# Going Green in China: Firms' Responses to Stricter Environmental Regulations

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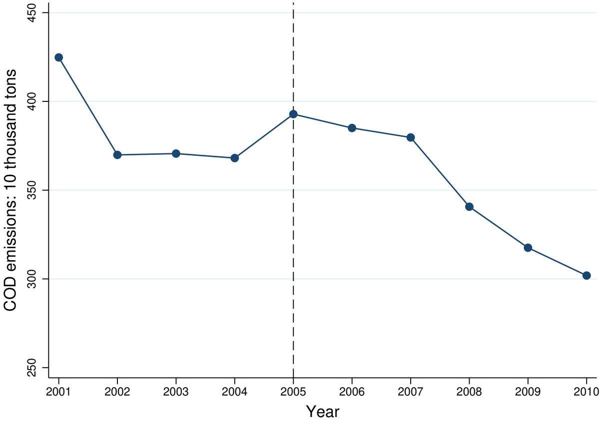
# Introduction

- The central government of China set a national emission cap starting from the 9th Five-Year Plan in 1996.
- Emissions target controls in China mainly focus on "critical pollutants" by setting national reduction targets followed by top-down subdivision from the central government to provinces then to cities.
- However, the program hasn't been seriously treated.The emissions reduction goal wasn't accomplished during the 9th Five-Year Plan period or in the term that followed.

Figure A1: Chemical Oxygen Demand Emissions in Chinese Manufacturing



# Introduction

- The turning point emerges in the 11th Five-Year Plan from 2006.
- The government substantively strengthened the emissions target control scheme in the 11th Five-Year Plan period from 2006 to 2010.
  - Evaluate the performance of government officers in fulfilling their duties relating to the emissions mandates, with potential impacts on their accountability and promotion.
- Moreover, other complementary regulations, such as Statistical Measures on Critical Pollutants Emissions Control Target and Interim Verifying Measures on Critical Pollutants Emissions Control Target, were enacted in 2006.
- As a result, the 10% reduction target of two "critical pollutants"—COD and SO2—lower than 2005 level was successfully achieved.

# Features of Emission Target Control in China

- Nationwide application and implementation through governments hierarchy.
- Differentiated emission targets for different provinces and cities by taking into account of their population, economic size, industrial structure, past emissions, and environmental quality.
- Varied regulation stringency reasonablly refected by their assigned emission target.

# the Plan for Controlling the COD I

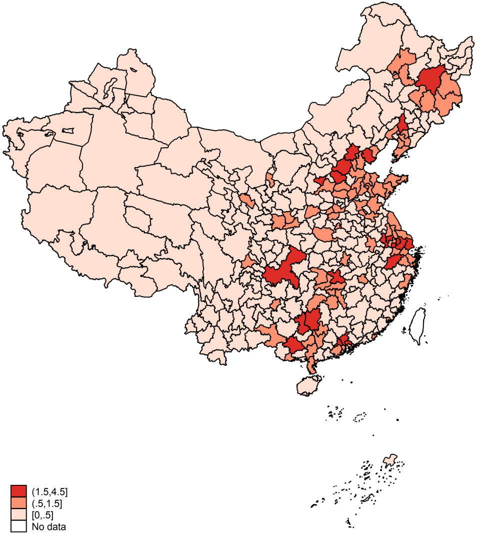
| area | Emission 2005 | Emission Cap 2010 | Rate (%) |
|---|---|---|---|
| Beijing | 11.6 | 9.9 | -14.7 |
| Tianjin | 14.6 | 13.2 | -9.6 |
| Hebei | 66.1 | 56.1 | -15.1 |
| Shanxi | 38.7 | 33.6 | -13.2 |
| Inner Mongolia | 29.7 | 27.7 | -6.7 |
| Liaoning | 64.4 | 56.1 | -12.9 |
| Dalian | 6.01 | 5.05 | -16.0 |
| Jilin | 40.7 | 36.5 | -10.3 |
| Heilongjiang | 50.4 | 45.2 | -10.3 |
| Shanghai | 30.4 | 25.9 | -14.8 |
| Jiangsu | 96.6 | 82.0 | -15.1 |
| Zhejiang | 59.5 | 50.5 | -15.1 |
| Ningbo | 5.22 | 4.44 | -14.9 |
| Anhui | 44.4 | 41.5 | -6.5 |
| Fujian | 39.4 | 37.5 | -4.8 |
| Xiamen | 5.56 | 4.94 | -11.2 |
| Jiangxi | 45.7 | 43.4 | -5.0 |
| Shandong | 77.0 | 65.5 | -14.9 |
| Qingdao | 5.79 | 4.75 | -18.0 |

