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Industrial Ownership and Environmental Performance Revisited:

Evidence from “the State Enterprises Advance, the Private Sectors Retreat” trends in China

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Abstract:
“The State Enterprises Advance, Private Firms Retreat” trends (simply referred to as “the re-centralization trends” hereafter) in China is always criticized for threatening the efficiency of the economy. However, few studies focus on its impacts on the environment. In this study we employ a panel dataset of 159 Chinese cities from 2003 to 2009, to explore its impacts on the industrial SO2 emission patterns. The findings are as follows: (1) State ownership is positively associated with the city-level SO2 emission according to the Fix-Effect model. Nevertheless, it also has a positive impact on SO2 removal rates. The dynamic panel model confirms the results of the Fix-Effect model. (2) Moreover, the outperformance of State-Owned Enterprises (SOEs) in desulfurization cannot be explained by the size effect and the profitability effect. (3) A further comparison between the effectiveness of the re-centralization trends and the desulfurization subsidy policy shows that the market-based subsidy policy has much larger impacts than re-centralization trends. More interestingly, compared with their private counterparts, SOEs respond significantly less to the subsidy policy. To sum up, our results suggest that desulfurization is to some extent a political mission for the SOEs, which is beyond the profit-seeking considerations, and may threaten the efficiency of mitigation activities.

Keywords: State Ownership, Environmental Performance, the State Enterprises Advance, the Private Sectors Retreat trend

1. Introduction

The "State Enterprises Advance, Private Firms Retreat[1]" trends (the so-called "Guo Jin Min Tui,") (simply referred to as "the re-centralization trends" hereafter) in China is always criticized for degrading the efficiency of the economy(Johansson & Feng, 2016; Liu & Otsuka, 2004; Wei, Varela, & Hassan, 2002). However, few studies focus on its impacts on the environment. Given that the State-Owned Enterprises(SOEs) are always engaged in the pollution-intensive industries, it is worthwhile to explore the environmental impacts of such re-centralization trends.

What's more, previous studies have found significant heterogeneities in emission patterns between SOEs and their private counterparts. Several factors would determine the differences in their mitigation efforts, including the credit constraints(Earnhart & Lizal, 2006), the bargaining power with the environmental authorities(Xiaojun Li & Chan, 2016), the profit-oriented nature (Meyer & Pac, 2013) and so on. However, according to the environmental Kuznets Curve Hypothesis, environmental policy is always endogenously determined, and the government would take a discretionary strategy in environmental protection(Dinda, 2004; Stern, 2004; Zheng, Kahn, Sun, & Luo, 2014). Therefore, the relationship between state ownership and environmental performance is dynamic. Given that the existing literature on state ownership and environmental performance in China is always out of date, it is necessary to reevaluate the relationship, through employing the updated evidence.

Moreover, few previous studies explored the interaction of state ownership and market based environmental policy instruments. This topic is important and interesting because it is of great concern both in theory and in practice that, whether the market-based policy could significantly promote the environmental performance of firms with heterogeneous ownership.

Therefore, in this study we employ the re-centralization trends in the thermal power industries, the iron and steel industries, and the cement industries in China from 2003 to 2009, to study the relationship between the state ownership and environmental performance. Distinct from the previous studies, in this study we use a novel measurement of environmental performance, the removal rate of SO_2 as the proxy of mitigation efforts. Compared with SO_2 emission per revenue, the SO_2 removal rate is more suitable for the measurement of desulfurization. In order to ensure the consistency of our estimators, we use the dynamic panel model for the robustness check, and the system-GMM estimator is reported. The major results are as follows:

Firstly, we discover a seemingly paradoxical pattern in the SO_2 emission. On one hand, the repaid expansions of SOEs in industrial sectors increase the total SO_2 emission, because SOEs are always engaged in the emission-intensive industries. On the other hand, SOEs have higher SO_2 removal rates, in other words, they make more efforts in SO2 mitigations.

Secondly, we explore another two possible alternative explanations for the outperformance of SOEs in desulfurization, namely the size effect and the profitability effect. Our results confirm the size effect. However, even after we control both size and profitability effects, the positive impacts of state ownership on desulfurization efforts still hold. Therefore, our results suggest that desulfurization is to some extent a political mission for the SOEs, which is beyond the profit-seeking considerations

Thirdly, we further compare the quasi-environmental policy instrument – the re-centralization trend with the market-based instrument – the desulfurization subsidy. Our results reveal that the impact of the re-centralization trends is significantly inferior to the subsidy policy. And more interestingly, SOEs respond significantly less to market-based instruments, even when they are under the same subsidy scheme as their private counterparts. Therefore, this result further confirms our assertion that, compared with the profit-seeking private firms, the SOEs may take more political responsibilities such as environmental protection, therefore, take less account of the profitability in their mitigation strategies.

Our study fills several gaps in the existing literature. Firstly, we illustrate a more comprehensive mitigation pattern for SOEs. Though SOEs emit more toxic flue gas in terms of total quantity, they are more active in mitigation and have higher desulfurization rates. Secondly, our study also expands the multitask theory of the reform of Chinese SOEs to environmental protections. Previous studies on the roles of SOEs in social stability focus on their provision of social securities, for example, the over

[1] Guo jin min tui(“国進民退”)

employments (Bai, Li, Tao, & Wang, 2000; Bai, Lu, & Tao, 2006; Bai & Xu, 2005). In this study, we provide evidence that the SOEs also contribute to the provision of public goods, such as environmental protection. And the central government may promote environmental governance by exerting its influence on the SOEs.

The rest of the article proceeds as follows. Section 1 is a concise illustration of the "gradual and selective privatization" in China. In Section 2 we review the former empirical studies on state ownership and environmental behaviors. In Section 3 we build our conceptual framework. Section 4 is a description of data and model specifications. Section 5, Section 6 and Section 7 represent our baseline results, which explore the relationship between state ownership and SO2 emission patterns. In Section 8, we investigate the interaction between the re-centralization trends and the desulfurization subsidy. Finally, come the conclusions and policy implications.

2. The Re-Centralization Trends during the 2000s

2.1 The gradual and selective privatization during the reforms and opening-up in China

A prominent phenomenon is the trends of privatization during the economic miracle in China, which was started soon after the reforms and opening-up policy was launched. During this trend the private firms took over the roles of SOEs in economies, which improved the overall economic efficiency(Bai et al., 2006). However, privatization did not proceed consistently in all the sectors. For example, the financial sector is still dominated by state-owned institutes even nowadays. In the manufacturing sector, several industries are regarded as essential for national securities according to the central government, and private firms, including the domestically owned private firms and the foreign equities, are strictly prohibited to invest in these industries. Figure 1 shows the gradual trend of privatization during the 2000s.

Bai et al. (2006) characterize the privatization process as a "gradual and selective" trend. On one hand, compared with the shock therapy in Eastern European countries, the privatization in China is a much slower process. On the other hand, privatization only occurs in selected industries. Industries that are redeemed by the central government as essential to national securities or social securities are still dominated by SOEs.

Economists have not come to a consensus about whether "the state enterprises advance, the private sectors retreat" trend occurred in the last several decades. For example, Lardy (2014) pointed out that, generally speaking, during the Hu-Wen era the private sectors actually surged a lot, and a significant proportion of economic growth is contributed by private sectors. Kroeber (2016) drew similar conclusions that the pace of SOEs decline relative to the market as a whole after the financial crisis in 2008.

In this study we draw the trend of SOE share in Figure 1. As is shown, the share of the industrial revenue produced by SOEs dropped from 42% in 2002 to 29% in 2005. However, after 2005 the proportion just fluctuates around. Therefore, at least we can assert that the privatization trends in industrial sectors stagnated after 2005.

2.2 Re-centralization emerges in several selected industries during the 2000s

Although in general we hardly find evidence for "the state enterprises advance, the private sectors retreat" trend, the re-centralization trend surely occurred in several selected industries in the late 2000s. These industries are usually considered to be essential for national securities, including the Power Industry, the Iron and Steel Industry and the Cement Industry.

The thermal power industry is among the several state-dominated industries. It is reported that the big five mega state-owned power groups produced over 46% of the total power generation in China. Figure 2 depicts the share of the industrial revenue produced by the SOEs from 2001 to 2009 in the power industry. There is a clear re-centralization trend. The share of SOEs declined from 82% to 74% before 2004 but increased again to 86% in 2009. In other words, the SOEs in power industries surged for sake of national securities.

Another example is the iron and steel industry. As shown in Figure 3, the proportion of the industrial revenue produced by SOEs decreased from 71% in 2002 to 53% in 2006 steeply, however, this privatization trends stopped in 2006, and the share of SOEs increased to 55% in 2009.

Given that these industries are always pollution intensive, it is worthwhile investigating whether the re-centralization trends during 2000s are beneficial or detrimental to the environment. In the next two sections, we shall conduct a concise literature review on the relationship between state ownership and environmental performance, and investigate the institutional background for SOEs in China, thereby develop our conceptual framework.

