# Environmental Regulation and Industrial Performance: Evidence from China*

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**Abstract**

Sizable evidence in developed countries substantiates considerable costs of environmental regulation on industry profits and productivity levels. We present new evidence that stringent environmental protection policies are likely to provide *positive* forces leading to improved productivity in developing countries, because regulations i) stimulate within-industry selection dynamics through the entry of more efficient and exit of less efficient firms, and ii) create incentives for innovations and/or adoptions of cleaner technologies and enhance productivities. Our findings shed light on productivity growth in regulated industries by the Two Control Zone policy in China. Our evidence supports both selection mechanism and induced technology at work. The findings are robust to inclusions of city- and industry-specific trends and key *ex ante* determinants of firm growth. Supportive of our argument, especially in comparison with spuriously confounding preexisting trends, are performance similarities during the policy's enactment between regulated and non-regulated cities accompanied by their slow growth in productivity over the next several years.

*JEL classifications*: L1, Q5, D2
*Keywords*: environmental regulation, productivity, selection dynamics, induced innovation

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channels partially offset or even lead to net *positive* effect of environmental regulation on industrial performance.

Our empirical strategy is designed to estimate the effect of TCZ regulations on industrial activities for different levels of pollution and energy intensities. Essentially, it is based on a difference-in-differences framework exploiting two sources of variation in regulatory intensity across cities and industries: firms located in TCZ cities are subject to relatively more stringent environmental regulations than those in non-TCZ cities, whereas pollution-intensive firms are affected more than non-polluting firms within a city. Importantly, this approach allows the estimated regulation effect to be purged of industry- and city-specific trends. This rectifies shortcomings associated with (a) a simple comparison between TCZ and non-TCZ cities capturing heterogeneities other than TCZ regulatory status (i.e., differential patterns of economic growth across cities), and (b) a simple comparison between polluting and non-polluting industries that confounds factors causing differential mean growth (i.e., demand or supply shocks).

To implement the analysis, we use plant-level data from the Annual Surveys of Industrial Production (ASIP) from 1998 through 2005, collected by the National Bureau of Statistics of China. The ASIP provides detailed annual financial and operational data for the census of state-owned firms and all non-state-owned firms with annual revenues above five million yuan.[2] We use the plant's location at the county level to identify its TCZ status, reported by the State Council. We also collected information on industry-level pollution intensity, measured by the share of coal consumption or sulfur dioxide ($SO_2$) emissions, and energy-intensity, measured by the share of energy consumption, from the National Bureau of Statistics of China. This complete dataset includes more than one million plant-by-year observations across 33 power and manufacturing industries.

Such a unique and comprehensive dataset adds credibility to our analysis in two ways. First, the longitudinal nature of the dataset allows us to trace individual firms throughout the period and to observe market dynamics via their entries and exits. Second, detailed information on various facets of firms' activities allows us to carry out a comprehensive analysis of regulation effects (i.e., sales, profits, return of assets, return on equity, return on capital employed, net income, and total factor productivity). Many previous studies, on the other hand, have looked at

[2] The yuan appreciated substantially after our study period, and currently $1 USD is worth about 6 yuan. The five million yuan threshold is based upon the nominal value of revenues, and using the then exchange rate, five million yuan was worth about $600,000 in the 1998-2005 period.

only a single variable, e.g., an abatement cost or employment, to measure the cost of regulations. However, if compliance with environmental regulations can spur better industrial performance, such benefits may partially or fully offset compliance costs.

Our findings highlight substantial improvements in performance in pollution-intensive industries, suggesting that the regulations had *positive* effects on productivity and competitiveness. In particular, firms in pollution-intensive industries are associated with higher revenues in TCZ cities, holding their energy consumption constant. Importantly, this effect is evident across many specifications, a variety of alternative measures of industrial performance, and an alternative measure of pollution intensity.