# the Plan for Controlling the COD II

| area | Emission 2005 | Emission Cap 2010 | Rate (%) |
|---|---|---|---|
| Henan | 72.1 | 64.3 | -10.8 |
| Hubei | 61.6 | 58.5 | -5.0 |
| Hunan | 89.5 | 80.5 | -10.1 |
| Guangdong | 105.8 | 89.9 | -15.0 |
| Shenzhen | 5.59 | 4.47 | -20.0 |
| Guangxi | 107.0 | 94.0 | -12.1 |
| Hainan | 9.5 | 9.5 | 0 |
| Chongqing | 26.9 | 23.9 | -11.2 |
| Sichuan | 78.3 | 74.4 | -5.0 |
| Guizhou | 22.6 | 21.0 | -7.1 |
| Yunnan | 28.5 | 27.1 | -4.9 |
| Tibet | 1.4 | 1.4 | 0 |
| Shaanxi | 35.0 | 31.5 | -10.0 |
| Gansu | 18.2 | 16.8 | -7.7 |
| Qinghai | 7.2 | 7.2 | 0 |
| Ningxia | 14.3 | 12.2 | -14.7 |
| Xinjiang | 27.1 | 27.1 | 0 |
| Jianshebingtuan | 1.43 | 1.43 | 0 |
| Total | 1414.2 | 1263.9 | -10.6 |

# Varied Regulation Stringency

Figure 2: City-Level Regulation Stringency of COD (10 Thousand Tons)



# Our main concern

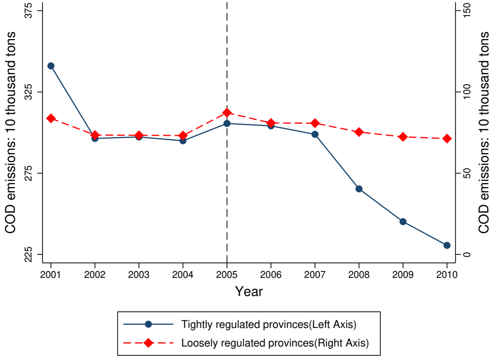
- First, whether there is an important role for environmental regulation in emission reduction
    - The causal effects between environmental regulation stringency and firms' responses, and how it varied across industries.
- Second, how firms respond, economically, environmentally and innovatively, to environmental regulations.

# What do we do and find?

- Difference-in-difference (DID) strategy to study the effect of environmental regulation stringency. We find that, more stringent environmental regulations induced greater probability of reducing COD emissions after 2006.
- A with-in firm decomposition shows that around 30% of reduction can be explained by within-firm "scale effect", whereas 70% can be explained by within-firm "technique effect"
- Heterogeneous effects across the firms in industries with different polluting intensity.
- Mechanisms
  - Firm's recycling practice
  - Adoption of pollution abatement facilities
  - Technological progress
- Examine the economic impacts on firms.

