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# The Relationship between Industrial Ownership and Environmental Pollution: Panel Data Evidence from China 2000-2010

**Abstract:** This paper empirically investigates the relationship between industrial ownership and environmental degradation in the People's Republic of China, with specific focus on two environmental indicators: volume of SO2 emissions and volume of industrial wastewater deemed unsafe for discharge. Sulfur dioxide and untreated wastewater emissions are considered some of the most problematic environmental and societal threats in China, generating concern both internationally and nationally. Identifying whether enterprise ownership is correlated with the existing volumes of these pollutants is important from a policy and regulation perspective. The sample of 286 observations has been collected from various editions of Provincial Statistical Yearbooks (available online at the Chinese Statistical Database), constituting to a panel dataset of 26 administrative regions spanning the years 2000-2010. A two-way fixed effects approach is used to conduct the empirical analysis. The main findings indicate that a higher public sector share, and thus a smaller private sector share, are positively correlated with SO2 emissions but negatively associated with toxic wastewater emissions. This implies that private sector enterprises may have better environmental performance that state-owned enterprises in China in terms of SO2 emissions, but worse environmental performance in terms of toxic wastewater discharge.

***Keywords:*** *China, Pollution, Industrial Ownership, Panel Data, Sulfur Dioxide, Toxic Wastewater.*

DEPARTMENT OF ECONOMICS

NEKN03: Master Thesis

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August 2016

ACKNOWLEDGEMENTS

I would like to express my utmost gratitude to my supervisor, Professor Sonja Opper, for her insightful advice and invaluable guidance throughout my entire thesis writing process. I would also like to thank Professor Joakim Westerlund for offering his econometric expertise in the feedback for my methodology section.  Lastly, I want to express my thanks to Sandra Donnally and Nico Valtonen for all their support and help I have received in the last months.

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# CHAPTER 1: INTRODUCTION

In just over three decades, The People's Republic of China (hereafter China) has transformed itself from a poor agrarian and centrally-commanded economy to the fastest growing nation and a globally acknowledged superpower, with a current GDP of 9.240 trillion USD and annual growth rates averaging 9.6% (The World Bank, 2015). China's performance, in terms of GDP growth, has historically been matched by no other economy in the world. However, other developments lag behind. Namely, rapid modernization and economic growth have also occurred at the expense of the environment. As claimed by the World Health Organisation (WHO) and supported by many economists, environmentalists and critics alike, China's biggest challenge for the upcoming decade is battling and restraining its environmental problems (Levi, Economy, O'Neil and Segal, 2010; The CNN, 2014; Wang, 2015).

The emerging private economy has been credited as the engine behind China's powerful growth. A topic of great debate, however, is whether the private sector is more or less harmful to the environment than the public sector. Empirical research and national statistics pinpoint industry as the main polluter, accounting for 70% of total wastewater discharge and 72% of total sulfur dioxide emissions, and the biggest polluters being electricity, steel, cement, coking and chemical production plants (Dasgupta, Wang and Wheeler, 1997). However, it is still relatively unclear whether the concept of ownership matters in terms of environmental performance. Walls, Berrone and Phan (2012) are amongst the scholars whom contest ownership to be a key determinant of firm-level environmental performance, which may in turn be reflected in aggregate emission levels depending on the composition of industry ownership.

The concept of ownership and its effects on environmental pollution is particularly interesting, especially in the case of China, where political and economic spheres are often intertwined. Furthermore, the private sector and environmental pollution have grown alongside each other, but potential causality between the two is undetermined. In search for environmental culprits, one needs to turn attention to the root of the problem: to the management and decision-making units of enterprises, where most effective actions emanate. Whether an enterprise is state- or privately-owned has important ramifications on the managerial incentives, profitability and the actions of individual enterprises, and these effects are likely to manifest in environmental performance as well (Boardman and Vining, 1989; Coase, 1960). Identifying whether the private or non-private sectors are at the cause of China's pollution crisis allows for better implementation of environmental regulation, and may assist the Chinese Communist party (hereafter CCP) in meeting some of its ambitious environmental targets, as set out in the last three five-year plans (Dasgupta, Laplante, Mamingi and Wang, 2001).

