# Do local government-industry linkages affect air quality? Evidence from cities in China

by

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## Abstract

I investigate the relationship between local government-industry linkages and pollution outcomes in Chinese cities over the period 2003 to 2010. For identification, I rely on the administrative rotation of city mayors, which is determined by political career considerations and retirement age cut-offs but unrelated to their environmental records. These transitions act as plausibly exogenous shocks that disrupt the relationship between the local government and enterprises at the city level. I employ several statistical models to investigate the leadership's impacts on environmental outcomes.

First, a simple t-test is used to evaluate the change in the pollution index when mayors with particular characteristics enter or leave office. In addition, empirical models are utilized to explore the correlation between mayoral characteristics and changes in city-level pollution. I find correlations between mayoral characteristics and city-level environmental outcomes, focusing specifically on $SO_2$ emissions, $SO_2$ emission intensities, and end-of-pipe $SO_2$ removal ratios. Finally, firm-level data allow me to identify the relationship between mayoral characteristics and pollution by enterprises of specific ownership types.

Mayors with different characteristics show distinct impacts on city-level pollution. I hypothesize that city leaders who have previous experience in industry pay more attention to local economic growth rather than environmental improvements, resulting in increased $SO_2$ emissions. Consistent with this hypothesis, I find that mayors with industry work background correspond to an increase (decrease) in city-level $SO_2$ emissions when they enter (leave) office after controlling for city and year fixed effects. Apart from this, I expect that leaders closer to retirement are under less pressure for promotion as they are going to retire soon and due to age cut-offs may not be eligible for higher positions; instead, they may feel less pressure to promote local businesses and pay more attention to environmental management. Evidence shows consistently that tenures of mayors on the verge of retirement are associated with reductions in city-level $SO_2$ emissions and increases in city-level end-of-pipe $SO_2$ removal rates.

Further investigation shows that mayors realize their environmental goals via enterprises of specific ownership types. I predict that mayors rotated from the central government are not under pressure of promotion and they are adherent to the central policy in reducing $SO_2$ emission intensities. I further predict that mayors from the local administration are expected to enforce the usage of $SO_2$ removal facilities, particularly among enterprises of low level authorities. Consistent with these hypotheses, results show that mayors with work background in central and local governments are associated with improved environmental outcomes, but through different channels. A central government work background results in intensity reduction, but not necessarily $SO_2$ emissions; however, local government work background is associated with short-term reductions in $SO_2$ intensities, possibly due to increases in $SO_2$ removal ratios, particularly among city SOEs.

In addition to the analysis of mayoral characteristics, my research reveals several additional interesting findings. I find that enterprises of lower rank more readily build linkages with local officials not only for economic development but also for environmental management as high-ranking enterprises may face a more stringent monitoring system and are more politically powerful. Implications for environmental policy design in China can be drawn from the results. First, industries are encouraged to behave independently from the government in economic activities as well as policy implementation. Second, environmental performance should be effectively and explicitly included in the evaluation program of officials. Third, government-industry linkages, to the extent that they undermine the economic and policy system, should be minimized as much as possible.

Thesis Supervisor: Valerie Karplus
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# Chapter 1

# Introduction

As a emerging country, China increasingly faces environmental problems as a byproduct of rapid economic growth. As a step towards better understanding the causes of these problems, this thesis explores the relationship between governmental leadership characteristics and environmental performance. In this chapter, I provide the context to understand my research question and introduce the problem generally behind my study. This is followed by a short discussion of my analytical strategy. Finally, the outline of the study is described.

## 1.1 Background

Governments in emerging countries face the challenge of developing the economy. Simultaneously, they also face pressure to minimize adverse environmental impacts while fostering economic growth. Therefore, against this backdrop, the government must decide how to prioritize economics and environmental goals in a dynamic sense. China, which has grown to be the second largest economy in the world, faces this dilemma. Since 2000, the annual GDP growth of China was reported to be above 8% through 2011 according to The World Bank

(World Bank, 2016). Although these statistics showed that China experienced a tremendous increase in economic development and living standards, China also suffered from an increasing severity of environmental degradation. Vennemo et al. (2009) stated that China had become the world's biggest emitter of $SO_2$ and its total emissions of $SO_2$ were almost the equivalent of the combination of Europe and United States. In addition, they concluded that the ambient air quality in China was the most degraded in the world. From 2000 to 2006, $SO_2$ emissions in China increased by 53%, from 21.7 Tg to 33.2 Tg, at an annual average growth rate of 7.3% (Lu et al., 2010). In addition to air pollution, water pollution causes serious concern in China. Approximately, 54% of the seven main rivers were considered to be unsafe for human consumption in China between 2001 and 2005 (10th Five-Year Plan) (World Bank, 2007). At the same time, water pollution worsened water scarcity and the associated annual cost was approximately 147 billion CNY (1% of the national GDP) in 2003 (World Bank, 2007). Health consequences of environmental degradation in China are severe. Because of mortality and morbidity, resulting from $PM_{2.5}$ air pollution in 2007, work time of Chinese employees in years was reduced and the estimated total economic losses were approximately 346 billion CNY (1.1% of the national GDP) (Xia et al., 2016). Thus, along with the development of economy, environmental degradation leads to serious concern among policymakers in the Chinese government.

Despite several decades of market-oriented reforms, the China's economy is heavily supported by state-owned enterprises (SOEs). These SOEs are systematically controlled by the central government. In the political system of China, *guoziwei* [1] is the agency designed to control SOEs at different authority levels. The *Nomenklatura* framework, utilized by the

[1]The agencies exist on different levels. For example, the state level agency is called State-owned Assets Supervision and Administration Commission of the State Council (*Guowuyuan Guoyou Zichan Jiandu Guanli Weiyuanhui*): http://www.sasac.gov.cn/. On city level, there exist similar agencies. For example, the similar organization in Shanghai is called State-owned Assets Supervision and Administration Commission of the Shanghai municipal government: http://www.shgzw.gov.cn/.

China Communist Party (CCP), is used to establish systematic Party and governmental leadership in China (Chan, 2004). As a result of this framework, the central Party maintains tight and continued control of those SOEs of significance to the China's economy. Party committees at different levels even have explicit lists indicating those institutions which can be controlled. Since the *Nomenklatura*, the Party's control over SOEs seems not to be diluted and the central Party seeks new ways to intensify party-building in various industries. The strategy is to retain tight authority over large SOEs and release control over relatively small SOEs (*zhuada fangxiao*) (Chan, 2004). However, there is still partial delegation and financial authority left in small businesses. In particular, the central government still retains the absolute personnel control over large SOEs and industries of significant importance to the infrastructure (e.g., power sector), economic livelihood, and China's security. On the local level (e.g., city, provincial), this type of control is attributed to local leaders (e.g., mayors, secretaries) through governing channels of *guoziwei*. The severity of pollution is correlated with economic development, especially in the power sector, which contributes more than 50% of total $SO_2$ emissions in China (Lu et al., 2010). This partial control of economic participants of significance to the economy by governmental agencies is hypothesized to indirectly impact environmental performance.

There are several reasons why government-industry linkages could affect pollution. Local political officials partially determine decisions of related SOEs through political control over the personnel system. As a result, motivations of those political officials are hypothesized to affect enterprise decision-making processes to some degree. First of all, most of political officials are incentivized by promotion tournaments, which make them care about promotion opportunities (Zhou, 2007). Within the promotion mechanism of China's political system, economic performance is considered to be of significance in the evaluation for promotion in the cadre management system in China (Li and Zhou, 2005). Li and Zhou

(2005) emphasized that economic performance was a key driving force for the promotion of political officials. Although this analysis was constructed over the turnover data of provincial level leaders, it provides suggestive information that economic performance counts in the promotion of officials below the provincial level as those lower level leaders are centrally managed by higher-level governmental leaders (Edin, 2003). Lin (2007) analyzed the promotion mechanism from prefectural level leaders and found that economic performance contributed to the promotion of local leaders. This evidence implies that the political system has a well established mechanism to incentivize local leaders to prioritize economic development and this priority is expected to simultaneously drive the development of related enterprises as well as the associated environmental impacts.

In addition to economic performance, environmental performance has also been considered as an incentive for the promotion of political officials since the 11th Five-Year Plan (FYP) [2] (Zheng et al., 2014). Zheng et al. (2014) found that in recent years in China, the cadre promotion system was restructured in some aspects and environmental performance became a promising factor with respect to the promotion of officials. As a result, city leaders' ambitions for political promotion might be expected to more directly affect environmental outcomes. With increasing concern on environmental cleanup alongside economic development, both the central government and public place pressure on the local government to mitigate environmental pollution (Zheng et al., 2014). However, compared to the GDP growth, the environmental performance's impacts on promotion is of less significance. Nevertheless, economic development induces adverse environmental outcomes as the corresponding increased consumption of energy is positively correlated with the severity of pollution. Thus, city leaders must make trade-offs between economic development and environmental perfor-

[2]Official information can be found via "Interim Procedures for Comprehensive Assessment and Evaluation of Local Leading Groups and Leading Cadre of CPC and Governments Embodying the Scientific Outlook on Development", published in 2006.

mance. In this study, I expect that mayors with different characteristics are associated with different degrees of trade-offs.

At the local level, there is further evidence that governments and industry leaders are mutually dependent on each other to conduct everyday functions (e.g., tax collection, business licensing and quality oversight). Prior research showed that SOEs and governments were strongly linked with each other and leaders were frequently exchanged between them (Yang et al., 2013). It is also reasonable to predict that individual leadership might be able to partly determine environmental outcomes in these settings as a result of lack of environmental monitoring capacity and enforcement system, which results from resource and personnel constraints (Zheng et al., 2014). Local leaders' impacts on the strategy of SOEs and related industries, together with local leaders' individual incentives from the politcal system and public, raise the research question: do leaders' personal characteristics affect local industries' environmental performance? **In this thesis, the main research question is to explore whether or not individual leader's characteristics can affect local pollution in China, and to identify potential channels of government-industry linkages through which this relationship arises.**

## 1.2 Analytical Strategy

My analytical approach involves analyzing pollution outcomes in cities as mayors rotate in and out of office using statistical techniques, mainly regression analysis, which relies on a difference-in-difference design. For this, the analysis needs a dataset that includes city-level annual pollution indices and city leaders with detailed personal characteristics. I begin by assembling the dataset using yearly prefectural city-level pollution indices and mayoral characteristics. Then, in order to explore different impacts corresponding to the interaction between city leaders with different characteristics and different types of enterprises, pollution indices are reported by enterprises of different ownership types in a city. In addition, I use other auxiliary data such as an economic output index to control for related changes in energy use and pollution. For the empirical model, different specifications are considered. In order to obtain robust results, panel regression models are examined based on the data. For instance, to account for the heterogeneity of cities, fixed effects and cluster errors across prefectural cities are included in the model.

## 1.3 Context, Contribution, and Outline of the Study

In the past several decades, China experienced a rapid economic growth as well as environmental degradation. Governments and leading groups face severe challenges. Of total environmental damages, SOEs of significance to the national economy make a non-negligible contribution. However, these SOEs are systematically controlled by the governmental leadership. Thus, governmental leadership directly confronts trade-offs between economy and environment. The cadre management system in China rotates leaders across positions and departments in a process which is exogenous to environmental outcomes and provides a quasi-experimental setting for me to investigate the correlation between mayors' personal characteristics and local polluting behaviors. Overall, this study represents a basic quantitative analysis of the leadership's impacts on environmental performance and lays a foundation for studying the relationship between institutional management and pollution.

The remainder of the thesis is organized as follows. In chapter 2, the motivation for this study is described in detail. In chapter 3, the policy setting in China is depicted. Chapter 4 provides the description of the respective datasets used in my analysis. In chapter 5, my empirical strategy and hypothesis are presented, the econometric models are established, and empirical results are reported and interpreted. Chapter 6 concludes the analysis.

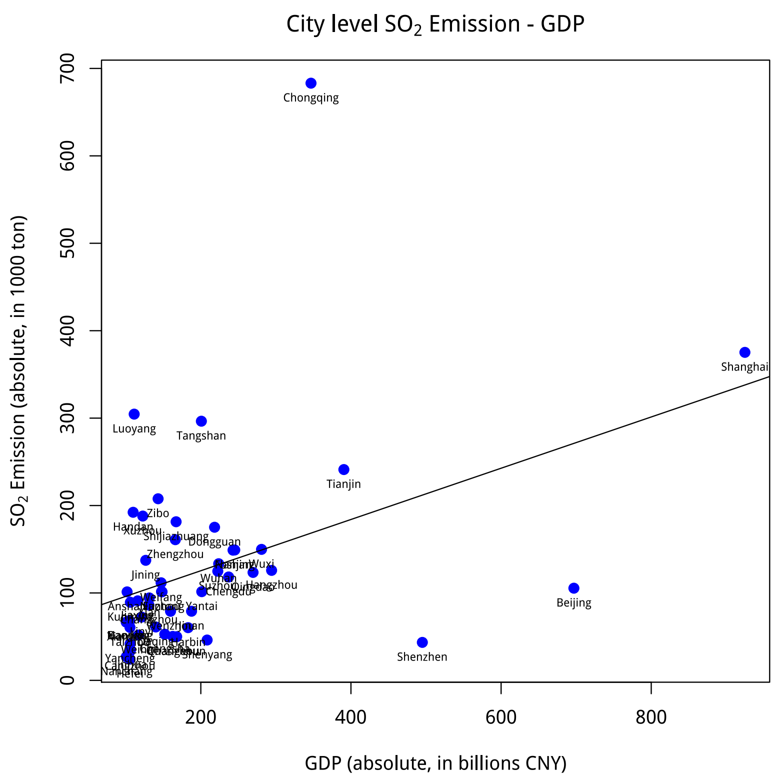
# Chapter 2

# Motivation

In this chapter, I discuss the motivation for this study in technology and policy. First, I introduce the current setting in China, focusing on how energy use has created various adverse environmental impacts. Then, I discuss the cause of this problem in several directions. Finally, the focus of this study is introduced.

## 2.1 Setting in China

Over the last several decades, China's economy has experienced a tremendous growth. However, this rapid economic growth in China has been accompanied by a large increase in energy consumption, resulting in severe environmental damages (Vennemo et al., 2009). At the same time, it is also associated with urbanization and industrialization in terms of increasing number of population, industries, and enterprises. Looking back at the development of China, it has been heavily supported by heavy industries since 1980s, especially those in energy intensive sectors. In 2005, the total consumption of coal was about 2.2 billion tons, which was about 3 times the consumption of coal in 1978 (China Statistical Yearbook, 2005,



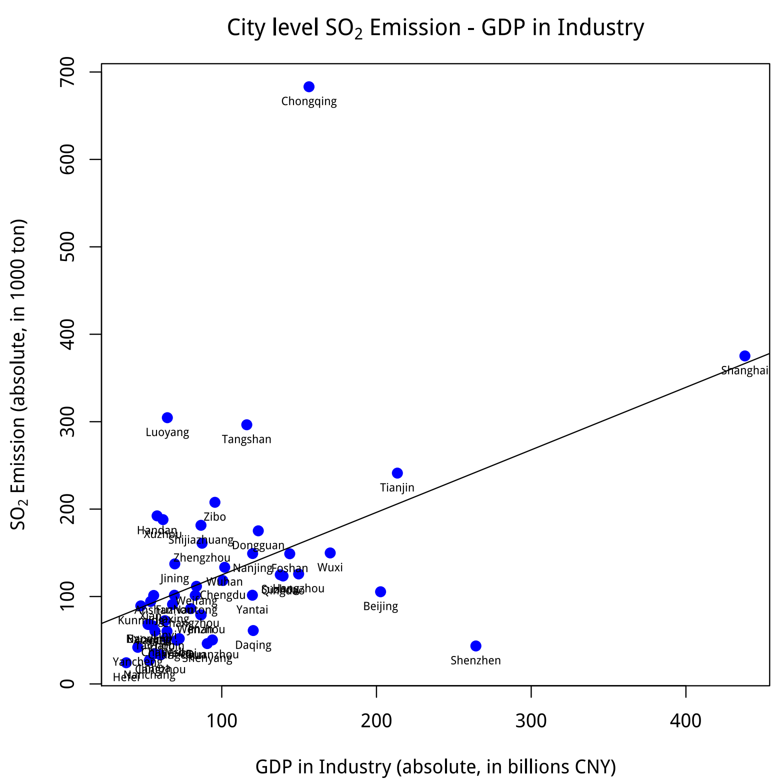




Figure 2-1. City level $SO_2$ emissions versus GDP and GDP in industry in 2005

Figure 2-2. Haze over the Forbidden City in Beijing on December 20, 2016. (McCann, 2016)

2006). Air pollutant emissions are closely related to energy consumption, because of the large reliance on fossil fuels. Thus, emissions of air pollutants associated with energy consumption have been experiencing the similar trend of growth. This is shown in Figure 2-1: the average GDP and average GDP in industry for mega cities are positively correlated with average $SO_2$ emissions of each city over the period 2003 - 2010. The number of days of poor air quality in mega cities is increasing. This can be reflected by a recent figure of Beijing: Figure 2-2. On average, about 10-30% of days exceeded Grade-II [1] standards in Beijing, Shanghai, Pearl River Delta region, and the respective vicinities (Chan and Yao, 2008). About 22% of cities in China with $SO_2$ concentrations exceeded the Grade-II standard and this caused acid rain problems in 38% of cities (Report of the State of the Environment in China, 2005). Negative consequences of pollution in air, water, and other circumstances damage physical resources, human health, and life quality. Solving this problem requires us to look further at China's economy, which induces increased energy consumption and the respective pollution

[1] Grade-II ($SO_2$) of Chinese National Ambient Air Quality Standards (CNAAQS) is 0.15 mg/m$^3$ for daily averages and 0.06 mg/m$^3$ for annual averages.

in the surrounding environment. In response to environmental problems, policies have been enacted by the government. However, top-down implementation of environmental policy interacts with local economic compositions and interests (Eaton and Kostka, 2014; Schreifels et al., 2012). Thus, a detailed understanding of the organization of China's economy and the respective leadership can give us more insights into the origins of the pollution problem and how the situation can be improved.

My analysis starts from a summary of adverse impacts from air pollution. Then, I discuss how the China's economy is organized, the role of SOEs, and how air pollution is related to economic activities. Next, I talk about how governments interact with industries. Until a reasonable linkage between governments and industries is established, I further discuss the motivation for this study and how it is related to technology and policy.

## 2.2 Adverse Impacts from Air Pollution

Health impacts of air pollution are well studied. Usually, negative impacts are measured in terms of morbidity and mortality. In order to estimate economic costs, metrics used frequently are willingness-to-pay (WTP) and associated additional costs in medical system. City level analysis of health costs suggests that consequences of air pollution cannot be neglected. Wang and Mauzerall (2006) implemented an integrated assessment procedure to estimate impacts of air pollution in *Zaozhuang* of China on public health. They showed that the estimated health cost associated with anthropogenic emissions in 2000 of *Zaozhuang* was approximately 0.28 billion USD and this amount was equivalent to 10% of the GDP in the city. Additionally, the projected health cost of the same cause in 2020 was about 2.7 billion USD, which accounts for 16% of the projected GDP in the same city. Zhang et al. (2010) connected energy use, air pollution, and public health impacts for an integrative assessment of air pollution in *Taiyuan* for 2000. The result suggested that the induced excessive deaths associated with particulate matter (PM) pollution in 2000 were about 2,200 in *Taiyuan*. Upon monetization of the health impact, this damage was equivalent to 0.8 – 1.7 billion CNY, which was within the range 2.4 – 4.9% of the city's GDP in 2000. For mega cities, Kan and Chen (2004) estimated that the total economic cost of health impacts attributed to PM air pollution in urban areas of Shanghai in 2001 was approximately 625.40 million USD. This number was equivalent to 1.03% of GDP of the city. On the country level, Matus et al. (2012) utilized an expanded version of a computable general equilibrium model to analyze the health damage from air pollution in China. The conclusion is that although the damage from air pollution in relative terms declined over the last decades, the cost in absolute terms increased to a high degree as the whole economy of China grew.

In addition to air pollution-related health impacts, damages also include polluted rivers, poor quality of drinking water, depleted ground water, and other environmental damages (Vennemo et al., 2009). Apart from this, a great deal of food produced in China is contaminated with pollutants. Wang et al. (2001) presented that in a short period, the irrigation of sewage water could induce increased metal in soil and crops and industrial wastes contributed partly to this type of contamination. Wang et al. (2003) showed that in polluted sites of China, heavy industries, metal mining, smelting and untreated wastewater induced heavy metal contamination in soil. They also pointed out that heavy metal contamination was one of the biggest health problems in China and part of this contamination was traced back to industrial activities (He et al., 2013; Li et al., 2014). Another important damage to environment from $SO_2$ emissions in China was the acidification of soil (Duan et al., 2013). Increased pollution in China can hinder efforts in production of food. Chameides et al. (1999) provided evidence that ozone pollution could affect crop yield in China and this effect was growing even in non-urban areas. Industrial enterprises induce agricultural loss as well.

Wei et al. (2014) analyzed and assessed 2,069 state-monitored units and the associated loss was estimated to be around 1.43 billion USD.

## 2.3 China's Economic Reform and SOEs

Although there is a decline of the output share of SOEs within the whole economy in China, the central Party maintains tight and continued control over SOEs of economic significance (Chan, 2004). The reform of China's SOEs started from 1978 and the ultimate goal was to transform China's economy into a market economy with Chinese characteristics, as shown in Figure 2-3. This is called captalism with Chinese characteristics, which is a function of political balance between market-driven China and state-led China (Huang, 2008). This balance is realized through two channels. The first tool is to encourage explicit private entrepreneurship and on the other hand, the government is to privatize part of SOEs. The financial reform is simultaneous and it is designed to channel a significant high level of credit to private sectors. In general, the reform was implemented with three characteristics:

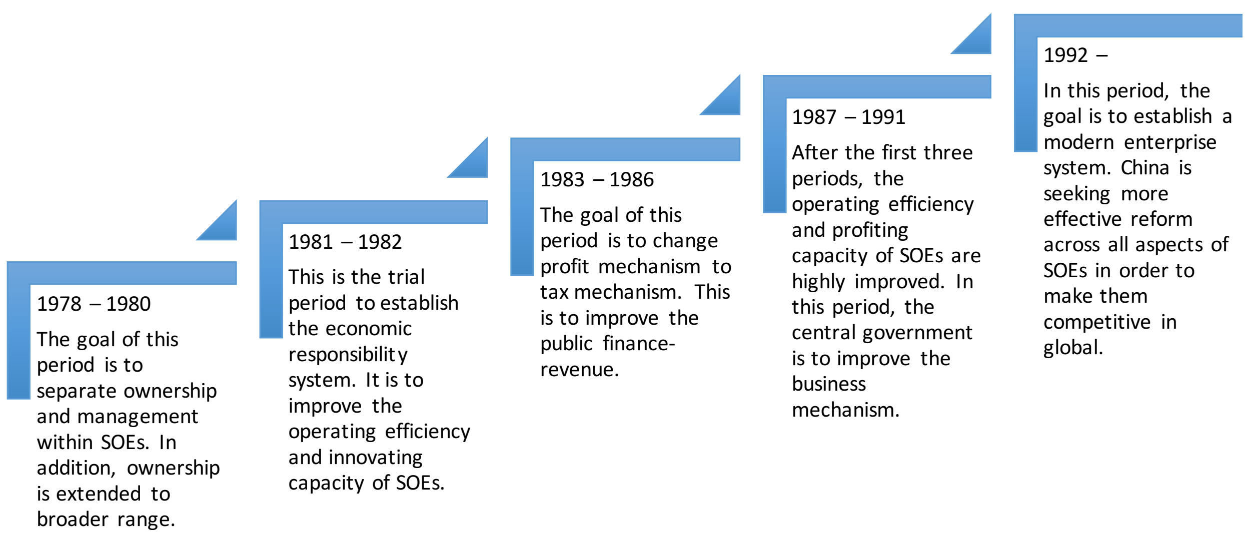



Figure 2-3. Timeline of economic reform in China (Xi, 2007)

decentralization in property rights of SOEs, change in enterprise management structure, and gradual liberalization of resource allocation (Li, 1997). In 1978, SOEs dominated China's economy in almost every aspect and they accounted for approximate 77.6% of the industrial output (Lin et al., 1998). This number has declined gradually since then (Jefferson et al., 2000), which was due to both declining output in SOEs and an increase of private and foreign enterprises' output. However, importantly, SOEs still employ a high percentage of urban workers and control large scale fixed assets in China's economy. This is realized by retaining SOEs' role in controlling fundamental sectors (e.g., power, telecommunication, and energy) in China. Figure 2-4 is compiled based on an unbalanced and balanced dataset including type information of enterprises in my analysis and it shows the absolute gross output for enterprises of different types of ownership from 2005 to 2009. Values are aggregated over enterprises in the whole country and rely mainly on data from an industrial survey of China.

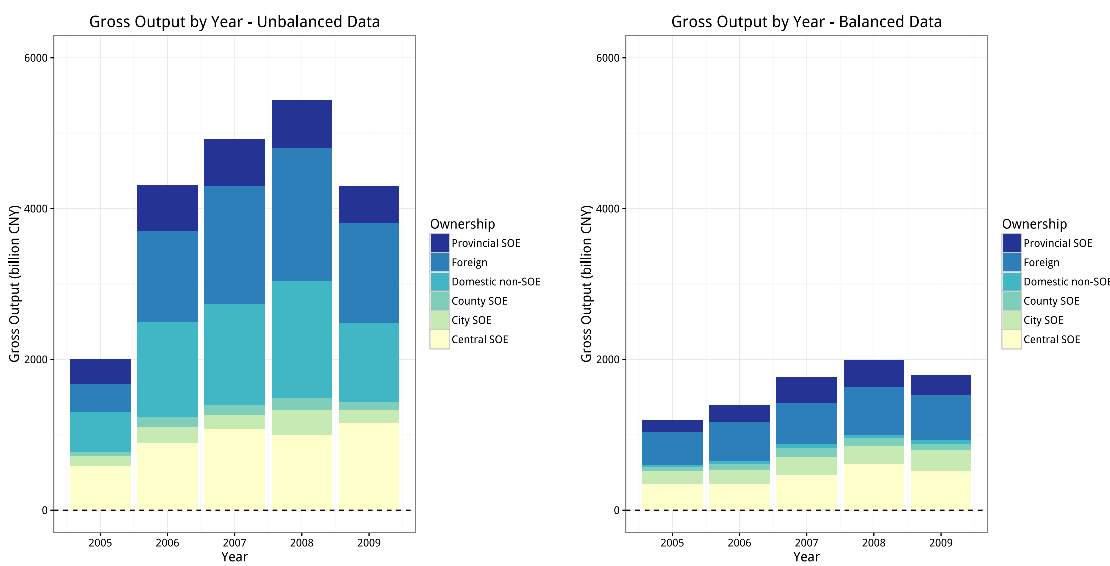



Figure 2-4. Economic output of enterprises of different types in China

Despite several decades of reform and privatization of SOEs, government-industry linkages remain tight, especially in energy and resource intensive sectors. For example, the energy consumption of the entire economy in China was 3,480 million tons of coal equiva-

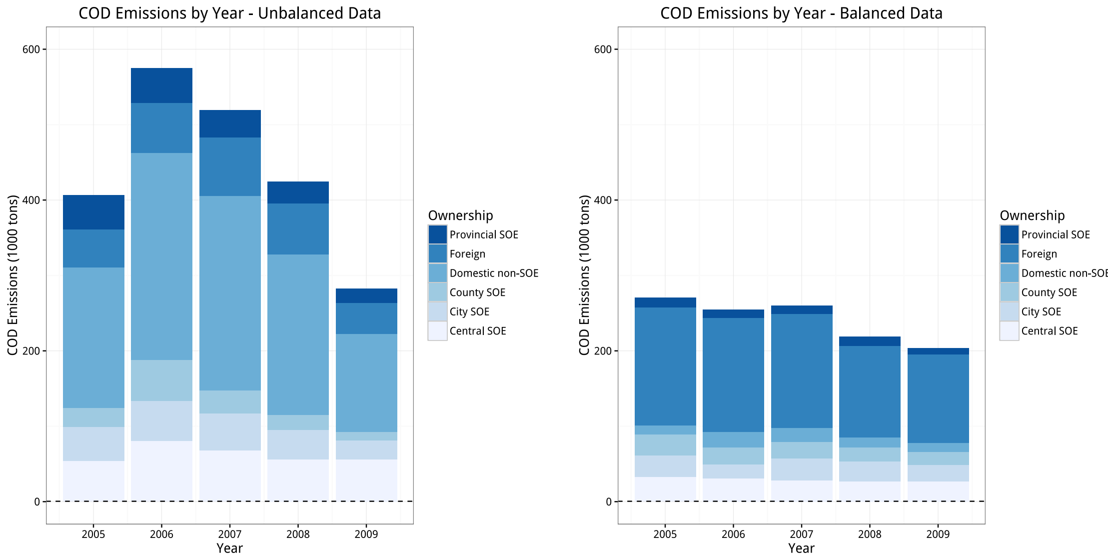



Figure 2-5. Emissions of chemical oxygen demand (COD) of enterprises of different types in China

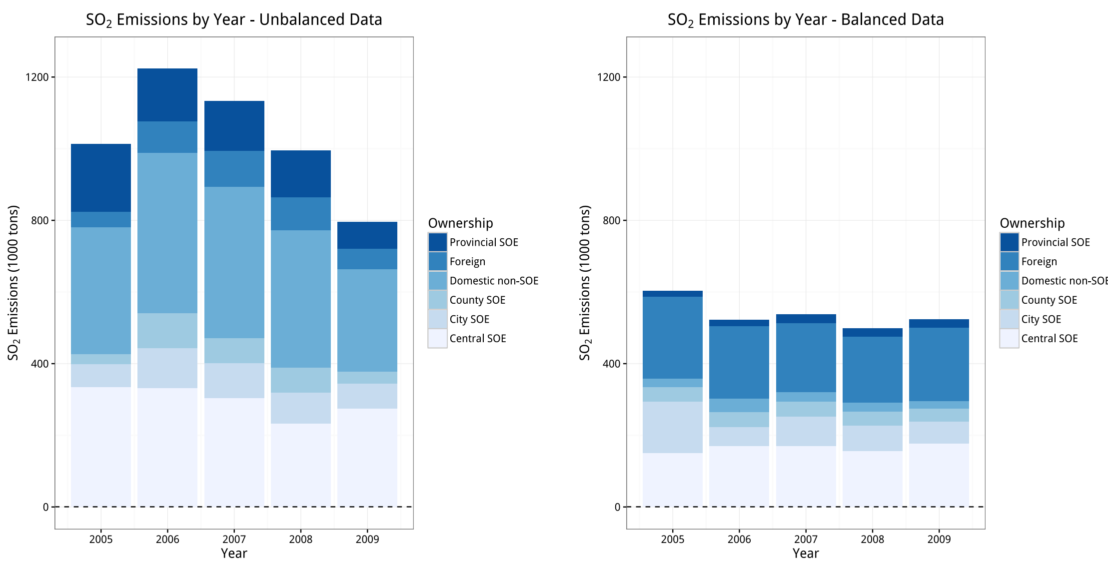



Figure 2-6. Emissions of sulfur dioxide ($SO_2$) of enterprises of different types in China

lents (Mtce) in 2011. Of the total energy consumption, industrial energy consumption was 2,464 Mtce in the same year and of this, the energy consumption of manufacturing was 2,004 Mtce. Finally, the respective energy consumption in the iron and steel sector was 589 Mtce, which accounted for 29%, 24%, and 17% of the manufacturing, industrial, and total energy consumption respectively (China Energy Statistical Yearbook, 2012). The estimated direct $CO_2$ emissions within the iron and steel industry was 920 million tons in 2007 in China (Shangguan et al., 2010) and this number was approximately equivalent to 15% of total emissions in China (Xu et al., 2013). Furthermore, this industry is tightly controlled by the state. On the structure of the ownership in the enterprise, the average number of employees in state-owned and state-holding enterprises is approximately equivalent to 41% of total employees in all iron and steel enterprises (Lin and Wang, 2014).

When looking at SOEs' impacts on the environment of China, the structure of chemical oxygen demand (COD) and $SO_2$ emissions in China is illustrated in Figure 2-5 and Figure 2-6 respectively and the value is the aggregate value of all firms belonging to the same type of enterprise. SOEs play an important role in China's emissions and pollution related industries.

## 2.4 Government-industry Linkages

Ties between SOEs and the government can be very close and SOEs in reality are systematically controlled by the central government. In the political system of China, *guoziwei* is the agency designed to control SOEs across different authority levels (e.g., state (central) level, provincial level, city level, and county level). The *guoziwei* is a governmental agency and the personnel system is partially determined by local leadership. In particular, rotation of personel between SOEs and governmental agencies exists. SOEs' leaders often rotate in and out of government positions in some situations (Yang et al., 2013). For example, the mayor of *Nanjing* in 2013, *Hongkun Jiang*, was previously the manager and party secretary of the state-owned *Mechanical Industrial Company of Shazhou County*. Such personnel management in the system is one way to cultivate the linkages between governments and industries.

Local leaders impact the implementation of policy principally due to three mechanisms in China: fiscal decentralization from the central government, unchanged economic incentives to local officials, and highly selective toleration of corruption behaviors (Fan and Grossman, 2001). Based on these three mechanisms, certain linkages between governments and industries can be established.