Further analyses provide evidence in support of both selection mechanisms and induced innovation at work. For instance, the environmental regulation have encouraged greater selection dynamics by inducing entries of more productive firms and exits of less productive ones. Also, in an effort to illustrate productivity dynamics via induced innovation free from selection mechanism, we use the balanced panel observations and find some lags in the inception of productivity growth for firms in TCZ cities with initial characteristics similar to their counterparts.

In addition, we simultaneously test whether the TCZ regulatory policy had an ciency were slow and occurred over several years is supportive of our argument, especially in comparison with spuriously confounding preexisting trends.

The rest of the paper is structured as follows. Section II provides background on related tional markets. There is indeed substantial evidence in the U.S. Clean Air Act is associated with distortions in productivity (Gollop and Roberts 1983; Barbera and McConnell 1990; Greenstone, List, and Syverson 2012), firm's location decisions (Henderson 1996; Becker and Henderson 2000; List et al. 2003); employment (Greenstone 2002; Deschenes 2010; Walker 2011; Walker 2012); and foreign direct investment inflows and outflows (Keller and Levinson 2002; Eskeland and Harrison 2003; Hanna 2010).[4]

This paper both extends and departs from the previous literature in a fundamental way. We present new evidence supporting a more recent perspective on

- Average annual pH values for precipitation were less than or equal to 4.5,
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100 tons of emissions per year reduced their $SO_2$ emissions to the standard between 1998 and 2000 among TCZs (He, Huo, and Zhang 2002). This translated into improved overall air quality; Tanaka (2014) shows that air pollution, as measured by TSP concentration and $SO_2$ concentration, fell relatively more in TCZ cities between 1991 and 2000. Between 1998 and 2005, the number of prefectures in the $SO_2$ pollution control zone (the acid rain control zone) meeting the Class II standard rose by 12.3 (3.3) percent, those meeting the Class III standard increased by 4.2 (7.9) percent, and those not meeting the Class III standard fell by 16.5 (11.2) percent (United Nations Environment Programme 2009).

Lastly, increasing number of firms was equipped with green technologies. By the end of 2000, the total power capacity with FGD equipment exceeded 10,000MW.

## D. Variation in Regulatory Stringency

This subsection descri

We restrict the sample in our main analysis in two ways. First, it is restricted to the manufacturing sector (which consists of 30 industries and accounts for 91.4% of the original data) and the power sector (which consists of 3 industries and accounts for 4% of the original data). Second, we restrict the sample to firms whose total number of units of industrial activity is one, allowing the main analysis to focus on observations at the plant level. The original dataset contains information regarding geographical location for the firm, in some cases where headquarter is located, but does not identify exact locations of each plant. This causes measurement error in determining the extent to which a firm is effectively regulated under the TCZ policy, when multiple plants operate in both TCZ and non-TCZ cities. The majority of the original sample (86.7%) is indeed plant-level observations.

*TCZ Information* – The TCZ regulatory status is reported in the document "Official Reply to the State Council Concerning Acid Rain Control Areas and Sulfur Dioxide Pollution Control Areas," published by the State Council in 1998. The document lists the names of all places that were designated either acid rain control zone or $SO_2$ control zone (Figure A1). We follow Tanaka (2014) in determining the TCZ status at the county level. The assignment was made primarily at the county level, which can be directly linked to ASIP. If the assignment was made at the prefecture level, all districts and cities that belong to the prefecture are given the same TCZ status assigned to the prefecture. The document states that impoverished counties are exempt from the regulations, even when they belong to a TCZ prefecture. Most prefectures specify exact counties that are or are not exempted, but when the names of exempted counties are not listed, we eliminate observations in these hesehese se07eimeiahes(t) 0.2 henot-0.2 (os)(s) -0.2 ( (l) 0.2) -69.4 (t) 0.2 (h

China.[12] An industry-level pollution-intensity is measured based on the national share of $SO_2$ emissions, or the national share of coal consumption. Coal consumption is highly correlated with emissions, as coal is a primary contributor of $SO_2$. Accordingly, the TCZ policy imposed strict requirements for the use of less polluting coals and the adoption of technologies to clean coal. Industry-level energy-intensity is measured by the national share of energy consumption.

