPZ
Jilin	Baicheng	2209	0	0	Guangdong	Foshan	4406	1	1
Heilongjiang	Harbin	2301	0	1	Guangdong	Jiangmen	4407	1	0
Heilongjiang	Qiqihar	2302	0	0	Guangdong	Zhanjiang	4408	1	1
Heilongjiang	Jixi	2303	0	0	Guangdong	Maoming	4409	0	0
Heilongjiang	Hegang	2304	0	0	Guangdong	Zhaoqing	4412	1	0
Heilongjiang	Shuangyashan	2305	0	0	Guangdong	Huizhou	4413	1	1
Heilongjiang	Daqing	2306	0	1	Guangdong	Meizhou	4414	0	0
Heilongjiang	Yichun	2307	0	0	Guangdong	Shanwei	4415	1	0
Heilongjiang	Jiamusi	2308	0	0	Guangdong	Heyuan	4416	0	0
Heilongjiang	Qitaihe	2309	0	0	Guangdong	Yangjiang	4417	0	0
Heilongjiang	Mudanjiang	2310	0	0	Guangdong	Qingyuan	4418	1	0
Heilongjiang	Heihe	2311	0	0	Guangdong	Dongguan	4419	1	0
Heilongjiang	Suihua	2314	0	0	Guangdong	Zhongshan	4420	1	1
Shanghai	Shanghai	3101	1	1	Guangdong	Chaozhou	4421	1	0
Jiangsu	Nanjing	3201	1	1	Guangdong	Jieyang	4424	1	0
Jiangsu	Wuxi	3202	1	1	Guangxi	Nanning	4501	1	1
Jiangsu	Xuzhou	3203	1	0	Guangxi	Liuzhou	4502	1	0
Jiangsu	Changzhou	3204	1	1	Guangxi	Guilin	4503	1	1
Jiangsu	Suzhou	3205	1	1	Guangxi	Wuzhou	4504	1	0
Jiangsu	Nantong	3206	1	1	Guangxi	Beihai	4505	0	1
Jiangsu	Lianyungang	3207	0	1	Guangxi	Yulin	4506	1	0
Jiangsu	Yancheng	3209	0	0	Guangxi	Baise	4507	0	0
Jiangsu	Yangzhou	3210	1	0	Guangxi	Hechi	4508	1	0
Jiangsu	Zhenjiang	3211	1	1	Guangxi	Qinzhou	4509	0	0
Jiangsu	Taizhou	3212	1	0	Guangxi	Fangchenggang	4512	0	0
Jiangsu	Suqian	3217	0	0	Guangxi	Guigang	4513	1	0
Jiangsu	Huaian	3221	0	0	Guangxi	Hezhou*	4516	1	0
Zhejiang	Hangzhou	3301	1	1	Hainan	Haikou	4601	0	1
Zhejiang	Ningbo	3302	1	1	Chongqing	Chongqing	5001	1	0
Zhejiang	Wenzhou	3303	1	1	Sichuan	Chengdu	5101	1	1
Zhejiang	Jiaxing	3304	1	0	Sichuan	Zigong	5103	1	0
Zhejiang	Huzhou	3305	1	0	Sichuan	Panzhihua	5104	1	0
Zhejiang	Shaoxing	3306	1	0	Sichuan	Luzhou	5105	1	0
Zhejiang	Jinhua	3307	1	0	Sichuan	Deyang	5106	1	0
Zhejiang	Quzhou	3308	1	0	Sichuan	Mianyang	5107	1	1
Zhejiang	Zhoushan	3309	0	0	Sichuan	Guangyuan	5108	0	0
Zhejiang	Lishui	3310	0	0	Sichuan	Suining	5109	1	0
Zhejiang	Taizhou	3311	1	0	Sichuan	Neijiang	5110	1	0
Anhui	Hefei	3401	0	1	Sichuan	Leshan	5111	1	0
Anhui	Wuhu	3402	1	1	Sichuan	Yibin	5114	1	0
Anhui	Bengbu	3403	0	0	Sichuan	Nanchong	5115	1	0
Anhui	Huainan	3404	0	0	Sichuan	Yaan	5117	0	0
Anhui	Maanshan	3405	1	0	Sichuan	Guangan*	5122	1	0
Anhui	Huaibei	3406	0	0	Guizhou	Guiyang	5201	1	1
Anhui	Tongling	3407	1	0	Guizhou	Liupanshui	5202	0	0
Anhui	Anqing	3408	0	0	Guizhou	Zunyi	5203	1	0
Anhui	Huangshan	3409	1	0	Guizhou	Anshun	5207	1	0
Anhui	Fuyang	3410	0	0	Yunnan	Kunming	5301	1	1
Anhui	Liuan	3413	0	0	Yunnan	Zhaotong	5303	1	0
Anhui	Xuancheng*	3414	1	0	Yunnan	Qujing	5304	1	0