Fiscal decentralization facilitates more linkages between local leadership and industries. Looking at the evolution of SOEs, they were originally developed not under market conditions but under the central plan prior to the economic reform. Thus, many of them retain socialist characteristics and these SOEs work as pillars in the region in terms of providing social benefits and welfare. In order to carry out this function, a coalition between local governments and SOEs is established in order to maintain SOEs' business (Zhu, 1999). Apart from this, fiscal decentralization facilitates collusion between local municipal governments and enterprises' managers when there is fiscal pressure from the central government (Broadman, 1995); and, this collusion can be beneficial to both local leadership and SOEs' managers as the increased revenue of enterprises can yield better evaluation of the performance for both government level and enterprise level leadership. This was confirmed by Li and Zhou (2005) and Lin (2007): better economic performance can contribute to the promotion of local leaders. Additionally, it was pointed out by Gordon and Li (1997) that local officials have much more strongly supported new non-state firms in China as local governments can receive additional taxes from those new firms.

Corruption is also a form of interaction between officials and enterprise leaders. The corruption in China emerges as a problem while in some cases, corruption can facilitate economic development (Huntington, 2006; Lui, 1985). Fan and Grossman (2001) argued that the political advantage of corruption was to provide a way to compensate those local officials who promoted the economic development. In China, the corruption behavior is embodied in two ways: *tanwu shouhui* and *nuoyong gongkuan*. The first behavior refers to extracting bribes or arranging nepotistic favors and the other refers to misappropriating public property or public funds for private benefits by officials. Thus, officials in the government are reasonably assumed to maintain an invisible linkage with local enterprises via *tanwu shouhui*. For example, some selected corruptions are published by the Central Commission for Discipline Inspection (CCDI) [2].

## 2.5 Motivation for Research

Severe environmental damages have accompanied rapid economic growth in China during the past several decades. In 2015, the Ministry of Environmental Protection estimated that economic burden of pollution could be as high as 6% of GDP during the Eleventh Five-Year Plan (2006-2010). Significant adverse impacts from air pollution include both residents' health and environmental damages. In China's economy, SOEs still play an important role and these SOEs retain tight control of fundamental business, especially in energy and resource intensive sectors, which emit the most of the source of air pollution. Linkages between SOEs and governments are pretty close and leaders rotate across SOEs and governmental agencies. In addition, top-down implementation of environmental policy can be ineffective due to local economic compositions and interests. Local economic interests are embodied by government-industry coalition, private incentives of promotion, and corruption. Therefore, analyzing solutions to China's environmental problems leads us to take a close look at the relationship between local leadership's characteristics and environmental performance. The connection is hypothesized to be built up via invisible government-industry linkages. Thus, a thorough understanding of the correlation between leadership's characteristics and envi-

[2] The official website is http://www.ccdi.gov.cn/.

ronmental performance can provide insights into improving the surrounding environment via institutional management.

## 2.6 Linkages to Technology and Policy

Leadership plays an important role in determining technology choice and adoption. City leadership can shape the industrial organization of a city to some degree. This is realized by the invisible government-industry linkage. In this sense, leadership's personal preference across different technologies can be reflected by the evolution of technologies in the respective city. Here, I begin the research by understanding city leadership's impacts on the outcome of technologies; and, the city leadership's impacts on the choice of technologies in the city could be further investigated. The result informs insights into the interaction between technology, policy, and society.

An important question is whether or not city leadership would foster the implementation and operation of $SO_2$ removal facilities. Particularly, flue gas desulfurization (FGD) is the main technology to improve $SO_2$ removal index in cities. The correlation between $SO_2$ removal rates and mayors' personal characteristics can tell us which mayors might promote the usage of these technologies. In the future, related follow-on work could be developed in order to understand similar questions such as how institutional management affects the development of the electrification of transportation and other clean energy transitions.

# Chapter 3

# Policy Setting in China

In this chapter, I provide the history of $SO_2$ regulation in China, as shown in Figure 3-1. Schreifels et al. (2012) described the evolution of China's $SO_2$ control systematically. I focus on the $SO_2$ control during the 10th and 11th Five-year Plans (FYP), which spanned the time period of my analysis. In general, the national policy imposed a target of 10% reduction at the beginning of each of the FYP. However, the realized reductions within the two periods were quite different. This phenomenon is attributable to several factors, to be discussed.

## 3.1 Market-based Tools

$SO_2$ is the pollutant which has received the most regulatory attention from the Chinese government. As a major contributor to surrounding air quality and acid rain, $SO_2$ has been regulated via a number of policy instruments and programs in China since 1990s. In fact, regulation was proposed as early as 1979's "Trial Environmental Law" and 1982's "Interim Procedure on Pollution Charges" but was delayed due to a lack of monitoring and enforcement capabilities.

The pollution levy has been implemented by the Chinese government as one of the market-based tools in regulating $SO_2$ emissions. At the beginning, the idea was to charge those emissions above a certain limit. However, owing to the limited monitoring and enforcement mechanism, the government altered the levy implementation in several dimensions to improve the capability of the levy such as changing the level of the levy, applying the levy to total emissions instead of those above the limit, and covering different industries and regions. However, the effectiveness of the levy was not obvious (Finamore and Szymanski, 2000). This is in part caused by the political system. In earlier phases of the policy, most of the levy was recycled to compensate for the pollution control cost of local firms, and the rest of the revenue was used to fund the local Environmental Protection Bureau (EPB) (Wang and Wheeler, 2005). However, in most cases, firms did not take advantage of the recycled levy to invest in reducing emissions (Ellerman, 2002). The levy was, in many cases, cheaper than emission control cost in later phases. This made firms directly pay the levy without reducing emissions (Gao et al., 2009). What's more, local EPBs were not powerful enough to enforce the implementation of the levy. For instance, the local government negotiated with local EPBs to reduce the levy in order to protect local firms in some cases, possibly due to the linkage between governments and industries.

In addition to the levy, subsidies have been utilized by the government to compensate for the cost of adopting flue gas desulfurization (FGD, i.e., $SO_2$ scrubbers) in curbing emissions from power plants. At the initial stage, this policy was not effective since subsidies were targeted at the installation of FGDs, while they were found in some cases not be operated once installed (Schreifels et al., 2012). Thus, most power plants only installed the equipment without running them. The portion of FGDs in power plants actually in use was quite low due to operational costs, lack of trained staff, and lack of effective monitoring systems by the end of 2005. In order to improve the usage of FGDs, the high-level administration considered and implemented several solutions including installing continuous emission monitoring systems (CEMS), differentiating the premium based on the usage of FGDs, and introducing a franchising mechanism for desulfurization (Li et al., 2011). The usage of FGDs increased to 86% by the end of 2010 (China Electricity Council, 2011).

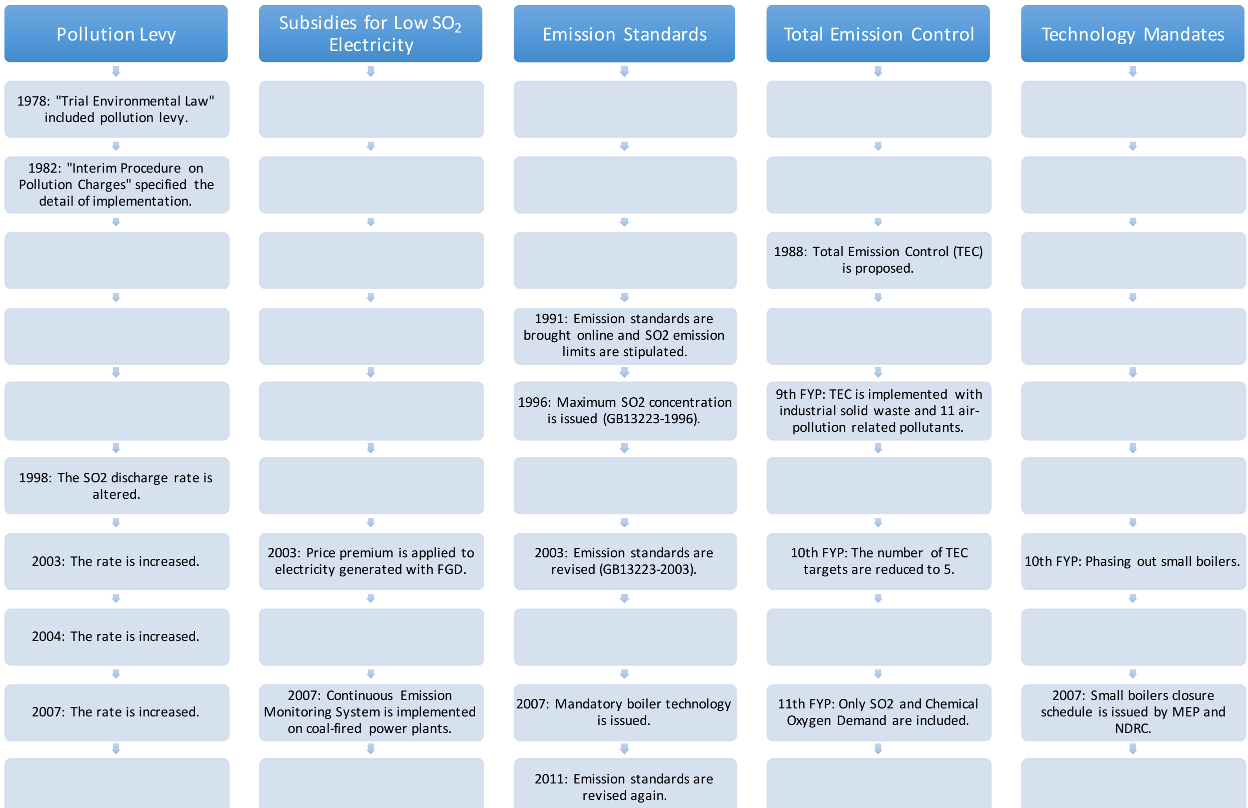



Figure 3-1. Timeline of emission policy evolution in China

## 3.2 Command-and-control Tools

The economy in China is characterized as market economy with Chinese characteristics. Local officials and SOEs in China are systematically controlled by the central government. This fact makes China an easier context in which to implement top-down command-and-control policy. The command-and-control tools can be classified into two categories: emission (performance) standards and technology mandates.

China introduced the first emission standard for power plants in 1991, focusing on regulating $SO_2$ emissions. To account for differences in conditions, the standard is differentiated across power plants based on different factors such as age, location, stack height, and meterological conditions. Power plants using high-sulfur coal have more stringent standards, while the standard is relaxed for plants with low-sulfur coal. Regionally speaking, power plants in eastern China face stricter limits than in western China. The idea is to help western areas to develop their economies; also, environmental conditions in western China are much better than that in eastern China (Schreifels et al., 2012). Since the enactment of this standard, it has been revised several times to be more stringent as technology has become available and economies have been more able to bear the cost.

In addition to firm-level control, the central government also introduced total emission control (TEC) on particular pollutants, such as $SO_2$, in the 1990s. The TEC policy is to set a cap on total emissions of $SO_2$ compared to the level of the final year in the previous FYP. The mechanism of the TEC policy is to distribute emission limits gradually from the central to local government (Schreifels et al., 2012). On the ground level, the local administration then negotiates a local allocation plan with stakeholders. Local governments implement and enforce the TEC program. Furthermore, failure to meet the TEC policy does not involve any violation of law, as a result of which the policy was not effective during the 10th FYP.

Technology mandates in China involve three elements: upgrading existing facilities, installing additional pollution-control facilities, and phasing out old or inefficient facilities. Williams and Kahrl (2008) mentioned that China introduced mandatory technology requirements on capacities and boiler technologies for new coal-fired generating units. This has improved the technology across coal-fired power plants on average. As noted previously, FGDs are subsidized by the local government to be installed in power plants. Although there were problems with the implementation of this policy, the administration in China has actively sought to figure out solutions to these problems. For example, the CEMS was created to improve the data accuracy (Zhang and Schreifels, 2011). Along with the fast growth of the economy in China, many small and inefficient power plants were constructed to meet the resulting growth in demand for electricity prior to the 10th FYP. Due to the inefficiency of these power plants, the central government planned to phase them out. However, this process was far more difficult than expected, owing to the lack of incentives, local resistance, and continued growth in demand for electricity (Schreifels et al., 2012). To make this much easier, the China's administration invented flexible ways to accelerate the process (Williams and Kahrl, 2008), and it came to be effective during the 11th FYP.

## 3.3 Total Emission Control of $SO_2$ in the 10th and 11th Five-Year Plan

With the degradation of the environment, environmental development has gradually become a significant part of the FYP. As one of regulated pollutants, TEC of $SO_2$ entered both the 10th and 11th FYP. The national policy imposed a target of 10% reduction during both the 10th and 11th FYP. However, realized reductions of $SO_2$ emissions within these two periods are quite different (Schreifels et al., 2012). This phenomenon is attributed to several factors to be discussed.

During the 10th FYP, the $SO_2$ emission reduction was set to be 10% in 2005 compared to the level in 2000. However, it was very difficult: $SO_2$ emissions were reported to increase by 28% in 2005 compared to the level in 2000. Among many factors contributing this significant increase of $SO_2$ emissions, economic growth was the most significant. During the 10th FYP, the annual growth rate of China's GDP was around 13.3%. This tremendous growth of the economy was accompanied by a similar growth of energy consumption, especially coal. In order to meet the growing consumption of electricity, the previous plan to close inefficient power plants encountered significant resistance for several reasons including shortages of electricity, opposite from local administrations, and lack of incentives. Apart from this, local leadership generally prioritized economic development instead of environmental management, as environmental progress did not enter into the evaluation score of local officials in the 10th FYP (Xu, 2011a). On the other hand, lack of effective enforcement mechanisms made the implementation of TEC by local governments more difficult, as exceeding TEC limits does not involve any violation of the law, and polluters do not face any penalty. Thus, total $SO_2$ emissions increased (instead of decreased) during the 10th FYP.

During the 11th FYP, the $SO_2$ emission reduction was set to be 10% in 2010 compared to the level in 2005. $SO_2$ emissions were reported to decrease by 14% in 2010 compared to the level in 2005. It is important to note that the benchmark level of the 11th FYP is the $SO_2$ emission level in 2005 while the benchmark level of the 10th FYP is the $SO_2$ emission level in 2000, and it is clear that the emission level in 2005 is much higher than that in 2000. However, both FYPs covered periods that were characterized by rapid economic growth. Therefore, although the benchmark level of the 11th FYP was higher than that in the 10th FYP, the environmental improvement was still much better in the 11th FYP than that in the 10th FYP. Several factors contributed to this progress. First, the central government paid closer attention to the environmental achievement of local governments and therefore, the supervision and monitoring system became more stringent (Moore, 2011; Xu, 2011a). At the same time, the Ministry of Environmental Protection (MEP) was elevated to a higher-level ministry in 2008. This increased its power and authority with respect to other government bodies, thereby improving its ability to enforce regulation. Second, technological innovation and knowledge improvement enabled a growing rate of installation and operation of FGDs (Xu, 2011b), leading to a greater degree of end-of-pipe $SO_2$ removal. Third, the process to close small or inefficient power plants was accelerated by designing several incentive mechanisms by local administrations. All in all, more effective measures were adopted to improve the environment, and China's government was equipped with more experience in terms of environmental management and control in the 11th FYP.

## 3.4 Government-industry Linkages in Policy Setting

SOEs are always led by *guoziwei*, the agency to manage state-owned assets, on different authority levels. As *guoziwei* is part of the government, the linkage between governments and industries is established.

From the perspective of policy, binding agreements exist between the government and state-owned industries to reduce $SO_2$ emissions associated with SOEs. The central and local government may consider the performance of pollution control measures taken by enterprises as one element in the evaluation of their managers (Guttman and Song, 2007). In addition to mandatory control and enforcement, the central and local government also provide suitable incentives (e.g., subsidies, special loans) for enterprises to adopt efficient pollution control measures such as installing FGDs, consuming low-sulfur energy, and updating existing facilities.

On the other hand, local interests might interact with central directives negatively or positively. In China, local EPBs face dual leadship: local governments and the central MEP. While the MEP directs them to fulfill national targets, the local government must provide the necessary resources (Schreifels et al., 2012). However, this local support might make the local EPB's behaviors conflict with the central MEP's objectives, as regional benefits are more important to local leadership in some cases and local leaders are expected to affect local EPBs' behaviors to protect local benefits. One reason for the non-compliance with respect to environmental targets in the 10th FYP is that local governments often prioritize economic development to environmental achievement. Thus, there existed cases where local leadership required the EPB to cut levies, in the name of protecting local economies. It is also possible that the monitoring system is weakened owing to the strong linkage between the local government and industries. From the perspective of local leaders, they may impose preference or discrimination across enterprises of different authority levels when negotiating allocation of national targets.

To conclude, the policy system enables the forming of linkages between the leadership and the decision-making processes of industries. This is reflected while not limited by facts mentioned above: negotiation of policy implementation, conflict of interests between local agencies and the central objective, and inability of monitoring system. However, the local leadership can play a role in the arising of these facts; and, this leads to my hypothesis that local leaders can directly or indirectly impact environmental outcomes via government-industry linkages.

# Chapter 4

# Data Description

In this chapter, datasets used in the analysis are introduced. Two main datasets are utilized in my analysis: city-level dataset and city-ownership dataset. In city-level analysis, I analyze leaders' impacts on the city-level environmental performance. In city-ownership analysis, the city-level polluting index is split into several categories - defined by firms' authority levels. In this sense, the dataset allows me to investigate the strength of linkages between leaders and enterprises of different authority levels.

## 4.1 City Level Analysis

Prefectural city level environmental performance is observed. At the same time, rotations of leaders across different prefectural cities are available. In some cases, a few cities and leaders' information is missing. Due to the limitation of data sources (e.g., $SO_2$ emissions), the time spans from year 2003 to 2010. In general, the number of distinct cities in the dataset is 276. Totally, there are 2,156 observations. However, not all cities are observed for all years while each city is at least observed for 4 years. Table 4.1 shows the balanced and unbalanced data sets respectively [1]. Additionally, Figure B-1 and Figure B-2 visualize the number of observed cities in each province across the whole country. It is noted that *Xizang* (Tibet) does not have any observations. In the rest of this section, I spend more time discussing the pollution data observed in my dataset. For leaders' characteristics, I have two different sources and I talk about them separately. Finally, I compare leaders' characteristics in different sources.

Table 4.1. Balanced and unbalanced information of observed cities

| Datasets | unbalanced | | | | balanced | Total |
|---|---|---|---|---|---|---|
| Number of years observed | 4 | 5 | 6 | 7 | 8 | - |
| Number of cities observed | 2 | 1 | 8 | 25 | 240 | 276 |

### 4.1.1 Pollution and Economic Index

The city level pollution data is from a commercial data source: CEIC [2]. It includes accurate micro and macro economic and pollution data for prefectural level cities in China. In my analysis, I heavily investigate three important pollution indices: $SO_2$ emissions, $SO_2$ emissions intensities [3], and $SO_2$ removal ratios. Within these indices, $SO_2$ emissions and end-of-pipe $SO_2$ removals are directly reported. For others, the definition is given by:

$$\text{SO}_2 \text{ emissions intensity} = \frac{\text{SO}_2 \text{ emissions}}{\text{Monetized Industrial Output}} \tag{4.1}$$

and

$$\text{SO}_2 \text{ removal ratio} = \frac{\text{SO}_2 \text{ removal}}{\text{SO}_2 \text{ removal } + \text{ SO}_2 \text{ emissions}} \tag{4.2}$$

where the $SO_2$ removal is the end-of-pipe removal of $SO_2$. Other economic indices are also observed in the data such as GDP, GDP in industry, and population for each city. All the

[1]Balanced cities are observed in 8 years while unbalanced ones are observed in less then 8 years: 2003 - 2010.
[2]The dataset can be found on https://www.ceicdata.com/en.
[3]This is based on industrial output. Monetized industrial output is in nominal term.

summary statistics are shown in Table 4.2.

Table 4.2. Pollution and economic index summary statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max | Unit |
|---|---|---|---|---|---|---|
| $SO_2$ emission | 2,156 | 64.48 | 64.59 | 0.01 | 710.8 | 1000 tons |
| $SO_2$ removal | 2,089 | 78.15 | 520.15 | 0.01 | 18399.5 | 1000 tons |
| $SO_2$ emission intensity | 2,156 | 2.64 | 3.42 | 0.00 | 43.13 | 1000 tons / Billion CNY |
| $SO_2$ removal ratio | 2,089 | 0.33 | 0.24 | 0.00 | 0.996 | - |
| Water discharge | 2,155 | 80.78 | 109.49 | 0.17 | 912.6 | Million tons |
| Water meet standard | 2,155 | 75.30 | 104.84 | 0.17 | 880.72 | Million tons |
| Water treatment rate | 2,155 | 0.90 | 0.13 | 0.01 | 1 | - |
| GDP | 2,156 | 94.96 | 138.74 | 3.18 | 1716.6 | Billion CNY |
| GDP in industry | 2,156 | 47.53 | 65.81 | 0.91 | 721.83 | Billion CNY |
| Population | 2,115 | 4346.17 | 3081.67 | 163.7 | 28846 | Thousand |
| GDP in agriculture | 2,156 | 9.18 | 7.11 | 0.08 | 68.538 | Billion CNY |
| GDP in service | 2,156 | 38.29 | 75.21 | 0.5 | 1060.1 | Billion CNY |
| Per capita GDP | 2,152 | 21180.38 | 17093.44 | 2126 | 175125 | CNY |
| Dust emission | 2,140 | 858.08 | 1066.52 | 0.00 | 9065.052 | 1000 tons |
| Dust removal | 2,152 | 25.38 | 25.15 | 0.03 | 250.308 | 1000 tons |
| GDP growth rate | 2,153 | 0.18 | 0.12 | -0.74 | 3.929471 | - |

## 4.2 Enterprise Level Analysis

The firm level balanced pollution data is from MEP [4] of China. The pollution data was collected from 2005 to 2009 by the MEP. The data covers 32 provinces, direct-controlled municipalities [5], and autonomous regions [6]. In addition, due to the limited availability of data, the pollution index is not available in *Xizang* (Tibet). Target establishments are determined by a collaborative effort between the central MEP and regional MEPs. It includes principal sectoral emitters of pollution such as agriculture, forestry, pasturage and fishery, mining and quarrying, manufacturing, production and supply of electric power and heat, production and supply of gas, and construction.

The MEP requires each establishment to self-report the pollution data for the previous

[4] Ministry of Environmental Protection of the People's Republic of China: http://www.mep.gov.cn/.
[5] There are four direct-controlled municipalities in China: Beijing, Tianjin, Shanghai, and Chongqing.
[6] There are five autonomous regions in China: Xinjiang, Inner-mongolia, Ningxia, Guangxi, and Xizang.

year and it also maintains monitoring and occasional investigating activities on polluting behaviors of targets. Any cheating behavior is to be punished (e.g., fining, deterring SOE leaders' promotion). Sources of pollution appearing in the data are $SO_2$ emissions, removal amount, and the respective economic gross output.

### 4.2.1 City and Ownership

In this part, I aggregate economic and pollution data according to the ownership type of enterprises. Six types are considered in my analysis: Central SOE, Provincial SOE, City SOE, County SOE, Domestic non-SOE, and Foreign. They are shown in Table 4.3.

Table 4.3. Pollution and economic index summary statistics - ownership level, balanced

| Variable | Ownership | Obs | Mean | Std. Dev. | Min | Max | Unit |
|---|---|---|---|---|---|---|---|
| $SO_2$ emission | Domestic Non-SOE | 1,328 | 2.82 | 3.85 | 0 | 39.69 | 1000 tons |
| | Provincial SOE | 620 | 3.06 | 7.27 | 0 | 88.80 | 1000 tons |
| | Central SOE | 439 | 3.73 | 9.24 | 0 | 68.31 | 1000 tons |
| | City SOE | 805 | 0.79 | 1.52 | 0 | 11.02 | 1000 tons |
| | County SOE | 800 | 0.54 | 1.07 | 0 | 16.30 | 1000 tons |
| | Foreign | 672 | 0.70 | 1.63 | 0 | 17.67 | 1000 tons |
| $SO_2$ removal | Domestic Non-SOE | 1,328 | 1.49 | 4.53 | 0 | 63.32 | 1000 tons |
| | Provincial SOE | 620 | 4.27 | 28.17 | 0 | 405.49 | 1000 tons |
| | Central SOE | 439 | 6.28 | 32.55 | 0 | 409.01 | 1000 tons |
| | City SOE | 805 | 0.59 | 1.91 | 0 | 16.63 | 1000 tons |
| | County SOE | 800 | 0.24 | 0.85 | 0 | 9.70 | 1000 tons |
| | Foreign | 672 | 0.42 | 2.15 | 0 | 44.33 | 1000 tons |
| $SO_2$ emission intensity | Domestic Non-SOE | 1,328 | 1.47 | 2.56 | 0 | 51.46 | 1000 tons / Billion CNY |
| | Provincial SOE | 620 | 1.88 | 8.36 | 0 | 189.38 | 1000 tons / Billion CNY |
| | Central SOE | 436 | 1.67 | 15.28 | 0 | 309.54 | 1000 tons / Billion CNY |
| | City SOE | 801 | 2.27 | 24.63 | 0 | 690 | 1000 tons / Billion CNY |
| | County SOE | 800 | 3.08 | 10.25 | 0 | 239.37 | 1000 tons / Billion CNY |
| | Foreign | 671 | 0.81 | 2.53 | 0 | 36.47 | 1000 tons / Billion CNY |
| $SO_2$ removal ratio | Domestic Non-SOE | 1,323 | 0.20 | 0.22 | 0 | 1.00 | - |
| | Provincial SOE | 594 | 0.25 | 0.30 | 0 | 1.00 | - |
| | Central SOE | 424 | 0.26 | 0.30 | 0 | 0.99 | - |
| | City SOE | 779 | 0.21 | 0.28 | 0 | 0.98 | - |
| | County SOE | 778 | 0.15 | 0.23 | 0 | 0.95 | - |
| | Foreign | 652 | 0.23 | 0.28 | 0 | 0.99 | - |
| Gross Output | Domestic Non-SOE | 1,328 | 4.42 | 8.45 | 0.00 | 102.94 | Billion CNY |
| | Provincial SOE | 620 | 5.54 | 15.13 | 0.01 | 168.62 | Billion CNY |
| | Central SOE | 439 | 8.98 | 21.20 | 0 | 174.04 | Billion CNY |
| | City SOE | 805 | 1.65 | 4.29 | 0 | 49.46 | Billion CNY |
| | County SOE | 800 | 0.82 | 2.22 | 0.00 | 28.09 | Billion CNY |
| | Foreign | 672 | 4.06 | 10.99 | 0 | 137.20 | Billion CNY |

### 4.2.2 City and Category

Different from the analysis in the previous part, I merge ownership types into four categories: Central and Provincial SOE, City or below SOE, Domestic non-SOE, and Foreign. They are shown in Table A.1.

## 4.3 Mayors' Characteristics

In this section, I describe the dataset including information of leadership's characteristics. The data is mainly scraped from online sources. I have two different datasets by scraping from different sources [7]. These characteristics are described as dummy variables and therefore, the mean value represents the percentage of mayors with the particular characteristic.

### 4.3.1 Mayors' Characteristics - Source 1

In the first data source, 19 characteristics of mayors are extracted [8]. The distribution of observed distinct mayors is presented in Figure B-3 and Figure B-4. The descriptive statistics can be found in Table 4.4. Identified by city and year, 2,080 observations are observed.

### 4.3.2 Mayors' Characteristics - Source 2

In this data source, 10 characteristics are extracted [9]. The distribution of observed distinct mayors is presented in Figure B-5 and Figure B-6. The descriptive statistics can be found in Table 4.5. Identified by city and year, around 1,500 observations are observed.

[7] Two online sources are www.baidu.com and www.weibo.com, collected by Professor Jing Cao at Tsinghua University and Professor Shanjun Li at Cornell University.

[8] This is from Professor Jing Cao at Tsinghua University.

[9] This is from Professor Shanjun Li at Cornell University.

Table 4.4. Leadership's characteristics - source 1

| Variable | Obs | Mean | Std. Dev. | Min | Max | Definition |
|---|---|---|---|---|---|---|
| retire | 2,080 | 0.01 | 0.12 | 0 | 1 | Going to retire after service. |
| mret50 | 2,080 | 0.55 | 0.50 | 0 | 1 | Age greater equal than 50. |
| mret51 | 2,080 | 0.47 | 0.50 | 0 | 1 | Age greater equal than 51. |
| mret53 | 2,080 | 0.27 | 0.45 | 0 | 1 | Age greater equal than 53. |
| mret55 | 2,080 | 0.14 | 0.35 | 0 | 1 | Age greater equal than 55. |
| mret57 | 2,080 | 0.06 | 0.23 | 0 | 1 | Age greater equal than 57. |
| local | 2,080 | 0.62 | 0.49 | 0 | 1 | Promoted from the same city. |
| ctr | 2,080 | 0.01 | 0.12 | 0 | 1 | Going to central government after appointment. |
| wbind | 2,080 | 0.17 | 0.38 | 0 | 1 | Industry workbackground. |
| wbctr | 2,080 | 0.03 | 0.18 | 0 | 1 | Central governmental workbackground. |
| wboth | 2,080 | 0.05 | 0.22 | 0 | 1 | Gov. workbackground in outside provinces. |
| wbsel | 2,080 | 0.83 | 0.37 | 0 | 1 | Governmental workbackground in same provinces. |
| wbpro | 2,080 | 0.51 | 0.50 | 0 | 1 | Provincial level governmental workbackground. |
| wbhig | 2,080 | 0.53 | 0.50 | 0 | 1 | Provincial level or higher gov. workbackground. |
| hum | 2,080 | 0.61 | 0.49 | 0 | 1 | Education in humanities. |
| eng | 2,080 | 0.21 | 0.41 | 0 | 1 | Education in engineering. |
| sci | 2,080 | 0.07 | 0.26 | 0 | 1 | Education in science. |
| med | 2,080 | 0.00 | 0.04 | 0 | 1 | Education in medical school. |
| phd | 2,080 | 0.16 | 0.36 | 0 | 1 | Ph.D. degree. |

Table 4.5. Leadership's characteristics - source 2

| Variable | Obs | Mean | Std. Dev. | Min | Max | Definition |
|---|---|---|---|---|---|---|
| termage | 1,572 | 2.59 | 1.52 | 1 | 11 | Age of mayor's term. |
| postgra | 1,551 | 0.64 | 0.48 | 0 | 1 | Graduate level education. |
| eduyear | 1,551 | 18.25 | 2.06 | 12 | 22 | Number of years of education. |
| fromdm | 1,553 | 0.43 | 0.50 | 0 | 1 | Promoted from deputy mayor. |
| birthprossame | 1,523 | 0.71 | 0.46 | 0 | 1 | Born in the same province. |
| birthcitysame | 1,516 | 0.10 | 0.30 | 0 | 1 | Born in the same city. |
| uni985 | 1,304 | 0.19 | 0.39 | 0 | 1 | Graduate from 985 universities. |
| unieco | 1,191 | 0.34 | 0.47 | 0 | 1 | Economic mayor in university. |
| unionjob | 1,300 | 0.37 | 0.48 | 0 | 1 | University education in on job. |
| biz | 1,510 | 0.42 | 0.49 | 0 | 1 | Industry workbackground. |

### 4.3.3 Consistency of the Two Sources of Data on Mayoral Characteristics

Due to that mayors' information in my analysis is from different data sources, I evaluate the consistency between the two data sources. In the city-aggregate dataset, each observation is identified by year and city name. In total, I have 2,156 observations covering 276 cities. From the data source 1, I can match 2,080 observations out of 2,156 with a mayor and the rest of observations are missing mayor's information. From the data source 2, I can match 1,572 observations out of 2,156 with a mayor and the rest of observations are missing mayor's information. Finally, I find that there are 1,496 observations matched with both mayors from different sources. However, 140 of these 1,496 observations are matched with different mayors. Among these 140 unmatched observations, 110 are owing to that in some cases, mayors enter office in the middle of the year while the data collector could count either of mayors of the city in the year. In addition, 17 out of 140 unmatched observations are due to the mistake (wrong entry) of either dataset. Finally, 13 out of 140 unmatched observations are due to the misspelling of either dataset. All these reasons lead to the minor inconsistency of mayors' information.

# Chapter 5

# Empirical Analysis

In this chapter, I first describe my empirical strategy and hypothesis. Then, I provide a thorough quantitative analysis of the relationship between mayoral characteristics and pollution. I construct the analysis in three separate parts: 1) compare year-to-year changes in $SO_2$ emissions when a mayor with particular characteristics enters and leaves office; 2) estimate average changes in $SO_2$ emissions, controlling for city and year fixed effects, when a mayor with particular characteristics is in office; and 3) evaluate whether or not changes in $SO_2$ emissions can be attributed to behaviors of enterprises of a particular ownership type.

## 5.1 Empirical Strategy

My analysis relies on the identifying assumption that the aggregate pollution index (by ownership type) in cities not under the government of mayors with the particular characteristic forms a valid counterfactual for the aggregate pollution index (by ownership type) in cities under the government of mayors with the particular characteristic, after conditioning on differences in fixed effects across ownership types and cities, preexisting trends, and other control variables.

Facts and regulations in the cadre system of China support my empirical strategy. In China, the formal regulation on the retirement of cadres says that the retiring age of most cadres is 60. This age limit negatively impacts the career prospect of cadres close to the limit. Landry (2005) suggested that the strict enforcement of cadre retirement regulations could give rise to the promotion of a greater share of secondary officials; on the other hand, it could shorten tenures of city leaders. This produces many more observations of mayors and enforced transitions of mayors can form groups that can serve to identify the impact of mayoral characteristics on city-level pollution. In addition, Eaton and Kostka (2012) argued that the high cadre turnover rate of cadres could curb the localism. This randomized control of city leaders is not related to the environmental performance and excludes the possibility of the endogeneity problem. Table A.33 and Table A.34 provide a posterior evidence showing the correlation between leadership characteristics, environmental achievement, and promotion. In particular, the correlation between the "greenness", relative reduction of emission intensity, of leaders and whether or not leaders are promoted to the central government or other agencies after appointment is tested and it shows that the correlation is small and not significant.