## B. Descriptive Statistics

In total, we have a sample of close to 140,000 firms in 1998 up to more than 250,000 firms in 2005, with 33 two-digit industries over the period of 1998 through 2005, resulting in a total of more than one million firms-by-year observations. The economic variables used in the

Overall, the panel structure of our dataset allows us to circumvent many endogeneity issues. In particular, estimated regulation effects are robust to unobserved transitory determinants of growth common in both more and less polluting industries and unobserved factors contributing to a firm's growth within a city whose effects are allowed to vary over time.

It is worth mentioning that the above efforts may help purge many potential sources of bias, if not all. There may be several other sources of bias. Namely, one of the key remaining issues would be differences in the permanent characteristics associated with polluting firms in TCZ cities. The inclusion of firm fixed effects is unfortunately not feasible because of multicolinearity with the time-invariant [illegible] values of the coefficients imply that the TCZ regulation led to an increase in the outcome vari

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bles follow the literature on firm productivity and growth (Dunne, Roberts, and Samuelson 1989; Greenstone 2002; Huang, Jin, and Qian 2013). The results are presented in column (3). The magnitude of the coefficient drops by about 23.8 percent, indicating that these variables help capture a large share of the differences in latent firm's productivity advantages but not completely—it continues to suggest that polluting firms received positive effects from the environmental regulation.

The results presented so far shed light on a strong positive association between TCZ policy and total revenues, but how will the revenues eventually be affected? We provide suggestive evidence by adding capital and labor based on the basic production function laid out in equation (1). Note that these two variables are both endogenous to the policy effect; any changes in the coefficients of interests should thus be interpreted as indicating that changes in capital and labor play a key role through which the environmental regulation affected overall revenues. The results are shown in column (4). Both capital and labor variables have reasonable signs and statistically significant effects on revenues at the 1 percent level. The coefficient of the interaction term between pollution intensity and TCZ status almost halves, suggesting that adjustments in these two important inputs have been made in response to the regulation. On the other hand, the coefficient remains highly significant, suggesting that there are other important mechanisms at work that improved the overall performance among polluting industries other than labor and capital adjustments. The result in column (5), which controls for initial differences at the key city-by-industry level adds support that these controls do not confound the effect.

Our identification strategy hinges on the relative similarity of performance between polluting firms in TCZ cities and polluting firms in non-TCZ cities, after controlling for mean differences between TCZ and non-TCZ cities (this interpretation is illustrated in equation 4). A major limitation in this analysis is that we do not have observations prior to the policy implementation. The notion that the better performance by polluting firms in TCZ cities reflects a causal impact of environmental regulation would be supported if the improvement does not reflect preexisting differences or heterogeneous pre-trends in performance. We look for such evidence by illustrating the dynamic effect on performance over this time period. In Figure 1, we plot on the y-axis the coefficients of the interaction term of TCZ status with pollution intensity in Panel A and

and others, such as foreign-owned firms. We compute their averages (and thus the share of firms under respective type) wh -4 (e) n28.16003cm BT 0.050.2 (ut)( ) -13 e with energy intensity in Panel B over the years on the x-axis, estimated from separate regressions by each year. All regressions control for industry and city fixed effects, initial industry-city characteristics and firm's characteristics to account for mean differences across cities and industries and adjustments through these variables.

If the improved performance estimated above was a mere reflection of a preexisting trend, we would expect to see a difference during the initial years. Or, if the environmental regulation indeed resulted in lower performance among polluting firms in TCZ cities, while their revenues remained higher than their counterparts in non-TCZ cities due to their initial differences, we would expect to see a gradual downward movement over the years, starting from substantially higher performance to somewhat lower. Both cases would produce (spurious) positive estimates in the main analysis.