Anhui	Chaohu	3415	1	0	Yunnan	Yuxi*	5306	1	0
Anhui	Chizhou*	3416	0	0	Yunnan	Simao*	5309	0	0
Fujian	Fuzhou	3501	1	1	Yunnan	Baoshan	5312	0	0
Fujian	Xiamen	3502	1	1	Yunnan	Lijiang*	5314	0	0
Fujian	Putian	3503	0	0	Yunnan	Lincang*	5317	0	0
Fujian	Sanming	3504	1	0	Shaanxi	Xian	6101	1	1
Fujian	Quanzhou	3505	1	0	Shaanxi	Tongchuan	6102	1	0
Fujian	Zhangzhou	3506	1	0	Shaanxi	Baoji	6103	0	1
Fujian	Nanping	3507	0	0	Shaanxi	Xianyang	6104	0	1
Fujian	Ningde	3508	0	0	Shaanxi	Weinan	6105	1	0
Fujian	Longyan	3509	1	0	Shaanxi	Hanzhong	6106	0	0
Jiangxi	Nanchang	3601	1	1	Shaanxi	Ankang	6107	0	0
Jiangxi	Jingdezhen	3602	0	0	Shaanxi	Shangluo*	6108	1	0
Jiangxi	Pingxiang	3603	1	0	Shaanxi	Yanan	6109	0	0
Jiangxi	Jiujiang	3604	1	0	Shaanxi	Yulin*	6110	0	0
Jiangxi	Xinyu	3605	0	0	Gansu	Lanzhou	6201	1	1
Jiangxi	Yingtan	3606	1	0	Gansu	Jiayuguan	6202	0	0
Jiangxi	Ganzhou*	3607	1	0	Gansu	Jinchang	6203	1	0
Jiangxi	Yichun	3608	0	0	Gansu	Baiyin	6204	1	0
Jiangxi	Shangrao	3609	0	0	Gansu	Tianshui	6205	0	0
Jiangxi	Jian	3610	1	0	Gansu	Jiuquan	6206	0	0
Jiangxi	Fuzhou	3611	1	0	Gansu	Zhangye	6207	1	0
Shandong	Jinan	3701	1	1	Gansu	Wuwei	6208	0	0
Shandong	Qingdao	3702	1	1	Gansu	Dingxi*	6209	0	0
Shandong	Zibo	3703	1	1	Gansu	Longnan*	6210	0	0
Shandong	Zaozhuang	3704	1	0	Gansu	Pingliang	6211	0	0
Shandong	Dongying	3705	0	0	Gansu	Qingyang*	6212	0	0
Shandong	Yantai	3706	1	1	Qinghai	Xining	6301	0	0
Shandong	Weifang	3707	1	1	Ningxia	Yinchuan	6401	1	0
Shandong	Jining	3708	1	0	Ningxia	Shizuishan	6402	1	0
Shandong	Taian	3709	1	0	Ningxia	Guyuan*	6404	0	0
Shandong	Weihai	3710	0	1	Xinjiang	Urumqi	6501	1	1
Shandong	Rizhao	3711	0	0	Xinjiang	Karamay	6502	0	0
Shandong	Dezhou	3713	1	0					

Cities marked with * are excluded from the regressions which control for GDP per capita due to missing or unreliable GDP information. SPZ denotes the presence of a special policy zone following Wang and Wei (2010).

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