Three additional facts also support my empirical strategy that the rotation of mayors is exogenous to their environmental performances. First, the economic development increases the probability that an official is promoted, while the official who is promoted faster also possesses a higher chance to be assigned to a more developed area (Lin, 2007). In this sense, the choice of leaders depends highly on the economic incentive of candidates instead of other factors. Second, there are rare cases that leaders are promoted from candidates who have a previous experience in environmental agencies. In my dataset, I can see that most city leaders are promoted from economic and propaganda related governmental institutions by extending the dataset with resumes of city leaders. Third, prefectural city leaders are assigned by higher level (provincial) leaders. Those who determine the appointment are more concerned with the compliance of those city leaders and maintain direct control over them to maximize overall benefits of the whole province.

These facts allow me to make basic assumptions for my analysis. To exclude endogeneity concerns, I assume that the choice of leaders is not correlated with the "greenness" of the candidates. In other words, incentives to increase the environmental performance of candidates do not affect or partly contribute to their becoming leaders of each city. In particular, the situation of pollution does not affect the choice of leaders from candidates in each city.

## 5.2 Hypothesis

Before the analysis, I made some hypotheses on leadership's impacts on city and sub-city level environmental performance. To this end, exploring the correlation between characteristics (e.g., going to retire) of city leaders and local environmental performance can give us insights into these causal pathways. In my analysis, all characteristics of city leaders are shown in Table 5.1. The respective descriptive statistics can be found in Table 4.4 and 4.5. Below, hypotheses about the interaction between leadership and enterprises are discussed as well.

The mechanism in the cadre management in China makes it possible that city leaders might have relative experience in SOEs. I expect that city leaders who have previous experience in industry pay more attention to local economic growth rather than environmental improvements. Thus, industry background can be used to proxy for the city leader's priority in economic development to environmental management. Additionally, city leaders with industry background are assumed to establish stronger government-industry linkages compared to other leaders. Importantly, this linkage might work as an instrument for leaders

Table 5.1. Hypothesized relationships between city-level index and leadership's characteristics

| Characteristic | Description | Expected impacts on *Economy* | *Pollution* |
|---|---|---|---|
| *mctr* | Mayors promoted to central government | + | + |
| *mprom* | Mayors promoted to central government or other agencies | + | + |
| mwbctr | Mayor with work background in central government | | – |
| mcorrupt | Mayor corrupted when in office | + | + |
| mwbind | Mayor with work background in industry | + | + |
| mret51 | Mayor likely to retire after serving ($\geq$ 51 years) | – | |
| mlocal | Mayor promoted from the same city | + | – |
| mwbpro | Provincial level governmental workbackground | | |
| mwbhig | Provincial or higher level governmental workbackground | | |
| mwboth | Governmental workbackground in outside provinces | | |
| mwbsel | Governmental workbackground in same provinces | | |
| mretire | Going to retire after service | – | – |
| mphd | Ph.D. degree | | |
| mhum | Education in humanities | | |
| msci | Education in science | | |
| meng | Education in engineering | | |
| mtermage | Age of mayors' term | + | – |
| mbcity | Born in the same city | | – |
| mbpro | Born in the same province | | – |

Note: *ex post* characteristics are shown in italic. Others are pre-existing characteristics.

to promote the local economy, which is the driving force for their own promotions. Additionally, I hypothesize that mayors with industrial work background may promote economic development and the associated emissions across most enterprises.

The other direction of government-industry linkage is whether city leaders are promoted from local administrations. The hypothesis is that local mayors are able to inherit the idea from the previous administration in terms of environment management and this consistency in environmental management can bring benefits to the local environment. As mentioned before, government officials and industry leaders are mutually dependent on each other to conduct regular functions. Therefore, leaders from local institutions are estimated to maintain a consistent connection with industry compared to leaders from other cities or provinces.

This consistency helps with the implementation of consistent environmental policies in reducing emissions. Eaton and Kostka (2012) stated that the high turnover rate of mayors could hinder environmental progresses. In the same sense, I can also hypothesize that mayors with higher term-age are going to achieve better environmental performance as they could consistently implement the policy in their term. In this sense, I expect that mayors promoted from the local administration are able to implement effective environmental policies in reducing emissions across all enterprises without discrimination.

In previous discussion, prior literature showed that contribution to economic development led to the promotion of leaders. A certain percentage of city leaders are then promoted into the central government after their service at local administration. Then, I can test whether or not an emphasis on local economic development while in office predicts promotion to the central government. To the extent that economic development coincides with environmental damage, environmental performance metrics for the city decline. One key element in the evaluation of cadres is the economic performance (Li and Zhou, 2005; Zhou, 2007). For mayors, they may directly impact the decision-making process of city or below SOEs to improve their performance and therefore, these enterprises are expected to be allowed to emit more to achieve better economic performance. Conversely, some local leaders could have previous experience in the central government. Normally, these officials are rotated from the central government and they are not under pressure of promotion. More importantly, those officials from the central government should have a broader scope and reflect the central government's ambition in reducing adverse environmental outcomes from economic activities. However, in most cases, they cannot establish strong linkages with local non-SOEs and the lack of monitoring capacity enables those enterprises to emit more.

Strict enforcement of cadre retirement regulations cultivates a number of secondary officials (Landry, 2005). In addition, in order to combat with the localism, the cadre's turnover rate is raised by the government and the rotational mechanism across positions is established (Eaton and Kostka, 2012). As a side effect, the tenure of city leaders is shortened and the respective chance of promotion is lowered for city leaders who are going to retire soon compared to younger leaders. In this sense, I predict that leaders closer to retirement are under less pressure of promotion. Additionally, retiring leaders should consider the public pressure in reducing negative environmental externalities to a higher extent than younger officials. Considering their hierarchy, they are expected to affect lower level SOEs more.

Finally, citizens expect to see that the surrounding environment is going to be better. When mayors face the same environmental problem, those in cities the same as their birth cities and provinces always endure much more pressure than others as they have more citizens who are more familiar with them. Considering this public pressure, mayors from the same birth city and province may feel more pressure to suppress $SO_2$ emissions. Thus, I made a hypothesis that mayors appointed to their birth cities or birth provinces are going to improve the city-level environmental performance. In particular, I expect that mayors appointed to their birth cities are going to take more efforts in reducing city-level emissions than mayors appointed to cities within their birth provinces [1]. Based on this hypotheis, mayors appointed to their birth cities would curb emissions from more enterprises than mayors appointed to their birth provinces.

## 5.3 Preliminary Evidence from City-level Pollution

According to my identifying assumption, I compare the change in the pollution index in cities on transitions of mayors with controlled characteristics to the change in the pollution index in cities on transitions of mayors lacking that specific characteristic. Figure B-7 shows

[1] Mayors assigned to cities within their birth provinces do not mean that they are assigned to cities exactly the same as their birth cities while they are in the same province.

the change in the pollution index in cities on transitions of mayors from those without industry background to those with industry background. Figure B-9 shows the change in the pollution index in cities on transitions of mayors from those without promotion after appointment to those with promotion after appointment. Figure B-11 shows the change in the pollution index in cities on transitions of mayors from those without central government work background to those with central government work background. Figure B-13 shows the change in the pollution index in cities on transitions of mayors promoted from the same city to those promoted from outside. Figure B-15 shows the change in the pollution index in cities on transitions of mayors from those not going to retire after appointment to those going to retire after appointment.

In addition, I conduct a two-sided t-test for the change of three pollution indices ($SO_2$ emissions, $SO_2$ emission intensities, and $SO_2$ removal ratios) with respect to each transition of mayors. For the treated and non-treated groups, I first test whether the change of pollution index is significantly different from zero. Then, the difference of the change of pollution index between treated and non-treated groups is tested as well. This is a difference-in-difference design conditioning on removing year and city trends. The results are shown in Table A.2, Table A.3, and Table A.4. Evidence reads that leaders with industry work background positively impact absolute $SO_2$ emissions and the respective emission intensity when they enter office. It shows consistently that absolute $SO_2$ emissions and the respective emission intensity are lowered when they are leaving office. Effects associated with other controlled characteristics are shown as well.

In Table 5.2, the result of two-sided t-test is summarized. I picked up those entries that indicate consistent impacts on environmental performance when leaders with particular characteristics enter and leave office. "+" means that leaders have a positive impact on the variable and "−" means that leaders have a negative impact on the variable. From the table,

Table 5.2. Two-sided t-test for change of de-meaned and de-trended $SO_2$ index on transitions of leaders

| Characteristic | $SO_2$ Emission | | $SO_2$ Emission Intensity | | $SO_2$ Removal Ratio | |
|---|---|---|---|---|---|---|
| | Balanced | Unbalanced | Balanced | Unbalanced | Balanced | Unbalanced |
| *mctr* | | | −** | | | |
| *mprom* | + | + | | | | |
| mcorrupt | − | − | − | − | | |
| mret51 | − | | | | + | + |
| mret53 | | | − | − | + | + |
| mwbctr | | | −** | | − | −** |
| mwbpro | | | + | | − | |
| mwbhig | | | + | − | − | |
| mwbind | +** | +* | | | −** | −** |
| mwboth | | | | +** | | |
| mwbsel | + | | +** | +** | | |
| mlocal | − | | − | − | + | + |
| mphd | | | | | | |
| mhum | | | + | + | +* | +* |
| msci | | | | | | − |
| meng | + | + | | − | −* | −* |

Note 1: *, **, *** mean 10%, 5%, 1% statistically significant respectively.
Note 2: *ex post* characteristics are shown in italic. Others are pre-existing characteristics.
Note 3: Only mayoral characteristics affecting the city level pollution consistently when they enter and leave office are marked.

I can find that mayors with industry work background (*mwbind*) have significant positive impacts on $SO_2$ emissions and negative impacts on $SO_2$ removal ratios. It shows consistently that mayors with industry work background might put more efforts in developing the local economy but less efforts in removing end-of-pipe $SO_2$ emissions. Additionally, I find that mayors promoted from the local administration devote consistent efforts in reducing $SO_2$

emissions and this supports my hypothesis that mayors from the local administration might inherit the same idea from the previous administration and this consistency can foster the reduction of emissions. Apart from this, as I can see, mayors with ages closer to retirement (*mret51* and *mret53*) have consistent negative impacts on $SO_2$ emissions and they also have positive efforts in removing end-of-pipe $SO_2$ emissions. In addition, other age cut-offs (*mret55* and *mret57*) are tested and they show consistent impacts on $SO_2$ removals. As discussed, retiring mayors are under less pressure of promotion and they are expected to pay more attention to reduce environment damages. It is also interesting to note that mayors with corruption behaviors (*mcorrupt*) are associated with a decrease in $SO_2$ emissions and $SO_2$ emission intensities. These effects might be due to the fact that corrupted officials are seeking private economic benefits instead of an overall fair economic development. Therefore, enterprises in that area are under weak incentives to develop and respectively, $SO_2$ emissions associated with economic development are reduced.

## 5.4 Regression Models

Let $e_{c,t}$ and $k_{c,t}$ [2] denote the pollution index and the characteristic of city leaders in year t of city c. The estimation equation can be written as

$$e_{c,t} = \alpha + \beta\, k_{c,t} + \gamma_c + \sigma_t + \varepsilon_{c,t}, \tag{5.1}$$

where $\gamma_c$ denotes the fixed effect for city c, $\sigma_t$ denotes the fixed effect for year t, and $\varepsilon_{c,t}$ denotes the error term. Equation 5.1 allows me to implement the analysis of $\beta$ for each characteristic of the city leader on city level analysis. In addition to this, considering the

[2]For convenience, I distinguish mayors and secretaries by adding "m" or "s" at the beginning of the characteristic variable (e.g., *mwbind* indicates that mayor has work background in industry).

interaction between city leaders and different enterprises for the ownership level analysis, the following equation is designed:

$$e_{c,o,t} = \alpha + \beta_o \, k_{c,t} \times i + \gamma_{c,o} + \sigma_t + \varepsilon_{c,o,t}, \tag{5.2}$$

where $e_{c,o,t}$ denotes the pollution index for enterprise of type o in year t in city c, o denotes different types of enterprises, $\gamma_{c,o}$ denotes the fixed effect for enterprise of type o in city c, $\sigma_t$ denotes the fixed effect for year t, i denotes the factor variable of different ownership types, and $\varepsilon_{c,o,t}$ denotes the error term.

## 5.5 Regression Results

Results based on the econometrics model specified in equation 5.1 are shown respectively from Table A.9 to Table A.26. In Table 5.3, coefficient directions of the regression are shown, which is a short summary of the regression results. The results generated by equation 5.2 is presented in Table A.35 until Table A.70. Additionally, the correlation between the dummy variable indicating whether mayors are promoted after appointment and mayors' other characteristics is investigated in Table A.33 and Table A.34. The achievement of each mayor in reducing $SO_2$ emission intensity (*green*) is also considered. This can also work as a posterior evidence to test my empirical assumption. Apart from this, the sensitivity of different mayor age cut-offs' impacts on environmental performance is examined from Table A.27 to Table A.32. In Table 5.4, the directional correlation between $SO_2$ emissions and the interaction between mayoral characteristics and enterprises is summarized.

### 5.5.1 *ex post* Characteristics

By using *ex post* characteristics as dependent variables, evidence can be found to support my empirical strategy. The result is in Table A.33 and Table A.34. They provide a posterior evidence showing that the correlation between leaders' characteristics and promotion is small and not significant. In particular, the correlation between the "greenness", relative reduction of emission intensity, of leaders and whether leaders are promoted to the central government or other agencies after appointment is tested and it shows that the correlation is quite small and not significant. In this sense, my assumption that environmental performance is exogenous to the rotation of mayors is supported by the data.

However, GDP affects the promotion to the central government of mayors positively and significantly. To the extent that economic development coincides with environmental damage, environmental performance metrics for the city decline. Mayors with future career paths to the central government are expected to increase $SO_2$ emissions in cities. In Table A.9, I can read that mayors with future career paths to the central government have significant positive impacts (17,900 tons on average) on $SO_2$ emissions in their governing cities. This is consistent with what I expect. Economic performance counts significantly in the evaluation of mayors. Thus, mayors who are promoted to the central government after appointment must put the economic development as the first priority. In this way, the associated pollution index is increased.

### 5.5.2 City Level Analysis

For this part, all regression results based on the balanced dataset are illustrated from Figure 5-1 to 5-3. These are regressions of three dependent variables: $SO_2$ emissions, $SO_2$ emission intensities, and $SO_2$ removal ratios. The horizontal axis represents the mayoral characteristic and the vertical axis reflects the magnitude of the co-efficient before the respective variable in the regression. In particular, error bars are presented in grey dashed lines, which are the range of 95% confidence intervals. Corresponding to this, co-efficient directions of mayoral characteristics are summarized in Table 5.3.

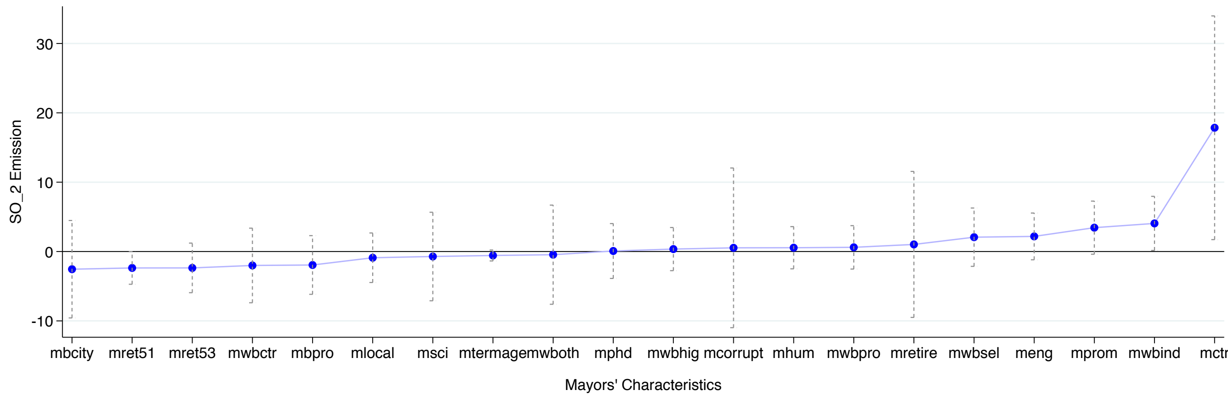



Figure 5-1. Coefficients on mayoral characteristics in the regressions of absolute $SO_2$ emissions (1000 tons)

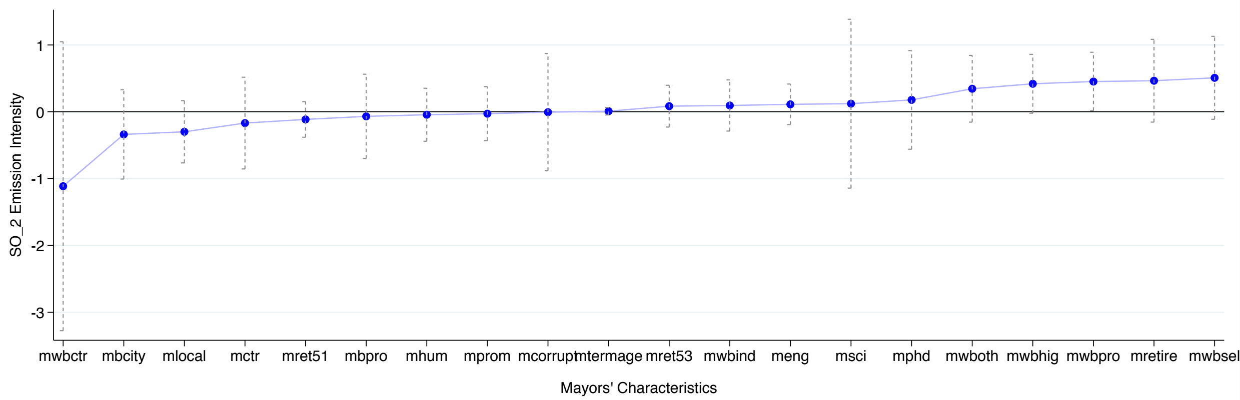



Figure 5-2. Coefficients on mayoral characteristics in the regressions of $SO_2$ emission intensity (1000 tons / billion CNY)

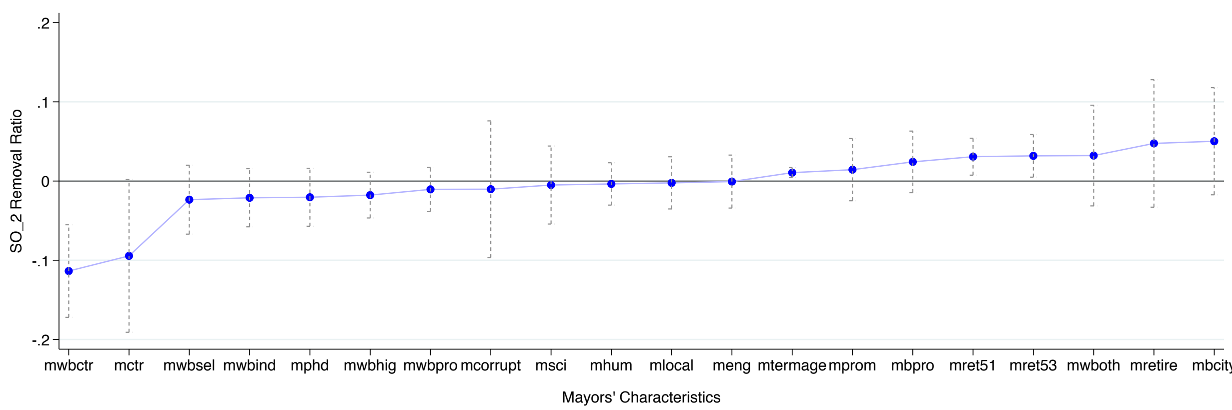



Figure 5-3. Coefficients on mayoral characteristics in the regressions of end-of-pipe $SO_2$ removal ratios

Contrary to mayors promoted to the central government, evidence shows that mayors with central government work background have a negative impact (-2,010 tons on average) on $SO_2$ emissions in the city while this is not statistically significant. This is also consistent with what I expect. These officials are rotated from the central government and they are not under pressure of promotion. Therefore, economic development is less prioritized for cities with those mayors than cities with mayors under higher pressure of promotion. More importantly, those officials from the central government should have a broader scope and reflect the central government's ambition in reducing environmental pollution.

Table A.9 shows that cities of mayors with industry work background have significant higher $SO_2$ emissions (4,060 tons on average) than others. This result is consistent with the hypothesis that I made about mayors with industry work background; and, this result is consistent across regressions of different dependent variables. Industry work background is a proxy for the city leader's priority in economic development to environmental management. Additionally, city leaders with industry work background are expected to establish stronger government-industry linkages compared to other leaders. This linkage can work complementarily to help leaders prioritize the economic development.

As hypothesized, retiring mayors are less promising in terms of their political ambitions and this places them under less pressure of promotion. In this way, they are expected to pay more attention on environmental management. In Table A.29, it shows consistently that mayors going to retire significantly increase $SO_2$ removal ratios (0.031 on average for *mret51*) of the respective city. For mayors with ages greater equal than 51, I find evidence that they are generally associated with a significant reduction (-2,370 tons on average) in $SO_2$ emissions, as shown in Table A.9. This is also reflected consistently across mayors with different age cut-offs. Additionally, retiring leaders are expected to consider the public pressure in terms of reducing negative environmental externalities to a higher extent than

Table 5.3. Co-efficient directions of leadership's characteristics in city-level regressions

| Characteristic | $SO_2$ Emission | | $SO_2$ Emission Intensity | | $SO_2$ Removal Ratio | |
|---|---|---|---|---|---|---|
| | Balanced | Unbalanced | Balanced | Unbalanced | Balanced | Unbalanced |
| *mctr* | +** | +** | – | – | –** | –** |
| *mprom* | +* | + | – | – | + | + |
| mcorrupt | + | + | – | + | – | – |
| mret51 | –** | –** | – | – | +*** | +*** |
| mret53 | – | –* | + | + | +** | +*** |
| mwbctr | – | + | – | – | –*** | –*** |
| mwbpro | + | + | +** | + | – | – |
| mwbhig | + | + | +** | + | – | – |
| mwbind | +** | +** | + | + | – | – |
| mwboth | – | – | + | + | + | + |
| mwbsel | + | + | +* | + | – | – |
| mretire | + | + | + | + | + | + |
| mlocal | – | – | – | – | – | + |
| mphd | + | – | + | + | – | – |
| mhum | + | + | – | – | – | + |
| msci | – | – | + | + | – | – |
| meng | + | + | + | + | –* | – |
| mtermage | – | – | + | + | +*** | +*** |
| mbcity | – | – | – | – | + | + |
| mbpro | – | – | – | – | + | + |

Note 1: *, **, *** mean 10%, 5%, 1% statistically significant respectively.
Note 2: *ex post* characteristics are shown in italic. Others are pre-existing characteristics.

younger officials.

The result also shows that mayors promoted from the same city decrease $SO_2$ emissions (-900 tons on average) and $SO_2$ emission intensities (-300 tons/billion-CNY on average).

This result is consistent across regressions of different dependent variables. As hypothesized, local mayors are able to inherit the idea from the previous administration in environment management and this consistency in policy implementation brings benefits to the local environment.

In Table A.21, it is interesting to note that the term-age of mayors is negatively correlated with city-level $SO_2$ emissions. This is also proved by the result in Table A.22 in terms of $SO_2$ emission intensities and Table A.23 in terms of $SO_2$ removal ratios (significant increase of 0.0096/year on average). This can be a second proof on that consistency of policy implementation is beneficial to environmental performance. I hypothesized that mayors promoted from the local administration can continue the environmental policy from the previous administration and this consistency brings benefits to the local environmental performance. Here, it shows that the environmental performance is better if it is in a higher term-age of the same mayor. For a mayor, he or she must be able to implement a consistent environmental policy from the starting year of his or her term and this is beneficial to the local environmental management.

It is also indicated by the data that mayors appointed to the same city as their birth cities reduce $SO_2$ emissions (-3,940 tons on average) in Table A.21; and, this result is consistent in Table A.22 in terms of $SO_2$ emission intensities (-430 tons/billion-CNY on average) and Table A.23 in terms of $SO_2$ removal ratios (0.052 on average). It is hypothesized that leaders care about the surrounding environment and they have many familiar citizens and environments in their birth cities. Thus, leaders who are able to manage their birth cities must put more efforts in environmental management than leaders from a different city. It is also shown that mayors appointed to cities within their birth provinces reduce $SO_2$ emissions (-2,400 tons on average) in Table A.21. However, this effect is not as large as the previous one and this tells that city leaders might pay more attention to manage the environment closer to their origins.

### 5.5.3 Enterprise and Category Level Analysis

For this part, I extract coefficient directions of interactions between leadership's characteristics and enterprise ownership types in the regression of $SO_2$ emissions and they are shown in Table 5.4. In addition, the significance level is marked.

In Table A.35, I can read that mayors with future career paths to the central government curb emissions from foreign enterprises consistently across indices. Foreign enterprises are expected to establish weaker linkages with the local government and thus, mayors would not prioritize their development. In order to facilitate their own promotions, they may pay more attention to the development of SOEs and simultaneously lower emissions from foreign enterprises to fulfill environment targets. In Table A.37, I observe that mayors with work background in the central government could enforce the reduction of emissions (intensities) from foreign and county SOEs. This suggests that mayors with work background in the central government establish weak linkages with local and foreign enterprises. The result is consistent across regressions of different dependent variables. Thus, leaders with work background in the central government might establish stronger linkages with higher level (city or above) SOEs.

In the case of mayors with industry work background, it is hard to tell the strength of linkages established between the administration and different enterprises due to the fact that mayors might work in different enterprises perviously. Thus, it is possible that the preference over different enterprises is different across mayors. In Table A.41 and A.42, it is interesting to note that mayors put more efforts in reducing emissions from city SOEs when they are going to retire. This makes sense because city leaders could establish a stronger linkage

Table 5.4. Co-efficient directions of leadership's characteristics in city-ownership-level regression of $SO_2$ emissions

| Characteristic | $SO_2$ Emissions | | | | | |
|---|---|---|---|---|---|---|
| | Domestic non-SOE | Provincial SOE | Central SOE | City SOE | County SOE | Foreign |
| *mctr* | – | – | –** | +** | +** | – |
| *mprom* | – | – | + | – | – | + |
| mwbctr | +* | – | + | + | – | – |
| mwbind | – | + | – | + | + | + |
| mretire | – | + | +*** | + | + | – |
| mlocal | – | –*** | – | – | + | –* |
| mwbpro | + | + | – | – | – | + |
| mwbhig | + | + | – | + | – | + |
| mret51 | –** | + | – | + | –** | +* |
| mwboth | – | –* | – | – | –* | + |
| mwbsel | + | +* | – | + | + | – |
| mphd | + | + | + | – | – | – |
| mhum | – | – | + | + | + | + |
| msci | + | + | – | + | + | – |
| meng | + | – | + | – | – | + |
| mbcity | – | + | – | – | –** | – |
| mbpro | + | +** | – | + | + | – |
| mcorrupt | + | + | + | +*** | – | – |

Note 1: *, **, *** mean 10%, 5%, 1% statistically significant respectively.
Note 2: *ex post* characteristics are shown in italic. Others are pre-existing characteristics.

with city level SOEs and therefore, these enterprises are prioritized to fulfill environmental performance.

According my hypothesis, mayors from local administration could implement consistent environmental policies in reducing emissions. In Table A.43 and A.44, it shows the regression result considering mayors promoted from the local administration. It is indicated that those mayors mitigate emissions from central SOEs, provincial SOEs, and foreign enterprises while emissions from domestic non-SOEs and city SOEs increase slightly. This evidence suggests that they are expected to establish stronger linkages with local domestic non-SOEs and city SOEs than other enterprises. This might be related to the decentralization of fiscal policies.

It is hypothesized that mayors closer to the retirement age are under less pressure for promotion, and thereby not aggressive in promoting economic development. Additionally, I hypothesize above that retiring leaders should consider the public pressure in reducing negative environmental externalities to a greater extent than younger officials. Considering their hierarchy, they are expected to affect lower level SOEs more. In Table A.49 and A.50, it can be found that foreign enterprises are estimated to emit more in cities of mayors with ages higher than or equal to 51. This might be due to the fact that linkages between foreign enterprises and governments are weaker and therefore, they are unable to enforce foreign enterprises to reduce emissions or operate end-of-pipe removal facilities. However, evidence shows that they result in effective reductions of emissions in county SOEs and domestic non-SOEs, which is consistent with my hypothesis that they are able to affect enterprises of lower level authority.

Finally, results with respect to other characteristics are worthy to be mentioned and interpreted. In Table A.45, A.46, A.47, and A.48, I can observe that mayors from provincial or higher level administration correspond to more efforts in reducing emissions from city level or below enterprises. In Table A.51, A.52, A.53, and A.54, impacts of mayors on environmental performace from inside and outside province are compared. It shows that mayors from outside are taking stronger efforts in reducing emissions from SOEs and domestic non-SOEs while foreign enterprises are predicted to emit more. However, mayors from inside are allowing more emissions. In this sense, linkages between enterprises and mayors from the same province are expected to be stronger and this leads to more emissions.

# Chapter 6

# Conclusion and Outlook

In this chapter, I conclude my study, interpret the results, and suggest possible future directions. Several conclusions can be drawn from my study. First, I analyze government-industry linkages through different channels. Second, leadership impacts on $SO_2$ emissions are analyzed with respect to different personal characteristics of leaders. Third, the interaction between leadership characteristics and enterprises of different ownership types is investigated and this indicates how leaders fulfill the intended goal via different channels. I now discuss some key implications of my study in this chapter.

## 6.1 Government-Industry Linkages

The characteristics of China's economy determine the organization of the industry. Although the economic system in China has been reshaped gradually from a planned into a market economy since last century, some significant characteristics keep the China's situation different from other capitalist countries. It is important to note that industries of significance to China's economy are still state-owned although the economic reform in China has increased the privatization of SOEs. The government retains tight control of fundamental sectors in the economy such as electricity, steel, and manufacturing. However these sectors are main contributors to air pollution. Thus, leaders of these industries play an important role in environmental management. SOEs are linked with the government via the agency *guozi-wei* and governmental leadership can influence behaviors of SOEs via political management such as rotating enterprise managers, enacting or revising related policies, and changing the city level industrial organization. Therefore, the government-industry linkage is likely to be non-negligible when considering the local economy and associated air pollution.

When it comes to implementing policy, previous research implied that the government-industry linkage did make an impact in determining local polluting behaviors. **My results in this study are consistent with this, showing that $SO_2$ emissions increase and decrease in systematic ways as mayors with specific characteristics rotate in and out of office.** Since the implementation of the pollution levy, local EPBs were funded by local administrations and the local governmental leadership could require the EPB to cut the pollution levy on local firms to protect local economic development. In addition, TEC required the local administration to negotiate with enterprises in allocating the national plan, and the local governmental-industry linkages could shape the allocation plan according to local incentives instead of national goals. Apart from this, it was well noted that the phasing out of inefficient small power plants met unintended resistance and the government-industry linkage in protecting local economy was a reason. In summary, the local government-industry linkage has been shown to exist and this is expected to affect the air pollution in China.

## 6.2 Leadership Characteristics' Impacts on Emissions

In the previous section, I explore leadership characteristics' impacts on $SO_2$ emissions through different modeling strategies. By estimating two regression models, I investigate leadership characteristics' impacts on city-level aggregate emissions and city-ownership-level emissions. Some implications can be drawn from this work. In the city aggregate analysis, I find that leaders with particular characteristics are associated with variations in the levels of different $SO_2$ indices. In particular, it is interesting to note that leaders with different characteristics implement $SO_2$ related policies via enterprises of different ownership types.

**Results show that mayors with work background in central and local governments are associated with improved environmental outcomes, but through different channels.** The central government is keen to reduce energy intensities across enterprises via policy programs such as the 1000-firm policy program during the 11th FYP (Karplus et al., 2016); and, central work background may make mayors more adherent to the central policy according to my hypothesis. Consistent with the hypothesis, evidence shows that a central government work background results in environmental improvements through intensity reduction, but not necessarily $SO_2$ emissions. In addition, these mayors are found to lower $SO_2$ removal ratios, which implies that end-of-pipe $SO_2$ control technologies play an limited role. I expect that local work background has mayors implement environmental policies more consistently and additionally, they may establish better government-industry linkages as they already own working connections with local industries. Therefore, it may be easier for them to implement end-of-pipe $SO_2$ removal policies through these linkages. This is consistent with the result that local government work background is associated with short-term reductions in $SO_2$ intensities, possibly due to increases in $SO_2$ removal ratios, particularly among city SOEs. This is also affirmed by the fact that a longer term in office is significantly associated with higher end-of-pipe $SO_2$ removal ratios.

**Tenures of mayors on the verge of retirement are associated with improved environmental outcomes.** I hypothesize that retiring mayors are associated with reduced incentives to promote economic growth. This may enable retiring mayors to achieve $SO_2$

reductions by limiting pollution-intensive industrial activities, and local public pressure can make it easier for them to enforce effective end-of-pipe $SO_2$ controls. Coinciding with my hypothesis, $SO_2$ emissions decline overall when retiring mayors are in office, but intensities remain unchanged. My analysis also indicates that $SO_2$ removal ratios increase overall, indicating that retiring mayors are enforcing end-of-pipe $SO_2$ removing technologies with strong efforts. In addition, ownership level analysis indicates that retiring mayors can put more efforts in reducing emissions from domestic non-SOEs and county SOEs, plausibly due to the fact that these enterprises are with lower authority levels.