Figure 1 demonstrates two important facts contrasting with these alternative hypotheses. First, it shows that polluting firms in TCZ out specifying critical details until later, thereby largely leaving implementation up to the local governments or individual firms.[15]

An increasing trend among pollution-intensive industries and a decreasing trend among energy intensive industries suggests that even taking account of variation in performance over time does not essentially alter the results. In particular, suppose we use the observation in 1998 as “pre-”reform evidence. In this case, the analysis is on a par with difference-in-differences-in-differences (DDD), where we regress the performance measure on the triple-interaction term between pollution (or energy) intensity, TCZ status, and pre-post observations based on;

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all, these findings using extensive measures with a variety of controls substantiate the improved performance among polluting firms in response to the environmental regulation.

## C. Effect on Firm Turnover and Selection Dynamics

The preceding subsections focus on the overall effect of the environmental regulation on industrial performance. These analyses, on the other hand, mask the dynamic effects of firms' entries and exits. In this subsection, we explore the behaviors of market dynamics. The longitudinal nature of our dataset using the unique firm identification allows us to exactly identify the year when each firm entered or exited the market. An "entry" is defined as:

again not consistent with an alternative hypothesis that polluting industries that are more profitable are likely to stay in TCZ cities, which spuriously creates a positive association between productivity and the interaction term. Instead, it is consistent with evidence that compliance costs associated with the environmental regulations are higher for firms that are more polluting to begin with, and thereby are more likely to exit the market.

Interestingly, the coefficients on energy-intensive firms are negative and significant, which is consistent with the previous finding that such firms would often remained in the market even while suffering from lower performance. These findings suggest that stagnated productivities with respect to financial outcomes may not be a key determinant of exit decisions for energy-intensive firms over the short-term period; rather, the expected long-term costs, along with short-term complying costs generated from environmental regulation, were a main factor affecting firm's exit decisions.

Evidence that the regulation had impacts on firms' entry and exit behaviors warrants a further analysis on how those firms that entered (exited) had behaved after (before) the market entry (exit). In column (5), we repeat the main analysis using only entrants: firms that were not in the market in 1998 and entered afterward. The coefficient represents the comparison of performance between TCZ and non-TCZ cities within the same industries. Because the control group is also comprised of entrants, estimated impacts are purged of any characteristics common to potential entrants so long as they are not correlated with TCZ status. The positive coefficient on polluting industries indicates that TCZ-city entrants performed better than those in non-TCZ cities, which is consistent with the conjecture of greater barriers to entry due to stricter environmental protection. At the same time, we find a negative coefficient on energy intensity, indicating that newly embarking firms did worse in the TCZ cities, refuting an alternative hypothesis that entrants to TCZ cities inevitably or innately perform better.

Column (6) focuses on dropouts: firms that exited the market at some point during the study period. The inclusion of city-by-year fixed effects and industry-by-year fixed effects controls for a number of factors driving firms out of the market. Namely, time-variant shocks at the city levels or time-variant industry-level shocks are controlled for. Further, our analysis of the comparison of dropouts between TCZ and non-TCZ cities controls even lower performance in TCZ cities, possibly due to the heavy compliance costs they already incurred.[18]

In sum, we find that greater market dynamics through entry and exit serve as an important selection control for various other adjustments in

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intensive) firms had greater *growth* (or *declines*) over time, even after taking into account of initial heterogeneities.

While these graphical illustrations are informative, we then formally test whether there existed any *ex-ante* disparities in performance. Specifically, we assess the effect of environmental regulation on performance from when the policy was introduced in 1998. Given the plausible notion that adjustments in response to heavy environmental protection take several years, especially in China where the government often sets targets without specifying details on attaining them, the observations in 1998 are likely to offer insights on how the firms behaved in the preceding years.