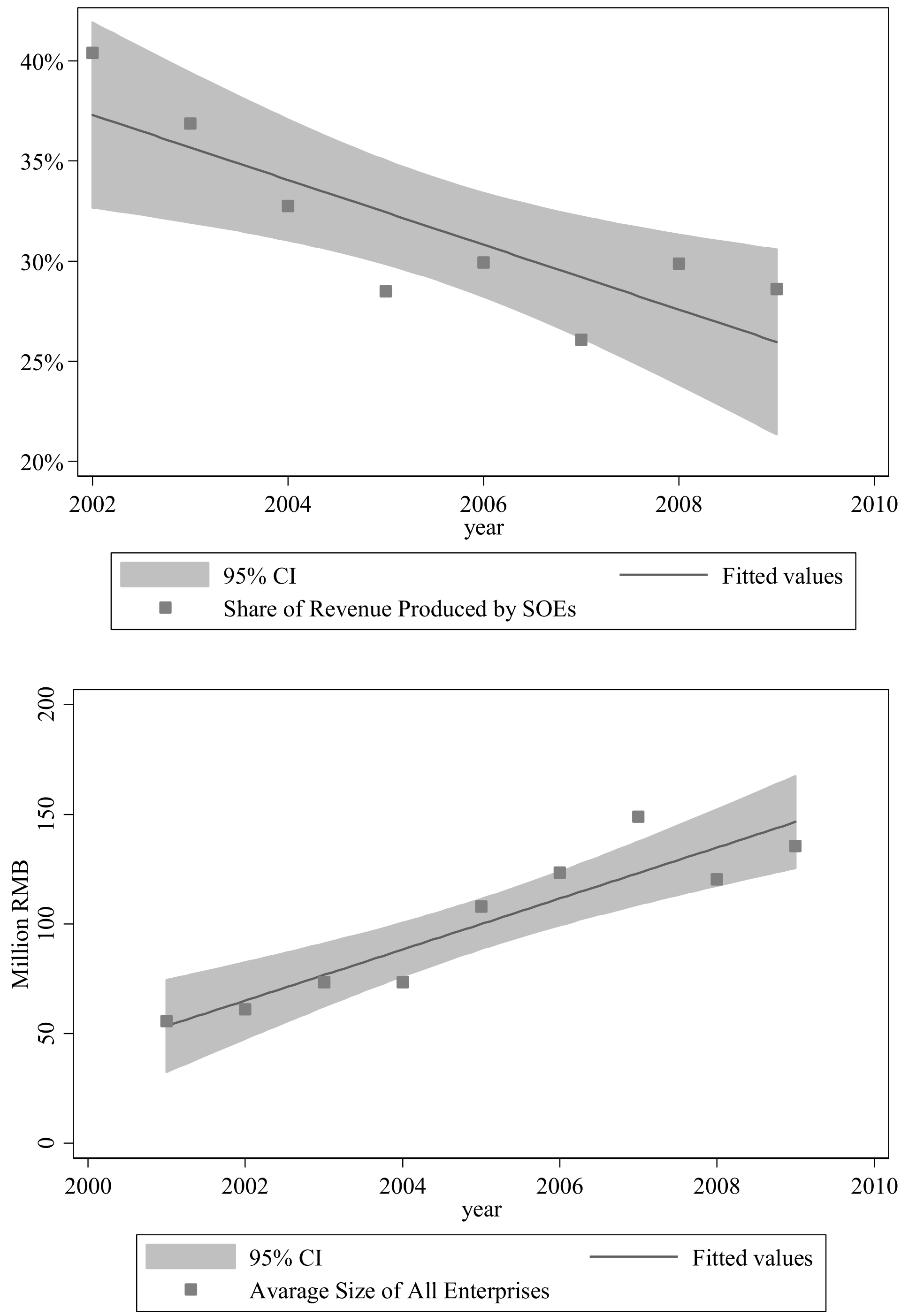

Figure 1: Upper panel: Proportion of Industrial Revenue Produced by SOEs(2002-2009); Lower Panel: Average Revenue of Firms(2002-2009); Calculated from the Chinese Industrial Enterprises Database

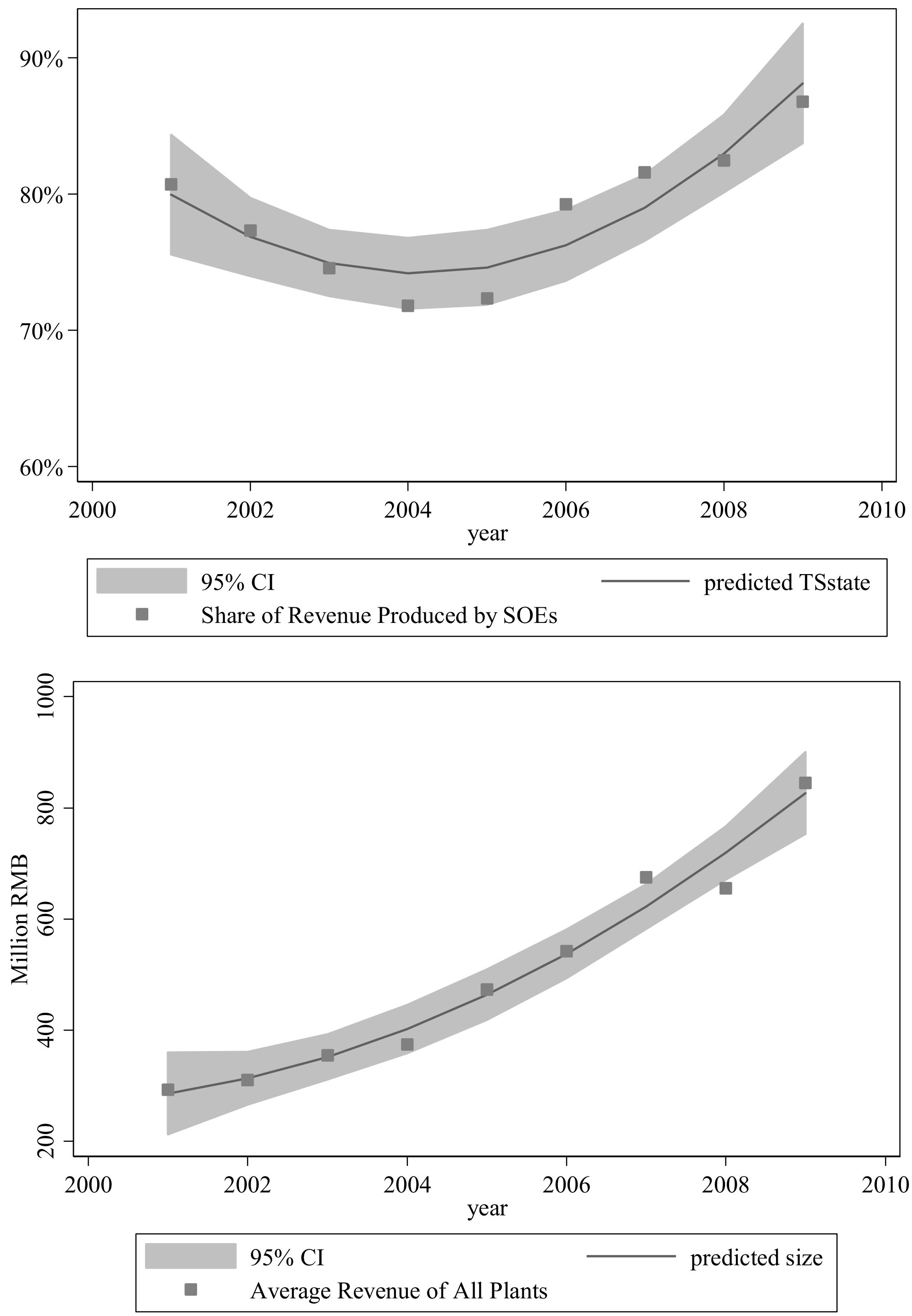

Figure 2: Upper panel: Proportion of Industrial Revenue Produced by State Owned Thermal Power Plants(2002-2009); Lower Panel: Average Revenue of Thermal Power Plants(2002-2009); Calculated from the *Chinese Industrial Enterprises Database*