**Industry work background may enable upgrading technologies while not enforcing the usage of end-of-pipe emission control facilities.** Evidence, consistent with my hypothesis, shows that overall $SO_2$ emissions increase when a mayor with industry work background enters or leaves office. In the political system of China, these mayors are all from large scale SOEs; and, it can be seen from the ownership and category analysis that these mayors are associated with raised $SO_2$ emissions across all ownership types except domestic non-SOEs and central SOEs. Central SOEs may face high-level pressure to meet nation-wide total emission control policies and domestic non-SOEs may be required to reduce emissions, possibly because they lack strong government-industry linkages. However, emission intensities are lowered in all enterprises, possibly as a result of that these mayors enable upgrading technologies of industries.

**Enterprises of lower level authorities may be incentivized to develop by officials with strong economic incentives.** As the economic performance has a great deal of significance in the promotion system in China, I hypothesize that mayors going to the central government after service have strong incentives to develop local economies and the associated $SO_2$ emissions increase. Consistent with the hypothesis, evidence shows that mayors going to the central government after service strategically focus on developing local (e.g., city, county) SOEs, which are easier for them to build linkages. Simultaneously, they can put more pressure on central and provincial SOEs to realize environmental goals. It can be seen that emissions from city and county SOEs increase while emissions from central SOEs decrease. Beside this, we might expect that leaders with higher political rank may face larger marginal rewards from promotion. Economic achievement is the key factor in evaluating leaders' performance. Evidence shows that mayors with higher level work background (e.g., provincial) are expected to promote economics and associated with worsened $SO_2$ indices. Additionally, they intend to increase $SO_2$ removal ratios of provincial level SOEs, possibly due to the fact that high level SOEs face a more stringent monitoring system.

**City leaders might pay more attention to manage the environment closer to their origins.** When mayors face the same environmental problem, those in cities the same as their birth cities and provinces always endure much more pressure than others as they have more citizens who are more familiar with them. Considering this public pressure, mayors from the same birth city and province are expected to feel more pressure to suppress $SO_2$ emissions. Evidence, consistent with the hypothesis, shows that mayors within their birth cities intend to suppress emissions across different enterprises. Although this effect with mayors within their birth provinces is not as effective as that with mayors within their birth cities, these two effects are consistent. It is also shown that mayors within their birth provinces are associated with higher $SO_2$ emissions and lower removal ratios of provincial SOEs. Mayors may consider the province-wide economic performance and this leads them to promote provincial level business.

**Corrupted government-industry linkages may be easier to be built between officials and enterprises of lower level authorities.** A few mayors may be involved in corruption behaviors during their terms, and this can be attributed to several reasons such as *nuoyong gongkuan* and *tanwu shouhui* [1]. Of these two categories, *tanwu shouhui* normally leads enterprises to violate policies, including environmental policies. Thus, it is hypothesized that they have weaker incentives to make environmental improvements. On the other hand, corrupted mayors are expected to develop related enterprises and, therefore, the associated $SO_2$ emissions are elevated. In particular, as shown in Table A.69, corrupted mayors intend to increase emissions and emission intensities of city SOEs and domestic non-SOEs. This is consistent with my hypothesis. In reality, enterprises of these two types are easier to build corruption linkages with leaders because other enterprises are under high-level political control and they face more stringent monitoring systems.

All in all, through the entire analysis, I find that mayors of different characteristics may affect city-aggregate polluting behaviors and their different impacts are mainly owing to that they face differentiated incentives related to their characteristics. Additionally, ownership level analysis suggests that mayors of different characteristics might realize their environmental and economic goals via different channels. This in the end reflects their trade-offs between economic development and environmental performance related to the government-industry linkage.

## 6.3 Policy Implications

Solving environmental problems in China needs simultaneous and coordinated efforts from different systems. China's economic system has special Chinese characteristics, which allow the existence of government-industry linkages in several ways. These linkages can work as an intermediate system linking leaders and environmental outcomes. Based on my analysis in this thesis, leaders' characteristics have certain impacts on $SO_2$ emissions. However, I do not

[1] Detailed definitions can be found in section 2.4 on page 29.

expect such linkages in a healthy economic system as it lowers the efficiency of the economic system. In order to conquer environmental challenges, China has spent tremendous efforts in designing, implementing, and evaluating policies regulating polluting behaviors. The existence of government-industry linkages lowers the efficiency of policies to some degree. Thus, dealing with government-industry linkages appropriately is helpful in establishing an efficient policy system in China.

On the one hand, the strength of the linkage should be weakened to improve the economic efficiency, which needs efforts to decouple governments and industries. In this way, an effective monitoring system should be established to make sure that all enterprises behave independently as rational participants in the economic system. In addition, I suggest that the system for governments and the system for industries should be mutually independent.

On the other hand, the evaluation system of officials incentivizes most officials to promote economic development and then, the importance of economic development is overestimated by neglecting side-effects in terms of air pollution. Therefore, an incorporation of environmental outcomes in the evaluation system for officials in China can stimulate their incentives in improving the surrounding environment. Since the 11th FYP, environmental performance has been accounted in the evaluation program of officials (Zheng et al., 2014). However, it is important to implement the system explicitly and effectively.

Finally, regulatory capture, which is a form of political failure, should be avoided via institutional management. Stigler (1971) stated that regulation is necessary to serve the interest of the public. The origin of environmental policy is to improve overall benefits of the society by regulating unreasonable polluting behaviors. However, regulatory capture, which is to serve other interest groups instead of the public by using regulation, can arise in this context. For example, government supported programs of 1970-1990s, to test hydraulic drilling and horizontal drilling techniques, were strongly supported in United States. However, it was found that some of these efforts were politically or commercially driven to serve particular interest groups (Grigas, 2017). In China, the local government is the only agency to enact and implement related policies in environmental management. In some cases, governmental leadership might manipulate regulating instruments to serve special interest groups by sacrificing public benefits, which should definitely be circumvented via institutional management. For example, a "peer review" process of policies and their implementation between provinces can be created to cut localism and avoid this political failure.

In one word, I hope that systems in China can work efficiently and they should not be utilized or affected by any irrational objective. From an economic perspective, synergy between systems can improve the overall utility of the society. Efficient systems can ensure an effective implementation of policy, which can reduce the negative externalities and increase social benefits. However, the existence of government-industry linkages could affect the realization of policies and change the equilibrium of the system according to my study. This external force arises from irrational objectives, which should be excluded from the system.

## 6.4 Limitations of This Study

In this study, I adopt several statistical methods to investigate whether government-industry linkages affect environmental outcomes in China. My analysis relies heavily on the identifying assumption that pollution in cities "untreated" by a mayor with a particular characteristic forms a valid counterfactual for pollution in "treated" cities, as mayoral rotation is quasi-random and exogenous to environmental performances across cities and ownership types. My empirical strategy is based on the assumption that the rotation of city mayors is plausibly exogenous to growth-normalized measures of environmental quality ($SO_2$ emissions) in a city.

First, however, I can not ensure that the rotation of mayors is completely random in the political system of China. Although the central government enacts the policy to enforce the rotation of officials across regions and departments, the rotation is somewhat determined by the department of human resource and high-level leaders. Second, facts support my assumption that the rotation of leaders is unrelated to environmental performance while I cannot completely exclude the possibility that environmental outcomes impact the rotation of city leaders. Third, observations of mayors of several characteristics are very few [2]. Although the error bar in regressions accomodates the number of observations, more observations can make the result more credible. Four, the $R^2$ in some regressions are small and this means that the explanatory variables lack explaining power. With respect to this problem, more empirical strategies may be tried to improve the situation. In addition, $SO_2$ emissions are used as the main index for air pollution, while air pollution is also partially determined by other factors and pollutants. Thus, it is important to partial out other factors' impacts.

Finally, cities across the whole country are somewhat different and they may focus on different industries and their political systems might be different from each other. Therefore, it is not powerful enough to assume that those "treated" and "untreated" cities are exactly the same except that mayors are with "treated" and "untreated" characteristics [3]. Nevertheless, this study provides a foundation for the analysis of government-industry linkages' impacts on environmental performance and the limitation of the work can inform some future directions.

## 6.5 Directions for Future Work

This study represents a basic quantitative analysis of leadership's impacts on environmental performance. In addition to improve the experimental design addressing several caveats

[2]See Table 4.4 and 4.5: mayors of several characteristics are rarely observed: *retire*, *ctr*, *wbctr*, and *med*.
[3]See Table A.5, A.6, A.7, and A.8, the respective t-test of changes of other indices on mayoral transitions.

mentioned in the previous section, some other directions for future work can be identified. First, it is important to find out how each mayor builds government-industry linkages in each city. Especially, the preference over enterprises for each mayor should be identified (e.g., tracing back to their previous industrial background). Then, a difference-in-difference design could be used to investigate how leadership impacts environmental behaviors of enterprises via linkages. Second, several case studies should be carried out. It would be great if interviews with officials could inform details about government-industry linkages. Then, this enables an analysis focusing on identifying leadership's impacts on environmental outcomes transferred through linkages. Taken together, this empirical analysis presents first insights into leadership's impacts on environmental behaviors and it lays the foundation for future work on the topic.

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# Appendix A

# Tables

Table A.1. Pollution and economic index summary statistics - category level, balanced

| Variable | Ownership | Obs | Mean | Std. Dev. | Min | Max | Unit |
|---|---|---|---|---|---|---|---|
| $SO_2$ emission | Central and Provincial SOE | 785 | 4.50 | 10.17 | 0 | 108.79 | 1000 tons |
| | Domestic Non-SOE | 1,328 | 2.82 | 3.85 | 0 | 39.69 | 1000 tons |
| | City or below SOE | 1,092 | 0.98 | 1.64 | 0 | 17.21 | 1000 tons |
| | Foreign | 672 | 0.70 | 1.63 | 0 | 17.67 | 1000 tons |
| $SO_2$ removal | Central and Provincial SOE | 785 | 6.88 | 34.99 | 0 | 409.01 | 1000 tons |
| | Domestic Non-SOE | 1,328 | 1.49 | 4.53 | 0 | 63.32 | 1000 tons |
| | City or below SOE | 1,092 | 0.61 | 1.85 | 0 | 18.63 | 1000 tons |
| | Foreign | 672 | 0.42 | 2.15 | 0 | 44.33 | 1000 tons |
| $SO_2$ emission intensity | Central and Provincial SOE | 785 | 1.86 | 10.84 | 0 | 223.65 | 1000 tons / Billion CNY |
| | Domestic Non-SOE | 1,328 | 1.47 | 2.56 | 0 | 51.46 | 1000 tons / Billion CNY |
| | City or below SOE | 1,091 | 2.72 | 22.45 | 0 | 690 | 1000 tons / Billion CNY |
| | Foreign | 671 | 0.81 | 2.53 | 0 | 36.47 | 1000 tons / Billion CNY |
| $SO_2$ removal ratio | Central and Provincial SOE | 761 | 0.26 | 0.30 | 0 | 1.00 | - |
| | Domestic Non-SOE | 1,323 | 0.20 | 0.22 | 0 | 1.00 | - |
| | City or below SOE | 1,066 | 0.19 | 0.26 | 0 | 0.97 | - |
| | Foreign | 652 | 0.23 | 0.28 | 0 | 0.99 | - |
| Gross Output | Central and Provincial SOE | 785 | 9.40 | 25.98 | 0.01 | 310.06 | Billion CNY |
| | Domestic Non-SOE | 1,328 | 4.42 | 8.45 | 0.00 | 102.94 | Billion CNY |
| | City or below SOE | 1,092 | 1.82 | 4.35 | 0 | 49.46 | Billion CNY |
| | Foreign | 672 | 4.06 | 10.99 | 0 | 137.20 | Billion CNY |

Table A.2. Two-sided t-test for change of de-meaned and de-trended $SO_2$ emissions on transitions

| Characteristic | Treated | | Non-Treated | | Difference | |
|---|---|---|---|---|---|---|
| | Before → In Office | In Office → After | Before → In Office | In Office → After | Before → In Office | In Office → After |
| | | | balanced Dataset | | | |
| mctr | -3.73(4.27) | -7.99(4.83) | -0.61(0.36) | -0.21(0.41) | -3.12(4.29) | -7.78(4.85) |
| mprom | 1.42(1.41) | -0.93(1.13) | -0.75(0.37)** | -0.2(0.43) | 2.17(1.46) | -0.72(1.21) |
| mcorrupt | -2.81(3.29) | 2.16(5.9) | -0.6(0.36) | -0.28(0.4) | -2.2(3.31) | 2.45(5.91) |
| mret51 | -1.03(0.95) | 0.01(1.09) | -0.54(0.38) | -0.3(0.44) | -0.48(1.02) | 0.32(1.18) |
| mret53 | -2.56(1.47)* | -1.47(1.46) | -0.34(0.35) | -0.1(0.42) | -2.22(1.51) | -1.37(1.52) |
| mwbctr | 0.27(2.58) | 3.78(1.07)** | -0.63(0.36) | -0.32(0.41) | 0.9(2.61) | 4.11(1.14)*** |
| mwbpro | 0.78(0.85) | 1.92(1.55) | -0.79(0.38)** | -0.46(0.42) | 1.58(0.93)* | 2.38(1.6) |
| mwbhig | 0.72(0.86) | 2.05(1.53) | -0.78(0.38)** | -0.47(0.42) | 1.5(0.94) | 2.52(1.59) |
| mwbind | 1.72(0.99)* | -2.04(1.45) | -0.73(0.37)* | -0.14(0.42) | 2.45(1.06)** | -1.9(1.51) |
| mwboth | 1.03(1.87) | 2.96(2.41) | -0.65(0.36)* | -0.34(0.41) | 1.68(1.91) | 3.3(2.45) |
| mwbsel | 0.13(1.1) | -1.26(1.59) | -0.67(0.37)* | -0.21(0.42) | 0.8(1.17) | -1.05(1.65) |
| mlocal | -2.05(1.21)* | 0.22(1.14) | -0.52(0.37) | -0.3(0.43) | -1.53(1.26) | 0.52(1.22) |
| mphd | -1.12(1.16) | -1.09(1.37) | -0.59(0.37) | -0.21(0.42) | -0.53(1.22) | -0.88(1.43) |
| mhum | -1.64(1.15) | -0.82(1.4) | -0.51(0.37) | -0.2(0.42) | -1.12(1.21) | -0.63(1.46) |
| msci | -6.43(3.73)* | -1.81(1.48) | -0.49(0.35) | -0.21(0.41) | -5.93(3.75) | -1.6(1.54) |
| meng | 0.91(1.33) | -1.67(1.64) | -0.71(0.37)* | -0.14(0.42) | 1.62(1.38) | -1.53(1.7) |
| | | | unbalanced Dataset | | | |
| mctr | -4.32(3.36) | -6.87(4.1) | -0.7(0.35) | -0.1(0.39) | -3.63(3.38) | -6.77(4.12) |
| mprom | 1.1(1.33) | -0.23(1.11) | -0.83(0.36)** | -0.14(0.41) | 1.93(1.38) | -0.09(1.18) |
| mcorrupt | -2.59(2.95) | 2.16(5.9) | -0.69(0.35)* | -0.17(0.39) | -1.89(2.97) | 2.33(5.91) |
| mret51 | -0.67(0.93) | -0.06(1.03) | -0.72(0.38)* | -0.16(0.42) | 0.05(1) | 0.09(1.12) |
| mret53 | -2.77(1.4)** | -0.96(1.39) | -0.42(0.35) | -0.05(0.4) | -2.35(1.44) | -0.92(1.45) |
| mwbctr | 3.11(3.19) | 4.95(1.53)** | -0.77(0.35)** | -0.22(0.39) | 3.88(3.21) | 5.17(1.58)** |
| mwbpro | 0.01(0.87) | 2.18(1.44) | -0.8(0.38)** | -0.36(0.4) | 0.81(0.95) | 2.54(1.49)* |
| mwbhig | -0.06(0.88) | 2.3(1.44) | -0.79(0.38)** | -0.37(0.4) | 0.73(0.96) | 2.67(1.5)* |
| mwbind | 1.78(1.36) | -1.43(1.58) | -0.83(0.36)** | -0.06(0.4) | 2.61(1.41)* | -1.37(1.63) |
| mwboth | 3.35(2.92) | 2.17(2.83) | -0.77(0.35)** | -0.2(0.39) | 4.12(2.94) | 2.37(2.86) |
| mwbsel | 0.1(1.08) | -0.07(1.76) | -0.76(0.37)** | -0.15(0.4) | 0.86(1.14) | 0.08(1.81) |
| mlocal | -2.06(1.16)* | -0.56(1.07) | -0.62(0.37)* | -0.1(0.41) | -1.44(1.22) | -0.46(1.15) |
| mphd | -1.04(1.13) | -1.48(1.29) | -0.69(0.37)* | -0.07(0.4) | -0.34(1.18) | -1.41(1.36) |
| mhum | -1.72(1.11) | -1.14(1.31) | -0.61(0.37) | -0.04(0.41) | -1.12(1.17) | -1.1(1.37) |
| msci | -6.1(3.48)* | -1.81(1.48) | -0.59(0.35) | -0.1(0.4) | -5.51(3.5) | -1.71(1.53) |
| meng | 0.34(1.38) | -1.91(1.59) | -0.77(0.36)** | -0.01(0.4) | 1.12(1.43) | -1.89(1.64) |

Notes: * means 10% statistically significant, ** means 5% statistically significant, and *** means 0.1% statistically significant.

## Table A.3. Two-sided t-test for change of de-meaned and de-trended $SO_2$ intensity on transitions

| Characteristic | Treated | | Non-Treated | | Difference | |
|---|---|---|---|---|---|---|
| | Before → In Office | In Office → After | Before → In Office | In Office → After | Before → In Office | In Office → After |
| balanced Dataset | | | | | | |
| mctr | 0(0.2) | 0.2(0.09)* | 0.01(0.04) | -0.02(0.04) | -0.01(0.21) | 0.22(0.1)** |
| mprom | 0.17(0.11) | 0.04(0.1) | 0(0.04) | -0.02(0.04) | 0.17(0.12) | 0.06(0.11) |
| mcorrupt | -0.07(0.35) | 0.25(0.36) | 0.01(0.04) | -0.02(0.04) | -0.08(0.35) | 0.27(0.36) |
| mret51 | -0.14(0.14) | -0.04(0.08) | 0.03(0.04) | -0.01(0.04) | -0.17(0.14) | -0.03(0.09) |
| mret53 | -0.06(0.16) | 0.02(0.09) | 0.02(0.04) | -0.02(0.04) | -0.07(0.17) | 0.04(0.1) |
| mwbctr | -0.28(0.4) | 0.58(0.27)* | 0.01(0.04) | -0.02(0.04) | -0.29(0.4) | 0.6(0.28)** |
| mwbpro | 0.09(0.08) | -0.14(0.12) | 0(0.05) | 0(0.04) | 0.09(0.09) | -0.13(0.13) |
| mwbhig | 0.09(0.08) | -0.05(0.13) | 0(0.05) | -0.01(0.04) | 0.09(0.09) | -0.04(0.14) |
| mwbind | 0.24(0.11)** | 0.01(0.1) | -0.01(0.04) | -0.02(0.04) | 0.25(0.12)** | 0.02(0.11) |
| mwboth | 0.23(0.1)** | 0.23(0.09)** | 0(0.04) | -0.02(0.04) | 0.23(0.11)** | 0.25(0.1)** |
| mwbsel | 0.23(0.11)** | -0.14(0.17) | -0.01(0.04) | -0.01(0.04) | 0.24(0.12)** | -0.13(0.18) |
| mlocal | -0.07(0.13) | 0.12(0.1) | 0.01(0.04) | -0.03(0.04) | -0.08(0.14) | 0.15(0.11) |
| mphd | 0.02(0.1) | 0.1(0.14) | 0.01(0.04) | -0.02(0.04) | 0.01(0.11) | 0.12(0.14) |
| mhum | 0.07(0.1) | -0.25(0.26) | 0(0.05) | 0.01(0.03) | 0.07(0.11) | -0.26(0.26) |
| msci | -1.06(0.84) | -0.38(0.19)* | 0.03(0.04) | 0(0.04) | -1.09(0.84) | -0.38(0.2)* |
| meng | 0.06(0.08) | 0.08(0.09) | 0(0.04) | -0.02(0.04) | 0.06(0.09) | 0.1(0.09) |
| unbalanced Dataset | | | | | | |
| mctr | -0.01(0.16) | 0.19(0.07)** | -0.05(0.04) | -0.06(0.04) | 0.04(0.17) | 0.25(0.08)** |
| mprom | 0.13(0.1) | 0.02(0.11) | -0.06(0.05) | -0.06(0.04) | 0.19(0.11)* | 0.08(0.12) |
| mcorrupt | -0.07(0.31) | 0.25(0.36) | -0.05(0.04) | -0.06(0.04) | -0.02(0.31) | 0.31(0.36) |
| mret51 | -0.13(0.13) | -0.09(0.09) | -0.03(0.05) | -0.05(0.05) | -0.1(0.14) | -0.04(0.1) |
| mret53 | -0.12(0.17) | 0.04(0.09) | -0.04(0.04) | -0.07(0.04) | -0.08(0.18) | 0.11(0.1) |
| mwbctr | -0.03(0.32) | 0.57(0.26)** | -0.05(0.05) | -0.07(0.04) | 0.02(0.32) | 0.63(0.26)** |
| mwbpro | -0.07(0.13) | -0.08(0.11) | -0.04(0.05) | -0.05(0.04) | -0.03(0.13) | -0.03(0.12) |
| mwbhig | -0.07(0.13) | -0.02(0.12) | -0.04(0.05) | -0.06(0.04) | -0.03(0.14) | 0.04(0.13) |
| mwbind | 0.2(0.14) | -0.04(0.13) | -0.06(0.05) | -0.06(0.04) | 0.26(0.15)* | 0.01(0.14) |
| mwboth | 0.32(0.14)** | -0.28(0.53) | -0.05(0.05) | -0.05(0.04) | 0.38(0.14)** | -0.23(0.53) |
| mwbsel | 0.19(0.11)* | -0.18(0.19) | -0.06(0.05) | -0.05(0.04) | 0.26(0.12)** | -0.13(0.2) |
| mlocal | -0.07(0.13) | 0.05(0.1) | -0.04(0.05) | -0.07(0.04) | -0.03(0.14) | 0.12(0.11) |
| mphd | 0.01(0.1) | 0.06(0.13) | -0.05(0.05) | -0.06(0.04) | 0.05(0.11) | 0.13(0.14) |
| mhum | 0.05(0.1) | -0.35(0.26) | -0.06(0.05) | -0.02(0.04) | 0.1(0.11) | -0.32(0.26) |
| msci | -0.98(0.78) | -0.38(0.19)* | -0.03(0.04) | -0.05(0.04) | -0.95(0.78) | -0.34(0.2)* |
| meng | -0.13(0.2) | 0.01(0.11) | -0.04(0.05) | -0.06(0.04) | -0.08(0.21) | 0.07(0.12) |

Notes: * means 10% statistically significant, ** means 5% statistically significant, and *** means 0.1% statistically significant.

Table A.4. Two-sided t-test for change of de-meaned and de-trended $SO_2$ removal ratios on transitions

| Characteristic | Treated | | Non-Treated | | Difference | |
|---|---|---|---|---|---|---|
| | Before → In Office | In Office → After | Before → In Office | In Office → After | Before → In Office | In Office → After |
| | | | balanced Dataset | | | |
| mctr | -0.08(0.05) | -0.01(0.02) | 0(0) | 0(0) | -0.08(0.05) | -0.01(0.02) |
| mprom | -0.01(0.02) | -0.01(0.01) | 0(0) | 0(0) | -0.01(0.02) | -0.01(0.01) |
| mcorrupt | -0.02(0.03) | -0.08(0.04)* | 0(0) | 0(0) | -0.02(0.03) | -0.08(0.04)** |
| mret51 | 0(0.01) | -0.01(0.01) | -0.01(0) | 0(0) | 0.01(0.01) | -0.01(0.01) |
| mret53 | 0(0.01) | -0.01(0.01) | 0(0) | 0(0) | 0(0.01) | -0.01(0.01) |
| mwbctr | -0.04(0.03) | 0.04(0.03) | 0(0) | 0(0) | -0.03(0.03) | 0.05(0.03) |
| mwbpro | -0.01(0.01) | 0(0.02) | 0(0) | 0(0) | -0.01(0.01) | 0(0.02) |
| mwbhig | -0.01(0.01) | 0(0.02) | 0(0) | 0(0) | -0.01(0.01) | 0.01(0.02) |
| mwbind | -0.02(0.02) | 0.03(0.02)* | 0(0) | 0(0) | -0.02(0.02) | 0.03(0.02)** |
| mwboth | 0.03(0.03) | 0.03(0.03) | 0(0) | 0(0) | 0.03(0.03) | 0.03(0.03) |
| mwbsel | 0(0.01) | 0.01(0.02) | 0(0) | 0(0) | 0(0.01) | 0.01(0.02) |
| mlocal | 0(0.01) | -0.02(0.02) | 0(0) | 0(0) | 0.01(0.01) | -0.02(0.02) |
| mphd | 0.01(0.02) | 0(0.02) | 0(0) | 0(0) | 0.01(0.02) | 0.01(0.02) |
| mhum | 0.01(0.01) | -0.02(0.01)* | -0.01(0) | 0(0) | 0.02(0.01) | -0.02(0.01)* |
| msci | 0(0.02) | 0(0.02) | 0(0) | 0(0) | 0.01(0.02) | 0.01(0.02) |
| meng | -0.02(0.01)* | 0.03(0.02)* | 0(0) | 0(0) | -0.02(0.01) | 0.03(0.02)* |
| | | | unbalanced Dataset | | | |
| mctr | -0.07(0.04) | -0.01(0.01) | 0(0) | 0(0) | -0.07(0.04)* | -0.01(0.01) |
| mprom | 0(0.02) | 0(0.01) | 0(0) | 0(0) | 0(0.02) | 0(0.01) |
| mcorrupt | -0.01(0.03) | -0.08(0.04)* | 0(0) | 0(0) | -0.01(0.03) | -0.08(0.04)** |
| mret51 | 0.01(0.01) | -0.01(0.01) | 0(0) | 0(0) | 0.01(0.01) | -0.01(0.01) |
| mret53 | 0(0.01) | -0.01(0.01) | 0(0) | 0(0) | 0.01(0.01) | -0.01(0.02) |
| mwbctr | -0.1(0.04)** | 0.04(0.03) | 0(0) | 0(0) | -0.1(0.04)** | 0.05(0.03) |
| mwbpro | -0.01(0.01) | -0.01(0.01) | 0(0) | 0(0) | -0.01(0.01) | -0.01(0.02) |
| mwbhig | -0.01(0.01) | 0.01(0.01) | 0(0) | 0(0) | 0(0.01) | 0.01(0.01) |
| mwbind | -0.02(0.01) | 0.04(0.02)** | 0(0) | 0(0) | -0.02(0.02) | 0.04(0.02)** |
| mwboth | 0.03(0.03) | 0.04(0.03) | 0(0) | 0(0) | 0.03(0.03) | 0.04(0.03) |
| mwbsel | 0(0.01) | 0.01(0.02) | 0(0) | 0(0) | 0(0.01) | 0.01(0.02) |
| mlocal | 0(0.01) | -0.01(0.02) | 0(0) | 0(0) | 0.01(0.01) | -0.01(0.02) |
| mphd | 0(0.02) | 0.01(0.02) | 0(0) | 0(0) | 0(0.02) | 0.01(0.02) |
| mhum | 0.02(0.01) | -0.02(0.01)* | 0(0) | 0(0) | 0.02(0.01)* | -0.03(0.01)* |
| msci | -0.01(0.02) | 0(0.02) | 0(0) | 0(0) | -0.01(0.02) | 0(0.02) |
| meng | -0.03(0.01)* | 0.03(0.02)* | 0(0) | 0(0) | -0.03(0.01)* | 0.03(0.02)* |

Notes: * means 10% statistically significant, ** means 5% statistically significant, and *** means 0.1% statistically significant.

Table A.5. Two-sided t-test for change of de-meaned and de-trended GDP on transitions

| Characteristic | Treated | | Non-Treated | | Difference | |
|---|---|---|---|---|---|---|
| | Before → In Office | In Office → After | Before → In Office | In Office → After | Before → In Office | In Office → After |
| **balanced Dataset** | | | | | | |
| mctr | -2.59(2.86) | 70.15(29.05)* | -0.66(0.58) | -0.91(0.61) | -1.93(2.92) | 71.06(29.06)** |
| mprom | -0.9(2.5) | -0.37(2.6) | -0.66(0.6) | -0.52(0.67) | -0.24(2.57) | 0.15(2.69) |
| mcorrupt | 14.89(10.87) | 9.27(13.3) | -0.79(0.58) | -0.61(0.65) | 15.68(10.89) | 9.88(13.32) |
| mret51 | -2.46(1.11)** | -3.64(1.1)** | -0.33(0.66) | 0.05(0.74) | -2.13(1.29)* | -3.69(1.33)** |
| mret53 | 1.83(1.91) | 1.43(2.11) | -1.03(0.61)* | -0.75(0.69) | 2.86(2) | 2.18(2.22) |
| mwbctr | 2.46(7.34) | 3.39(6.4) | -0.71(0.58) | -0.57(0.66) | 3.16(7.37) | 3.96(6.43) |
| mwbpro | -0.72(1.83) | -1.76(1.69) | -0.66(0.61) | -0.4(0.7) | -0.05(1.93) | -1.37(1.83) |
| mwbhig | -0.64(1.85) | -2.25(1.5) | -0.67(0.61) | -0.35(0.7) | 0.03(1.95) | -1.9(1.66) |
| mwbind | -2.95(1.9) | 3.71(3.58) | -0.56(0.6) | -0.78(0.66) | -2.38(1.99) | 4.49(3.64) |
| mwboth | 17.62(10.14)* | -2.12(1.93) | -0.96(0.56) | -0.47(0.67) | 18.58(10.16)* | -1.65(2.04) |
| mwbsel | -4.43(0.85)*** | 2.59(4.73) | -0.42(0.62) | -0.64(0.65) | -4.01(1.05)*** | 3.22(4.77) |
| mlocal | -1.9(2.29) | 0.35(2.2) | -0.58(0.6) | -0.59(0.68) | -1.32(2.37) | 0.94(2.31) |
| mphd | 4.62(3.46) | -2.89(1.86) | -1(0.58)* | -0.37(0.68) | 5.62(3.51) | -2.52(1.98) |
| mhum | -3.33(1.12)** | -1.67(1.92) | -0.39(0.63) | -0.39(0.69) | -2.94(1.28)** | -1.28(2.04) |
| msci | -1.59(4.7) | -0.26(5.03) | -0.65(0.59) | -0.52(0.66) | -0.94(4.73) | 0.26(5.07) |
| meng | -2.03(1.81) | -3.64(1.08)** | -0.59(0.61) | -0.26(0.7) | -1.44(1.91) | -3.38(1.29)** |
| **unbalanced Dataset** | | | | | | |
| mctr | -3.75(2.5) | 56.81(27.22)* | -0.88(0.55) | -1.45(0.56)** | -2.87(2.56) | 58.25(27.22)** |
| mprom | -1.76(2.29) | -1.79(2.15) | -0.83(0.57) | -1.03(0.61)* | -0.93(2.36) | -0.76(2.24) |
| mcorrupt | 11.6(10.27) | 9.27(13.3) | -0.99(0.55) | -1.19(0.58)** | 12.59(10.28) | 10.46(13.32) |
| mret51 | -2.16(1.09)** | -3.99(1.02)*** | -0.65(0.62) | -0.6(0.67) | -1.52(1.25) | -3.4(1.22)** |
| mret53 | 2.38(1.89) | 0.6(1.96) | -1.36(0.57)** | -1.3(0.62)** | 3.74(1.98)* | 1.91(2.05) |
| mwbctr | -0.06(5.37) | 2.36(6.05) | -0.9(0.56) | -1.15(0.59)* | 0.84(5.4) | 3.51(6.08) |
| mwbpro | -1.12(1.69) | -2.2(1.48) | -0.86(0.59) | -0.99(0.63) | -0.26(1.78) | -1.21(1.61) |
| mwbhig | -1.06(1.71) | -2.54(1.33)* | -0.87(0.58) | -0.96(0.63) | -0.19(1.8) | -1.57(1.47) |
| mwbind | -3.42(1.74)* | 2.58(3.31) | -0.77(0.57) | -1.33(0.59)** | -2.66(1.83) | 3.91(3.36) |
| mwboth | 16.37(9.68) | -2.81(1.83) | -1.16(0.54)** | -1.06(0.6)* | 17.53(9.69)* | -1.75(1.93) |
| mwbsel | -4.61(0.81)*** | 1.21(3.88) | -0.64(0.59) | -1.2(0.59)** | -3.97(1)*** | 2.42(3.92) |
| mlocal | -2.22(2.21) | -0.38(1.9) | -0.8(0.57) | -1.17(0.62)* | -1.42(2.28) | 0.79(2) |
| mphd | 4.13(3.32) | -2.15(1.87) | -1.19(0.55)** | -1.04(0.61)* | 5.32(3.37) | -1.11(1.97) |
| mhum | -3.54(1.09)** | -2.16(1.71) | -0.62(0.6) | -0.99(0.63) | -2.92(1.24)** | -1.18(1.82) |
| msci | -1.78(4.36) | -0.26(5.03) | -0.87(0.56) | -1.12(0.59)* | -0.91(4.39) | 0.86(5.06) |
| meng | -2.17(1.73) | -3.62(1.05)*** | -0.81(0.58) | -0.91(0.63) | -1.36(1.83) | -2.7(1.22)** |

Notes: * means 10% statistically significant, ** means 5% statistically significant, and *** means 0.1% statistically significant.