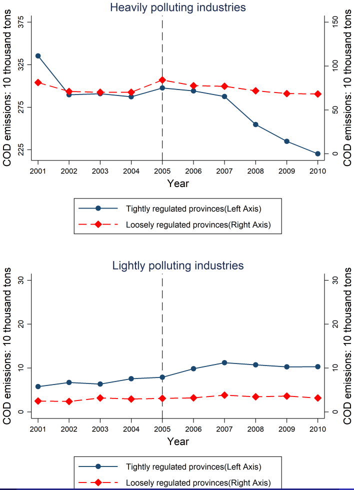
# Stylized Facts

Figure 1: COD Emissions in Manufacturing in Tightly and Loosely Regulated Provinces



# Stylized Facts

Figure 2: COD Emissions in Manufacturing with Different Pollution Intensities in Tightly and Loosely Regulated Provinces



# Stylized Facts

- *Stylized fact 1. In response to different environmental regulation stringency, firms in tightly regulated regions reduce more pollutants than those in loosely regulated regions.*
- *Stylized fact 2. The effect of environmental regulation stringency on firms' COD emissions varied across industries with different polluting intensity. Industrial polluting intensity positively reinforces the effect of environmental regulation stringency on firms' pollution reduction.*

# A Statistical Decomposition

- Manufacturing pollution

$$P = \sum_s p_s = \sum_s y_s e_s = Y \sum_s v_s e_s. \qquad (1)$$

where $v_s$ indicates to each industry's share of total output

- In vector notation

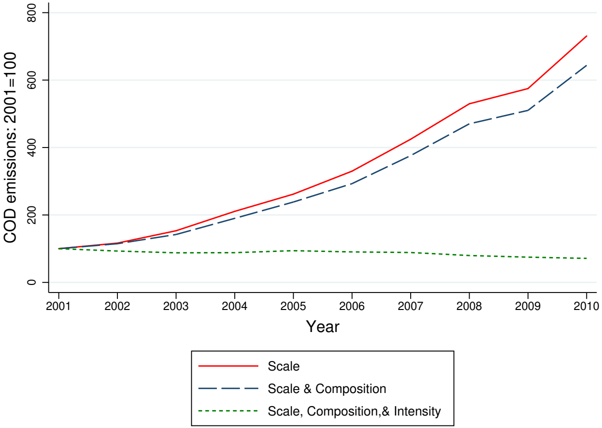
$$P = Yv'e, \qquad (2)$$

- Differentiating Equation 2 totally, we obtain

$$dP = \underbrace{v'edY}_{\text{Scale Effect}} + \underbrace{Yedv'}_{\text{Composition Effect}} + \underbrace{Yv'de}_{\text{Technique Effect}}. \qquad (3)$$

# A Statistical Decomposition

Figure 3: Decomposition of the Three Main Effects Causing COD Emissions



# A Statistical Decomposition

- *Stylized Fact 3. "Composition effect" (adjustment of market share of each industry) and "technique effect" (lowered pollution intensity brought by technological progress) are both responsible for a decline of COD emissions from Chinese manufacturing upon stricter environmental regulations. The environmental improvement is, however, mostly brought about by "technique effect".*

# Empirical Specification

- DID strategy

$$y_{it} = \beta_1 \mathrm{R}_c \times \mathrm{Post}_t + \gamma \mathrm{Z}_{c,t-1} + \varphi_i + \varphi_t + \epsilon_{it}, \qquad (4)$$

  - $y_{it}$, refers to firm $i$'s pollution-related activities, including log value of COD, output, and pollution intensity at year $t$.
  - $R_c$ is a measure of environmental regulation stringency denoted by the total COD reduction target mandated by the $11^{th}$ Five-Year Plan for city $c$ from 2006 to 2010.
  - $Post_t$ is a dummy variable equals to 0 for all years before 2006, and to 1 from 2006 and onward. A vector of city-level characteristics $Z_{c,t-1}$
  - $\varphi_i$ and $\varphi_t$ are firm fixed effect and year fixed effect
  - $\epsilon_{it}$ is the standard errors clustered at city level

# Empirical Specification

- We follow Chen et al. (2018) to construct emissions reduction targets at the city level $R_c$

$$\Delta COD_{c,05-10} = \Delta COD_{p,05-10} \times \sum_{i=1}^{39} u_i \frac{\text{output value of industry } i \text{ in city } c}{\text{output value of industry } i \text{ in province } p}, \tag{5}$$

- Noted that we use equation (5) rather than the actual COD emissions of each city due to the endogeneity concern.
- In addition, we use the proportion of a city's actual COD emissions in its province for robustness check, which is specified as follows,

$$\Delta COD_{c,05-10} = \Delta COD_{p,05-10} \times \frac{P_{c,2005}}{\sum_{j=1}^{J} P_{j,2005}} \tag{6}$$