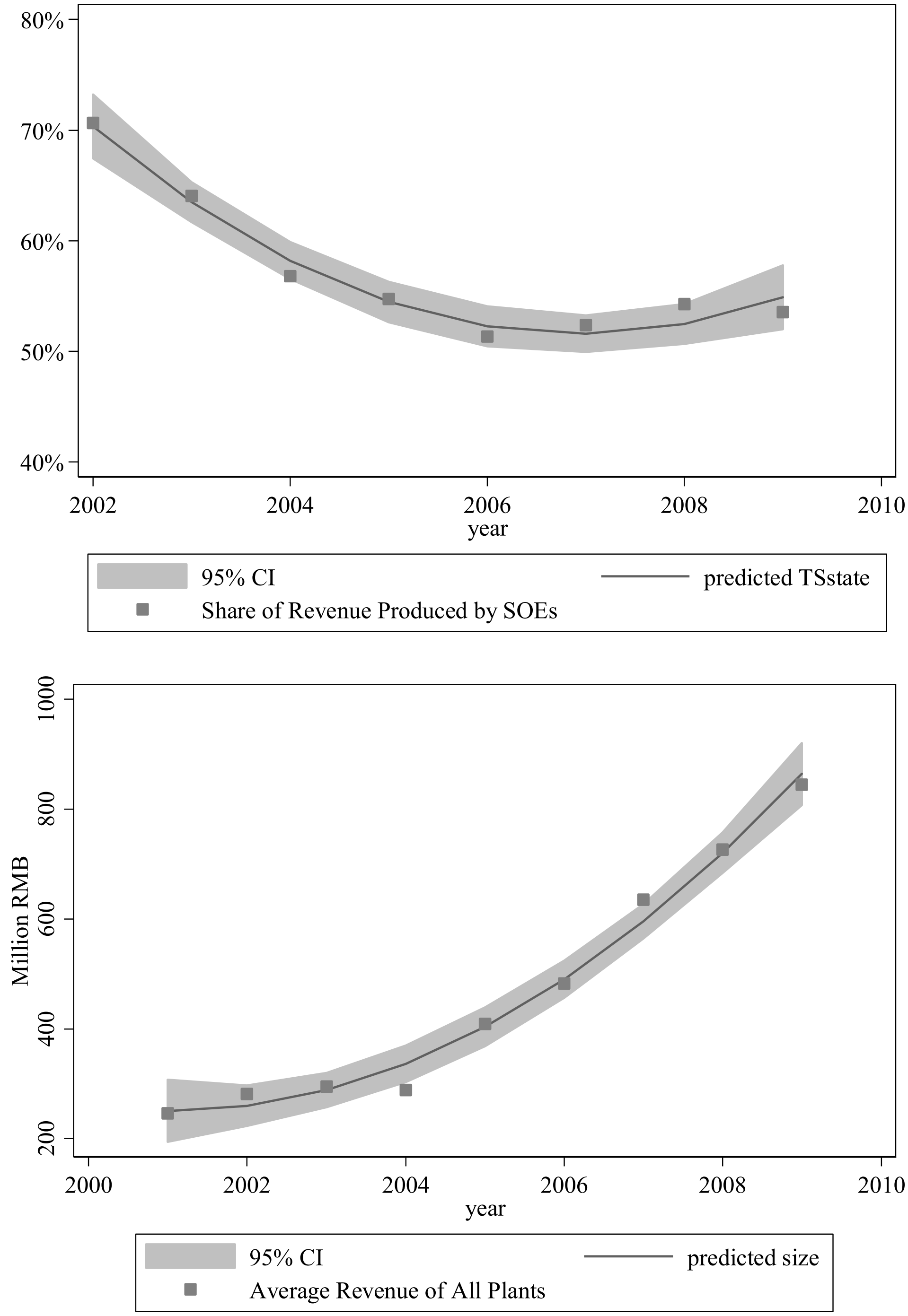

Figure 3 Upper panel: Proportion of Industrial Revenue Produced by State Owned Iron and Steel Plants (2002-2009); Lower Panel: Average Revenue of Iron and Steel Plants(2002-2009); Calculated from the *Chinese Industrial Enterprises Database*

3. Literature review

Previous studies have found significant heterogeneities in emission patterns between SOEs and their private counterparts. Several factors are identified to determine the differences in mitigation efforts, including the credit constraints(Earnhart & Lizal, 2006), the power of bargaining with the environmental authorities(Xiaojun Li & Chan, 2016), the profit-oriented nature (Meyer & Pac, 2013) and so on. We explored the most relevant empirical literature and divided them into three branches. The first is the evidence from the shock therapy in central and eastern European countries. The second is the literature on the relationship between Corporate Social Responsibility(CSR) and state ownership in China. And the third is the literature on the relationship between state ownership and environmental performance in China.

3.1 Privatization and Environmental Performance: Evidence from the Shock Therapy in Central and Eastern European countries

Several studies take advantage of the privatization reform during the shock therapy in Central and Eastern European countries to investigate the relationship between environmental performance and state ownership. However, their results are controversial. For instance, Earnhart and Lizal (2006) study the air pollution of Czech firms from 1993 to 1998, soon after the Velvet Revolution. They provide evidence that the state ownership improves environmental performance even though the state is more likely to retain ownership in high-polluting industries after the privatization. They argue that the profit-seeking nature of the private firms undermine their efforts in pollution mitigation. On the contrary, Meyer and Pac (2013) compare the SO2 emissions of SOEs and private enterprises in power industries in several former Soviet Republics during the late 2000s. They find that privatization is associated with a reduction of 55% emissions. They deem that the SOEs may receive fewer regulations and have lower concerns for environmental protection.

3.2 State Ownership and CSR in China

Corporate Social Responsibility (CSR) is a comprehensive measure of self-regulations for firms. The territory of CSR always covers environmental performance (Carroll, 1991, 1999; Garriga & Melé, 2004). Therefore, the studies of the relationship between state ownership and CSR would facilitate our understandings of the environmental performance of SOEs. See (2009) studies the impacts of a social initiative – the “Harmonious Society” policy on the CSR of Chinese firms. The results suggest that the SOEs improved their CSR performance due to political considerations, while the private firms did not due to a lack of political motivations. W. Li and Zhang (2010) also reveal a positive association among CSR and state ownership in the Chinese listed firms, they argue that the government, as the largest stakeholder of SOEs, would incentivize the managers to divert wealth to obtain social stability. In general, previous studies on state ownership found its positive association with CSR in China.

3.3 Ownership and Environmental performance in China: Empirical Evidence

Previous empirical studies discover fragmented and controversial results in the relationship between ownership and environmental performance in China.

Wang and Wheeler conduct a series of pioneer empirical studies in this field. For example, H. Wang and Wheeler (2003) employ a provincial panel data from 1987 to 1996 and prove that SOEs are more pollutional than other firms. And H. Wang and Wheeler (2005) confirm their previous study by using cross-sectional firm data in 1993. H. Wang and Jin (2007) further compare the environmental performance of SOEs, Collectively owned enterprises (COEs) and privately-owned enterprises (POEs). They prove that COEs have a significantly better performance than POEs, and SOEs have the worst environmental performance when measured in pollution discharge intensity. Notably they use a sample comprising of Chinese firms in 1993.

Y. Li and Shen (2008) provide evidence of provincial mitigation data from 1996 to 2006 that a one percentage increment in SOE proportion will increase 30% of pollution emissions per GDP. Xiaojun Li and Chan (2016) use the data from a survey of 1,000 industrial firms in 2006 and discover that small and medium-size SOEs spend less on pollution mitigation technologies, while large SOEs match the environmental performance of their private counterparts. Their case study on Baoshan steel group compliments their assertion that large SOEs outperforms in environmental protections.

Eaton and Kostka (2017) employ a unique database of pollution incidents from 2004 to 2016, and reveal that 62% of all 2,370 reported violations are related to six mega central SOE firms. They criticize that under current environmental governance institutions, the central SOEs are reluctant to comply with environmental guidelines and regulations due to the central protectionism.

3.4 Critiques of previous studies

However, the results of previous studies should be taken with caution.

Firstly, the conclusions of Wang and Wheeler are drawn based on the samples from the late 1980s to the early 1990s. Considering the swift transitions of Chinese economy, the relationship may have changed. A similar question exists in Y. Li and Shen (2008) and Xiaojun Li and Chan (2016). According to the environmental Kuznets Curve Hypothesis, environmental policy is always endogenously determined, and the government would take a discretionary strategy in environmental protection(Dinda, 2004; Stern, 2004; Zheng et al., 2014). Therefore, the relationship between state ownership and environmental performance are dynamic. Given that the existing literature on state ownership and environmental performance in China is always out of date, it is necessary to reevaluate the relationship, through employing the updated evidence.

Secondly, the methods of Eaton and Kostka (2017)are questionable as mentioned in their paper, for that the incident dataset is incomplete and therefore, the possible selection bias limits the insight into the comparisons of SOEs and private firms.

Thirdly, previous researchers haven't explicitly distinguished the differences between emission quantity and the mitigation patterns. They only provide incomplete evidence and fail to illustrate a comprehensive pattern for the mitigation patterns of SOEs. Therefore, there is a lack of literature which explicitly differentiates the impacts on the absolute emissions and the mitigation efforts.

Therefore, we propose to update the previous studies on the relationship between environmental performance and state ownership in China, taking advantage of the "the State Enterprises Advance, the Private Sectors Retreat" trend" during the 2000s. Our investigation would draw a more comprehensive and up-to-date picture for the environmental performance of SOEs in China.

4. Institutional Background and Conceptual Framework

In this section, we start our conceptual analysis by investigating the governance structure of SOEs, which could help to figure out a comprehensive picture on the determinants of environmental governance for SOEs in China.

4.1 The Governance Structure of SOEs in China

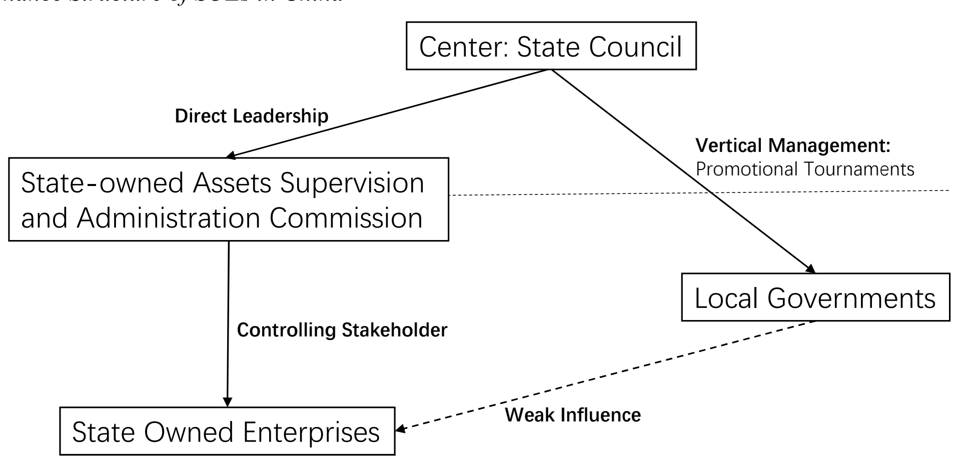

Figure 4 The Governance Structure of SOEs in China: Example of Central SOEs

Figure 4 shows the relationships among SOEs, local governments and the state council. According to *the Interim Regulation on the Supervision and Administration of State-owned Assets of Enterprises*, the SOEs are under the direct supervision of State-owned Assets Supervision and Administration Commission (SASAC). The SASAC established a comprehensive evaluation system for SOE managers, and the managers of SOEs are promoted or demoted accordingly. Since SASAC is under the direct leadership of the Centre, therefore, the SOE managers are more likely to be influence by the Centre.