It is worth noting here before presenting the results that positive estimates have mixed inferences, indicating either initial differences in performance or the immediate impact of the regulation after one year (remember our dataset observes end-of-year financial estimates). On the other hand, the similarity in characteristics (i.e., non-significant estimates or even negative estimates) provides a strong signal against concern that the main analysis is positively biased.

As it turns out, Table 5 column 1 shows an even worse performance among polluting firms in TCZ cities. Figure 2 suggests that we can expect similar estimates even for a balanced panel using the subsample of firms staying in business throughout the period and thus performing well. The finding provides added support to the identification strategy because it rejects an alternative hypothesis that polluting firms had better economic performance in TCZ cities in the first place even in the absence of the regulation. Rather, the evidence suggests that inferences from the main findings do not alter even after controlling for initial differences.

This finding helps overcome two shortcomings inherent in our analysis. One is that we do not observe performance in years prior to the policy reform. The other is that there are technically no industries that are free from regulation impacts, making us unable to formulate a counterfactual. The finding suggests, if anything, that bias arising from these two channels goes against the findings in the main analysis.

## B. Price Effect

Our use of extensive profitability measures in assessing business performance offers insights on productivity effects. However, an important component embodied in these measures is idiosyncratic demand shocks within industries. For example, Foster, Haltiwanger, and Syversion (2008) argue that plant-

their performance in response to the environmental regulations. Additional evidence suggests that enhanced industrial performance is driven both by greater market dynamics via the entry of efficient firms and the exit of low-productivity firms, and by induced innovation among existing firms. The results are robust to various specifications, measures of productivity, and inclusions of city-by-year fixed effects, industry-by-year fixed effects, and pre-determined characteristics of a firm's growth at the industry-city level.

Our findings offer two major insights on the future prospect of environmental protection in China and other developing countries. First, although the direct effect of environmental protection, measured by compliance costs, may not be trivial, changes in the industry composition and induced innovation can give rise to net positive improvements in productivity and competitiveness within domestic industries. This is particularly true when the economy initially has extensive resource misallocation. Second, when the power sector is subject to stringent environmental regulations, as is often the case with developing countries, energy-intensive firms are likely to receive negative externality effects for a given level of pollution intensity. Within this context, it would be interesting to investigate differential incentives and barriers to adopting clean and energy-efficient technologies, and/or policies promoting the development and deployment of these technologies.

Our findings may be unique to circumstances in developing countries; various studies found that the U.S. Clean Air Act depressed competitiveness of U.S. manufacturing firms. However, our finding on the selection dynamics driven by environmental regulation may still be noteworthy. For academic purposes, the overall cost of environmental protection may be overstated by focusing on an existing firm (or plant) without taking into account a firm's turnover. For the purpose of policy design, environmental standards, such as New Source Performance Standards set by the US Environmental Protection Agency, often target newly entering firms, while existing firms are exempt from the rule. In designing a policy, policymakers need to be aware of the potential roles played by new entrants when setting a standard and need to pay more attention to incentives for technology adoption among new and existing firms.

, since overtaking the United States in 2005 and produced more than 20 percent of the world's emissions in 2008. Our finding - that stringent environmental regulation may spur productivity growth - is new and striking. This study presents substantial policy implications, not only for future environmental protection in China but also for mitigating global worming.