Table A.6. Two-sided t-test for change of de-meaned and de-trended GDP in industry on transitions

| Characteristic | Treated | | Non-Treated | | Difference | |
|---|---|---|---|---|---|---|
| | Before → In Office | In Office → After | Before → In Office | In Office → After | Before → In Office | In Office → After |
| **balanced Dataset** | | | | | | |
| mctr | -1.89(1.36) | 29.46(18.39) | -0.17(0.31) | -0.14(0.34) | -1.72(1.39) | 29.59(18.4) |
| mprom | -0.22(1.44) | 0.31(1.51) | -0.18(0.31) | 0.01(0.37) | -0.04(1.48) | 0.3(1.55) |
| mcorrupt | 6.77(4.75) | 3.95(6.54) | -0.23(0.31) | -0.01(0.36) | 7(4.76) | 3.96(6.55) |
| mret51 | -1.01(0.55)* | -1.06(0.71) | -0.02(0.35) | 0.22(0.41) | -1(0.65) | -1.28(0.82) |
| mret53 | 0.83(0.82) | 1.52(1.21) | -0.32(0.33) | -0.16(0.38) | 1.16(0.88) | 1.67(1.27) |
| mwbctr | 2.19(4.87) | -0.61(3.01) | -0.21(0.31) | 0.04(0.37) | 2.39(4.88) | -0.65(3.04) |
| mwbpro | -0.28(0.99) | -0.55(1.02) | -0.17(0.32) | 0.08(0.38) | -0.11(1.04) | -0.63(1.09) |
| mwbhig | -0.21(1) | -1.28(0.78) | -0.17(0.32) | 0.15(0.39) | -0.04(1.05) | -1.43(0.87)* |
| mwbind | -1.29(1.11) | 1.41(1.68) | -0.13(0.32) | -0.06(0.37) | -1.17(1.16) | 1.47(1.72) |
| mwboth | 10.66(6.07)* | -0.83(1.07) | -0.35(0.29) | 0.05(0.37) | 11.01(6.07)* | -0.88(1.14) |
| mwbsel | -2.33(0.46)*** | 2.42(3) | -0.04(0.33) | -0.07(0.36) | -2.3(0.57)*** | 2.48(3.02) |
| mlocal | -0.4(1.29) | 0.65(1.21) | -0.16(0.32) | -0.03(0.38) | -0.23(1.33) | 0.67(1.27) |
| mphd | 3.17(1.98) | -1.3(1.09) | -0.39(0.3) | 0.11(0.38) | 3.56(2)* | -1.41(1.15) |
| mhum | -1.68(0.58)** | -1(0.87) | -0.02(0.33) | 0.14(0.39) | -1.66(0.67)** | -1.14(0.96) |
| msci | -2.27(0.82)** | 0.8(3.3) | -0.13(0.31) | 0.01(0.36) | -2.14(0.88)** | 0.8(3.32) |
| meng | -0.77(1.1) | -1.54(0.66)** | -0.14(0.32) | 0.16(0.39) | -0.62(1.15) | -1.69(0.76)** |
| **unbalanced Dataset** | | | | | | |
| mctr | -2.32(1.13) | 23.52(16.15) | -0.25(0.29) | -0.42(0.31) | -2.07(1.17)* | 23.93(16.15) |
| mprom | -0.61(1.32) | -0.47(1.24) | -0.23(0.3) | -0.26(0.34) | -0.37(1.35) | -0.22(1.29) |
| mcorrupt | 5.09(4.57) | 3.95(6.54) | -0.3(0.29) | -0.31(0.32) | 5.39(4.58) | 4.27(6.55) |
| mret51 | -0.79(0.54) | -1.25(0.66)* | -0.16(0.33) | -0.11(0.36) | -0.64(0.63) | -1.14(0.75) |
| mret53 | 1.13(0.83) | 1.04(1.12) | -0.46(0.31) | -0.43(0.34) | 1.58(0.89)* | 1.48(1.17) |
| mwbctr | 0.8(3.54) | -0.97(2.83) | -0.27(0.29) | -0.26(0.33) | 1.07(3.55) | -0.71(2.85) |
| mwbpro | -0.45(0.91) | -0.77(0.88) | -0.23(0.31) | -0.23(0.35) | -0.22(0.96) | -0.54(0.95) |
| mwbhig | -0.4(0.92) | -1.36(0.69)* | -0.24(0.31) | -0.17(0.35) | -0.16(0.97) | -1.18(0.77) |
| mwbind | -1.51(1.02) | 0.94(1.55) | -0.2(0.3) | -0.35(0.33) | -1.31(1.06) | 1.29(1.59) |
| mwboth | 9.97(5.78) | -1.19(1.02) | -0.42(0.28) | -0.25(0.33) | 10.39(5.79)* | -0.94(1.07) |
| mwbsel | -2.33(0.45)*** | 1.66(2.45) | -0.12(0.31) | -0.36(0.32) | -2.21(0.54)*** | 2.02(2.47) |
| mlocal | -0.56(1.24) | 0.13(1.03) | -0.24(0.3) | -0.32(0.34) | -0.32(1.28) | 0.45(1.08) |
| mphd | 2.88(1.9) | -1.07(1.03) | -0.44(0.29) | -0.23(0.34) | 3.32(1.92)* | -0.84(1.08) |
| mhum | -1.79(0.56)** | -1.16(0.78) | -0.1(0.32) | -0.18(0.35) | -1.68(0.64)** | -0.97(0.85) |
| msci | -2.15(0.79)** | 0.8(3.3) | -0.21(0.3) | -0.3(0.32) | -1.93(0.84)** | 1.11(3.32) |
| meng | -0.82(1.06) | -1.52(0.63)** | -0.22(0.3) | -0.18(0.35) | -0.59(1.1) | -1.34(0.72)* |

Notes: * means 10% statistically significant, ** means 5% statistically significant, and *** means 0.1% statistically significant.

Table A.7. Two-sided t-test for change of de-meaned and de-trended population (thousand) on transitions

| Characteristic | Treated | | Non-Treated | | Difference | |
|---|---|---|---|---|---|---|
| | Before → In Office | In Office → After | Before → In Office | In Office → After | Before → In Office | In Office → After |
| balanced Dataset | | | | | | |
| mctr | 7.75(34.94) | 328.62(175.9) | -3.6(2.68) | -6.82(2.59)** | 11.35(35.04) | 335.43(175.92)* |
| mprom | -7.81(7.31) | -3.34(9.38) | -3.3(2.8) | -5.03(3)* | -4.51(7.83) | 1.69(9.85) |
| mcorrupt | 62.67(49.15) | 44.07(41.45) | -4.04(2.66) | -5.41(2.86)* | 66.71(49.22) | 49.48(41.55) |
| mret51 | 2.62(7.87) | -17.94(3.88)*** | -4.72(2.81)* | -2.58(3.29) | 7.34(8.36) | -15.36(5.09)** |
| mret53 | 0.21(9.82) | -5.38(6.31) | -4.11(2.7) | -4.84(3.12) | 4.32(10.18) | -0.54(7.04) |
| mwbctr | 5.78(19.57) | 7.28(30.3) | -3.67(2.69) | -5.1(2.87)* | 9.45(19.76) | 12.37(30.44) |
| mwbpro | -5.41(7.55) | -8.87(7.68) | -3.34(2.85) | -4.54(3.05) | -2.07(8.07) | -4.34(8.26) |
| mwbhig | -5.32(7.67) | -11.03(7.64) | -3.35(2.85) | -4.34(3.05) | -1.97(8.18) | -6.69(8.23) |
| mwbind | -15.27(6.17)** | 18.3(20.76) | -3.02(2.78) | -6.4(2.74)** | -12.25(6.77)* | 24.7(20.94) |
| mwboth | 47.47(34.44) | -7.05(8.76) | -4.4(2.65) | -4.84(2.93)* | 51.88(34.55) | -2.21(9.24) |
| mwbsel | -13.99(4.18)** | 5.86(15.86) | -2.86(2.83) | -5.33(2.91)* | -11.13(5.05)** | 11.2(16.12) |
| mlocal | -10.04(9.15) | -15.44(7.24)** | -3.11(2.79) | -3.91(3.06) | -6.93(9.56) | -11.53(7.86) |
| mphd | 8.46(13.28) | -2.48(8.2) | -4.3(2.72) | -5.04(2.99)* | 12.76(13.56) | 2.56(8.72) |
| mhum | -16.3(3.12)*** | -3.74(11.87) | -2.21(2.93) | -5.02(2.91)* | -14.1(4.29)** | 1.29(12.23) |
| msci | 21.07(38) | -5.99(12.32) | -4.13(2.59) | -4.87(2.93)* | 25.2(38.09) | -1.13(12.67) |
| meng | -16.66(4.72)*** | -17.3(4.25)*** | -2.78(2.81) | -3.89(3.07) | -13.88(5.5)** | -13.41(5.25)** |
| unbalanced Dataset | | | | | | |
| mctr | 1.81(27.71) | 268.15(155.83) | -4.78(2.53) | -7.28(2.35)** | 6.59(27.83) | 275.43(155.85)* |
| mprom | -8.42(6.74) | -6.01(7.87) | -4.52(2.65)* | -5.57(2.72)** | -3.9(7.25) | -0.44(8.32) |
| mcorrupt | 46.64(46.21) | 44.07(41.45) | -5.14(2.52)* | -6.06(2.57)** | 51.78(46.28) | 50.13(41.53) |
| mret51 | 0.5(7.48) | -16.7(3.69)*** | -5.73(2.65)** | -3.69(2.95) | 6.23(7.93) | -13.01(4.73)** |
| mret53 | 1.52(9.59) | -5.53(5.97) | -5.67(2.53)** | -5.61(2.8)** | 7.19(9.92) | 0.09(6.59) |
| mwbctr | 0.94(14.35) | 7.74(28.21) | -4.84(2.55)* | -5.81(2.58)** | 5.78(14.58) | 13.55(28.33) |
| mwbpro | -7.5(6.95) | -9.13(6.81) | -4.41(2.7) | -5.27(2.75)* | -3.09(7.46) | -3.86(7.34) |
| mwbhig | -7.46(7.06) | -11.22(6.85) | -4.43(2.7) | -5.08(2.75)* | -3.03(7.56) | -6.14(7.38) |
| mwbind | -15.56(5.68)** | 15.62(19.02) | -4.24(2.63) | -6.93(2.47)** | -11.32(6.26)* | 22.55(19.18) |
| mwboth | 44.65(32.7) | -7.37(8.16) | -5.55(2.51)** | -5.56(2.64)** | 50.21(32.8) | -1.81(8.58) |
| mwbsel | -15.98(4.03)*** | 5.21(13.12) | -4(2.68) | -6.09(2.63)** | -11.98(4.84)** | 11.29(13.38) |
| mlocal | -10.61(8.81) | -15.12(6.28)** | -4.36(2.63) | -4.64(2.77)* | -6.25(9.19) | -10.48(6.87) |
| mphd | 7.8(12.7) | -4.97(7.66) | -5.5(2.56)** | -5.64(2.69)** | 13.3(12.95) | 0.67(8.12) |
| mhum | -16.56(3.02)*** | -3.78(10.56) | -3.55(2.76) | -5.8(2.63)** | -13.01(4.09)** | 2.01(10.88) |
| msci | 16.83(35.26) | -5.99(12.32) | -5.25(2.45)** | -5.59(2.63)** | 22.09(35.34) | -0.4(12.6) |
| meng | -16.58(4.53)*** | -18.01(4.1)*** | -4.07(2.66) | -4.67(2.75)* | -12.51(5.25)** | -13.34(4.94)** |

Notes: * means 10% statistically significant, ** means 5% statistically significant, and *** means 0.1% statistically significant.

Table A.8. Two-sided t-test for change of de-meaned and de-trended average wage (CNY) on transitions

| Characteristic | Treated | | Non-Treated | | Difference | |
|---|---|---|---|---|---|---|
| | Before → In Office | In Office → After | Before → In Office | In Office → After | Before → In Office | In Office → After |
| balanced Dataset | | | | | | |
| mctr | -518.03(468.23) | 1685.23(1067.78) | -33.78(36.21) | -43.97(40.46) | -484.24(469.62) | 1729.2(1068.55) |
| mprom | -35.19(104.43) | -454.62(204.08)** | -35.51(37.85) | 0.41(40.67) | 0.31(111.08) | -455.03(208.09)** |
| mcorrupt | -67.27(284.82) | -58.1(262.11) | -35.24(36.34) | -34.04(41.16) | -32.04(287.13) | -24.06(265.32) |
| mret51 | -115.21(73.98) | -99.88(122.58) | -20.26(40.62) | -22.58(42.87) | -94.95(84.4) | -77.3(129.86) |
| mret53 | 87.67(101.36) | -1.22(139.94) | -53.1(38.64) | -38.41(42.5) | 140.77(108.47) | 37.18(146.25) |
| mwbctr | -630.1(697.45) | -300.18(329.73) | -28.6(35.65) | -30.04(41.14) | -601.5(698.36) | -270.14(332.29) |
| mwbpro | -5.07(119.98) | -93.81(108.15) | -39.15(37.82) | -28.81(43.46) | 34.08(125.8) | -64.99(116.56) |
| mwbhig | 29.88(123.28) | -103.92(107.74) | -43.22(37.68) | -27.89(43.46) | 73.1(128.91) | -76.04(116.18) |
| mwbind | 111.54(145.31) | 373.87(158.59)** | -42.27(37.18) | -60.58(42.09) | 153.81(149.99) | 434.45(164.08)** |
| mwboth | -255.21(548.27) | -112.56(185.72) | -31.95(35.67) | -32.3(41.6) | -223.27(549.43) | -80.27(190.32) |
| mwbsel | -77.94(112.35) | 0.06(187.61) | -32.7(37.79) | -35.68(41.81) | -45.24(118.54) | 35.74(192.21) |
| mlocal | -46.81(136.82) | 32.87(122.68) | -34.7(37.46) | -40.53(43.15) | -12.11(141.86) | 73.41(130.05) |
| mphd | -36.93(137.72) | -204.55(114.85)* | -35.4(37.41) | -24.17(42.69) | -1.53(142.71) | -180.38(122.53) |
| mhum | -82.36(141.64) | 28.9(120.81) | -30.51(37.04) | -40.85(43.29) | -51.85(146.4) | 69.75(128.33) |
| msci | -162.03(261.65) | 394.11(198.53)* | -32.64(36.47) | -46.63(41.55) | -129.39(264.18) | 440.74(202.83)** |
| meng | 30.72(115.95) | 42.5(134.11) | -39.38(37.63) | -40.41(42.77) | 70.1(121.91) | 82.91(140.76) |
| unbalanced Dataset | | | | | | |
| mctr | -619.21(376.53) | 1297.93(954) | -33.55(34.29) | -24(38.04) | -585.65(378.09) | 1321.92(954.75) |
| mprom | -21.95(97.91) | -337.68(177.9)* | -36.87(35.88) | 13.27(38.41) | 14.92(104.28) | -350.94(182)* |
| mcorrupt | 111.4(311.16) | -58.1(262.11) | -37.17(34.39) | -15.72(38.59) | 148.58(313.06) | -42.38(264.93) |
| mret51 | -92.52(71.95) | -57.23(115.32) | -25.26(38.33) | -8.98(40.29) | -67.26(81.52) | -48.25(122.16) |
| mret53 | 82.53(97.26) | 11.38(129.88) | -52.82(36.52) | -19.41(39.99) | 135.35(103.89) | 30.79(135.9) |
| mwbctr | -498.3(508.01) | -203.5(321.82) | -29.03(33.87) | -13.25(38.59) | -469.27(509.13) | -190.25(324.13) |
| mwbpro | -31.53(111.2) | -83.1(105.77) | -36.5(35.91) | -9.74(40.73) | 4.96(116.85) | -73.37(113.34) |
| mwbhig | 0.08(114.14) | -84.67(106.45) | -40.29(35.79) | -9.67(40.7) | 40.37(119.62) | -75(113.97) |
| mwbind | 124.06(134.92) | 356.22(149.02)** | -43.51(35.24) | -39.34(39.51) | 167.56(139.45) | 395.56(154.17)** |
| mwboth | -301.08(520.64) | -52.57(177.92) | -31.76(33.79) | -15.2(39.01) | -269.32(521.73) | -37.37(182.15) |
| mwbsel | -73.6(106.82) | -3.21(184.8) | -33.45(35.78) | -16.67(39.18) | -40.15(112.66) | 13.46(188.9) |
| mlocal | -54.95(133.39) | 36.36(110.7) | -34.67(35.39) | -21.39(40.68) | -20.28(138.01) | 57.75(117.94) |
| mphd | -26.21(132.9) | -156.01(113.88) | -36.54(35.38) | -8.14(39.96) | 10.33(137.53) | -147.86(120.69) |
| mhum | -94.25(137.15) | 44.69(112.65) | -30(35.01) | -22.45(40.65) | -64.25(141.55) | 67.14(119.76) |
| msci | -110.71(244.67) | 394.11(198.53)* | -34.26(34.55) | -26.57(38.91) | -76.44(247.1) | 420.68(202.31)** |
| meng | 37.74(112.63) | 16.09(134.88) | -40.17(35.58) | -18.47(39.93) | 77.91(118.12) | 34.56(140.66) |

Notes: * means 10% statistically significant, ** means 5% statistically significant, and *** means 0.1% statistically significant.

## Table A.9. Regressions of $SO_2$ emissions (1000 tons) - balanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | 17.9** | | | | | | | | | | | | | | | | |
| | (7.66) | | | | | | | | | | | | | | | | |
| mprom | | 3.44* | | | | | | | | | | | | | | | |
| | | (1.82) | | | | | | | | | | | | | | | |
| mcorrupt | | | 0.53 | | | | | | | | | | | | | | |
| | | | (5.46) | | | | | | | | | | | | | | |
| mret51 | | | | -2.37** | | | | | | | | | | | | | |
| | | | | (1.12) | | | | | | | | | | | | | |
| mret53 | | | | | -2.36 | | | | | | | | | | | | |
| | | | | | (1.70) | | | | | | | | | | | | |
| mwbctr | | | | | | -2.01 | | | | | | | | | | | |
| | | | | | | (2.55) | | | | | | | | | | | |
| mwbpro | | | | | | | 0.60 | | | | | | | | | | |
| | | | | | | | (1.49) | | | | | | | | | | |
| mwbhig | | | | | | | | 0.35 | | | | | | | | | |
| | | | | | | | | (1.48) | | | | | | | | | |
| mwbind | | | | | | | | | 4.06** | | | | | | | | |
| | | | | | | | | | (1.85) | | | | | | | | |
| mwboth | | | | | | | | | | -0.46 | | | | | | | |
| | | | | | | | | | | (3.39) | | | | | | | |
| mwbsel | | | | | | | | | | | 2.07 | | | | | | |
| | | | | | | | | | | | (2.00) | | | | | | |
| mretire | | | | | | | | | | | | 1.02 | | | | | |
| | | | | | | | | | | | | (5.00) | | | | | |
| mlocal | | | | | | | | | | | | | -0.90 | | | | |
| | | | | | | | | | | | | | (1.69) | | | | |
| mphd | | | | | | | | | | | | | | 0.074 | | | |
| | | | | | | | | | | | | | | (1.88) | | | |
| mhum | | | | | | | | | | | | | | | 0.55 | | |
| | | | | | | | | | | | | | | | (1.44) | | |
| msci | | | | | | | | | | | | | | | | -0.72 | |
| | | | | | | | | | | | | | | | | (3.03) | |
| meng | | | | | | | | | | | | | | | | | 2.18 |
| | | | | | | | | | | | | | | | | | (1.60) |
| _cons | 54.8*** | 52.3*** | 55.1*** | 55.9*** | 55.6*** | 55.1*** | 54.8*** | 54.9*** | 54.3*** | 55.1*** | 53.5*** | 55.1*** | 55.6*** | 55.1*** | 54.8*** | 55.1*** | 54.6*** |
| | (1.15) | (1.70) | (1.17) | (1.21) | (1.22) | (1.14) | (1.21) | (1.22) | (1.13) | (1.17) | (1.87) | (1.14) | (1.62) | (1.17) | (1.44) | (1.17) | (1.18) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 |
| $R^2$ | 0.119 | 0.116 | 0.112 | 0.115 | 0.114 | 0.112 | 0.112 | 0.112 | 0.116 | 0.112 | 0.113 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.114 |

## Table A.10. Regressions of $SO_2$ emissions (1000 tons) - unbalanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | 16.7** | | | | | | | | | | | | | | | | |
| | (7.28) | | | | | | | | | | | | | | | | |
| mprom | | 2.39 | | | | | | | | | | | | | | | |
| | | (1.71) | | | | | | | | | | | | | | | |
| mcorrupt | | | 0.84 | | | | | | | | | | | | | | |
| | | | (5.28) | | | | | | | | | | | | | | |
| mret51 | | | | -2.41** | | | | | | | | | | | | | |
| | | | | (1.08) | | | | | | | | | | | | | |
| mret53 | | | | | -2.97* | | | | | | | | | | | | |
| | | | | | (1.67) | | | | | | | | | | | | |
| mwbctr | | | | | | 0.069 | | | | | | | | | | | |
| | | | | | | (2.30) | | | | | | | | | | | |
| mwbpro | | | | | | | 0.85 | | | | | | | | | | |
| | | | | | | | (1.39) | | | | | | | | | | |
| mwbhig | | | | | | | | 0.66 | | | | | | | | | |
| | | | | | | | | (1.40) | | | | | | | | | |
| mwbind | | | | | | | | | 3.69** | | | | | | | | |
| | | | | | | | | | (1.84) | | | | | | | | |
| mwboth | | | | | | | | | | -0.022 | | | | | | | |
| | | | | | | | | | | (3.33) | | | | | | | |
| mwbsel | | | | | | | | | | | 1.82 | | | | | | |
| | | | | | | | | | | | (1.90) | | | | | | |
| mretire | | | | | | | | | | | | 2.36 | | | | | |
| | | | | | | | | | | | | (4.61) | | | | | |
| mlocal | | | | | | | | | | | | | -1.28 | | | | |
| | | | | | | | | | | | | | (1.58) | | | | |
| mphd | | | | | | | | | | | | | | -0.025 | | | |
| | | | | | | | | | | | | | | (1.83) | | | |
| mhum | | | | | | | | | | | | | | | 0.45 | | |
| | | | | | | | | | | | | | | | (1.40) | | |
| msci | | | | | | | | | | | | | | | | -0.28 | |
| | | | | | | | | | | | | | | | | (2.92) | |
| meng | | | | | | | | | | | | | | | | | 2.23 |
| | | | | | | | | | | | | | | | | | (1.56) |
| _cons | 53.8*** | 52.1*** | 54.0*** | 54.8*** | 54.6*** | 54.0*** | 53.7*** | 53.7*** | 53.3*** | 54.0*** | 52.7*** | 54.0*** | 54.8*** | 54.0*** | 53.8*** | 54.0*** | 53.5*** |
| | (1.14) | (1.65) | (1.16) | (1.21) | (1.23) | (1.14) | (1.18) | (1.20) | (1.13) | (1.16) | (1.79) | (1.14) | (1.59) | (1.16) | (1.43) | (1.16) | (1.17) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 |
| $R^2$ | 0.115 | 0.110 | 0.108 | 0.112 | 0.112 | 0.108 | 0.109 | 0.109 | 0.112 | 0.108 | 0.109 | 0.109 | 0.109 | 0.108 | 0.108 | 0.108 | 0.110 |

Table A.11. Regressions of $SO_2$ emission intensity (1000 tons / billion CNY) - balanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | -0.17 | | | | | | | | | | | | | | | | |
| | (0.33) | | | | | | | | | | | | | | | | |
| mprom | | -0.028 | | | | | | | | | | | | | | | |
| | | (0.19) | | | | | | | | | | | | | | | |
| mcorrupt | | | -0.0056 | | | | | | | | | | | | | | |
| | | | (0.42) | | | | | | | | | | | | | | |
| mret51 | | | | -0.11 | | | | | | | | | | | | | |
| | | | | (0.13) | | | | | | | | | | | | | |
| mret53 | | | | | 0.084 | | | | | | | | | | | | |
| | | | | | (0.15) | | | | | | | | | | | | |
| mwbctr | | | | | | -1.11 | | | | | | | | | | | |
| | | | | | | (1.03) | | | | | | | | | | | |
| mwbpro | | | | | | | 0.45** | | | | | | | | | | |
| | | | | | | | (0.21) | | | | | | | | | | |
| mwbhig | | | | | | | | 0.42** | | | | | | | | | |
| | | | | | | | | (0.21) | | | | | | | | | |
| mwbind | | | | | | | | | 0.094 | | | | | | | | |
| | | | | | | | | | (0.18) | | | | | | | | |
| mwboth | | | | | | | | | | 0.34 | | | | | | | |
| | | | | | | | | | | (0.24) | | | | | | | |
| mwbsel | | | | | | | | | | | 0.51* | | | | | | |
| | | | | | | | | | | | (0.29) | | | | | | |
| mretire | | | | | | | | | | | | 0.46 | | | | | |
| | | | | | | | | | | | | (0.29) | | | | | |
| mlocal | | | | | | | | | | | | | -0.30 | | | | |
| | | | | | | | | | | | | | (0.22) | | | | |
| mphd | | | | | | | | | | | | | | 0.18 | | | |
| | | | | | | | | | | | | | | (0.35) | | | |
| mhum | | | | | | | | | | | | | | | -0.044 | | |
| | | | | | | | | | | | | | | | (0.19) | | |
| msci | | | | | | | | | | | | | | | | 0.12 | |
| | | | | | | | | | | | | | | | | (0.60) | |
| meng | | | | | | | | | | | | | | | | | 0.11 |
| | | | | | | | | | | | | | | | | | (0.14) |
| _cons | 3.87*** | 3.89*** | 3.87*** | 3.91*** | 3.85*** | 3.91*** | 3.69*** | 3.69*** | 3.85*** | 3.85*** | 3.49*** | 3.87*** | 4.06*** | 3.84*** | 3.90*** | 3.86*** | 3.85*** |
| | (0.17) | (0.23) | (0.17) | (0.17) | (0.16) | (0.18) | (0.13) | (0.13) | (0.17) | (0.17) | (0.18) | (0.17) | (0.26) | (0.17) | (0.17) | (0.18) | (0.17) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 | 1788 |
| $R^2$ | 0.267 | 0.267 | 0.267 | 0.267 | 0.267 | 0.273 | 0.274 | 0.273 | 0.267 | 0.268 | 0.272 | 0.267 | 0.269 | 0.267 | 0.267 | 0.267 | 0.267 |

Table A.12. Regressions of $SO_2$ emission intensity (1000 tons / billion CNY) - unbalanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | -0.17 | | | | | | | | | | | | | | | | |
| | (0.30) | | | | | | | | | | | | | | | | |
| mprom | | -0.084 | | | | | | | | | | | | | | | |
| | | (0.18) | | | | | | | | | | | | | | | |
| mcorrupt | | | 0.0049 | | | | | | | | | | | | | | |
| | | | (0.40) | | | | | | | | | | | | | | |
| mret51 | | | | -0.12 | | | | | | | | | | | | | |
| | | | | (0.12) | | | | | | | | | | | | | |
| mret53 | | | | | 0.091 | | | | | | | | | | | | |
| | | | | | (0.14) | | | | | | | | | | | | |
| mwbctr | | | | | | -0.78 | | | | | | | | | | | |
| | | | | | | (0.85) | | | | | | | | | | | |
| mwbpro | | | | | | | 0.43** | | | | | | | | | | |
| | | | | | | | (0.19) | | | | | | | | | | |
| mwbhig | | | | | | | | 0.40** | | | | | | | | | |
| | | | | | | | | (0.19) | | | | | | | | | |
| mwbind | | | | | | | | | 0.058 | | | | | | | | |
| | | | | | | | | | (0.18) | | | | | | | | |
| mwboth | | | | | | | | | | 0.35 | | | | | | | |
| | | | | | | | | | | (0.23) | | | | | | | |
| mwbsel | | | | | | | | | | | 0.46 | | | | | | |
| | | | | | | | | | | | (0.28) | | | | | | |
| mretire | | | | | | | | | | | | 0.52* | | | | | |
| | | | | | | | | | | | | (0.27) | | | | | |
| mlocal | | | | | | | | | | | | | -0.27 | | | | |
| | | | | | | | | | | | | | (0.21) | | | | |
| mphd | | | | | | | | | | | | | | 0.18 | | | |
| | | | | | | | | | | | | | | (0.34) | | | |
| mhum | | | | | | | | | | | | | | | -0.061 | | |
| | | | | | | | | | | | | | | | (0.18) | | |
| msci | | | | | | | | | | | | | | | | 0.14 | |
| | | | | | | | | | | | | | | | | (0.57) | |
| meng | | | | | | | | | | | | | | | | | 0.12 |
| | | | | | | | | | | | | | | | | | (0.14) |
| _cons | 3.88*** | 3.94*** | 3.88*** | 3.92*** | 3.86*** | 3.90*** | 3.71*** | 3.70*** | 3.87*** | 3.85*** | 3.54*** | 3.88*** | 4.05*** | 3.85*** | 3.91*** | 3.87*** | 3.85*** |
| | (0.16) | (0.21) | (0.16) | (0.16) | (0.16) | (0.17) | (0.13) | (0.13) | (0.16) | (0.16) | (0.17) | (0.16) | (0.24) | (0.16) | (0.16) | (0.17) | (0.16) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 | 1940 |
| $R^2$ | 0.273 | 0.273 | 0.273 | 0.273 | 0.273 | 0.276 | 0.280 | 0.279 | 0.273 | 0.274 | 0.277 | 0.273 | 0.275 | 0.273 | 0.273 | 0.273 | 0.273 |

## Table A.13. Regressions of $SO_2$ emission removal ratio - balanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | -0.094** | | | | | | | | | | | | | | | | |
| | (0.05) | | | | | | | | | | | | | | | | |
| mprom | | 0.014 | | | | | | | | | | | | | | | |
| | | (0.02) | | | | | | | | | | | | | | | |
| mcorrupt | | | -0.010 | | | | | | | | | | | | | | |
| | | | (0.04) | | | | | | | | | | | | | | |
| mret51 | | | | 0.031*** | | | | | | | | | | | | | |
| | | | | (0.01) | | | | | | | | | | | | | |
| mret53 | | | | | 0.032** | | | | | | | | | | | | |
| | | | | | (0.01) | | | | | | | | | | | | |
| mwbctr | | | | | | -0.11*** | | | | | | | | | | | |
| | | | | | | (0.03) | | | | | | | | | | | |
| mwbpro | | | | | | | -0.010 | | | | | | | | | | |
| | | | | | | | (0.01) | | | | | | | | | | |
| mwbhig | | | | | | | | -0.018 | | | | | | | | | |
| | | | | | | | | (0.01) | | | | | | | | | |
| mwbind | | | | | | | | | -0.021 | | | | | | | | |
| | | | | | | | | | (0.02) | | | | | | | | |
| mwboth | | | | | | | | | | 0.032 | | | | | | | |
| | | | | | | | | | | (0.03) | | | | | | | |
| mwbsel | | | | | | | | | | | -0.024 | | | | | | |
| | | | | | | | | | | | (0.02) | | | | | | |
| mretire | | | | | | | | | | | | 0.047 | | | | | |
| | | | | | | | | | | | | (0.04) | | | | | |
| mlocal | | | | | | | | | | | | | -0.0023 | | | | |
| | | | | | | | | | | | | | (0.02) | | | | |
| mphd | | | | | | | | | | | | | | -0.020 | | | |
| | | | | | | | | | | | | | | (0.02) | | | |
| mhum | | | | | | | | | | | | | | | -0.0036 | | |
| | | | | | | | | | | | | | | | (0.01) | | |
| msci | | | | | | | | | | | | | | | | -0.0050 | |
| | | | | | | | | | | | | | | | | (0.02) | |
| meng | | | | | | | | | | | | | | | | | -0.00069 |
| | | | | | | | | | | | | | | | | | (0.02) |
| _cons | 0.22*** | 0.21*** | 0.22*** | 0.21*** | 0.21*** | 0.22*** | 0.22*** | 0.23*** | 0.22*** | 0.22*** | 0.24*** | 0.22*** | 0.22*** | 0.22*** | 0.22*** | 0.22*** | 0.22*** |
| | (0.01) | (0.02) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.02) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 | 1734 |
| $R^2$ | 0.402 | 0.400 | 0.400 | 0.405 | 0.404 | 0.408 | 0.400 | 0.401 | 0.401 | 0.401 | 0.401 | 0.400 | 0.400 | 0.401 | 0.400 | 0.400 | 0.400 |