By contrast, local governments could only exert a minor influence on SOEs. Notably, in some cases, the administrative level of SOE managers is higher than the level of local governors. What's more, the personnel in SOEs and governments are exchangeable in practice. For instance, many senior managers in SOEs are former political figures, and some of the managers are promoted to be local officials.

Therefore, Lieberthal (1997) characterizes the dual supervision in the political system in China as the "fragmented authoritarianism". He argues that in order to make the dual supervision system work smoothly, the SOE managers are mainly required to report to the Central. Bai et al. (2000) built up a multitask theory for the SOE reform in China. According to this theory, the SOEs are required by the central government to provide social security services, to ensure social stability, for that profit-oriented private firms have few incentives to provide public goods. Like the social security regime, the determination of the central governments on environmental protection would improve the environmental governance of SOEs significantly.

4.2 "Central Protectionism" or "Central Environmentalism"?

Though most previous studies agree that the environmental performance of SOEs are significantly influenced by the determination of environmental protection for the central government, they cannot reach a consensus whether the Centre promotes environmental performance of SOEs, or the Centre shelters their pollution. Two competing hypotheses emerge in this field, namely "Central Protectionism" and "Central Environmentalism".

The first branch is the "Central protectionism" Hypothesis. Eaton and Kostka (2017) argue that under the current governance structure, the SOEs are unlikely to comply with environmental regulation due to "central protectionism". According to their arguments, on one hand, the administrative level of CEOs in central SOEs are higher than the local governors, which undermines the determinations of the local Environmental Protection Administrations (EPA) to enforce the environmental laws strictly, and to punish the SOEs for their pollution. On the other hand, tempted by the "go bigger and go stronger" and "maintaining and increasing the value of state assets" strategies, SASAC has insufficient incentives to promote the environmental performance of SOEs under its supervision.

On the contrary, many scholars support the "Central Environmentalism" hypothesis. Public concerns on pollution are emerging in the last decades. T. Li, Wang, and Zhao (2016) provide evidence that the environmental Kuznets hypothesis holds for several air pollutants in Chinese provinces, and they further discover that the GDP per capita in the rich coastal areas has climbed over the peak of the Kuznets Curve. Zheng and Kahn (2013) believe that the demands for the better environment are surging, especially in urban areas where the richer and better-educated citizens pay more attention to the detrimental impacts of environmental degradations on their health. Therefore, the Centre is confronted with growing public pressure for better environment.

4.3 Environmental performance of SOEs under "Central Environmentalism"

Most studies show that the Centre is more motivated to mitigate pollution(Ran, 2017; Van Rooij, Zhu, Na, & Qiliang, 2017; Wong & Karplus, 2017; Zhang, 2017). Firstly, the state council takes the roles of the central planner in China, and is always blamed for the nationwide serious air pollution. Secondly, for transboundary environmental problems, local cadres are tempted to allow the firms to "pollute their neighbors"(H. Cai, Chen, & Gong, 2016), while the Centre should coordinate the regional environmental governance. Last but foremost, the incentive mechanism mentioned above deteriorates the determinacy for local cadres to combat against the SOE polluters.

Therefore, the Centre is anticipated to exert its influence in order to deter pollution, through a handful of pathways, including "the introduction of stricter national environmental laws and sanctions, the use of binding environmental targets for local leaders, the reliance on nationwide central enforcement campaigns, and the introduction of a centralized verification program of local emission data" (Kostka & Nahm, 2017). And a more direct way for the Centre to fulfill its national mitigation targets is to directly allocate the mitigation targets to the SOEs.

To wrap up, compared with their private counterparts, SOE managers would treat the pollution mitigation as a political mission. Revenue n and try to improve their environmental performance in order to release the public concerns on pollution, and they would help the politicians fulfill the national mitigation targets. In the next section, we will describe our sample and empirical methods to revisit the relationship between state ownership and environmental performance in China, taking the advantage of "the State Enterprises Advance, the Private Sectors Retreat" trend during the 2000s.

5. The Sample and Empirical Methods

5.1 The sample

Due to a lack of the well-established environmental information transparency scheme in China, neither did the firms make their emission information open to the public, nor did the government release the firm-level pollution data for open access, which contains our direct examination of our hypothesis through firm-level datasets. Therefore, the city-level sample is our second-best choice, though less than ideal. In this study, we employ 159 prefectural observations from 2003 to 2009. Most of the prefectural variables are derived from the Chinese City Statistics Yearbook, which provides a wide range of variables on environmental governance, economic development, and fiscal status.

We also use the Chinese Industrial Enterprise Survey Database as a complementary source. This firm-level database is built up originally to provide information to the National Bureau of Statistics for compilations of statistical yearbooks. And it is well known for its completeness in the sample of industrial enterprises above designated size(Brandt, Van Biesebroeck, & Zhang, 2012; Nie, Jiang, & Yang, 2012).

5.2 Variables

5.2.1 The prefectural environmental performance

In former literature on the environmental Kuznets Curve Hypothesis, total SO_2 emission is frequently used as the proxy for regional environmental governance(Grossman & Krueger, 1995; M. Wang & Huang, 2015). "Total SO2 emissions" measure the absolute pollution in a prefecture, rather than its mitigation determinacy or efforts. In this study, we construct a novel variable, the SO_2 removal rate, as the major proxy of the city-level environmental performance. Since the total quantity of industrial SO_2 emissions, as well as the quantity of SO_2 removed by the Flue Gas Desulfurization(FGD) facilities are reported to the local EPA, mainly based on the information provided by the monitoring facilities. Therefore, we define the SO_2 removal rate as follows:

$$Industrial\ SO_2\ \mathrm{Re}moval\ Rate\ =\frac{Quantity\ of\ SO_2\ \mathrm{Re}moval\ by\ FGD\ Equipments}{Total\ Quantity\ of\ Industrial\ SO_2\ Generated} \tag{1}$$

Although both two variables are used to measure the environmental performance, there are slight but essential differences. Compared with the quantity of SO_2 emissions, The SO_2 removal rate is more relevant in characterizing the corporate mitigation behaviors. Given that the SOEs are always engaging in pollution incentive industries, it is worthwhile to explicitly distinguish the difference between the total emissions and their mitigation efforts. In our study the total SO_2 emissions are also used, to makes our results more comparable with previous studies.

5.2.2 The State Ownership

State ownership is key to our analysis. We collect the ownership information by aggregating the ownership of individual firms from *the Chinese Industrial Enterprise Survey Database* to the prefectural level. To be specific, we first identify the ownership of individual firms. Noticing that there may be misclassifications in the firms' legal registration type(Hsieh & Song, 2015), we use the types of controlling stakeholders to identify the types of ownership. The database reports the controlling stakeholders of firms, including the state, the collective, the private, the foreign, and the Hong Kong-Macao-Taiwan firms/individuals. Therefore, we define a firm as state-owned if its controlling stakeholder is the state. Moreover, we double-check the validness of our definition by directly calculating the share owned by the state. Notably, in this definition the SOEs comprise central SOEs as well as the local SOEs whose controlling stakeholders are local governments. Then, it is convenient to aggregate the variables to city level.

SO_2 is mainly emitted during the combustion of coal. Several industries combust bulk quantities of coal, including the thermal power industry, the iron and steel industry as well as the cement industry. These industries contribute to more than half of the industrial SO_2 emissions nationwide, according to an estimation by a large national pollution source survey in 2015. Therefore, following Shi, Zhou, Zheng, and Zhang (2016), we only take into account the share of industrial revenue produced by SOEs in these three industries in a certain city as our definition of state ownership.

5.2.3 Control Variables

We control a series of variates according to the former literature. Firstly, the GDP per capita is believed to have an invert U shape relationship with pollution intensities in cities in China(M. Wang & Huang, 2015; Zheng et al., 2014), thus we include GDP per capita and its quadratic term. Secondly, the prefectural fiscal deficits are included in order as a proxy for the financial shortage for monitoring activities and fiscal expenditure of urban governments in environmental protection (Qi & Zhang, 2014). Thirdly, the proportion of value-added for secondary industry is also included to control the regional economic structure. Lastly, FDI inflow may impact the local environment. On one hand, the foreign-invested enterprises are more sophisticated in techniques of cleaner production, which is always referred to as the technological impacts(Hoffmann, Lee, Ramasamy, & Yeung, 2005). On the other hand, according to the Pollution Haven Hypothesis(X. Cai, Che, Zhu, Zhao, & Xie, 2018; Cole, 2004; Javorcik & Wei, 2004), the inflow of FDI would increase the demand for energy, which will, in turn, increase the emission of SO_2. Table 1 presents the definitions and descriptive statistics for the main variables.

Table 1 Variable definitions and summary statistics.