# Empirical Specification

- To investigate the varied reaction of firms across industries with different pollution intensity, we further run a DDD regression:

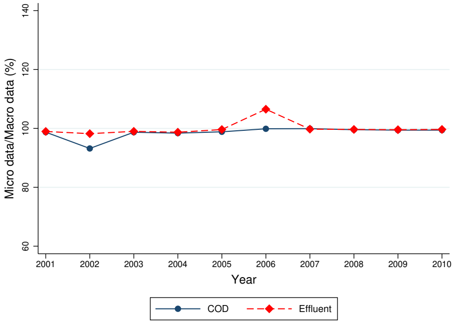
$$\begin{aligned} y_{it} = & \beta_1 \mathrm{R}_c \times \mathrm{Post}_t + \beta_2 \mathrm{R}_c \times \mathrm{Post}_t \times \mathrm{Dirty}_s + \beta_3 \mathrm{Dirty}_s \times \mathrm{Post}_t \\ & + \gamma \mathrm{Z}_{c,t-1} + \varphi_i + \varphi_t + \epsilon_{it}, \end{aligned} \tag{7}$$

where $Dirty_s$ is the industrial polluting intensity.

# Data Description

- Firms' Pollution Data
  - The data on firms' pollution emissions come from Annual Environmental Survey of Polluting Firms (AESPF) of China from 2001 to 2010.

Figure 4: Comparison between Micro-Data and Macro-Data on COD and Effluent



# Data Description

- Other Firm-Level Data
  - Firms' economic performance data is from the Annual Survey of Industrial Firms (ASIF) maintained by the National Bureau of Statistics of China (NBSC)
  - The green patent data we use comes from the Chinese Patent Dataset, maintained by the China National Intellectual Property Administration (CNIPA)
  - Environmental administrative penalties data from the Institute of Public and Environmental Affairs (IPEA)
  - Firms' relocation data from the State Administration of Industry and Commerce (SAIC) database in China.

# Main Results

- We follow Martin (2011) to decompose the within-firm sample as follows:

$$e_{i,t} = y_{i,t} \times \frac{e_{i,t}}{y_{i,t}} \tag{8}$$

- Taking the log of both sides of equation 8, we have:

$$\Delta log(e_{i,t}) = \underbrace{\Delta log(y_{i,t})}_{\text{Scale Effect}} + \underbrace{\Delta log(\frac{e_{i,t}}{y_{i,t}})}_{\text{Technique Effect}} \tag{9}$$

# Main Results

Table 2: Baseline Results

| | COD | | Output | | $\frac{\text{COD}}{\text{Output}}$ | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $R_c \times Post_t$ | -0.063*** | -0.073*** | -0.021* | -0.022* | -0.043* | -0.051** |
| | (0.022) | (0.018) | (0.012) | (0.012) | (0.025) | (0.021) |
| Log GDP per capita | | 0.386 | | 0.042 | | 0.345 |
| | | (0.305) | | (0.064) | | (0.349) |
| Log Population | | -0.099 | | 0.043 | | -0.142 |
| | | (0.116) | | (0.058) | | (0.131) |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 437,253 | 437,253 | 437,253 | 437,253 | 437,253 | 437,253 |
| Adj R-Square | 0.800 | 0.801 | 0.885 | 0.885 | 0.782 | 0.782 |

# Main Results

Table 3: Other Pollutant Results

| | NH3-N | | $\frac{NH3-N}{Output}$ | | Smoke and Dust | | $\frac{\text{Smoke and Dust}}{\text{Output}}$ | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $R_c \times Post_t$ | 0.013 | 0.014 | 0.038 | 0.042 | -0.002 | -0.008 | 0.024 | 0.025 |
| | (0.040) | (0.041) | (0.036) | (0.036) | (0.045) | (0.042) | (0.044) | (0.041) |
| City-level Controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 232,430 | 232,430 | 232,430 | 232,430 | 169,432 | 169,432 | 169,432 | 169,432 |
| Adj R-Square | 0.777 | 0.777 | 0.770 | 0.770 | 0.842 | 0.842 | 0.822 | 0.822 |