## Table A.14. Regressions of $SO_2$ emission removal ratio - unbalanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | -0.098** | | | | | | | | | | | | | | | | |
| | (0.04) | | | | | | | | | | | | | | | | |
| mprom | | 0.019 | | | | | | | | | | | | | | | |
| | | (0.02) | | | | | | | | | | | | | | | |
| mcorrupt | | | -0.014 | | | | | | | | | | | | | | |
| | | | (0.04) | | | | | | | | | | | | | | |
| mret51 | | | | 0.035*** | | | | | | | | | | | | | |
| | | | | (0.01) | | | | | | | | | | | | | |
| mret53 | | | | | 0.037*** | | | | | | | | | | | | |
| | | | | | (0.01) | | | | | | | | | | | | |
| mwbctr | | | | | | -0.13*** | | | | | | | | | | | |
| | | | | | | (0.03) | | | | | | | | | | | |
| mwbpro | | | | | | | -0.011 | | | | | | | | | | |
| | | | | | | | (0.01) | | | | | | | | | | |
| mwbhig | | | | | | | | -0.020 | | | | | | | | | |
| | | | | | | | | (0.01) | | | | | | | | | |
| mwbind | | | | | | | | | -0.022 | | | | | | | | |
| | | | | | | | | | (0.02) | | | | | | | | |
| mwboth | | | | | | | | | | 0.029 | | | | | | | |
| | | | | | | | | | | (0.03) | | | | | | | |
| mwbsel | | | | | | | | | | | -0.023 | | | | | | |
| | | | | | | | | | | | (0.02) | | | | | | |
| mretire | | | | | | | | | | | | 0.017 | | | | | |
| | | | | | | | | | | | | (0.05) | | | | | |
| mlocal | | | | | | | | | | | | | 0.0038 | | | | |
| | | | | | | | | | | | | | (0.02) | | | | |
| mphd | | | | | | | | | | | | | | -0.024 | | | |
| | | | | | | | | | | | | | | (0.02) | | | |
| mhum | | | | | | | | | | | | | | | 0.0012 | | |
| | | | | | | | | | | | | | | | (0.01) | | |
| msci | | | | | | | | | | | | | | | | -0.012 | |
| | | | | | | | | | | | | | | | | (0.02) | |
| meng | | | | | | | | | | | | | | | | | -0.0048 |
| | | | | | | | | | | | | | | | | | (0.02) |
| _cons | 0.22*** | 0.20*** | 0.22*** | 0.21*** | 0.21*** | 0.22*** | 0.22*** | 0.22*** | 0.22*** | 0.21*** | 0.23*** | 0.22*** | 0.21*** | 0.22*** | 0.22*** | 0.22*** | 0.22*** |
| | (0.01) | (0.02) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 | 1879 |
| $R^2$ | 0.384 | 0.383 | 0.381 | 0.388 | 0.387 | 0.395 | 0.382 | 0.383 | 0.383 | 0.382 | 0.383 | 0.381 | 0.381 | 0.383 | 0.381 | 0.382 | 0.381 |

Table A.15. Regressions of water discharge (million tons) - balanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | 37.4 | | | | | | | | | | | | | | | | |
| | (25.58) | | | | | | | | | | | | | | | | |
| mprom | | 4.03 | | | | | | | | | | | | | | | |
| | | (3.42) | | | | | | | | | | | | | | | |
| mcorrupt | | | 3.08 | | | | | | | | | | | | | | |
| | | | (5.92) | | | | | | | | | | | | | | |
| mret51 | | | | 0.62 | | | | | | | | | | | | | |
| | | | | (2.45) | | | | | | | | | | | | | |
| mret53 | | | | | 2.25 | | | | | | | | | | | | |
| | | | | | (3.08) | | | | | | | | | | | | |
| mwbctr | | | | | | 9.41 | | | | | | | | | | | |
| | | | | | | (18.40) | | | | | | | | | | | |
| mwbpro | | | | | | | -3.10* | | | | | | | | | | |
| | | | | | | | (1.70) | | | | | | | | | | |
| mwbhig | | | | | | | | -3.51** | | | | | | | | | |
| | | | | | | | | (1.71) | | | | | | | | | |
| mwbind | | | | | | | | | 5.24** | | | | | | | | |
| | | | | | | | | | (2.12) | | | | | | | | |
| mwboth | | | | | | | | | | -5.24 | | | | | | | |
| | | | | | | | | | | (7.10) | | | | | | | |
| mwbsel | | | | | | | | | | | -1.50 | | | | | | |
| | | | | | | | | | | | (4.16) | | | | | | |
| mretire | | | | | | | | | | | | 15.0** | | | | | |
| | | | | | | | | | | | | (7.57) | | | | | |
| mlocal | | | | | | | | | | | | | 2.52 | | | | |
| | | | | | | | | | | | | | (1.93) | | | | |
| mphd | | | | | | | | | | | | | | 1.68 | | | |
| | | | | | | | | | | | | | | (5.76) | | | |
| mhum | | | | | | | | | | | | | | | -1.73 | | |
| | | | | | | | | | | | | | | | (1.80) | | |
| msci | | | | | | | | | | | | | | | | 4.76 | |
| | | | | | | | | | | | | | | | | (5.28) | |
| meng | | | | | | | | | | | | | | | | | 1.33 |
| | | | | | | | | | | | | | | | | | (2.26) |
| _cons | 74.7*** | 71.9*** | 75.1*** | 74.9*** | 74.7*** | 74.9*** | 76.4*** | 76.6*** | 74.2*** | 75.5*** | 76.3*** | 75.2*** | 73.6*** | 74.9*** | 76.1*** | 74.9*** | 74.8*** |
| | (2.32) | (3.44) | (2.35) | (2.25) | (2.29) | (2.73) | (2.25) | (2.26) | (2.38) | (2.52) | (3.39) | (2.34) | (2.73) | (2.88) | (2.47) | (2.31) | (2.42) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 |
| $R^2$ | 0.027 | 0.019 | 0.018 | 0.018 | 0.018 | 0.019 | 0.019 | 0.019 | 0.019 | 0.018 | 0.018 | 0.019 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 |

Table A.16. Regressions of water discharge (million tons) - unbalanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | 35.1 | | | | | | | | | | | | | | | | |
| | (23.91) | | | | | | | | | | | | | | | | |
| mprom | | 3.14 | | | | | | | | | | | | | | | |
| | | (3.22) | | | | | | | | | | | | | | | |
| mcorrupt | | | 3.48 | | | | | | | | | | | | | | |
| | | | (5.66) | | | | | | | | | | | | | | |
| mret51 | | | | 0.64 | | | | | | | | | | | | | |
| | | | | (2.34) | | | | | | | | | | | | | |
| mret53 | | | | | 2.25 | | | | | | | | | | | | |
| | | | | | (2.92) | | | | | | | | | | | | |
| mwbctr | | | | | | 7.41 | | | | | | | | | | | |
| | | | | | | (15.03) | | | | | | | | | | | |
| mwbpro | | | | | | | -2.62 | | | | | | | | | | |
| | | | | | | | (1.72) | | | | | | | | | | |
| mwbhig | | | | | | | | -2.99* | | | | | | | | | |
| | | | | | | | | (1.74) | | | | | | | | | |
| mwbind | | | | | | | | | 4.19* | | | | | | | | |
| | | | | | | | | | (2.24) | | | | | | | | |
| mwboth | | | | | | | | | | -5.25 | | | | | | | |
| | | | | | | | | | | (6.90) | | | | | | | |
| mwbsel | | | | | | | | | | | -0.86 | | | | | | |
| | | | | | | | | | | | (4.01) | | | | | | |
| mretire | | | | | | | | | | | | 12.3* | | | | | |
| | | | | | | | | | | | | (7.09) | | | | | |
| mlocal | | | | | | | | | | | | | 2.01 | | | | |
| | | | | | | | | | | | | | (1.88) | | | | |
| mphd | | | | | | | | | | | | | | 0.98 | | | |
| | | | | | | | | | | | | | | (5.57) | | | |
| mhum | | | | | | | | | | | | | | | -2.13 | | |
| | | | | | | | | | | | | | | | (1.77) | | |
| msci | | | | | | | | | | | | | | | | 4.58 | |
| | | | | | | | | | | | | | | | | (5.09) | |
| meng | | | | | | | | | | | | | | | | | 1.89 |
| | | | | | | | | | | | | | | | | | (2.22) |
| _cons | 73.2*** | 71.2*** | 73.6*** | 73.5*** | 73.2*** | 73.5*** | 74.8*** | 75.0*** | 72.9*** | 74.0*** | 74.3*** | 73.7*** | 72.4*** | 73.6*** | 74.9*** | 73.4*** | 73.3*** |
| | (2.23) | (3.30) | (2.25) | (2.15) | (2.20) | (2.57) | (2.19) | (2.20) | (2.29) | (2.40) | (3.30) | (2.25) | (2.63) | (2.74) | (2.38) | (2.21) | (2.32) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 |
| $R^2$ | 0.025 | 0.017 | 0.017 | 0.017 | 0.017 | 0.018 | 0.018 | 0.018 | 0.018 | 0.017 | 0.017 | 0.018 | 0.017 | 0.017 | 0.017 | 0.017 | 0.017 |

Table A.17. Regressions of water meet standard (million tons) - balanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | 33.4 | | | | | | | | | | | | | | | | |
| | (22.47) | | | | | | | | | | | | | | | | |
| mprom | | 3.06 | | | | | | | | | | | | | | | |
| | | (3.21) | | | | | | | | | | | | | | | |
| mcorrupt | | | 3.61 | | | | | | | | | | | | | | |
| | | | (5.70) | | | | | | | | | | | | | | |
| mret51 | | | | 0.10 | | | | | | | | | | | | | |
| | | | | (2.49) | | | | | | | | | | | | | |
| mret53 | | | | | 1.29 | | | | | | | | | | | | |
| | | | | | (3.52) | | | | | | | | | | | | |
| mwbctr | | | | | | 11.8 | | | | | | | | | | | |
| | | | | | | (22.32) | | | | | | | | | | | |
| mwbpro | | | | | | | -2.92* | | | | | | | | | | |
| | | | | | | | (1.69) | | | | | | | | | | |
| mwbhig | | | | | | | | -3.43** | | | | | | | | | |
| | | | | | | | | (1.68) | | | | | | | | | |
| mwbind | | | | | | | | | 5.57*** | | | | | | | | |
| | | | | | | | | | (2.10) | | | | | | | | |
| mwboth | | | | | | | | | | -8.72 | | | | | | | |
| | | | | | | | | | | (5.96) | | | | | | | |
| mwbsel | | | | | | | | | | | -0.41 | | | | | | |
| | | | | | | | | | | | (3.90) | | | | | | |
| mretire | | | | | | | | | | | | 15.3** | | | | | |
| | | | | | | | | | | | | (7.56) | | | | | |
| mlocal | | | | | | | | | | | | | 1.78 | | | | |
| | | | | | | | | | | | | | (1.81) | | | | |
| mphd | | | | | | | | | | | | | | 3.43 | | | |
| | | | | | | | | | | | | | | (6.42) | | | |
| mhum | | | | | | | | | | | | | | | -1.90 | | |
| | | | | | | | | | | | | | | | (1.74) | | |
| msci | | | | | | | | | | | | | | | | 4.21 | |
| | | | | | | | | | | | | | | | | (4.98) | |
| meng | | | | | | | | | | | | | | | | | 1.96 |
| | | | | | | | | | | | | | | | | | (2.04) |
| _cons | 68.5*** | 66.5*** | 68.9*** | 68.9*** | 68.7*** | 68.6*** | 70.1*** | 70.4*** | 67.9*** | 69.6*** | 69.2*** | 68.9*** | 67.8*** | 68.4*** | 70.0*** | 68.7*** | 68.5*** |
| | (2.10) | (3.23) | (2.11) | (1.99) | (1.98) | (2.59) | (2.00) | (2.01) | (2.15) | (2.22) | (3.14) | (2.11) | (2.48) | (2.76) | (2.18) | (2.09) | (2.22) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 |
| $R^2$ | 0.028 | 0.022 | 0.021 | 0.021 | 0.021 | 0.024 | 0.022 | 0.023 | 0.023 | 0.023 | 0.021 | 0.023 | 0.021 | 0.022 | 0.022 | 0.022 | 0.021 |

Table A.18. Regressions of water meet standard (million tons) - unbalanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | 31.1 | | | | | | | | | | | | | | | | |
| | (21.02) | | | | | | | | | | | | | | | | |
| mprom | | 2.29 | | | | | | | | | | | | | | | |
| | | (3.02) | | | | | | | | | | | | | | | |
| mcorrupt | | | 4.17 | | | | | | | | | | | | | | |
| | | | (5.46) | | | | | | | | | | | | | | |
| mret51 | | | | 0.21 | | | | | | | | | | | | | |
| | | | | (2.38) | | | | | | | | | | | | | |
| mret53 | | | | | 1.37 | | | | | | | | | | | | |
| | | | | | (3.34) | | | | | | | | | | | | |
| mwbctr | | | | | | 9.19 | | | | | | | | | | | |
| | | | | | | (18.26) | | | | | | | | | | | |
| mwbpro | | | | | | | -2.57 | | | | | | | | | | |
| | | | | | | | (1.69) | | | | | | | | | | |
| mwbhig | | | | | | | | -3.02* | | | | | | | | | |
| | | | | | | | | (1.70) | | | | | | | | | |
| mwbind | | | | | | | | | 4.67** | | | | | | | | |
| | | | | | | | | | (2.18) | | | | | | | | |
| mwboth | | | | | | | | | | -8.60 | | | | | | | |
| | | | | | | | | | | (5.80) | | | | | | | |
| mwbsel | | | | | | | | | | | 0.067 | | | | | | |
| | | | | | | | | | | | (3.75) | | | | | | |
| mretire | | | | | | | | | | | | 12.4* | | | | | |
| | | | | | | | | | | | | (7.16) | | | | | |
| mlocal | | | | | | | | | | | | | 1.25 | | | | |
| | | | | | | | | | | | | | (1.78) | | | | |
| mphd | | | | | | | | | | | | | | 2.67 | | | |
| | | | | | | | | | | | | | | (6.22) | | | |
| mhum | | | | | | | | | | | | | | | -2.32 | | |
| | | | | | | | | | | | | | | | (1.71) | | |
| msci | | | | | | | | | | | | | | | | 4.01 | |
| | | | | | | | | | | | | | | | | (4.80) | |
| meng | | | | | | | | | | | | | | | | | 2.53 |
| | | | | | | | | | | | | | | | | | (2.02) |
| _cons | 66.8*** | 65.3*** | 67.1*** | 67.1*** | 66.9*** | 66.9*** | 68.2*** | 68.5*** | 66.3*** | 67.7*** | 67.1*** | 67.2*** | 66.4*** | 66.8*** | 68.5*** | 66.9*** | 66.6*** |
| | (2.02) | (3.07) | (2.03) | (1.91) | (1.91) | (2.43) | (1.97) | (1.98) | (2.07) | (2.13) | (3.07) | (2.03) | (2.40) | (2.62) | (2.10) | (2.01) | (2.14) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 |
| $R^2$ | 0.028 | 0.022 | 0.022 | 0.021 | 0.022 | 0.023 | 0.022 | 0.023 | 0.023 | 0.023 | 0.021 | 0.023 | 0.022 | 0.022 | 0.022 | 0.022 | 0.022 |

## Table A.19. Regressions of water treatment rate - balanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | 0.013 | | | | | | | | | | | | | | | | |
| | (0.02) | | | | | | | | | | | | | | | | |
| mprom | | -0.0043 | | | | | | | | | | | | | | | |
| | | (0.01) | | | | | | | | | | | | | | | |
| mcorrupt | | | -0.0042 | | | | | | | | | | | | | | |
| | | | (0.02) | | | | | | | | | | | | | | |
| mret51 | | | | -0.0010 | | | | | | | | | | | | | |
| | | | | (0.01) | | | | | | | | | | | | | |
| mret53 | | | | | -0.0080 | | | | | | | | | | | | |
| | | | | | (0.01) | | | | | | | | | | | | |
| mwbctr | | | | | | -0.016 | | | | | | | | | | | |
| | | | | | | (0.02) | | | | | | | | | | | |
| mwbpro | | | | | | | 0.0010 | | | | | | | | | | |
| | | | | | | | (0.01) | | | | | | | | | | |
| mwbhig | | | | | | | | -0.0032 | | | | | | | | | |
| | | | | | | | | (0.01) | | | | | | | | | |
| mwbind | | | | | | | | | 0.020*** | | | | | | | | |
| | | | | | | | | | (0.01) | | | | | | | | |
| mwboth | | | | | | | | | | -0.012 | | | | | | | |
| | | | | | | | | | | (0.02) | | | | | | | |
| mwbsel | | | | | | | | | | | 0.014 | | | | | | |
| | | | | | | | | | | | (0.01) | | | | | | |
| mretire | | | | | | | | | | | | 0.041 | | | | | |
| | | | | | | | | | | | | (0.04) | | | | | |
| mlocal | | | | | | | | | | | | | -0.010 | | | | |
| | | | | | | | | | | | | | (0.01) | | | | |
| mphd | | | | | | | | | | | | | | -0.00092 | | | |
| | | | | | | | | | | | | | | (0.01) | | | |
| mhum | | | | | | | | | | | | | | | -0.0098 | | |
| | | | | | | | | | | | | | | | (0.01) | | |
| msci | | | | | | | | | | | | | | | | 0.028* | |
| | | | | | | | | | | | | | | | | (0.02) | |
| meng | | | | | | | | | | | | | | | | | -0.0048 |
| | | | | | | | | | | | | | | | | | (0.01) |
| _cons | 0.86*** | 0.86*** | 0.86*** | 0.86*** | 0.86*** | 0.86*** | 0.86*** | 0.86*** | 0.86*** | 0.86*** | 0.85*** | 0.86*** | 0.87*** | 0.86*** | 0.87*** | 0.86*** | 0.86*** |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 | 1787 |
| $R^2$ | 0.092 | 0.092 | 0.092 | 0.092 | 0.093 | 0.092 | 0.092 | 0.092 | 0.095 | 0.092 | 0.093 | 0.093 | 0.093 | 0.092 | 0.093 | 0.095 | 0.092 |

## Table A.20. Regressions of water treatment rate - unbalanced, source 1

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mctr | 0.010 | | | | | | | | | | | | | | | | |
| | (0.02) | | | | | | | | | | | | | | | | |
| mprom | | -0.0087 | | | | | | | | | | | | | | | |
| | | (0.01) | | | | | | | | | | | | | | | |
| mcorrupt | | | 0.0046 | | | | | | | | | | | | | | |
| | | | (0.02) | | | | | | | | | | | | | | |
| mret51 | | | | -0.0029 | | | | | | | | | | | | | |
| | | | | (0.01) | | | | | | | | | | | | | |
| mret53 | | | | | -0.0098 | | | | | | | | | | | | |
| | | | | | (0.01) | | | | | | | | | | | | |
| mwbctr | | | | | | -0.0022 | | | | | | | | | | | |
| | | | | | | (0.03) | | | | | | | | | | | |
| mwbpro | | | | | | | 0.0017 | | | | | | | | | | |
| | | | | | | | (0.01) | | | | | | | | | | |
| mwbhig | | | | | | | | -0.0018 | | | | | | | | | |
| | | | | | | | | (0.01) | | | | | | | | | |
| mwbind | | | | | | | | | 0.020*** | | | | | | | | |
| | | | | | | | | | (0.01) | | | | | | | | |
| mwboth | | | | | | | | | | -0.012 | | | | | | | |
| | | | | | | | | | | (0.02) | | | | | | | |
| mwbsel | | | | | | | | | | | 0.012 | | | | | | |
| | | | | | | | | | | | (0.01) | | | | | | |
| mretire | | | | | | | | | | | | 0.037 | | | | | |
| | | | | | | | | | | | | (0.04) | | | | | |
| mlocal | | | | | | | | | | | | | -0.013 | | | | |
| | | | | | | | | | | | | | (0.01) | | | | |
| mphd | | | | | | | | | | | | | | -0.00079 | | | |
| | | | | | | | | | | | | | | (0.01) | | | |
| mhum | | | | | | | | | | | | | | | -0.011 | | |
| | | | | | | | | | | | | | | | (0.01) | | |
| msci | | | | | | | | | | | | | | | | 0.035* | |
| | | | | | | | | | | | | | | | | (0.02) | |
| meng | | | | | | | | | | | | | | | | | -0.0022 |
| | | | | | | | | | | | | | | | | | (0.01) |
| _cons | 0.85*** | 0.86*** | 0.85*** | 0.86*** | 0.86*** | 0.85*** | 0.85*** | 0.85*** | 0.85*** | 0.85*** | 0.85*** | 0.85*** | 0.86*** | 0.85*** | 0.86*** | 0.85*** | 0.85*** |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 | 1939 |
| $R^2$ | 0.095 | 0.095 | 0.095 | 0.095 | 0.096 | 0.095 | 0.095 | 0.095 | 0.098 | 0.095 | 0.096 | 0.096 | 0.097 | 0.095 | 0.096 | 0.099 | 0.095 |

## Table A.21. Regressions of $SO_2$ emissions (1000 tons), source 2

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mtermage | -0.62 | | | | | | | | | |
| | (0.43) | | | | | | | | | |
| mpostgra | | -0.11 | | | | | | | | |
| | | (1.66) | | | | | | | | |
| meduyear | | | -0.10 | | | | | | | |
| | | | (0.42) | | | | | | | |
| mfromdm | | | | 1.24 | | | | | | |
| | | | | (1.71) | | | | | | |
| mbirthprosame | | | | | -2.40 | | | | | |
| | | | | | (1.85) | | | | | |
| mbirthcitysame | | | | | | -3.94 | | | | |
| | | | | | | (3.00) | | | | |
| muni985 | | | | | | | 0.36 | | | |
| | | | | | | | (2.01) | | | |
| munieco | | | | | | | | -3.20 | | |
| | | | | | | | | (2.31) | | |
| munionjob | | | | | | | | | -1.64 | |
| | | | | | | | | | (2.12) | |
| mbiz | | | | | | | | | | 0.86 |
| | | | | | | | | | | (1.45) |
| _cons | 54.2*** | 53.1*** | 54.8*** | 52.4*** | 54.8*** | 53.9*** | 53.0*** | 54.3*** | 54.7*** | 53.6*** |
| | (1.49) | (1.38) | (7.45) | (1.36) | (1.81) | (1.40) | (1.37) | (1.92) | (1.84) | (1.33) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1432 | 1419 | 1419 | 1421 | 1396 | 1388 | 1190 | 1090 | 1186 | 1384 |
| $R^2$ | 0.133 | 0.125 | 0.125 | 0.126 | 0.128 | 0.127 | 0.128 | 0.129 | 0.123 | 0.114 |

## Table A.22. Regressions of SO2 emission intensity (1000 tons / billion CNY), source 2

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mtermage | 0.0015 | | | | | | | | | |
| | (0.03) | | | | | | | | | |
| mpostgra | | -0.069 | | | | | | | | |
| | | (0.17) | | | | | | | | |
| meduyear | | | 0.010 | | | | | | | |
| | | | (0.03) | | | | | | | |
| mfromdm | | | | 0.077 | | | | | | |
| | | | | (0.15) | | | | | | |
| mbirthprosame | | | | | -0.075 | | | | | |
| | | | | | (0.28) | | | | | |
| mbirthcitysame | | | | | | -0.43 | | | | |
| | | | | | | (0.29) | | | | |
| muni985 | | | | | | | 0.39 | | | |
| | | | | | | | (0.30) | | | |
| munieco | | | | | | | | -0.31* | | |
| | | | | | | | | (0.16) | | |
| munionjob | | | | | | | | | -0.048 | |
| | | | | | | | | | (0.19) | |
| mbiz | | | | | | | | | | 0.088 |
| | | | | | | | | | | (0.16) |
| _cons | 3.60*** | 3.68*** | 3.46*** | 3.61*** | 3.64*** | 3.68*** | 3.45*** | 3.71*** | 3.76*** | 3.59*** |
| | (0.15) | (0.20) | (0.62) | (0.17) | (0.20) | (0.17) | (0.16) | (0.22) | (0.20) | (0.16) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1432 | 1419 | 1419 | 1421 | 1396 | 1388 | 1190 | 1090 | 1186 | 1384 |
| $R^2$ | 0.242 | 0.245 | 0.245 | 0.245 | 0.240 | 0.244 | 0.227 | 0.218 | 0.235 | 0.243 |

Table A.23. Regressions of SO2 emission removal ratio, source 2

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mtermage | 0.0096*** | | | | | | | | | |
| | (0.00) | | | | | | | | | |
| mpostgra | | -0.046*** | | | | | | | | |
| | | (0.02) | | | | | | | | |
| meduyear | | | -0.0097*** | | | | | | | |
| | | | (0.00) | | | | | | | |
| mfromdm | | | | 0.0077 | | | | | | |
| | | | | (0.02) | | | | | | |
| mbirthprosame | | | | | 0.020 | | | | | |
| | | | | | (0.02) | | | | | |
| mbirthcitysame | | | | | | 0.052 | | | | |
| | | | | | | (0.03) | | | | |
| muni985 | | | | | | | 0.019 | | | |
| | | | | | | | (0.02) | | | |
| munieco | | | | | | | | -0.0099 | | |
| | | | | | | | | (0.02) | | |
| munionjob | | | | | | | | | -0.0063 | |
| | | | | | | | | | (0.02) | |
| mbiz | | | | | | | | | | -0.0026 |
| | | | | | | | | | | (0.02) |
| _cons | 0.21*** | 0.26*** | 0.40*** | 0.23*** | 0.22*** | 0.22*** | 0.23*** | 0.23*** | 0.23*** | 0.23*** |
| | (0.01) | (0.01) | (0.07) | (0.01) | (0.02) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1398 | 1386 | 1386 | 1388 | 1363 | 1355 | 1160 | 1063 | 1157 | 1351 |
| $R^2$ | 0.310 | 0.311 | 0.310 | 0.304 | 0.304 | 0.304 | 0.308 | 0.300 | 0.308 | 0.304 |

Table A.24. Regressions of water discharge (million tons), source 2

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mtermage | -0.88 | | | | | | | | | |
| | (0.70) | | | | | | | | | |
| mpostgra | | -3.10 | | | | | | | | |
| | | (3.63) | | | | | | | | |
| meduyear | | | -1.02 | | | | | | | |
| | | | (1.11) | | | | | | | |
| mfromdm | | | | 6.76** | | | | | | |
| | | | | (2.98) | | | | | | |
| mbirthprosame | | | | | -1.47 | | | | | |
| | | | | | (2.11) | | | | | |
| mbirthcitysame | | | | | | 11.4* | | | | |
| | | | | | | (6.69) | | | | |
| muni985 | | | | | | | -0.17 | | | |
| | | | | | | | (2.52) | | | |
| munieco | | | | | | | | -4.12* | | |
| | | | | | | | | (2.29) | | |
| munionjob | | | | | | | | | -0.27 | |
| | | | | | | | | | (2.16) | |
| mbiz | | | | | | | | | | 1.28 |
| | | | | | | | | | | (1.73) |
| _cons | 76.2*** | 76.0*** | 92.4*** | 71.0*** | 75.4*** | 72.8*** | 73.5*** | 75.6*** | 75.6*** | 73.0*** |
| | (1.99) | (2.58) | (19.82) | (2.17) | (1.93) | (1.86) | (1.95) | (2.02) | (1.97) | (1.87) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1431 | 1418 | 1418 | 1420 | 1395 | 1387 | 1189 | 1089 | 1185 | 1383 |
| $R^2$ | 0.024 | 0.023 | 0.025 | 0.030 | 0.024 | 0.033 | 0.013 | 0.014 | 0.015 | 0.021 |

Table A.25. Regressions of water meet standard (million tons), source 2

| | (1) b/se | (2) b/se | (3) b/se | (4) b/se | (5) b/se | (6) b/se | (7) b/se | (8) b/se | (9) b/se | (10) b/se |
|---|---|---|---|---|---|---|---|---|---|---|
| mtermage | -0.87<br>(0.66) | | | | | | | | | |
| mpostgra | | -2.96<br>(3.57) | | | | | | | | |
| meduyear | | | -1.08<br>(1.09) | | | | | | | |
| mfromdm | | | | 6.52**<br>(2.93) | | | | | | |
| mbirthprosame | | | | | -0.49<br>(2.09) | | | | | |
| mbirthcitysame | | | | | | 10.4<br>(6.60) | | | | |
| muni985 | | | | | | | 0.29<br>(2.49) | | | |
| munieco | | | | | | | | -3.76*<br>(2.20) | | |
| munionjob | | | | | | | | | -0.58<br>(2.12) | |
| mbiz | | | | | | | | | | 2.54<br>(1.72) |
| _cons | 69.8***<br>(1.87) | 69.5***<br>(2.50) | 87.1***<br>(19.54) | 64.8***<br>(2.14) | 68.3***<br>(1.88) | 66.6***<br>(1.81) | 66.9***<br>(1.81) | 69.4***<br>(1.84) | 69.1***<br>(1.83) | 66.1***<br>(1.84) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1431 | 1418 | 1418 | 1420 | 1395 | 1387 | 1189 | 1089 | 1185 | 1383 |
| $R^2$ | 0.029 | 0.028 | 0.030 | 0.034 | 0.028 | 0.036 | 0.022 | 0.018 | 0.022 | 0.026 |

Table A.26. Regressions of water treatment rate, source 2

| | (1) b/se | (2) b/se | (3) b/se | (4) b/se | (5) b/se | (6) b/se | (7) b/se | (8) b/se | (9) b/se | (10) b/se |
|---|---|---|---|---|---|---|---|---|---|---|
| mtermage | -0.0017<br>(0.00) | | | | | | | | | |
| mpostgra | | -0.00053<br>(0.01) | | | | | | | | |
| meduyear | | | -0.00019<br>(0.00) | | | | | | | |
| mfromdm | | | | 0.00017<br>(0.01) | | | | | | |
| mbirthprosame | | | | | -0.00052<br>(0.01) | | | | | |
| mbirthcitysame | | | | | | -0.0024<br>(0.01) | | | | |
| muni985 | | | | | | | 0.020*<br>(0.01) | | | |
| munieco | | | | | | | | -0.0063<br>(0.01) | | |
| munionjob | | | | | | | | | -0.012<br>(0.01) | |
| mbiz | | | | | | | | | | 0.014<br>(0.01) |
| _cons | 0.87***<br>(0.01) | 0.87***<br>(0.01) | 0.87***<br>(0.03) | 0.87***<br>(0.01) | 0.87***<br>(0.01) | 0.87***<br>(0.01) | 0.86***<br>(0.01) | 0.87***<br>(0.01) | 0.87***<br>(0.01) | 0.86***<br>(0.01) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1431 | 1418 | 1418 | 1420 | 1395 | 1387 | 1189 | 1089 | 1185 | 1383 |
| $R^2$ | 0.061 | 0.071 | 0.071 | 0.062 | 0.066 | 0.071 | 0.096 | 0.081 | 0.093 | 0.076 |

Table A.27. Regressions of $SO_2$ emissions (1000 tons) on different age cut-offs - balanced (1-5) / unbalanced (6-10)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mret50 | -1.63 | | | | | -1.46 | | | | |
| | (1.11) | | | | | (1.06) | | | | |
| mret51 | | -2.37** | | | | | -2.41** | | | |
| | | (1.12) | | | | | (1.08) | | | |
| mret53 | | | -2.36 | | | | | -2.97* | | |
| | | | (1.70) | | | | | (1.67) | | |
| mret55 | | | | 0.69 | | | | | 0.032 | |
| | | | | (2.40) | | | | | (2.34) | |
| mret57 | | | | | 0.34 | | | | | 0.25 |
| | | | | | (3.96) | | | | | (3.83) |
| _cons | 55.8*** | 55.9*** | 55.6*** | 55.0*** | 55.1*** | 54.6*** | 54.8*** | 54.6*** | 54.0*** | 54.0*** |
| | (1.26) | (1.21) | (1.22) | (1.18) | (1.13) | (1.25) | (1.21) | (1.23) | (1.18) | (1.12) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1788 | 1788 | 1788 | 1788 | 1788 | 1940 | 1940 | 1940 | 1940 | 1940 |
| $R^2$ | 0.114 | 0.115 | 0.114 | 0.112 | 0.112 | 0.110 | 0.112 | 0.112 | 0.108 | 0.108 |

Table A.28. Regressions of $SO_2$ emission intensity (1000 tons / billion CNY) on different age cut-offs - balanced (1-5) / unbalanced (6-10)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mret50 | -0.051 | | | | | -0.063 | | | | |
| | (0.11) | | | | | (0.10) | | | | |
| mret51 | | -0.11 | | | | | -0.12 | | | |
| | | (0.13) | | | | | (0.12) | | | |
| mret53 | | | 0.084 | | | | | 0.091 | | |
| | | | (0.15) | | | | | (0.14) | | |
| mret55 | | | | 0.049 | | | | | 0.041 | |
| | | | | (0.15) | | | | | (0.15) | |
| mret57 | | | | | -0.41 | | | | | -0.41 |
| | | | | | (0.27) | | | | | (0.26) |
| _cons | 3.89*** | 3.91*** | 3.85*** | 3.87*** | 3.89*** | 3.90*** | 3.92*** | 3.86*** | 3.87*** | 3.89*** |
| | (0.18) | (0.17) | (0.16) | (0.16) | (0.17) | (0.17) | (0.16) | (0.16) | (0.16) | (0.16) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1788 | 1788 | 1788 | 1788 | 1788 | 1940 | 1940 | 1940 | 1940 | 1940 |
| $R^2$ | 0.267 | 0.267 | 0.267 | 0.267 | 0.268 | 0.273 | 0.273 | 0.273 | 0.273 | 0.274 |

Table A.29. Regressions of $SO_2$ emission removal ratio on different age cut-offs - balanced (1-5) / unbalanced (6-10)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mret50 | 0.033*** | | | | | 0.036*** | | | | |
| | (0.01) | | | | | (0.01) | | | | |
| mret51 | | 0.031*** | | | | | 0.035*** | | | |
| | | (0.01) | | | | | (0.01) | | | |
| mret53 | | | 0.032** | | | | | 0.037*** | | |
| | | | (0.01) | | | | | (0.01) | | |
| mret55 | | | | 0.031* | | | | | 0.035** | |
| | | | | (0.02) | | | | | (0.02) | |
| mret57 | | | | | 0.039* | | | | | 0.046** |
| | | | | | (0.02) | | | | | (0.02) |
| _cons | 0.21*** | 0.21*** | 0.21*** | 0.22*** | 0.22*** | 0.20*** | 0.21*** | 0.21*** | 0.21*** | 0.21*** |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1734 | 1734 | 1734 | 1734 | 1734 | 1879 | 1879 | 1879 | 1879 | 1879 |
| $R^2$ | 0.406 | 0.405 | 0.404 | 0.402 | 0.401 | 0.389 | 0.388 | 0.387 | 0.384 | 0.384 |