Variables	Definition	Obs.	mean	Std. dev.
SO_2 Removal Rate (%)	see in Equation (1).	1086	0.313	0.238
SOE share (%)	Share of industrial revenue produced by SOEs in a certain city.	1086	0.558	0.316
SOE Revenue	Total industrial revenue produced by SOEs in a certain city.	1086	8669	15802
GDP per capita	Regional gross domestic product per capita.	1085	21754	16072
Regional GDP	Regional gross domestic product.	1086	9802061	1.11e+07
Share of Secondary Sector(%)	Share of gross domestic product contributed by the secondary sector.	1085	50.65	10.57
FDI inflow	Annual foreign direct investment inflow.	1065	46835	90720
Deficit Rate(%)	=(Fiscal Expense – Fiscal Income)/Fiscal Income.	1086	1.196	1.159
Average Size	Average assets of industrial firms.	1086	12.810	0.974
Average Profitability(%)	Average profit margin of industrial firms.	1086	0.039	0.055

5.3 Empirical specifications

5.3.1 The Fixed Effects Model

In this study, we employ the panel data regression model. Compared with OLS, the panel model allows us to control the unobserved time-unvarying individual-specific effects which may correlate with the dependent variable(Mundlak, 1978), and thereby ensures the consistency for our regression. Specifically, we assume that there is a linear relationship in city i represented in the following regression equation:

$$\mathrm{Re}moval_{it} = \beta \times SOEshare_{it} + Z'_{it}\Gamma + \eta_i + \alpha_t + \varepsilon_{it} \quad (2)$$

$\mathrm{Re}moval_{it}$ is the industrial SO_2 removal rate in the year t. $SOEshare_{it}$ is the share of the revenue produced by SOEs. Z'_{it} is other control variables described in the above subsection, η_i is time-unvarying city-specific effects, α_t is the year dummy, ε_{it} is the error term.

5.3.2 The Dynamic Panel Model

We employ the dynamic panel model in order to deal with endogeneity problems. The dynamic panel model allows possible endogeneity in some regressors and provides consistent estimators(Roodman, 2009).

In our case, the targets of the "state advance, private retreat" policy are to restructure the state sector and to improve the efficiency of SOEs, which has less to do with environmental performance. Thus the possible simultaneous causal problem in our baseline model is minor.

However, we cannot deny there are possible overlapping between the "state advance, private retreat" policy and the "Forcibly Shut-down Small Heavy Polluting Business" policy. Meanwhile, though the fixed effects model facilitates to control time-varying individual effects, there may be some other omitted variables which vary with both time and city. In addition, the dynamic panel model facilitates to control the possible correlation between the unobserved panel level effects and the lag of the dependent variables. And it helps to explore the dynamic patterns of the SO_2 removals at the city level.

Specification of the dynamic model is shown in Equation (3):

$$\mathrm{Re}moval_{it} = \gamma \mathrm{Re}moval_{i,t-1} + \beta \times SOEshare_{it} + Z'_{it}\Gamma + \eta_i + \alpha_t + \varepsilon_{it} \quad (3)$$

In order to estimate the dynamic"small T, large N" panel model, Anderson and Hsiao (1981, 1982) propose employing further lags of the level and the difference of the dependent variable as instrumental variables(IVs) of the first-order lagged dependent variable in the regression equation. Furthermore, the difference GMM and system GMM estimators are developed by a series of econometrical works(Arellano & Bond, 1991; Arellano & Bover, 1995; Blundell & Bond, 1998). Blundell, Bond, and Windmeijer (2001) prove that in limited sample cases, the system GMM estimator is more effective than the difference GMM estimator. Therefore, we estimate the Equation (3) by the two-step system-GMM approach.

6. The results of the fixed effects model

In this chapter, we report our baseline results on the relationship between city-level industrial sulfur dioxide removal rates and the share of industrial revenue produced by the SOEs.

Figure 5 illustrates the SO_2 removal rates for cities with lower SOE share and higher SOE share. A consistent and profound difference is shown in the SO_2 removal rates for these two groups after 2004. The cities with low SOE share outperform their counterparts with high SOE share.

6.1 the Fixed Effects Results: taking the SO2 Removal Rates as the Dependent Variable

Table 2 reports the baseline results. In Column (1) we report the pooled OLS results. Column (2)-Column (7) present the regression results of fixed effects model. Specifically, Column (2) is a reexamination of Environmental Kuznets hypothesis, in which we only include SOE share and the linear and quadratic term of GDP per capita(log) in the left hand. From Column (3) to Column (6), we gradually add the year dummy, the share of secondary industry in total GDP, the annual FDI inflow(log) and the fiscal deficit rate. In Column (7), we control all the explanatory variables.

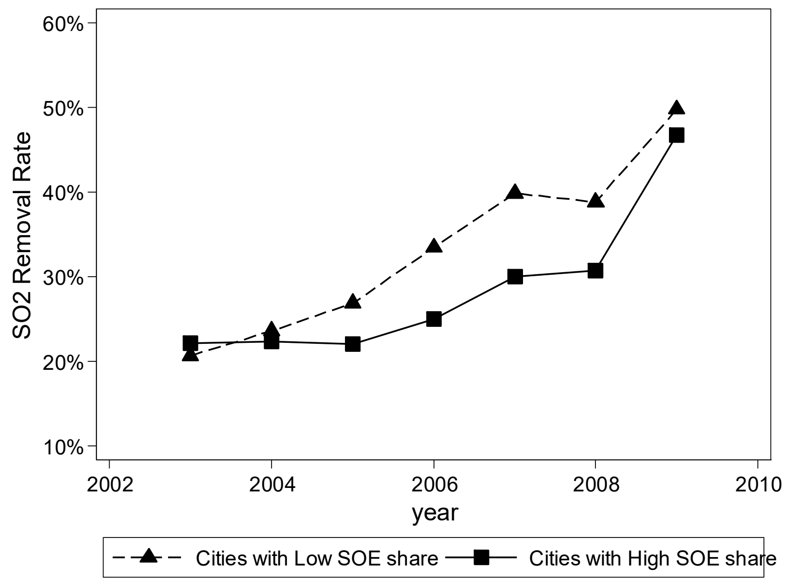

Figure 5 Comparison of Average SO_2 Removal Rates by the Share of SOE Productions. **Note:** The dotted line: lower half of the samples; The solid line: upper half of the samples. **Data Source:** China City Statistical Yearbook and Chinese Industrial Enterprise Survey Database

We report the Chi2 for the Hausman Test in the bottom line of Table 2. For all Fixed effects regressions, the null hypothesis that the individual fixed effects are not correlated with other repressors is rejected at 95% confidence level(Hsiao, 2014). Therefore, the Fixed effects estimators are preferred to the Random-effects estimators in our panel studies. Meanwhile, we report the F-statistics for joint test for all coefficients, by which all of the null hypotheses are rejected. The adjusted R^2 suggests that the explanatory power of panel model is much larger than the Pooled OLS estimation. The parameter Rho suggests that around 70% of the variance in the dependent variable is due to the differences across panels.

The results of pooled OLS are similar as is shown in Figure 5. Cities with more SOEs are negatively related to their SO_2 removal. However, the Fixed Effects estimators show a reverse relationship in Column (2) to Column (7). On average a variation of 1 percentage in SOE share explains 0.05% percentage of increase in SO_2 removal rates.

It is intuitive to show the difference between the Pooled OLS estimator and the FE estimators. The Pooled OLS estimator is mainly dominated by the between-group variations while the FE estimators are mainly explained by the within-group variations(in other words, the variations over time within groups) after controlling the time-unvarying individual effects(Wooldridge, 2010).

In our case, the SOEs are usually extremely large firms engaged in resource-intensive industries, the cities with higher SOE ownership will have lower SO_2 removal rates on average because of their heavy cost burden compared with their counterparts. However, when we focus on the variations within the same city, the SO_2 removal rates increase more across years in the cities with high SOE share. In other words, the cities with higher SOE share perform worse in industrial SO_2 removal, however, they catch up more rapidly with a higher rate. This result is in line with the common experience in China that, cities with more heavy industries were worse in air pollution, however, they improved rapidly during the 2000s.

The year dummy is usually taken as a proxy for technological advance and nationwide environmental policies which are homogeneous across cities(Grossman & Krueger, 1995; M. Wang & Huang, 2015). The FE model in Column (2) doesn't control the year dummy, and a significant U-shape relationship is found between the average regional GDP per capita and SO_2 removal rate. This finding confirms the Environmental Kuznets Curve Hypothesis for Chinese Cities. However, after controlling the year dummy in Column (3), the U-shape relationship still exists but insignificant. It implies that the impact of economic growth on environment could be largely explained by the environment friendly technological advances and nationwide environmental policies. Specifically, the coefficients of the year dummies from 2005 to 2009 are significantly beyond zero compared with that of the year 2003, which suggests that the national desulfurization subsidy policy started in 2005 improved the industrial SO_2 removal significantly.

In Table 2 we also report regression results with other alternative sets of control variables. The share of industrial value-added in GDP is negatively correlated with the SO_2 removal rate. This result is intuitive because industrial production is always correlated with SO_2 emissions. We didn't find significant relationship between fiscal deficit rate and environmental performance.

Surprisingly, the amount of FDI inflow is negatively related to SO_2 removal. Prior researchers find controversial results on the impact of FDI on local environment. On one hand, the foreign-invested enterprises are more sophisticated in techniques of cleaner production, which is always referred to as the technological impacts(Hoffmann et al., 2005). On the other hand, according to the Pollution Haven Hypothesis(X. Cai et al., 2018; Cole, 2004; Javorcik & Wei, 2004), the inflow of FDI would increase the demand for energy, which will, in turn, increase the SO_2 emissions. We interpret our result as the pollution heaven effect, which overweighs the former impacts.