# Heterogeneous Effects by Industry

Table 4: Heterogeneous Results

| | COD | | Output | | $\frac{COD}{Output}$ | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $R_c \times Post_t$ | -0.041* | -0.051** | -0.010 | -0.012 | -0.031 | -0.039* |
| | (0.025) | (0.020) | (0.012) | (0.012) | (0.026) | (0.020) |
| $R_c \times Post_t \times Dirty_s$ | -0.343*** | -0.339*** | -0.133* | -0.136* | -0.210* | -0.203* |
| | (0.123) | (0.130) | (0.072) | (0.073) | (0.120) | (0.123) |
| $Post_t \times Dirty_s$ | 0.280 | 0.288 | 0.525*** | 0.531*** | -0.245 | -0.243 |
| | (0.183) | (0.187) | (0.098) | (0.098) | (0.187) | (0.191) |
| City-level Controls | No | Yes | No | Yes | No | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 437,253 | 437,253 | 437,253 | 437,253 | 437,253 | 437,253 |
| Adj R-Square | 0.800 | 0.801 | 0.885 | 0.885 | 0.782 | 0.782 |

# Environmental Penalties

Table 5: Polluter Penalty Results

| | Polluter Penalty Dum | | Polluter Penalty Num | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $R_c \times Post_t$ | 0.016** | 0.013* | 0.016** | 0.013* |
| | (0.007) | (0.007) | (0.007) | (0.007) |
| $R_c \times Post_t \times Dirty_s$ | | 0.048*** | | 0.049*** |
| | | (0.017) | | (0.018) |
| $Post_t \times Dirty_s$ | | 0.083*** | | 0.097*** |
| | | (0.029) | | (0.030) |
| City-level Controls | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Observations | 437,253 | 437,253 | 437,253 | 437,253 |
| Adj R-Square | 0.124 | 0.124 | 0.119 | 0.120 |

# Further Decomposing Within-Firm Pollution Activities

- We execute a finer within-firm decomposition based on Section 4.1 by introducing another pollutant—effluent.

$$\Delta log(f_{i,t}) = \Delta log(y_{i,t}) + \Delta log(\frac{f_{i,t}}{y_{i,t}}), \tag{10}$$

# Further Decomposing Within-Firm Pollution Activities

Table 6: Effluent Results

| | Effluent | | $\frac{\text{Effluent}}{\text{Output}}$ | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $R_c \times Post_t$ | -0.059*** | -0.027 | -0.035** | -0.013 |
| | (0.014) | (0.018) | (0.017) | (0.017) |
| $R_c \times Post_t \times Dirty_s$ | | -0.471** | | -0.348* |
| | | (0.191) | | (0.207) |
| $Post_t \times Dirty_s$ | | 0.847*** | | 0.325* |
| | | (0.174) | | (0.190) |
| City-level Controls | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Observations | 435,555 | 435,555 | 427,583 | 427,583 |
| Adj R-Square | 0.852 | 0.852 | 0.799 | 0.799 |

# Water-Related Energy Consumption

Table 7: Energy Results

| | Industrial Water Output | | Fresh Water Output | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $R_c \times Post_t$ | -0.033** | -0.023 | -0.033* | -0.011 |
| | (0.016) | (0.019) | (0.018) | (0.020) |
| $R_c \times Post_t \times Dirty_s$ | | -0.150 | | -0.340* |
| | | (0.107) | | (0.192) |
| $Post_t \times Dirty_s$ | | 0.189 | | 0.297* |
| | | (0.134) | | (0.178) |
| City-level Controls | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Observations | 437,123 | 437,123 | 437,090 | 437,090 |
| Adj R-Square | 0.808 | 0.808 | 0.797 | 0.797 |