Table A.30. Regressions of water discharge (million tons) on different age cut-offs - balanced (1-5) / unbalanced (6-10)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mret50 | 2.26 | | | | | 1.93 | | | | |
| | (1.81) | | | | | (1.75) | | | | |
| mret51 | | 0.62 | | | | | 0.64 | | | |
| | | (2.45) | | | | | (2.34) | | | |
| mret53 | | | 2.25 | | | | | 2.25 | | |
| | | | (3.08) | | | | | (2.92) | | |
| mret55 | | | | 5.31 | | | | | 5.20 | |
| | | | | (3.51) | | | | | (3.39) | |
| mret57 | | | | | 6.04 | | | | | 5.44 |
| | | | | | (4.64) | | | | | (4.52) |
| _cons | 74.2*** | 74.9*** | 74.7*** | 74.6*** | 74.9*** | 72.9*** | 73.5*** | 73.2*** | 73.2*** | 73.5*** |
| | (2.45) | (2.25) | (2.29) | (2.52) | (2.37) | (2.35) | (2.15) | (2.20) | (2.41) | (2.27) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1787 | 1787 | 1787 | 1787 | 1787 | 1939 | 1939 | 1939 | 1939 | 1939 |
| $R^2$ | 0.018 | 0.018 | 0.018 | 0.020 | 0.019 | 0.017 | 0.017 | 0.017 | 0.019 | 0.017 |

Table A.31. Regressions of water meet standard (million tons) on different age cut-offs - balanced (1-5) / unbalanced (6-10)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mret50 | 1.94 | | | | | 1.63 | | | | |
| | (1.77) | | | | | (1.70) | | | | |
| mret51 | | 0.10 | | | | | 0.21 | | | |
| | | (2.49) | | | | | (2.38) | | | |
| mret53 | | | 1.29 | | | | | 1.37 | | |
| | | | (3.52) | | | | | (3.34) | | |
| mret55 | | | | 3.86 | | | | | 3.80 | |
| | | | | (3.01) | | | | | (2.92) | |
| mret57 | | | | | 4.91 | | | | | 4.38 |
| | | | | | (4.16) | | | | | (4.06) |
| _cons | 68.1*** | 68.9*** | 68.7*** | 68.5*** | 68.7*** | 66.5*** | 67.1*** | 66.9*** | 66.8*** | 67.0*** |
| | (2.22) | (1.99) | (1.98) | (2.20) | (2.13) | (2.13) | (1.91) | (1.91) | (2.11) | (2.05) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1787 | 1787 | 1787 | 1787 | 1787 | 1939 | 1939 | 1939 | 1939 | 1939 |
| $R^2$ | 0.022 | 0.021 | 0.021 | 0.022 | 0.022 | 0.022 | 0.021 | 0.022 | 0.023 | 0.022 |

Table A.32. Regressions of water treatment rate on different age cut-offs - balanced (1-5) / unbalanced (6-10)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mret50 | -0.0013 | | | | | -0.0020 | | | | |
| | (0.01) | | | | | (0.01) | | | | |
| mret51 | | -0.0010 | | | | | -0.0029 | | | |
| | | (0.01) | | | | | (0.01) | | | |
| mret53 | | | -0.0080 | | | | | -0.0098 | | |
| | | | (0.01) | | | | | (0.01) | | |
| mret55 | | | | -0.016* | | | | | -0.018** | |
| | | | | (0.01) | | | | | (0.01) | |
| mret57 | | | | | -0.014* | | | | | -0.014 |
| | | | | | (0.01) | | | | | (0.01) |
| _cons | 0.86*** | 0.86*** | 0.86*** | 0.86*** | 0.86*** | 0.85*** | 0.86*** | 0.86*** | 0.86*** | 0.85*** |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| City FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year FE | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| N | 1787 | 1787 | 1787 | 1787 | 1787 | 1939 | 1939 | 1939 | 1939 | 1939 |
| $R^2$ | 0.092 | 0.092 | 0.093 | 0.094 | 0.092 | 0.095 | 0.095 | 0.096 | 0.097 | 0.095 |

Table A.33. Predicting promotion to central government (mctr)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mret51 | -0.0031 | | | | | | | | | | | | | | | |
| | (0.01) | | | | | | | | | | | | | | | |
| mret53 | | 0.0046 | | | | | | | | | | | | | | |
| | | (0.01) | | | | | | | | | | | | | | |
| mret55 | | | 0.017* | | | | | | | | | | | | | |
| | | | (0.01) | | | | | | | | | | | | | |
| mret57 | | | | 0.054*** | | | | | | | | | | | | |
| | | | | (0.01) | | | | | | | | | | | | |
| mretire | | | | | -0.010 | | | | | | | | | | | |
| | | | | | (0.03) | | | | | | | | | | | |
| gdp | | | | | | 0.00011*** | | | | | | | | | | |
| | | | | | | (0.00) | | | | | | | | | | |
| pcgdp | | | | | | | 0.00000021 | | | | | | | | | |
| | | | | | | | (0.00) | | | | | | | | | |
| green | | | | | | | | -0.00032 | | | | | | | | |
| | | | | | | | | (0.00) | | | | | | | | |
| mwbind | | | | | | | | | 0.0081 | | | | | | | |
| | | | | | | | | | (0.01) | | | | | | | |
| mhum | | | | | | | | | | -0.0014 | | | | | | |
| | | | | | | | | | | (0.01) | | | | | | |
| msci | | | | | | | | | | | 0.013 | | | | | |
| | | | | | | | | | | | (0.02) | | | | | |
| meng | | | | | | | | | | | | 0.0037 | | | | |
| | | | | | | | | | | | | (0.01) | | | | |
| mmed | | | | | | | | | | | | | -0.010 | | | |
| | | | | | | | | | | | | | (0.07) | | | |
| mphd | | | | | | | | | | | | | | -0.0013 | | |
| | | | | | | | | | | | | | | (0.01) | | |
| mlocal | | | | | | | | | | | | | | | -0.0021 | |
| | | | | | | | | | | | | | | | (0.01) | |
| mwbctr | | | | | | | | | | | | | | | | 0.069*** |
| | | | | | | | | | | | | | | | | (0.02) |
| _cons | 0.012** | 0.0086* | 0.0071* | 0.0062 | 0.010*** | -0.0016 | 0.0052 | 0.010*** | 0.0087** | 0.011* | 0.0093** | 0.0093** | 0.010*** | 0.010** | 0.011* | 0.0075* |
| | (0.01) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) |
| N | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 |
| $R^2$ | 0.000 | 0.000 | 0.004 | 0.019 | 0.000 | 0.030 | 0.002 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.017 |

Table A.34. Predicting promotion to central government or other agencies (mprom)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se | b/se |
| mret51 | 0.027 | | | | | | | | | | | | | | | |
| | (0.03) | | | | | | | | | | | | | | | |
| mret53 | | 0.0069 | | | | | | | | | | | | | | |
| | | (0.03) | | | | | | | | | | | | | | |
| mret55 | | | -0.032 | | | | | | | | | | | | | |
| | | | (0.04) | | | | | | | | | | | | | |
| mret57 | | | | -0.15** | | | | | | | | | | | | |
| | | | | (0.06) | | | | | | | | | | | | |
| mretire | | | | | 0.20 | | | | | | | | | | | |
| | | | | | (0.13) | | | | | | | | | | | |
| gdp | | | | | | 0.000018 | | | | | | | | | | |
| | | | | | | (0.00) | | | | | | | | | | |
| pcgdp | | | | | | | -0.00000045 | | | | | | | | | |
| | | | | | | | (0.00) | | | | | | | | | |
| green | | | | | | | | 0.0027 | | | | | | | | |
| | | | | | | | | (0.00) | | | | | | | | |
| mwbind | | | | | | | | | -0.020 | | | | | | | |
| | | | | | | | | | (0.04) | | | | | | | |
| mhum | | | | | | | | | | -0.014 | | | | | | |
| | | | | | | | | | | (0.03) | | | | | | |
| msci | | | | | | | | | | | 0.0022 | | | | | |
| | | | | | | | | | | | (0.06) | | | | | |
| meng | | | | | | | | | | | | 0.059 | | | | |
| | | | | | | | | | | | | (0.04) | | | | |
| mmed | | | | | | | | | | | | | 0.20 | | | |
| | | | | | | | | | | | | | (0.28) | | | |
| mphd | | | | | | | | | | | | | | -0.049 | | |
| | | | | | | | | | | | | | | (0.04) | | |
| mlocal | | | | | | | | | | | | | | | 0.030 | |
| | | | | | | | | | | | | | | | (0.03) | |
| mwbctr | | | | | | | | | | | | | | | | -0.030 |
| | | | | | | | | | | | | | | | | (0.08) |
| _cons | 0.78*** | 0.80*** | 0.80*** | 0.81*** | 0.80*** | 0.80*** | 0.81*** | 0.80*** | 0.80*** | 0.81*** | 0.80*** | 0.78*** | 0.80*** | 0.81*** | 0.78*** | 0.80*** |
| | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) | (0.02) |
| N | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 | 693 |
| $R^2$ | 0.001 | 0.000 | 0.001 | 0.009 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.001 | 0.002 | 0.001 | 0.000 |

Table A.35. mctr×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mctr× Domestic non – SOE | -0.66 | -0.65 | 0.025 |
| | (0.45) | (0.71) | (0.11) |
| mctr× Provincial SOE | -0.35 | -1.91 | -0.11 |
| | (0.47) | (2.72) | (0.09) |
| mctr× Central SOE | -0.57** | -1.07*** | 0.011 |
| | (0.28) | (0.39) | (0.01) |
| mctr× City SOE | 0.78** | 2.26 | -0.091 |
| | (0.34) | (2.62) | (0.09) |
| mctr× County SOE | 0.37** | 0.12 | 0.074 |
| | (0.18) | (0.39) | (0.06) |
| mctr× Foreign | -0.12 | -0.39 | 0.045 |
| | (0.12) | (0.66) | (0.11) |
| _cons | 2.15*** | 3.41*** | 0.20*** |
| | (0.10) | (0.84) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.004 | 0.003 |

Table A.36. mctr×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mctr× Central and provincial SOE | -0.55 | -1.93 | -0.10 |
| | (0.45) | (2.69) | (0.09) |
| mctr× Domestic non – SOE | -0.67 | -0.68 | 0.027 |
| | (0.45) | (0.72) | (0.11) |
| mctr× City or below SOE | 0.55 | -0.14 | -0.024 |
| | (0.38) | (0.70) | (0.04) |
| mctr× Foreign | -0.14 | -0.38 | 0.046 |
| | (0.13) | (0.72) | (0.11) |
| _cons | 2.56*** | 3.53*** | 0.20*** |
| | (0.12) | (0.95) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.007 | 0.005 | 0.004 |

Table A.37. mwbctr×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbctr× Domestic non – SOE | 0.38* | -0.096 | 0.010 |
| | (0.20) | (0.50) | (0.02) |
| mwbctr× Provincial SOE | -0.43 | 0.35 | 0.040 |
| | (0.46) | (0.78) | (0.02) |
| mwbctr× Central SOE | 0.73 | 1.16 | -0.10 |
| | (0.56) | (1.10) | (0.10) |
| mwbctr× City SOE | 0.065 | 0.80 | -0.071 |
| | (0.28) | (0.57) | (0.04) |
| mwbctr× County SOE | -0.11 | -2.86 | -0.017 |
| | (0.18) | (3.88) | (0.05) |
| mwbctr× Foreign | -0.28 | -0.14 | -0.027 |
| | (0.29) | (0.60) | (0.03) |
| _cons | 2.14*** | 3.40*** | 0.20*** |
| | (0.10) | (0.83) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.005 | 0.003 |

Table A.38. mwbctr×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbctr× Central and provincial SOE | -0.12 | 0.44 | -0.0088 |
| | (0.44) | (0.61) | (0.04) |
| mwbctr× Domestic non – SOE | 0.38* | -0.080 | 0.0092 |
| | (0.20) | (0.51) | (0.02) |
| mwbctr× City or below SOE | -0.097 | 1.15 | -0.061 |
| | (0.22) | (1.06) | (0.04) |
| mwbctr× Foreign | -0.27 | -0.12 | -0.029 |
| | (0.29) | (0.61) | (0.03) |
| _cons | 2.56*** | 3.50*** | 0.20*** |
| | (0.12) | (0.94) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.007 | 0.005 | 0.004 |

Table A.39. mwbind×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbind× Domestic non – SOE | -0.13 | -0.30 | -0.0085 |
| | (0.12) | (0.19) | (0.02) |
| mwbind× Provincial SOE | 0.12 | -0.18 | 0.016 |
| | (0.38) | (0.26) | (0.04) |
| mwbind× Central SOE | -0.065 | -0.46 | -0.065 |
| | (0.09) | (0.37) | (0.05) |
| mwbind× City SOE | 0.0042 | -0.66 | 0.024 |
| | (0.09) | (0.49) | (0.03) |
| mwbind× County SOE | 0.12 | -0.17 | -0.027 |
| | (0.09) | (0.76) | (0.03) |
| mwbind× Foreign | 0.092 | -0.044 | -0.012 |
| | (0.16) | (0.38) | (0.04) |
| _cons | 2.14*** | 3.47*** | 0.20*** |
| | (0.11) | (0.87) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.004 | 0.003 |

Table A.40. mwbind×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbind× Central and provincial SOE | 0.10 | -0.27 | -0.023 |
| | (0.33) | (0.25) | (0.04) |
| mwbind× Domestic non – SOE | -0.13 | -0.32 | -0.0074 |
| | (0.12) | (0.20) | (0.02) |
| mwbind× City or below SOE | 0.12 | -0.69* | -0.0077 |
| | (0.09) | (0.39) | (0.03) |
| mwbind× Foreign | 0.083 | -0.068 | -0.0098 |
| | (0.16) | (0.39) | (0.04) |
| _cons | 2.55*** | 3.59*** | 0.20*** |
| | (0.12) | (0.98) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.006 | 0.005 | 0.003 |

Table A.41. mretire×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mretire× Domestic non – SOE | -0.24 | 0.58* | 0.017 |
| | (0.31) | (0.31) | (0.08) |
| mretire× Provincial SOE | 0.0099 | 0.81** | 0.11 |
| | (0.19) | (0.37) | (0.11) |
| mretire× Central SOE | 0.31*** | 0.85*** | 0.033 |
| | (0.12) | (0.23) | (0.03) |
| mretire× City SOE | 0.024 | -38.9 | -0.074** |
| | (0.56) | (36.92) | (0.04) |
| mretire× County SOE | 0.0098 | -2.42 | -0.075 |
| | (0.41) | (2.93) | (0.07) |
| mretire× Foreign | -0.021 | 2.06 | -0.011 |
| | (0.22) | (1.41) | (0.08) |
| _cons | 2.14*** | 3.40*** | 0.20*** |
| | (0.10) | (0.82) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.023 | 0.003 |

Table A.42. mretire×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mretire× Central and provincial SOE | 0.22 | 0.85** | 0.088 |
| | (0.20) | (0.33) | (0.09) |
| mretire× Domestic non – SOE | -0.22 | 0.61* | 0.013 |
| | (0.31) | (0.33) | (0.08) |
| mretire× City or below SOE | -0.068 | -37.4 | -0.046 |
| | (0.56) | (34.33) | (0.06) |
| mretire× Foreign | 0.0020 | 2.07 | -0.014 |
| | (0.22) | (1.40) | (0.08) |
| _cons | 2.56*** | 3.53*** | 0.20*** |
| | (0.12) | (0.95) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.006 | 0.025 | 0.004 |

Table A.43. mlocal×ownership - balanced

| | (1) SO2 Emission | (2) SO2 Emission Intensity | (3) SO2 Emission Removal Ratio |
|---|---|---|---|
| | b/se | b/se | b/se |
| mlocal× Domestic non – SOE | -0.16 | 0.33 | -0.012 |
| | (0.23) | (0.40) | (0.02) |
| mlocal× Provincial SOE | -0.61*** | -0.71 | 0.067* |
| | (0.22) | (0.69) | (0.03) |
| mlocal× Central SOE | -0.35 | -0.25 | 0.041 |
| | (0.22) | (0.30) | (0.05) |
| mlocal× City SOE | -0.088 | -0.73 | 0.056** |
| | (0.07) | (0.57) | (0.03) |
| mlocal× County SOE | 0.13 | 0.66 | 0.0081 |
| | (0.10) | (1.25) | (0.03) |
| mlocal× Foreign | -0.11* | -0.46 | 0.076*** |
| | (0.06) | (0.76) | (0.03) |
| _cons | 2.25*** | 3.46*** | 0.18*** |
| | (0.13) | (0.86) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.008 | 0.005 | 0.008 |

Table A.44. mlocal×category - balanced

| | (1) SO2 Emission | (2) SO2 Emission Intensity | (3) SO2 Emission Removal Ratio |
|---|---|---|---|
| | b/se | b/se | b/se |
| mlocal× Central and provincial SOE | -0.67*** | -1.10** | 0.070** |
| | (0.24) | (0.48) | (0.03) |
| mlocal× Domestic non – SOE | -0.16 | 0.32 | -0.012 |
| | (0.23) | (0.40) | (0.02) |
| mlocal× City or below SOE | -0.020 | -0.53 | 0.015 |
| | (0.08) | (0.51) | (0.02) |
| mlocal× Foreign | -0.11* | -0.45 | 0.076*** |
| | (0.06) | (0.76) | (0.02) |
| _cons | 2.69*** | 3.72*** | 0.18*** |
| | (0.15) | (0.97) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.009 | 0.005 | 0.009 |

Table A.45. mwbpro×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbpro× Domestic non – SOE | 0.065 | 0.10 | -0.011 |
| | (0.15) | (0.31) | (0.02) |
| mwbpro× Provincial SOE | 0.17 | 0.32 | 0.052* |
| | (0.27) | (0.30) | (0.03) |
| mwbpro× Central SOE | -0.22 | 0.41 | 0.031 |
| | (0.22) | (0.34) | (0.05) |
| mwbpro× City SOE | -0.023 | 0.23 | -0.029 |
| | (0.10) | (0.40) | (0.02) |
| mwbpro× County SOE | -0.074 | -1.86 | -0.019 |
| | (0.09) | (1.71) | (0.03) |
| mwbpro× Foreign | 0.022 | 0.60* | -0.0077 |
| | (0.08) | (0.36) | (0.03) |
| _cons | 2.14*** | 3.44*** | 0.20*** |
| | (0.10) | (0.84) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.005 | 0.005 |

Table A.46. mwbpro×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbpro× Central and provincial SOE | -0.034 | 0.48* | 0.034 |
| | (0.24) | (0.28) | (0.03) |
| mwbpro× Domestic non – SOE | 0.072 | 0.13 | -0.013 |
| | (0.15) | (0.32) | (0.02) |
| mwbpro× City or below SOE | -0.049 | -1.01 | -0.020 |
| | (0.10) | (1.12) | (0.02) |
| mwbpro× Foreign | 0.028 | 0.61* | -0.0084 |
| | (0.09) | (0.37) | (0.03) |
| _cons | 2.55*** | 3.53*** | 0.20*** |
| | (0.12) | (0.95) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.006 | 0.005 | 0.005 |

Table A.47. mwbhig×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbhig× Domestic non – SOE | 0.083 | 0.12 | -0.014 |
| | (0.15) | (0.32) | (0.02) |
| mwbhig× Provincial SOE | 0.17 | 0.28 | 0.057** |
| | (0.28) | (0.30) | (0.03) |
| mwbhig× Central SOE | -0.22 | 0.51 | 0.022 |
| | (0.23) | (0.33) | (0.05) |
| mwbhig× City SOE | 0.024 | 0.33 | -0.041 |
| | (0.10) | (0.43) | (0.03) |
| mwbhig× County SOE | -0.074 | -1.98 | -0.020 |
| | (0.10) | (1.83) | (0.03) |
| mwbhig× Foreign | 0.033 | 0.66* | -0.013 |
| | (0.09) | (0.37) | (0.03) |
| _cons | 2.13*** | 3.43*** | 0.21*** |
| | (0.10) | (0.84) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.005 | 0.005 |

Table A.48. mwbhig×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbhig× Central and provincial SOE | -0.042 | 0.48* | 0.032 |
| | (0.26) | (0.29) | (0.03) |
| mwbhig× Domestic non – SOE | 0.090 | 0.15 | -0.016 |
| | (0.15) | (0.33) | (0.02) |
| mwbhig× City or below SOE | -0.027 | -0.99 | -0.027 |
| | (0.10) | (1.17) | (0.02) |
| mwbhig× Foreign | 0.040 | 0.66* | -0.014 |
| | (0.09) | (0.38) | (0.03) |
| _cons | 2.55*** | 3.52*** | 0.20*** |
| | (0.12) | (0.95) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.006 | 0.005 | 0.005 |

Table A.49. mret51×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mret51× Domestic non – SOE | -0.20** | -0.048 | 0.042*** |
| | (0.10) | (0.18) | (0.01) |
| mret51× Provincial SOE | 0.12 | 0.15 | -0.024 |
| | (0.15) | (0.55) | (0.03) |
| mret51× Central SOE | -0.87 | 0.34 | 0.034 |
| | (0.71) | (0.26) | (0.05) |
| mret51× City SOE | 0.094 | -0.98 | -0.011 |
| | (0.07) | (1.63) | (0.02) |
| mret51× County SOE | -0.17** | -2.20 | 0.054** |
| | (0.08) | (1.82) | (0.02) |
| mret51× Foreign | 0.10* | -0.0047 | -0.0049 |
| | (0.05) | (0.31) | (0.02) |
| _cons | 2.20*** | 3.65*** | 0.19*** |
| | (0.14) | (1.01) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.010 | 0.005 | 0.008 |

Table A.50. mret51×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mret51× Central and provincial SOE | -0.41 | 0.23 | 0.011 |
| | (0.41) | (0.36) | (0.03) |
| mret51× Domestic non – SOE | -0.20** | -0.051 | 0.042*** |
| | (0.10) | (0.19) | (0.01) |
| mret51× City or below SOE | -0.074 | -2.37 | 0.022 |
| | (0.07) | (1.69) | (0.02) |
| mret51× Foreign | 0.11* | 0.022 | -0.0062 |
| | (0.06) | (0.33) | (0.02) |
| _cons | 2.64*** | 3.82*** | 0.19*** |
| | (0.16) | (1.15) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.008 | 0.006 | 0.007 |

## Table A.51. mwboth×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwboth× Domestic non – SOE | -0.37 | -1.61 | -0.035 |
| | (0.39) | (1.37) | (0.03) |
| mwboth× Provincial SOE | -0.29* | -0.29 | 0.094** |
| | (0.17) | (0.45) | (0.04) |
| mwboth× Central SOE | -1.13 | -0.64 | 0.20* |
| | (0.76) | (0.63) | (0.12) |
| mwboth× City SOE | -0.17 | -0.50 | 0.018 |
| | (0.11) | (0.87) | (0.04) |
| mwboth× County SOE | -0.36* | 0.21 | 0.021 |
| | (0.18) | (1.97) | (0.03) |
| mwboth× Foreign | 0.44 | 0.20 | -0.057 |
| | (0.44) | (0.48) | (0.06) |
| _cons | 2.16*** | 3.43*** | 0.20*** |
| | (0.11) | (0.84) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.007 | 0.004 | 0.006 |

## Table A.52. mwboth×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwboth× Central and provincial SOE | -0.89* | -0.26 | 0.16** |
| | (0.46) | (0.42) | (0.07) |
| mwboth× Domestic non – SOE | -0.37 | -1.61 | -0.035 |
| | (0.39) | (1.37) | (0.03) |
| mwboth× City or below SOE | -0.35* | 0.18 | 0.011 |
| | (0.19) | (1.27) | (0.03) |
| mwboth× Foreign | 0.44 | 0.20 | -0.057 |
| | (0.43) | (0.52) | (0.06) |
| _cons | 2.57*** | 3.53*** | 0.20*** |
| | (0.12) | (0.95) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.008 | 0.005 | 0.007 |

Table A.53. mwbsel×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbsel× Domestic non – SOE | 0.040 | 0.33 | -0.015 |
| | (0.11) | (0.28) | (0.02) |
| mwbsel× Provincial SOE | 0.64* | 0.53 | 0.060* |
| | (0.34) | (0.48) | (0.03) |
| mwbsel× Central SOE | -0.32 | 0.38 | 0.14** |
| | (0.36) | (0.42) | (0.06) |
| mwbsel× City SOE | 0.15 | 0.20 | 0.0093 |
| | (0.11) | (0.49) | (0.04) |
| mwbsel× County SOE | 0.061 | -0.37 | -0.043 |
| | (0.13) | (1.04) | (0.04) |
| mwbsel× Foreign | -0.099 | 0.67 | -0.017 |
| | (0.17) | (0.44) | (0.03) |
| _cons | 2.07*** | 3.19*** | 0.20*** |
| | (0.11) | (0.69) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.007 | 0.004 | 0.007 |

Table A.54. mwbsel×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mwbsel× Central and provincial SOE | 0.27 | 0.60 | 0.095** |
| | (0.36) | (0.40) | (0.04) |
| mwbsel× Domestic non – SOE | 0.048 | 0.37 | -0.017 |
| | (0.11) | (0.31) | (0.02) |
| mwbsel× City or below SOE | 0.11 | -0.049 | 0.0017 |
| | (0.12) | (0.54) | (0.03) |
| mwbsel× Foreign | -0.090 | 0.69 | -0.018 |
| | (0.18) | (0.46) | (0.03) |
| _cons | 2.49*** | 3.23*** | 0.19*** |
| | (0.14) | (0.79) | (0.02) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.006 | 0.005 | 0.007 |

Table A.55. mphd×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mphd× Domestic non – SOE | 0.43 | 0.12 | -0.0033 |
| | (0.31) | (0.23) | (0.02) |
| mphd× Provincial SOE | 0.070 | -0.38 | -0.042 |
| | (0.31) | (0.55) | (0.05) |
| mphd× Central SOE | 1.47 | 0.60* | 0.0073 |
| | (1.41) | (0.33) | (0.08) |
| mphd× City SOE | -0.14 | -0.54 | 0.0086 |
| | (0.09) | (0.73) | (0.04) |
| mphd× County SOE | -0.10 | -1.17 | -0.014 |
| | (0.13) | (1.14) | (0.03) |
| mphd× Foreign | -0.17 | -0.13 | 0.040 |
| | (0.13) | (0.44) | (0.03) |
| _cons | 2.12*** | 3.44*** | 0.20*** |
| | (0.09) | (0.82) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.012 | 0.005 | 0.003 |

Table A.56. mphd×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mphd× Central and provincial SOE | 0.85 | -0.018 | -0.031 |
| | (0.85) | (0.49) | (0.05) |
| mphd× Domestic non – SOE | 0.43 | 0.15 | -0.0044 |
| | (0.31) | (0.25) | (0.02) |
| mphd× City or below SOE | -0.10 | -0.51 | -0.0084 |
| | (0.11) | (0.49) | (0.02) |
| mphd× Foreign | -0.17 | -0.13 | 0.040 |
| | (0.13) | (0.45) | (0.03) |
| _cons | 2.53*** | 3.52*** | 0.20*** |
| | (0.10) | (0.93) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.010 | 0.005 | 0.004 |

Table A.57. mhum×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mhum× Domestic non – SOE | -0.027 | 0.37 | 0.019 |
| | (0.12) | (0.30) | (0.02) |
| mhum× Provincial SOE | -0.034 | 2.05 | 0.048 |
| | (0.33) | (1.51) | (0.03) |
| mhum× Central SOE | 0.12 | 0.96** | 0.054 |
| | (0.10) | (0.42) | (0.05) |
| mhum× City SOE | 0.11 | 0.14 | -0.037 |
| | (0.07) | (0.44) | (0.03) |
| mhum× County SOE | 0.083 | 0.36 | 0.063** |
| | (0.08) | (0.89) | (0.03) |
| mhum× Foreign | 0.0011 | -0.61 | 0.063** |
| | (0.11) | (0.55) | (0.03) |
| _cons | 2.13*** | 3.14*** | 0.18*** |
| | (0.11) | (0.80) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.005 | 0.010 |

Table A.58. mhum×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mhum× Central and provincial SOE | 0.045 | 1.98* | 0.055 |
| | (0.25) | (1.14) | (0.04) |
| mhum× Domestic non – SOE | -0.022 | 0.39 | 0.018 |
| | (0.12) | (0.30) | (0.02) |
| mhum× City or below SOE | 0.13* | 0.042 | 0.017 |
| | (0.08) | (0.37) | (0.02) |
| mhum× Foreign | 0.0071 | -0.59 | 0.062** |
| | (0.11) | (0.56) | (0.03) |
| _cons | 2.54*** | 3.27*** | 0.18*** |
| | (0.12) | (0.90) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.006 | 0.006 | 0.008 |

Table A.59. msci×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| msci× Domestic non – SOE | 0.038 | 0.14 | -0.013 |
| | (0.14) | (0.27) | (0.03) |
| msci× Provincial SOE | 0.26 | -3.69 | 0.031 |
| | (0.47) | (4.68) | (0.09) |
| msci× Central SOE | -0.15 | -0.31 | -0.045 |
| | (0.18) | (0.42) | (0.08) |
| msci× City SOE | 0.10 | -1.24 | 0.050 |
| | (0.23) | (0.76) | (0.06) |
| msci× County SOE | 0.13 | 1.42 | -0.058 |
| | (0.14) | (1.29) | (0.04) |
| msci× Foreign | -0.088 | 0.14 | -0.13** |
| | (0.16) | (0.76) | (0.06) |
| _cons | 2.14*** | 3.44*** | 0.20*** |
| | (0.11) | (0.84) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.005 | 0.005 |

Table A.60. msci×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| msci× Central and provincial SOE | 0.11 | -3.47 | -0.027 |
| | (0.39) | (3.38) | (0.06) |
| msci× Domestic non – SOE | 0.034 | 0.13 | -0.013 |
| | (0.14) | (0.29) | (0.03) |
| msci× City or below SOE | 0.26 | 0.25 | -0.0078 |
| | (0.19) | (0.43) | (0.04) |
| msci× Foreign | -0.092 | 0.080 | -0.13** |
| | (0.16) | (0.81) | (0.06) |
| _cons | 2.55*** | 3.57*** | 0.20*** |
| | (0.12) | (0.95) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.006 | 0.005 | 0.006 |

Table A.61. meng×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| meng× Domestic non – SOE | 0.00098 | -0.23 | -0.023 |
| | (0.24) | (0.17) | (0.02) |
| meng× Provincial SOE | -0.12 | -1.15* | -0.031 |
| | (0.42) | (0.66) | (0.05) |
| meng× Central SOE | 0.080 | -0.93** | -0.038 |
| | (0.14) | (0.45) | (0.06) |
| meng× City SOE | -0.11 | 0.16 | 0.023 |
| | (0.10) | (0.56) | (0.03) |
| meng× County SOE | -0.079 | -0.61 | -0.032 |
| | (0.09) | (1.18) | (0.04) |
| meng× Foreign | 0.082 | 0.19 | -0.018 |
| | (0.13) | (0.37) | (0.03) |
| _cons | 2.15*** | 3.47*** | 0.21*** |
| | (0.10) | (0.85) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.005 | 0.004 |

Table A.62. meng×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| meng× Central and provincial SOE | -0.022 | -1.22* | -0.042 |
| | (0.28) | (0.65) | (0.05) |
| meng× Domestic non – SOE | -0.0021 | -0.25 | -0.022 |
| | (0.24) | (0.18) | (0.02) |
| meng× City or below SOE | -0.092 | 0.19 | -0.014 |
| | (0.08) | (0.43) | (0.02) |
| meng× Foreign | 0.078 | 0.18 | -0.017 |
| | (0.13) | (0.38) | (0.03) |
| _cons | 2.56*** | 3.57*** | 0.21*** |
| | (0.12) | (0.96) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.006 | 0.005 | 0.005 |

Table A.63. mbirthcitysame×ownership - balanced

| | (1)<br>SO2 Emission<br>b/se | (2)<br>SO2 Emission Intensity<br>b/se | (3)<br>SO2 Emission Removal Ratio<br>b/se |
|---|---|---|---|
| mbirthcitysame× Domestic non – SOE | -0.040 | 0.11 | 0.041 |
| | (0.23) | (0.33) | (0.03) |
| mbirthcitysame× Provincial SOE | 0.12 | -0.21 | -0.0057 |
| | (0.35) | (0.71) | (0.07) |
| mbirthcitysame× Central SOE | -0.13 | -1.16** | 0.14 |
| | (0.09) | (0.58) | (0.09) |
| mbirthcitysame× City SOE | -0.030 | 0.85 | 0.024 |
| | (0.12) | (0.67) | (0.05) |
| mbirthcitysame× County SOE | -0.19** | -7.36 | 0.095 |
| | (0.08) | (5.88) | (0.08) |
| mbirthcitysame× Foreign | -0.14 | -2.49 | 0.10* |
| | (0.15) | (1.51) | (0.06) |
| _cons | 2.07*** | 3.44*** | 0.20*** |
| | (0.09) | (0.90) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3480 | 3474 | 3398 |
| $R^2$ | 0.005 | 0.007 | 0.008 |