Table 2 The impacts of State Ownership on city-level industrial sulfur dioxide treatment

	(1) SO_2 Removal Rates	(2) SO_2 Removal Rates (%)	(3) SO_2 Removal Rates (%)	(4) SO_2 Removal Rates (%)	(5) SO_2 Removal Rates (%)	(6) SO_2 Removal Rates (%)	(7) SO_2 Removal Rates (%)
	OLS	FE	FE	FE	FE	FE	FE
SOE Share(%)	-0.072***	0.064**	0.064**	0.063**	0.057**	0.063**	0.053*
	(0.022)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
GDP per capita (log)		-0.433**	-0.276	-0.126	-0.281	-0.231	-0.053
		(0.203)	(0.197)	(0.211)	(0.205)	(0.200)	(0.222)
(GDP per capita)^2 (log)		0.034***	0.014	0.008	0.015	0.011	0.005
		(0.010)	(0.010)	(0.011)	(0.011)	(0.010)	(0.011)
Share of Secondary Sector(%)				-0.003**			-0.004**
				(0.002)			(0.002)
FDI inflow(log)					-0.012*		-0.014**
					(0.006)		(0.006)
Deficit Rate(%)						-0.012	-0.011
						(0.008)	(0.009)
year = 2003(base)							
year = 2004			0.024	0.022	0.020	0.025	0.019
			(0.016)	(0.016)	(0.017)	(0.016)	(0.017)
year = 2005			0.043**	0.031	0.038*	0.046**	0.027
			(0.019)	(0.020)	(0.020)	(0.019)	(0.021)
year = 2006			0.088***	0.076***	0.084***	0.093***	0.074***
			(0.023)	(0.024)	(0.023)	(0.023)	(0.024)
year = 2007			0.151***	0.136***	0.147***	0.157***	0.135***
			(0.028)	(0.029)	(0.029)	(0.029)	(0.031)
year = 2008			0.151***	0.133***	0.149***	0.162***	0.137***
			(0.034)	(0.035)	(0.036)	(0.035)	(0.037)
year = 2009			0.281***	0.256***	0.278***	0.294***	0.260***
			(0.037)	(0.039)	(0.039)	(0.039)	(0.042)
Constant	0.350***	1.246	1.549	0.827	1.611	1.390	0.569
	(0.014)	(0.982)	(0.972)	(1.035)	(1.005)	(0.978)	(1.079)
Year Dummy	N	N	Y	Y	Y	Y	Y
City Dummy	N	Y	Y	Y	Y	Y	Y
Samples	1113	1112	1112	1111	1085	1112	1084
Groups		159	159	159	157	159	157
Adj R2	0.008	0.160	0.245	0.247	0.241	0.245	0.245
Within R2		0.282	0.358	0.361	0.357	0.359	0.362
F-test of all	10.3***	124***	58.5***	53.1***	51.0***	52.9***	43.2***
F test of all u_i=0	-	14.3***	14.8***	14.8***	13.5***	14.6***	13.4***
Rho	-	0.725	0.696	0.701	0.693	0.693	0.693
Hausman chi2		47.6***	10.0**	12.9**	23.9***	10.1**	27.2***

Notes: The dependent variable is the city-level industrial sulfur dioxide removal rate. Standard errors in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*.

6.2 the Fixed Effects Results: taking the SO_2 Emissions as the Dependent Variable

To make our research more comparable, we replace the SO_2 removal rates with the total industrial SO_2 emissions as the dependent variable. The regressors are also replaced by their counterparts. Thus Table 3 reports the impact of state ownership on the total quantity of city-level industrial SO_2 emissions. Our key explanatory variable is the industrial revenue produced by SOEs.

The correlation between SOE revenue and the SO_2 Emissions is consistent across all the columns in Table 3. On average one percent in the variation of SOE revenue will increase the total SO_2 emissions by 4%. This result is in line with the study of Y. Li and Shen (2008), and further confirms the common assertion that more SOE share would increase the total amount of SO_2 emissions. We'd like to emphasize that though opposite in direction, this result doesn't contradict the results in Table 2. The dependent variables are the SO_2 removal rates and the total industrial SO_2 emissions in Table 2 and Table 3 respectively. The former characterizes the corporate desulfurization behaviors, while the latter illustrates the SO_2 generations during the production processes, which to some extent hinge on the nature of the production.

In conclusion, the results in Table 2 and Table 3 illustrate a comprehensive profile for the SO_2 emissions in China. On one hand, the SOEs are the major contributors for air pollution, for that the SOEs are always engaged in the emission-intensive industries. On the other hand, the SOEs have higher removal rates of SO_2 in their flue gas emissions. Our results imply that, although the SOEs always make headlines when their subsidiaries violate the environmental regulations, their mitigation efforts dominate that of their private counterparts.

Table 3 Impact of State Ownership on city-level industrial sulfur dioxide Emission

	(1) SO_2 Emissions	(2) SO_2 Emissions	(3) SO_2 Emissions	(4) SO_2 Emissions	r SO_2 Emissions	(6) SO_2 Emissions
SOE	0.058^{***}	0.041^{***}	0.037^{***}	0.042^{***}	0.039^{***}	0.036^{***}
Revenue(log)	(0.014)	(0.013)	(0.013)	(0.014)	(0.013)	(0.014)
Regional GDP	2.742^{***}	2.209^{***}	1.666^{***}	2.757^{***}	2.269^{***}	2.137^{***}
(log)	(0.393)	(0.380)	(0.398)	(0.417)	(0.380)	(0.450)
$(\text{Regional GDP})^2$	-0.084^{***}	-0.069^{***}	-0.056^{***}	-0.085^{***}	-0.073^{***}	-0.071^{***}
(log)	(0.013)	(0.013)	(0.013)	(0.014)	(0.013)	(0.014)
Share of Secondary			0.013^{***}			0.013^{***}
Sector(%)			(0.003)			(0.003)
FDI inflow				0.004		0.009
(log)				(0.013)		(0.013)
Deficit Rate					-0.043^{**}	-0.039^{**}
(%)					(0.017)	(0.017)
Constant	-11.693^{***}	-7.014^{**}	-2.452	-11.697^{***}	-7.012^{**}	-6.064^{*}
	(3.055)	(2.985)	(3.150)	(3.308)	(2.977)	(3.595)
Year Dummy	N	Y	Y	Y	Y	Y
City Dummy	Y	Y	Y	Y	Y	Y
Samples	1113	1113	1112	1086	1113	1085
Groups	159	159	159	157	159	157
Adj R2	-0.028	0.066	0.082	0.075	0.071	0.093
Within R2	0.121	0.206	0.221	0.217	0.211	0.233
Overall R2	0.245	0.172	0.068	0.216	0.133	0.106
Between R2	0.287	0.236	0.043	0.250	0.155	0.084
F	43.618	27.263	26.755	25.434	25.290	23.219
Rho	0.824	0.851	0.863	0.843	0.855	0.856

Notes: The dependent variable is the city-level industrial sulfur dioxide emissions. Standard errors in parentheses, clustered at the city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*.

The coefficients of other control variables just have the opposite directions compared with Table 2, though there are minor differences in their significances. For example, we find that the Environmental Kuznets Curve Hypothesis is valid even after we control the year dummy(see in 错误!未找到引用源。). Moreover, the impact of the inflow of FDI loses its significance though still positive. And the fiscal deficits will increase the SO2 emissions significantly, which suggests the essential role of governments in environmental governance.

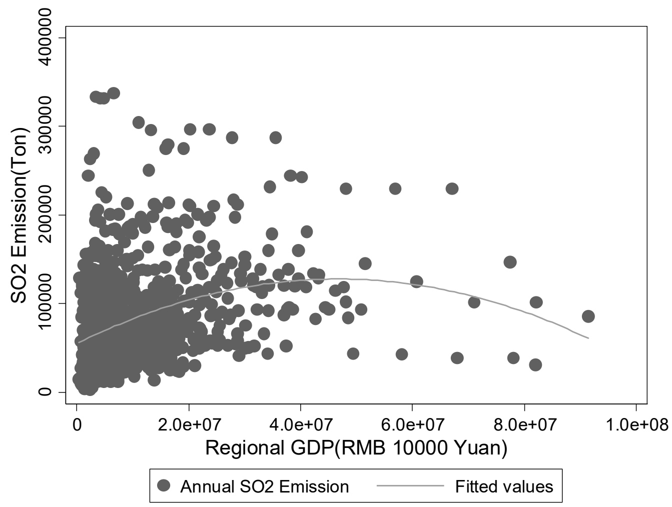

Figure 6 The quadric relationship between regional GDP and SO_2Emission. **Data Source:** China City Statistical Yearbook and Chinese Industrial Enterprise Survey Database

7 The results of the dynamic panel model

Table 4 reports the results of the dynamic panel model. In order to ensure its validity, we report two branches of tests of model specifications. The first branch is the over-identification test for instrumental variables, including the Sargan test and Hansen test. We report the P-value for the Sargan test and the Hansen test. Most P-values of Sargan and Hansen tests are beyond 0.2, which indicate no over-identification problem for our set of instrumental variables. The second branch is the test of autocorrelations in the idiosyncratic disturbance term. We report the Arellano-Bond test for AR (1) and AR (2) in first differences(Arellano & Bond, 1991). The results indicate that no second-order or higher serial correlations.