# Adoption of Pollution Control Devices

Table 8: Facilities Results

| | Facilities Output | | Facilities Effluent | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $R_c \times Post_t$ | 0.028*** | 0.017* | 0.067*** | 0.030* |
| | (0.009) | (0.009) | (0.015) | (0.016) |
| $R_c \times Post_t \times Dirty_s$ | | 0.136* | | 0.525*** |
| | | (0.071) | | (0.191) |
| $Post_t \times Dirty_s$ | | -0.481*** | | -0.688*** |
| | | (0.109) | | (0.184) |
| City-level Controls | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Observations | 297,752 | 297,752 | 291,735 | 291,735 |
| Adj R-Square | 0.863 | 0.863 | 0.826 | 0.826 |

# Patents

Table 9: Green Patent Results

| | Green Patent | | Water Patent | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $R_c \times Post_t$ | -0.0002 | -0.0003 | -0.0002 | -0.0001 |
| | (0.0003) | (0.0005) | (0.0003) | (0.0004) |
| $R_c \times Post_t \times Dirty_s$ | | 0.0013 | | -0.0005 |
| | | (0.0036) | | (0.0024) |
| $Post_t \times Dirty_s$ | | -0.0155*** | | 0.0007 |
| | | (0.0057) | | (0.0035) |
| City-level Controls | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Observations | 437,253 | 437,253 | 437,253 | 437,253 |
| Adj R-Square | 0.232 | 0.232 | 0.147 | 0.147 |

# Firms' Other Economic Performance

Table 10: Performance Results

| | Profit | | Capital | | Labor | | Market Share | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $R_c \times Post_t$ | -0.1664*** | -0.1474*** | -0.0577*** | -0.0418*** | -0.0100* | -0.0004 | -0.0029*** | -0.0027** |
| | (0.0222) | (0.0228) | (0.0094) | (0.0116) | (0.0051) | (0.0071) | (0.0009) | (0.0011) |
| $R_c \times Post_t \times Dirty_s$ | | -0.2889** | | -0.2394*** | | -0.1450** | | -0.0025 |
| | | (0.1173) | | (0.0889) | | (0.0602) | | (0.0055) |
| $Post_t \times Dirty_s$ | | 0.6034*** | | 0.6814*** | | 0.2072*** | | 0.0296*** |
| | | (0.2033) | | (0.1195) | | (0.0724) | | (0.0076) |
| City-level Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 169,311 | 169,311 | 222,149 | 222,149 | 220,575 | 220,575 | 222,780 | 222,780 |
| Adj R-Squared | 0.753 | 0.753 | 0.907 | 0.907 | 0.917 | 0.917 | 0.870 | 0.870 |

# Firms' Other Economic Performance

Table 11: Entry Results

| | Entry Number | | Entry Capital | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $R_c \times Post_t$ | -0.097*** | -0.096*** | -0.193*** | -0.194*** |
| | (0.033) | (0.033) | (0.038) | (0.039) |
| City-level Controls | No | Yes | No | Yes |
| City FE | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Observations | 2,860 | 2,860 | 2,860 | 2,860 |
| Adj R-Squared | 0.959 | 0.959 | 0.828 | 0.828 |

# Conclusion: main findings

- We find that more stringent environmental regulations faced by firms is positively associated with a greater magnitude of COD emission reduction after 2006, while no such effects on other pollutants out of the target control program.
- Also, firms in heavily polluting industries cut down more pollutant in contrast to those in less-polluting industries.
- Our analyses suggest that stricter environmental regulations have induced firms to pay more efforts to COD emissions-related issues.
- The result is informative to the innovation effect of environmental regulation stringency, as poluting firms are able to license and adopt green technologies innovated by other sectors.

# Conclusion: potential contribution

- the success in water pollution control in China pro- vide a hint on how developing countries improve their environmental quality through well-designed regulatory mechanisms.
- We provide a comprehensive chain of evidences on how firms respond to varied tightness of regulatory oversight to fill the gap in existing literature.
- We complement the literature by not only implementing intra-industry decomposition to find out the contribution of manufacturing scale, composition of industries and technology, but also decomposing within-firm behaviors to more clearly portray the role of within-firm scale effect and within-firm technique effect.

# Thank You!