Table A.64. mbirthcitysame×category - balanced

| | (1)<br>SO2 Emission<br>b/se | (2)<br>SO2 Emission Intensity<br>b/se | (3)<br>SO2 Emission Removal Ratio<br>b/se |
|---|---|---|---|
| mbirthcitysame× Central and provincial SOE | 0.032 | -0.49 | 0.075 |
| | (0.29) | (0.71) | (0.07) |
| mbirthcitysame× Domestic non – SOE | -0.047 | 0.043 | 0.043 |
| | (0.23) | (0.36) | (0.03) |
| mbirthcitysame× City or below SOE | -0.23 | -3.92 | 0.034 |
| | (0.16) | (3.90) | (0.05) |
| mbirthcitysame× Foreign | -0.14 | -2.55* | 0.11* |
| | (0.16) | (1.52) | (0.06) |
| _cons | 2.49*** | 3.55*** | 0.19*** |
| | (0.11) | (1.04) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 2871 | 2869 | 2815 |
| $R^2$ | 0.005 | 0.006 | 0.009 |

Table A.65. mbirthprosame×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mbirthprosame× Domestic non – SOE | 0.0069 | 0.060 | 0.028* |
| | (0.13) | (0.14) | (0.02) |
| mbirthprosame× Provincial SOE | 0.68** | 0.49 | -0.033 |
| | (0.31) | (0.44) | (0.03) |
| mbirthprosame× Central SOE | -0.0052 | 0.18 | 0.0027 |
| | (0.18) | (0.31) | (0.07) |
| mbirthprosame× City SOE | 0.042 | 0.20 | 0.060** |
| | (0.11) | (0.53) | (0.03) |
| mbirthprosame× County SOE | 0.0041 | -3.13 | 0.0012 |
| | (0.09) | (2.78) | (0.04) |
| mbirthprosame× Foreign | -0.074 | -0.43 | 0.046 |
| | (0.14) | (0.69) | (0.03) |
| _cons | 2.00*** | 3.52*** | 0.19*** |
| | (0.11) | (1.01) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3513 | 3507 | 3425 |
| $R^2$ | 0.007 | 0.004 | 0.005 |

Table A.66. mbirthprosame×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mbirthprosame× Central and provincial SOE | 0.63** | 0.63 | -0.0039 |
| | (0.29) | (0.48) | (0.04) |
| mbirthprosame× Domestic non – SOE | 0.0069 | 0.059 | 0.028* |
| | (0.13) | (0.15) | (0.02) |
| mbirthprosame× City or below SOE | -0.025 | -1.86 | 0.030 |
| | (0.10) | (1.76) | (0.03) |
| mbirthprosame× Foreign | -0.075 | -0.42 | 0.047 |
| | (0.14) | (0.69) | (0.03) |
| _cons | 2.40*** | 3.60*** | 0.19*** |
| | (0.13) | (1.14) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 2900 | 2898 | 2841 |
| $R^2$ | 0.007 | 0.004 | 0.006 |

Table A.67. mprom×ownership - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mprom× Domestic non – SOE | -0.031 | 0.11 | 0.011 |
| | (0.12) | (0.22) | (0.02) |
| mprom× Provincial SOE | -0.10 | 0.071 | 0.025 |
| | (0.38) | (0.52) | (0.04) |
| mprom× Central SOE | 0.27 | 0.11 | -0.077* |
| | (0.27) | (0.26) | (0.05) |
| mprom× City SOE | -0.056 | -0.30 | 0.043 |
| | (0.11) | (0.38) | (0.03) |
| mprom× County SOE | -0.11 | -2.48 | -0.024 |
| | (0.10) | (2.69) | (0.03) |
| mprom× Foreign | 0.25 | -0.71 | -0.050 |
| | (0.20) | (0.67) | (0.03) |
| _cons | 2.14*** | 3.84*** | 0.21*** |
| | (0.13) | (1.03) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.006 | 0.005 | 0.006 |

Table A.68. mprom×category - balanced

| | (1) SO2 Emission b/se | (2) SO2 Emission Intensity b/se | (3) SO2 Emission Removal Ratio b/se |
|---|---|---|---|
| mprom× Central and provincial SOE | 0.090 | -0.26 | -0.050 |
| | (0.32) | (0.38) | (0.04) |
| mprom× Domestic non – SOE | -0.032 | 0.11 | 0.011 |
| | (0.12) | (0.22) | (0.02) |
| mprom× City or below SOE | -0.0078 | -2.36 | 0.0088 |
| | (0.12) | (1.66) | (0.02) |
| mprom× Foreign | 0.24 | -0.72 | -0.049 |
| | (0.20) | (0.67) | (0.03) |
| _cons | 2.52*** | 4.15*** | 0.21*** |
| | (0.14) | (1.14) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.006 | 0.006 | 0.006 |

Table A.69. mcorrupt×ownership - balanced

| | (1) | (2) | (3) |
|---|---|---|---|
| | SO2 Emission | SO2 Emission Intensity | SO2 Emission Removal Ratio |
| | b/se | b/se | b/se |
| mcorrupt× Domestic non – SOE | 0.086 | 1.07*** | -0.11*** |
| | (0.33) | (0.34) | (0.04) |
| mcorrupt× Provincial SOE | 1.21 | -1.36 | -0.13 |
| | (1.41) | (1.32) | (0.09) |
| mcorrupt× Central SOE | 0.099 | 1.21*** | -0.16*** |
| | (0.09) | (0.40) | (0.06) |
| mcorrupt× City SOE | 0.23*** | 1.39*** | -0.27 |
| | (0.06) | (0.45) | (0.20) |
| mcorrupt× County SOE | -0.025 | 19.0 | 0.034 |
| | (0.28) | (16.66) | (0.09) |
| mcorrupt× Foreign | -1.42 | 0.62 | -0.063 |
| | (1.13) | (0.47) | (0.07) |
| _cons | 2.14*** | 3.31*** | 0.20*** |
| | (0.10) | (0.81) | (0.01) |
| City-ownership FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 4119 | 4112 | 4022 |
| $R^2$ | 0.007 | 0.008 | 0.007 |

Table A.70. mcorrupt×category - balanced

| | (1) | (2) | (3) |
|---|---|---|---|
| | SO2 Emission | SO2 Emission Intensity | SO2 Emission Removal Ratio |
| | b/se | b/se | b/se |
| mcorrupt× Central and provincial SOE | 1.24 | 0.26* | -0.10 |
| | (1.41) | (0.14) | (0.06) |
| mcorrupt× Domestic non – SOE | 0.085 | 1.08*** | -0.11*** |
| | (0.33) | (0.33) | (0.04) |
| mcorrupt× City or below SOE | 0.056 | 15.1 | -0.0083 |
| | (0.20) | (13.48) | (0.09) |
| mcorrupt× Foreign | -1.42 | 0.70 | -0.064 |
| | (1.13) | (0.52) | (0.07) |
| _cons | 2.56*** | 3.42*** | 0.20*** |
| | (0.12) | (0.92) | (0.01) |
| City-category FE | YES | YES | YES |
| Year FE | YES | YES | YES |
| N | 3412 | 3410 | 3350 |
| $R^2$ | 0.008 | 0.008 | 0.006 |

# Appendix B

# Figures

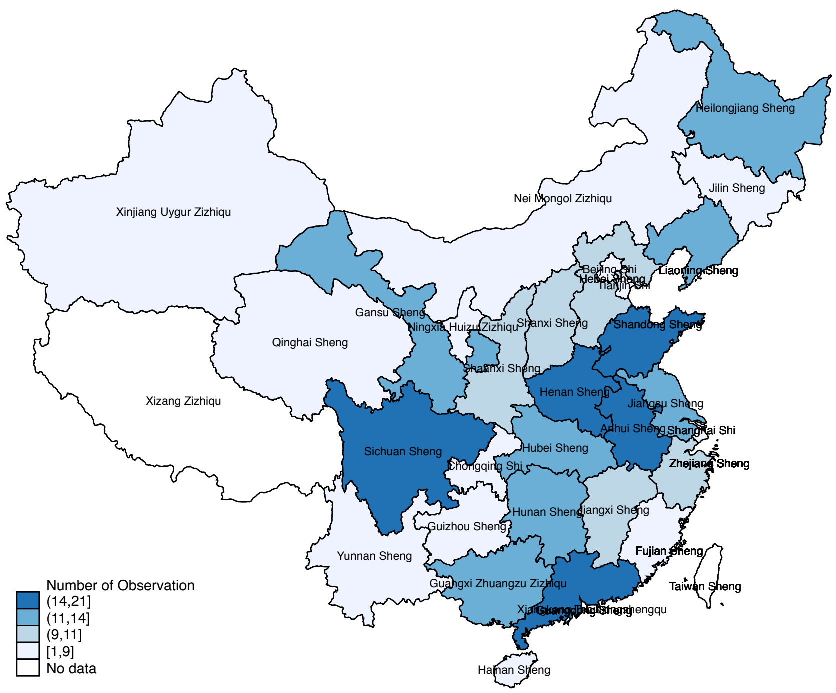


Figure B-1. Observed number of distinct cities for each province - all

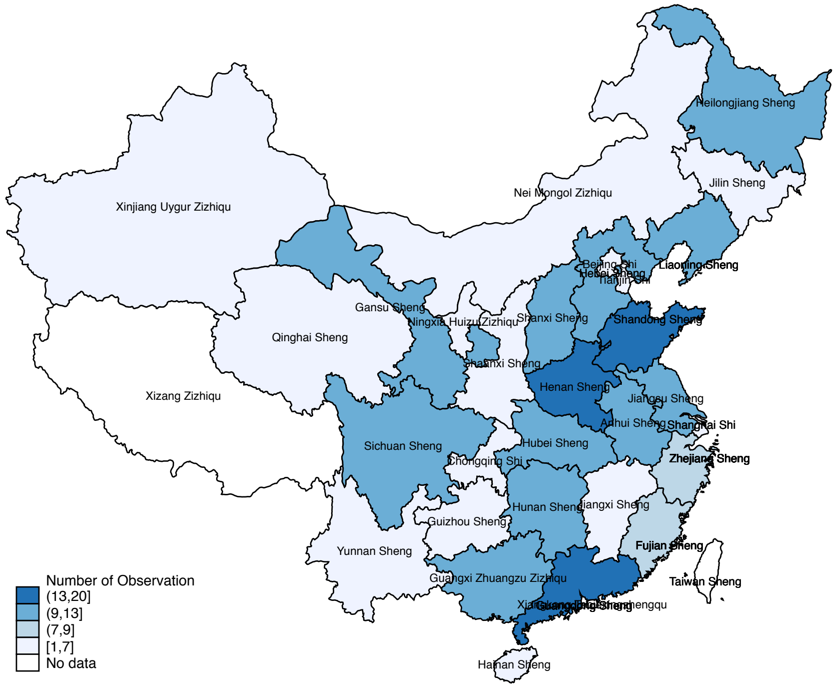


Figure B-2. Observed number of distinct cities for each province - balanced

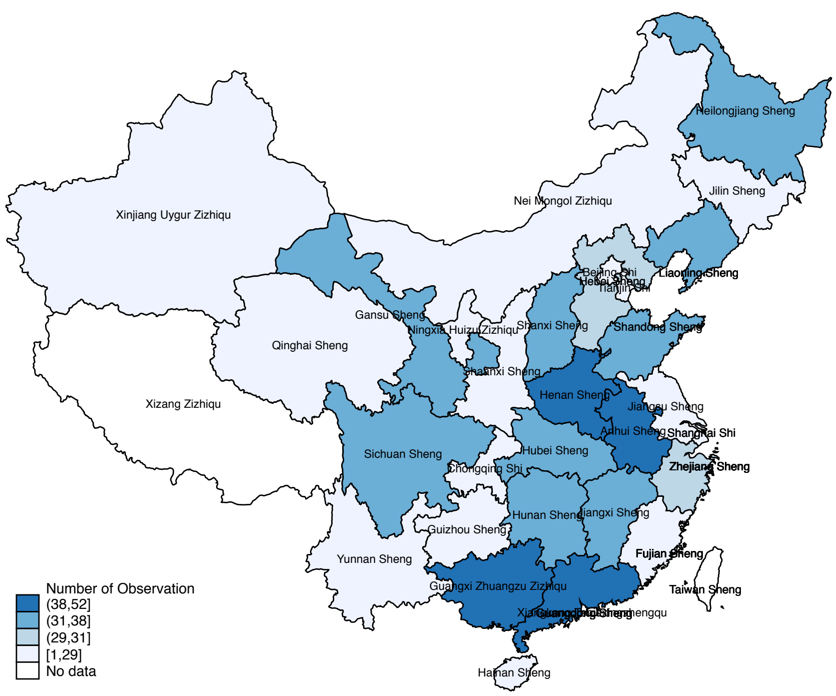


Figure B-3. Observed number of distinct mayors for each province - all, Source 1

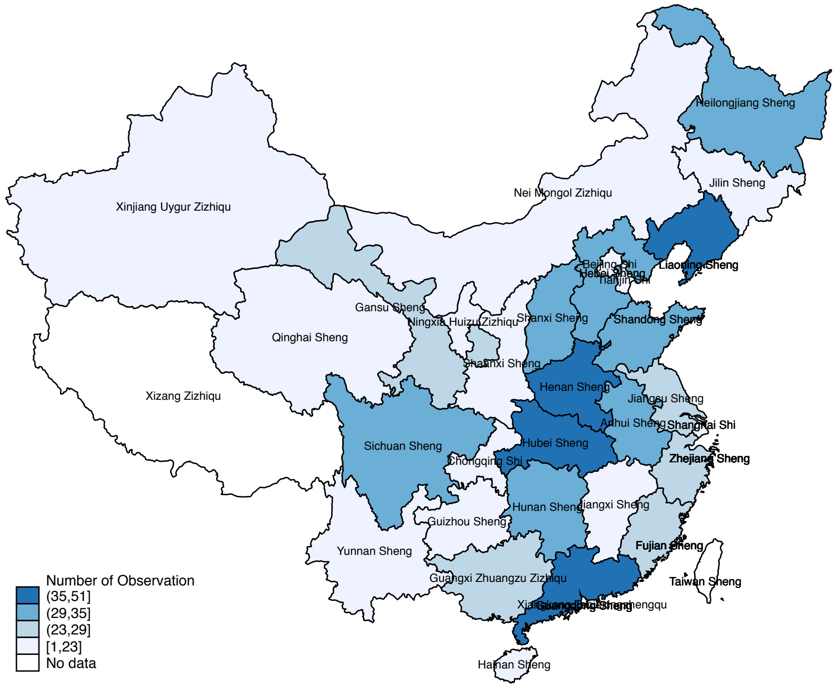


Figure B-4. Observed number of distinct mayors for each province - balanced, Source 1

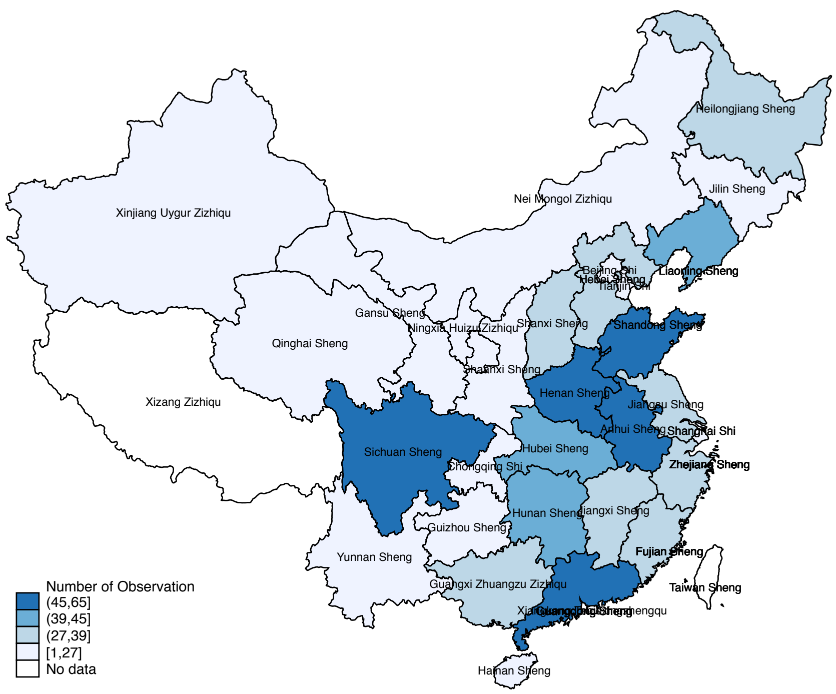


Figure B-5. Observed number of distinct mayors for each province - all, Source 2

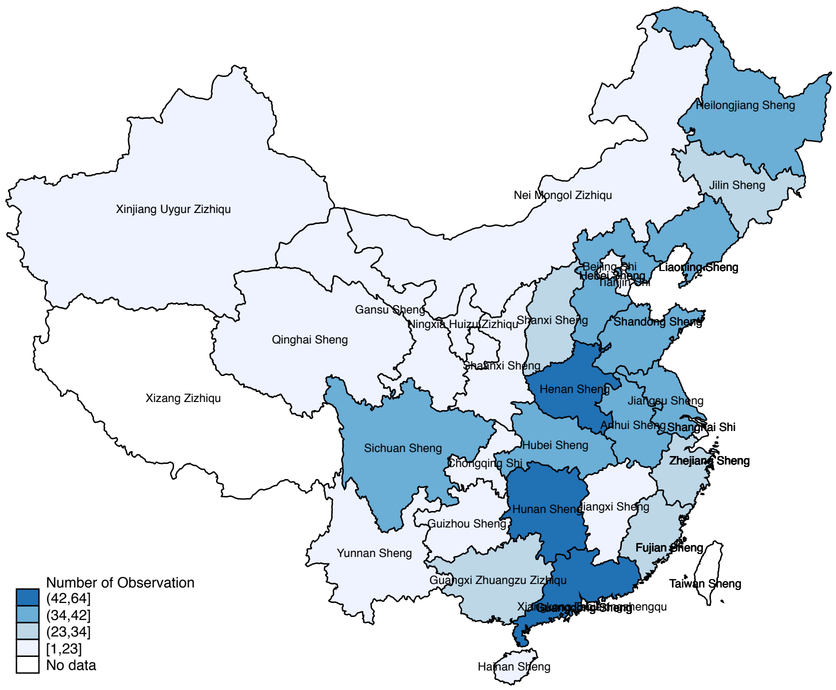


Figure B-6. Observed number of distinct mayors for each province - balanced, Source 2

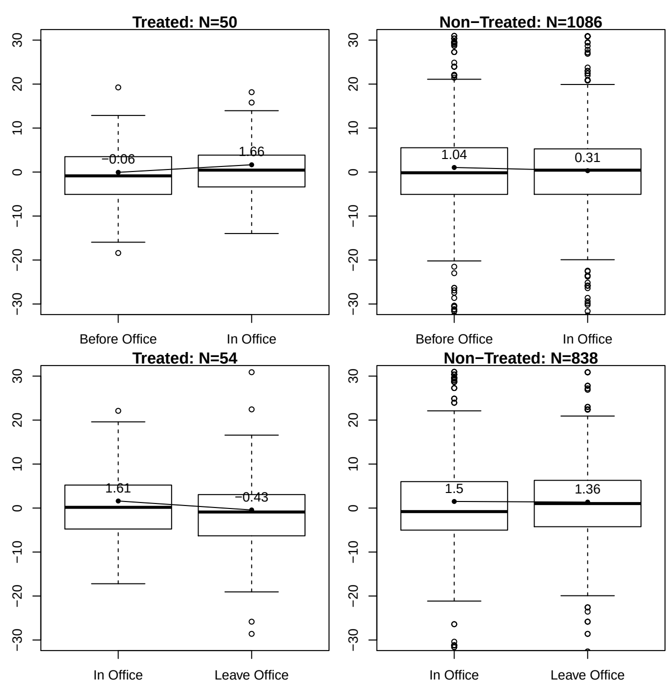


Figure B-7. Change of de-meaned and de-trended $SO_2$ emission on mayors (mwbind) entering and leaving office - balanced

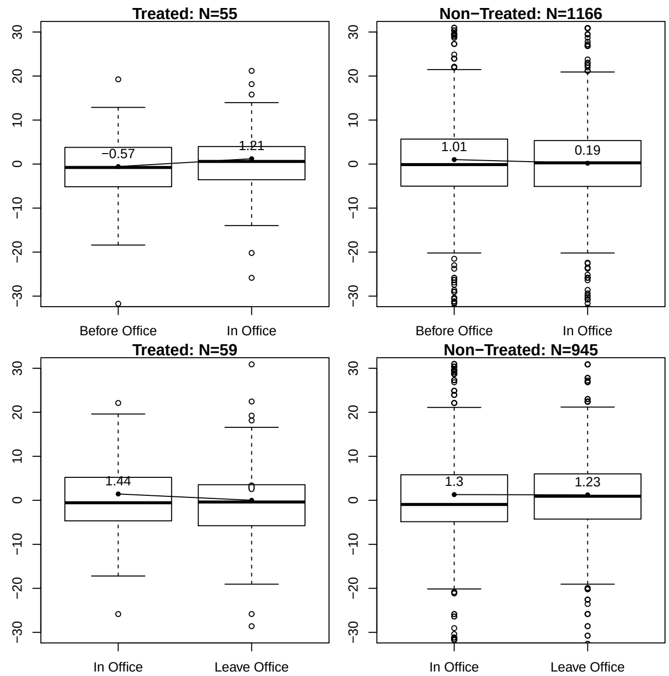


Figure B-8. Change of de-meaned and de-trended $SO_2$ emission on mayors (mwbind) entering and leaving office - unbalanced

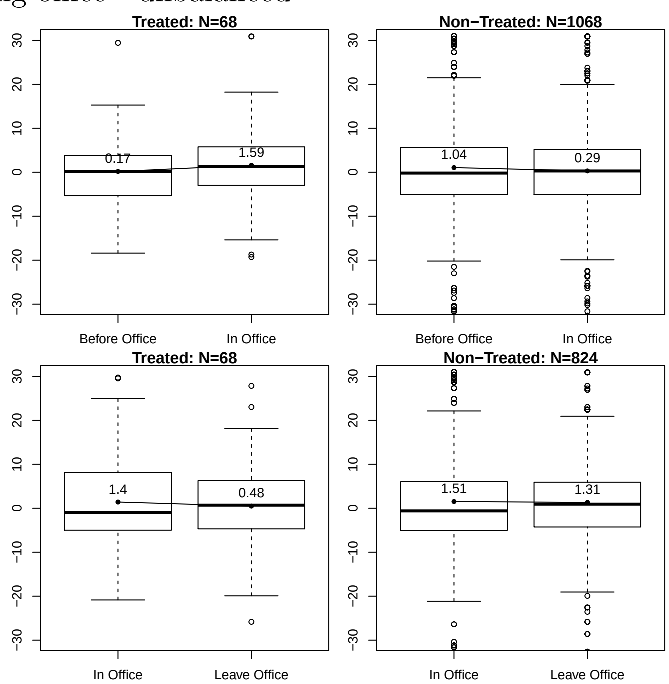


Figure B-9. Change of de-meaned and de-trended $SO_2$ emission on mayors (mprom) entering and leaving office - balanced

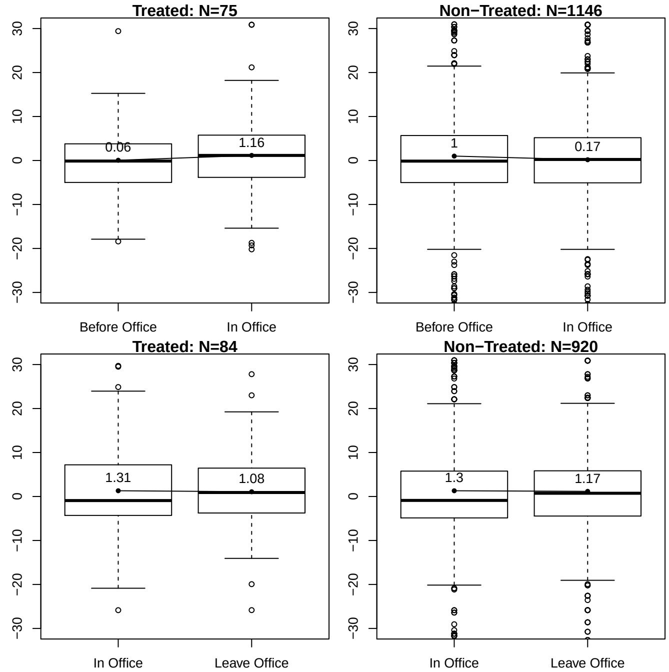


Figure B-10. Change of de-meaned and de-trended $SO_2$ emission on mayors (mprom) entering and leaving office - unbalanced

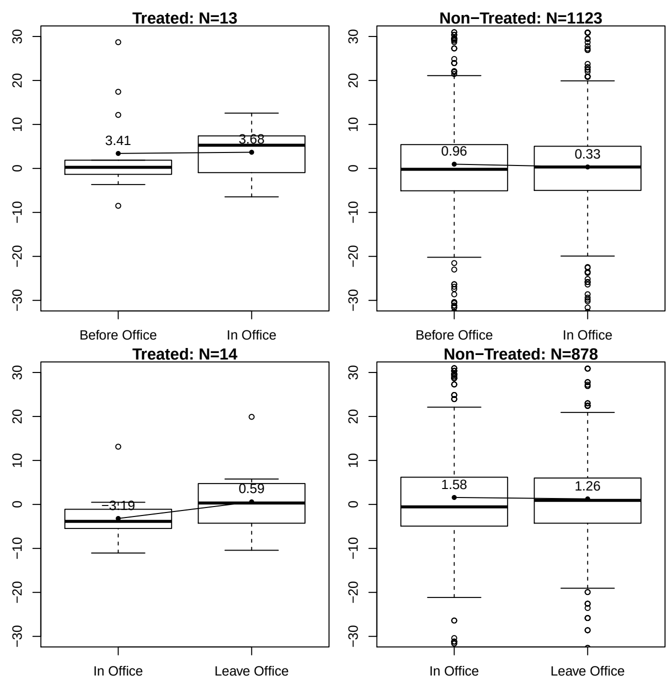


Figure B-11. Change of de-meaned and de-trended $SO_2$ emission on mayors (mwbctr) entering and leaving office - balanced

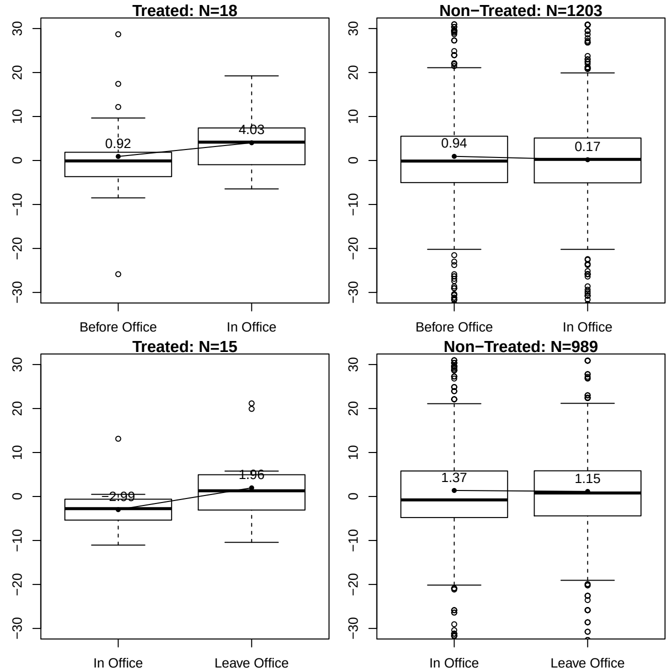


Figure B-12. Change of de-meaned and de-trended $SO_2$ emission on mayors (mwbctr) entering and leaving office - unbalanced

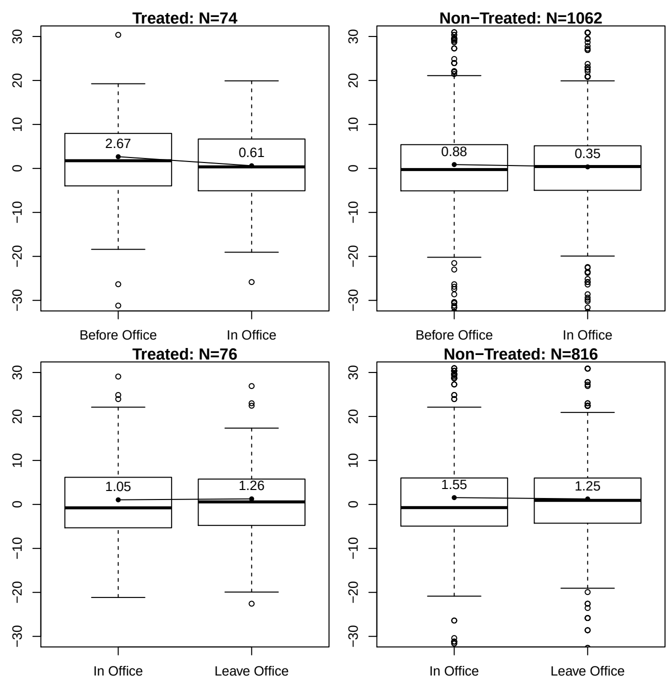


Figure B-13. Change of de-meaned and de-trended $SO_2$ emission on mayors (mlocal) entering and leaving office - balanced

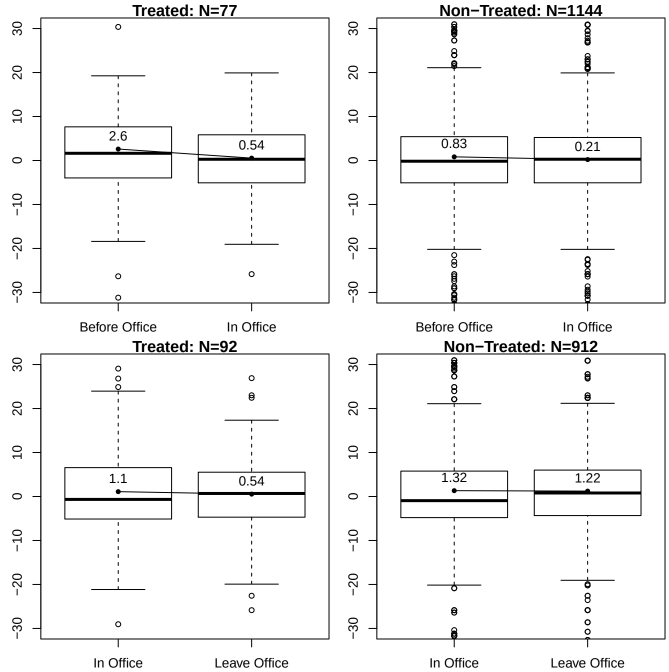


Figure B-14. Change of de-meaned and de-trended $SO_2$ emission on mayors (mlocal) entering and leaving office - unbalanced

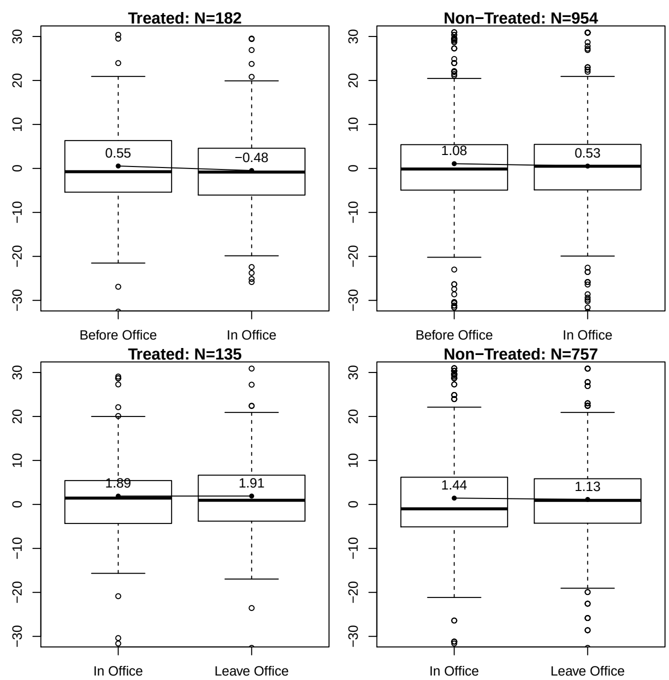


Figure B-15. Change of de-meaned and de-trended $SO_2$ emission on mayors (mret51) entering and leaving office - balanced

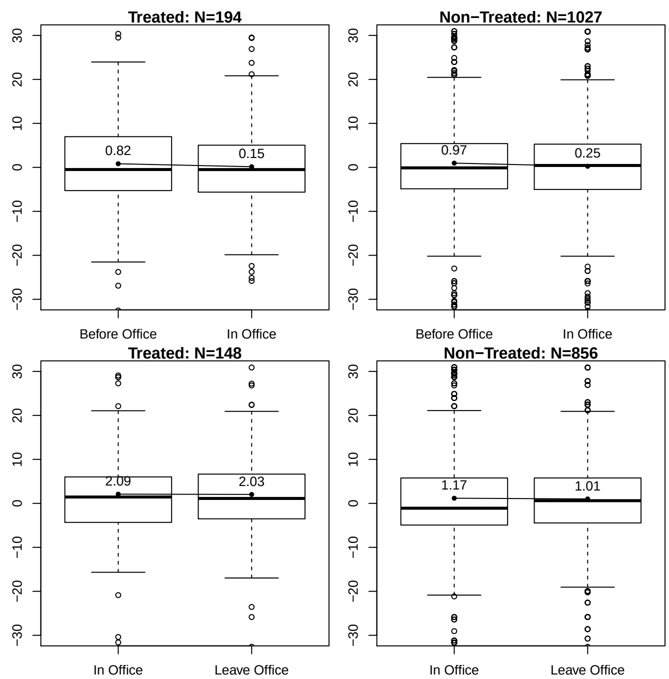


Figure B-16. Change of de-meaned and de-trended $SO_2$ emission on mayors (mret51) entering and leaving office - unbalanced