Table 4 The Dynamic Panel Regression Results

	(1) Dynamic Panel	(2) Dynamic Panel	(3) Dynamic Panel	(4) Dynamic Panel	(5) Dynamic Panel
	SO_2 removal Rates(%)	SO_2 removal Rates(%)	SO_2 removal Rates(%)	SO_2 removal Rates(%)	SO_2 removal Rates(%)
L1. SO_2 Removal Rate(%)	0.854***	0.829***	0.850***	0.848***	0.818***
	(0.039)	(0.039)	(0.037)	(0.039)	(0.031)
SOE share(%)	0.034**	0.030*	0.030**	0.047***	0.047***
	(0.015)	(0.016)	(0.014)	(0.015)	(0.016)
GDP per capita (log)	0.202	0.255*	0.305**	0.199	0.321**
	(0.132)	(0.131)	(0.138)	(0.127)	(0.148)
$(\text{GDP per capita})^2$ (log)	-0.009	-0.012*	-0.013**	-0.008	-0.013*
	(0.007)	(0.006)	(0.007)	(0.006)	(0.007)
Share of Secondary Sector(%)		-0.000			-0.001
		(0.001)			(0.001)
FDI inflow(log)			-0.006		-0.005
			(0.006)		(0.006)
Deficit Rate(%)				0.010*	0.010*
				(0.005)	(0.006)
Constant	-1.054	-1.338**	-1.593**	-1.114*	-1.724**
	(0.659)	(0.652)	(0.690)	(0.636)	(0.721)
Year Dummy	Y	Y	Y	Y	Y
City Dummy	Y	Y	Y	Y	Y
Samples	953	952	932	953	931
Groups	159	159	157	159	157
Sargan Test: P-value	0.191	0.395	0.165	0.237	0.341
Hansen Test: P-value	0.129	0.262	0.093	0.154	0.248
AR(1)	0.000	0.000	0.000	0.000	0.000
AR(2)	0.405	0.412	0.446	0.442	0.471

Notes: The dependent variable is the city-level industrial sulfur dioxide removal rate. Standard errors in parentheses, clustered at city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*.

As shown in Table 4, the coefficients are 0.8 on average for the first-order lag of dependent variable. This indicates that environmental performance is significantly positively related to the past performance. Moreover, the coefficients of SOE share are still significant, though the magnitude is a little smaller than the results of the fixed effects model.

According to the multitask theory, besides accretions of state assets, the SOEs are entitled to maintain social stability, including creating jobs and providing social insurance (Bai et al., 2000). That is, profits are not the only objective of the Central government when entering into contracts with SOE managers(Bai & Xu, 2005). The SOE managers are expected to help fulfilling diversified governmental objective, or they will get demoted.

Since the year 2006 desulfurization has been made as a binding target in the national social and economic five plan by the central government. Although the desulfurization subsidy policy was launched in order to motivate the power plants, it is estimated that the subsidy was too low to make up the abatement costs(Shi et al., 2016). Therefore, the private firms were reluctant to install desulfurization scrubbers, or to maintain proper operations of their scrubbers. Confronted with the difficulties in mitigations, the national targets are allocated to the giant SOEs. Our results show that, the SOEs are more active in desulfurization, because the desulfurization targets are more likely to be political missions for the SOE managers.

8 Alternative explanations: the economies of scales effect and profitability effect?

In the former chapters, we show that the SOEs outperform their private counterparts in terms of SO_2 removal rates. However, as revealed in the literature review, there may be alternative explanations other than state ownership of this phenomena, among which are the economies of scales hypothesis and the profitability hypothesis.

As the economies of scales hypothesis puts it that, desulfurization benefits from economies of scales(Xiao Li, Qiao, & Shi, 2017). Large plants will take advantage of their scales to dilute the average desulfurization costs such as capital costs and operating costs. Therefore, the desulfurization decision is materially influenced by the size of the plants. Cities with larger plants would have higher SO_2 removal rates. Moreover, since we cannot eliminate the possible overlapping between the “state advance, private retreat” policy and the “Forcibly Shut-down Small Heavy Polluting Business” policy, it is highly recommended to control the size effect.

During the “state advance, private retreat” campaign, the size of individual plants was increased steeply. As shown in Figure 2, the average annual revenue of thermal plants was about 300 million RMB yuan in 2001, and in 2009 it increased to around 900 million RMB yuan, which tripled in eight years. Similar trends occurred in the steel and iron industry shown in Figure 3.

Combining the arguments in the above two paragraphs, one alternative explanation emerges for the relationship between state ownership and SO_2 removal. That is, the SOEs are usually larger than the private plants, therefore, they are more inclined to install and operate desulfurization facilities. The baseline results may disappear if the size effect is considered.

Profitability also impacts corporate environmental governance. Several studies have provided evidence for the positive casual impacts. For example, Earnhart and Lizal (2006) point out that firms with lower profit margins would invest less in pollution mitigation because of their liquidity constraints.

However, it is still controversial whether SOEs are less profitable in China. On one hand, most researchers believe that the SOEs are less productive because of their distorted management system. On the other hand, the SOEs always have access to exclusive markets, or they are big enough to dominate in the segmented market, which will contribute a lot to their monopolistic profits. In Figure 7 we don’t find any consistent advantage or disadvantage for SOEs in terms of profit margin.

In Table 5 we report the FE estimators after we control the size effect and the profitability effect. In Column (2) the average size is found to be a significant factor for SO_2 removal rate. In Column (4) we didn’t find evidence for the profitability effect on environmental performance. Notably, we cannot deny that there may be inverse causality problem that threats the consistency of the coefficient of profitability.

In Column (6) after considering the size effect and the profitability effect, the impacts of SOE share are smaller in magnitude but still significant. Since we control for the average firm size and the average profitability, the effect of state ownership captures variations that is orthogonal to variations in the size effects and the profitability effects.

Table 5 Test of Alternative Mechanisms: Economies of scales and Environmental Capacity

	(1) SO_2 Removal Rates (%)	(2) SO_2 Removal Rates (%)	(3) SO_2 Removal Rates (%)	(4) SO_2 Removal Rates (%)	(5) SO_2 Removal Rates (%)	(6) SO_2 Removal Rates (%)
SOE Share (%)	0.058**		0.051*		0.057**	0.049*
	(0.028)		(0.028)		(0.028)	(0.028)
Average Size(log)		0.039***	0.038***			0.041***
		(0.013)	(0.013)			(0.013)
Average Profitability (%)				-0.126	-0.118	-0.174
				(0.109)	(0.109)	(0.110)
GDP per capita(log)	0.049	-0.070	-0.057	0.030	0.039	-0.081
	(0.224)	(0.226)	(0.226)	(0.225)	(0.224)	(0.226)
$(\text{GDP per capita})^2$ (log)	-0.000	0.006	0.005	0.001	0.000	0.006
	(0.011)	(0.012)	(0.012)	(0.011)	(0.011)	(0.012)
Share of Secondary Sector (%)	-0.004**	-0.004**	-0.004**	-0.004**	-0.004**	-0.003**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
FDI inflow(log)	-0.016**	-0.018***	-0.017**	-0.017**	-0.016**	-0.018***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Deficit Rate (%)	-0.012	-0.010	-0.010	-0.013	-0.012	-0.010
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Constant	0.067	0.205	0.135	0.203	0.125	0.226
	(1.092)	(1.088)	(1.088)	(1.095)	(1.093)	(1.088)
Samples	1057	1057	1057	1057	1057	1057
Groups	157	157	157	157	157	157
Adj R2	0.251	0.256	0.258	0.249	0.252	0.259
Within R2	0.371	0.374	0.377	0.368	0.371	0.378
Overall R2	0.092	0.095	0.079	0.111	0.092	0.078
Between R2	0.025	0.008	0.017	0.009	0.024	0.016
F	43.555	44.285	41.235	43.179	40.304	38.536
Rho	0.698	0.698	0.707	0.689	0.698	0.708

Notes: The dependent variable is the city-level industrial sulfur dioxide removal rate. Standard errors in parentheses, clustered at city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*.

To sum up, our study explains to what extent the increase of SO_2 removal rates relies on the size effects and the profitability effects from 2003 to 2009. However, the impacts of "the State Enterprises Advance, the Private Sectors Retreat" trends on environmental governance remain after we control these effects, which implies that the state ownership effect moves beyond these effects.