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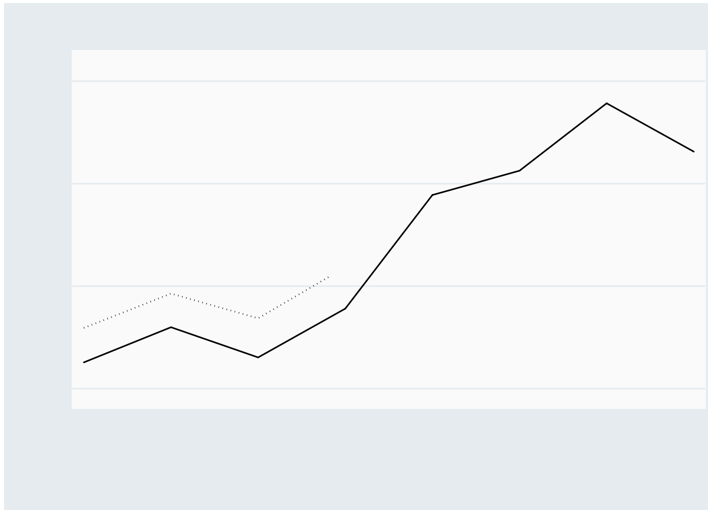
Figure 1: Dynamic Effect of Environmental Regulation

Panel A



Panel B

*Notes*: These figures present the coefficients of the interaction term based on equation 2 of pollution intensity in Panel A and of energy-intensity in Panel B and their 90% confidence interval, from separated regressions by year. The dependent variable is log of total revenues. All regressions control for initial industry-city characteristics as well firm's characteristics (capital, labor, asset, age, dummy of state ownership, leverage, and capital intensity). The sample covers the entire observations. Standard errors are clustered at the industry-city level.

Figure 2

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Table 1: Descriptive Statistics of Key Variables

| Variables | Obs. | Mean | Std. Dev. |
|---|---|---|---|
| Revenues | 1,133,821 | 56,057.18 | 457,823.49 |
| Profits | 1,133,839 | 2,429.30 | 41,888.42 |
| ROA | 1,136,103 | 0.11 | 0.34 |
| ROE | 1,136,103 | 0.22 | 0.77 |
| ROCE | 1,136,103 | 0.31 | 0.79 |
| Net income | 1,136,103 | 2,361.82 | 42,544.76 |
| Capital | 1,133,324 | 16,212.70 | 112,342.87 |
| Labor | 1,136,101 | 253.14 | 761.45 |
| Asset | 1,120,791 | 64,229.70 | 572,319.89 |
| Age | 1,103,556 | 9.41 | 10.51 |
| Capital intensiveness | 1,120,847 | 87.22 | 993.62 |
| State ownership | 1,136,103 | 0.22 | 0.41 |
| Leverage | 1,119,529 | 0.62 | 0.54 |
| Firms in TCZ | 1,136,103 | 0.69 | 0.46 |
| Share of coal consumption | 1,136,103 | 0.02 | 0.04 |
| Share of $SO_2$ consumption | 1,136,103 | 0.02 | 0.05 |
| Share of energy consumption | 1,136,103 | 0.03 | 0.04 |

*Notes:* The level of observation is at firm-by-year over the period of 1998-2005 for 138,617 firms in 1998, growing up to 250,844 firms in 2005. All monetary values are in constant thousand of 2000 RMB. ROA is returns on assets, calculated by the ratio of profits to the beginning-of-year assets, ROE is returns of equity, calculated by profits divided by equity ownership rights, ROCE is returns on capital employed, calculated

Table 2: Effect of TCZ Policy on Industrial Performance

| | *Dependent var*: Ln(Revenue) | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | |
| Coal Share TCZ | 1.353*** | 3.621*** | 2.761*** | 1.718*** | 1.318*** |
| | (0.173) | (0.229) | (0.246) | (0.188) | (0.213) |
| Energy Share TCZ | | -4.132*** | -3.574*** | -1.611*** | -1.405*** |
| | | (0.249) | (0.287) | (0.188) | (0.222) |
| Ln(Capital) | | | | 0.252*** | 0.252*** |
| | | | | (0.00204) | (0.00250) |
| Ln(Labor) | | | | 0.598*** | 0.594*** |
| | | | | (0.00319) | (0.00387) |
| Constant | 10.65*** | 10.66*** | 12.82*** | 5.172*** | 6.288*** |
| | (0.0695) | (0.0693) | (1.947) | (0.0579) | (1.307) |
| Observations | 1,107,642 | 1,107,642 | 842,792 | 1,093,171 | 831,734 |
| R-squared | 0.224 | 0.225 | 0.245 | 0.591 | 0.596 |
| City-by-Industry controls | No | No | Yes | No | Yes |
| City-by-Year FE | Yes | Yes | | | |