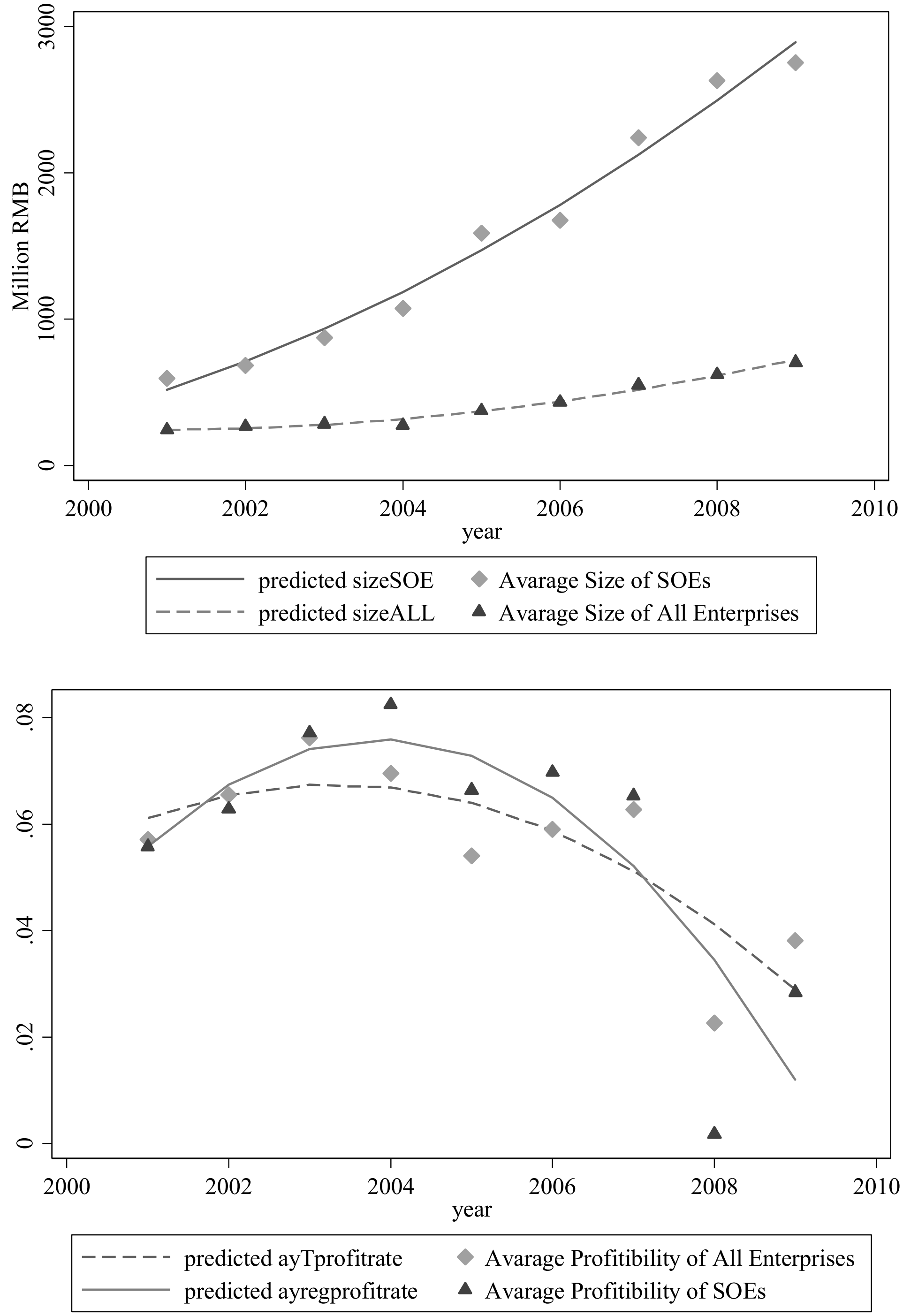

Figure 7 Comparisons of Average Size (Upper Panel) and Profitability(Lower Panel) for SOEs and average industrial firms. **Data Sources:** China City Statistical Yearbooks and Chinese Industrial Enterprise Survey Database

9 Interaction with Desulfurization Policy

In this study, we further compare the impacts of state ownership to the effectiveness of the desulfurization subsidy. Launched in 2004, the desulfurization subsidy policy is an incentive-based policy that compensates the operating costs of scrubbers for coal fueled thermal power units. Shi et al. (2016) provide evidence that the subsidy policy is effective to mitigate the SO_2 emissions, however, they leave it untouched to identify the heterogeneous impacts among firms with different ownership structures.

Following Shi et al. (2016), we set up the following year dummy as an proxy for the subsidy policy:

$$Desulfurization\ Subsidy = \begin{cases} 1 & if\ year > 2004 \\ 0 & if\ year \leqslant 2004 \end{cases}$$

And we add the policy proxy and its interaction term with the share of SOEs in Equation (2). The fixed-effects model is established to estimate the coefficients.

Table 6 Interaction with the Desulfurization Subsidy Policy

	(1) SO_2 Removal Rates (%) FE	(2) SO_2 Removal Rates (%) FE	(3) SO_2 Removal Rates (%) FE	(4) SO_2 Removal Rates (%) FE
SOE Share (%)	0.064**		0.053*	0.094***
	(0.028)		(0.028)	(0.034)
Desulfurization Subsidy	0.281***	0.271***	0.260***	0.287***
	(0.037)	(0.037)	(0.042)	(0.044)
SOE Share× Desulfurization Subsidy				-0.059**
				(0.029)
GDP per capita(log)	-0.276	-0.293	-0.053	-0.032
	(0.197)	(0.198)	(0.222)	(0.222)
$(\text{GDP per capita})^2$ (log)	0.014	0.015	0.005	0.004
	(0.010)	(0.010)	(0.011)	(0.011)
Share of Secondary Sector (%)			-0.004**	-0.004***
			(0.002)	(0.002)
FDI inflow(log)			-0.014**	-0.013**
			(0.006)	(0.006)
Deficit Rate (%)			-0.011	-0.011
			(0.009)	(0.009)
Constant	1.549	1.647*	0.569	0.407
	(0.972)	(0.973)	(1.079)	(1.080)
Year Dummy	Y	Y	Y	Y
City Dummy	Y	Y	Y	Y
Samples	1112	1112	1084	1084
Groups	159	159	157	157
Adj R2	0.245	0.241	0.245	0.248
Within R2	0.358	0.354	0.362	0.365
Overall R2	0.110	0.134	0.097	0.102
Between R2	0.027	0.000	0.017	0.009
F	58.542	64.864	43.269	40.409
Rho	0.696	0.686	0.693	0.692

Notes: The dependent variable is the city-level industrial sulfur dioxide removal rate. Standard errors in parentheses, clustered at city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*.

Table 6 reports the regression results. Column (1) is our baseline results. In Column (2), we only include the subsidy policy as the explanatory variable. In Column (3) and Column (4) we add the SOE share and the interaction term in our model.

The results are intuitive. In Column (2). The subsidy policy is more effective than any other influential factors. It improves the SO_2 removal rate by 0.27% per year, the largest in magnitude compared with other variables. This further confirms the results of Shi et al. (2016) that, the incentive-based environmental instruments are effective in China. In Column (3) and Column (4), we find that after controlling the impacts of subsidy policy, the coefficient of SOE share is still positively significant, which ensures the robustness of our baseline results.

More interestingly, the coefficient of the interaction term is significantly below zero, which implies that the private firms respond more to the incentive-based policy than the SOEs, even when they are under the same subsidy scheme. This result shows that compared with the profit-seeking private firms, SOEs may take environmental protection as their political responsibilities.

Our results are in line with the studies on Chinese SOEs. According to the multi-task theory of SOE reform established by Bai et al. (2000), SOEs are needed to continuously provide social welfare such as maintaining employment during the economic transitions, which will improve the overall social welfare. Bai and Xu (2005) provide evidence that the profits are not the only objective of the Chinese government in designing CEO contracts of SOEs. In addition, Liang and Langbein (2021) show that Chinese SOEs get conflicting roles in their governance. On the one hand, they perform as profit-oriented entities as their private counterparts, on the other hand, as the major policy implementors, they need to pursuit the demands of political principals. Therefore, the SOE managers need to stick a deliberate balance in both the nation's economic development and the environmental well-beings. We add evidence to this branch of literature that the effectiveness of market-based mitigation policy is sensitive to the ownership structure due to the conflicting roles of the SOEs.

10 Conclusions and policy implications

The relationship between environmental performance and state ownership are still controversial in former literature. Therefore, it is essential for us to explore the environmental impacts of "the State Enterprises Advance, the Private Sectors Retreat" trend in China during 2000s, for that the expansion of SOEs may deteriorate the environment and worsen the pollution problem. Based a prefectural panel model from 2003 to 2009, we document the following conclusions:

(1) We illustrate a seemingly paradoxical pattern in the SO2 emissions. On one hand, the repaid expansion of SOEs in industrial sectors promotes the emission because they are always engaged in the pollution-intensive industries. On the other hand, SOEs have higher SO2 removal rates, in other words, they make more efforts in SO2 mitigations.

(2) Even after we control both size effect and the profitability effect, the positive impacts of state ownership on desulfurization efforts still hold. Therefore, our results imply that desulfurization is to some extent a political mission for the SOEs, which is beyond the profit-seeking consideration.

(3) We further reveal that, comparing with the desulfurization subsidy policy, the impact of re-centralization trend is significantly inferior. And more interestingly, SOEs respond significantly less to market-based instrument, even when they are under the same subsidy scheme as their private counterparts. This result further confirms our assertion that, compared with the profit-seeking private firms, the SOEs may take more political responsibilities such as environmental protection, and therefore, take less account of the profitability in their mitigation strategies.

Our study has important policy implications. For instance, the ongoing mixed-ownership reform of SOEs may reduce their incentives for social stability. Therefore, how to keep the environmental performance of SOEs is challenging for the designation of the reform. This study also sheds some light on carbon mitigation in China. The SOEs dominate in the power industry and some other energy-intensive industries. Therefore, the effectiveness of carbon mitigation policy hinges on the low carbon strategies of SOEs. The current low carbon price discourages the private firms from adopting the low carbon technologies, however, the SOEs will response more to the national carbon mitigation targets even when the carbon price is low.

One limitation of our study is that, though we discuss the effectiveness of the re-centralization trends on environmental performance, the efficiency of these measures remains untouched. Given that the re-centralization trends are reported to threatening the efficiency of the overall economic activities, it is worthwhile study the efficiency of such trend in future.

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