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Table 3: Effect of TCZ Policy on Industrial Performance using Alternative Measures

Table 4: Effect on Firm Turnover and Selection Dynamics

| Dep. Var. | Enter1 | Enter2 |
| --- | --- | --- |

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Table 5: Testing Alternative Hypotheses

| Dep. Var. | | Ln(Revenue) | TFPQ | TFPR | Ln(Revenue) | Ln(Revenue) | Ln(Revenue) |
|---|---|---|---|---|---|---|---|
| Sample | | 1998 | All | All | State-owned | Private | All |
| | | (1) | (2) | (3) | (4) | (5) | (6) |
| Coal Share | TCZ | -0.620*** | 2.779*** | 0.555*** | 0.457*** | 1.261*** | 0.765*** |
| | | (0.212) | (0.267) | | | | |

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Table 6: Robustness Check with Using $SO_2$ Share for Pollution Intensity

| | | *Dependent var*: Ln(Revenue) | | | | |
|---|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) | (5) |
| $SO_2$ Share | TCZ | 1.426*** | | | | |

**NOT FOR PUBLICATION**

# Environmental Regulation and Industrial Performance: Evidence from China

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# Online Appendix I

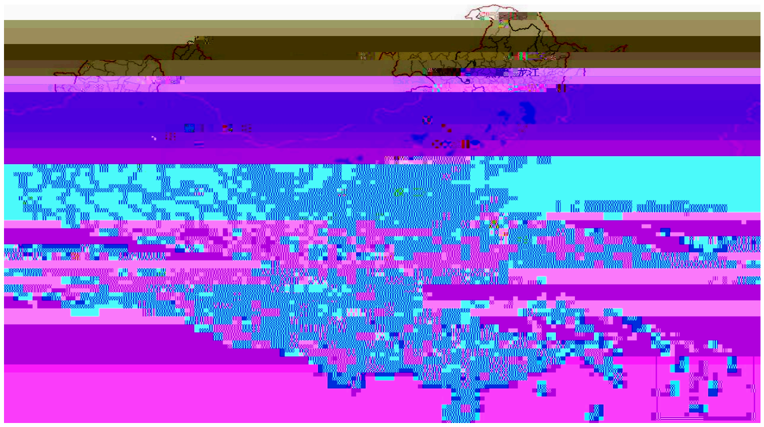
Table A1: Pollution and Energy Intensity, by industry

| Code | Industry | $SO_2$ |
| --- | --- | --- |

# Online Appendix II

# Online Appendix III

Figure A1: Distribution of Two Control Zones



*Notes*: The green shaded prefectures represent $SO_2$ Control Zone, and the red shaded prefectures represent Acid Rain Control Zone, designated by the Two Control Zone policy in 1998.
*Source*: China Atlas of Population and Environment (1990-1999).

# Online Appendix IV

Table A2: Effect of TCZ Policy on Industrial Performance using $SO_2$ Emission as Pollution Intensity

| | *Dependent variable* | | | | |
|---|---|---|---|---|---|
| | Profits | ROA | ROE | ROCE | Net Income |
| | (1) | (2) | (3) | (4) | (5) |
| *Panel A: With no control* | | | | | |
| $SO_2$ Share TCZ | 41,565*** | 0.0399* | 0.0880 | 0.0529 | 34,147*** |
| | (10,359) | (0.0232) | (0.0611) | (0.0494) | (9,109) |
| Energy Share TCZ | -19,428** | 0.0364 | 0.0818 | 0.103 | -14,239** |