On the list of China's worst polluters, the top-dwellers include oil giants China Natural Petroleum Corp (CNPC) and Sinopec, both of which are wholly state-owned. In 2013, both companies were heavily sanctioned and prohibited from building new petroleum refineries, as a response to years of lacking environmental accountability and failure to meet national environmental standards (Reuters, 2013). Is it by chance that the companies which score lowest on environmental performance are also state-owned? The intuition behind ownership and environmental performance, especially in the case of China, is not clear-cut. Existing empirical literature is also divided on the debate, as state-ownership has been found to be linked with higher environmental performance in some countries but lower in others (Wang and Jin, 2007; Beladi and Chao, 2006).

## 1.1 AIM

Why does ownership matter in terms of environmental performance, and can this be seen from an aggregate perspective? Environmental pollution is a likely consequence of the structural changes that have occurred throughout China's transition to a market economy; however, this paper intends to dig deeper and investigate the relationship between industrial ownership and environmental degradation, with specific focus on two environmental indicators: volume of sulfur dioxide (SO2) emissions and volume of industrial wastewater deemed unsafe for discharge. The research question of the present study is the following:

*"How does industrial ownership affect the emission of sulfur dioxide and toxic wastewater on a provincial level?"*

The findings from the present study will give an indication on whether different industrial ownership compositions have a significant effect on total emission levels of SO2 and industrial wastewater. Prior economic literature either adopts a firm-level approach, in which environmental performance of individual firms is assessed with respect to the ownership structure, or a macroeconomic approach, which combine a number of aggregate indicators as the determinants of various pollution indicators, with industrial ownership often neglected and left out of the regression (for example, see Li and Chan, 2016; Wang and Jin, 2002; Wang and Wheeler, 2003). This research will employ solely macroeconomic data but will consider a firm-level perspective in building a theoretical foundation for ownership effects. In this way, the present study aims to further contribute to the stream of empirical literature which still, to my knowledge, lacks material on the relationship between the environmental performance of provincial economies, in terms of total SO2 and wastewater emissions, and industrial ownership compositions through different stages of private sector development during the period 2000-2010 in China.

Although China's growth performance is in a class of its own, identifying some of the causal determinants of the country's uncontrolled pollution may lead a better path for other developing nations to follow. In particular, this may be especially relevant to the third wave of emerging Asian economies, that including Vietnam, for example, which seem to adopting China's economic model of export-oriented growth (Lin, Cai and Li, 1996; Chaponnière and Cling, 2009). Environmental pollution may be an inevitable part of economic modernization and industrial expansion, as argued by Grossman and Krueger (1994), but identifying some of the main sources of the pollution from the onset may have important long-term ramifications for other developing or transitioning economies.

## 1.2 Methods and Limitations

This study adopts provincial panel data from 26 Chinese provinces over a ten-year period from 2000 to 2010 in order to analyse the relationship between the composition of industrial ownership and the volume of sulfur dioxide and industrial wastewater emissions at a regional level, while holding other factors constant. All data for the contained variables of the model are collected from Provincial Statistical Yearbooks (2001-2011) on the Chinese Statistical Yearbook database. The most apparent limitations of this study abide within its data availability. Due to divergent statistical reporting between provinces, there exist various data inconsistencies. As a result of this, from the total 31 administrative regions in China, five regions were excluded from model testing, due to shortage of data on environmental statistics and certain control variables. For similar reasons, the time frame is restricted to a period of ten years, as reports on environmental statistics were largely missing in many administrative regions prior to the year 2000. However, due to the superiority of panel data over cross-sectional data, in its ability to capture both individual and time effects, a period of 10 years is sufficient to capture the effects of industrial ownership on provincial environmental performance. Lastly, another potential limitation concerns the reliability of China's environmental statistics, as Chinese environmental reports have been under critique for being misreported and underestimated on several occasions (Sinton, 2001; Chow, 2006). However, the provincial yearbooks are currently considered the most thorough, consistent and varied source of Chinese provincial data. Furthermore, Chinese statistics are collected and reported by a number governmental organizations, semi-government organizations and by private sector institutions, which would make the manipulation of data by a single source rather difficult.

### 1.3 OUTLINE

The remainder of this study is structured as follows:  Chapter 2 will provide background on China's current environmental, economic and political situation as well as the ownership changes that have occurred throughout the country since economic reforms were initiated in 1978. Chapter 3 includes a theoretical framework on the the role of property rights and budget constraints within enterprises of different legal status, as well as arguments for private- and public-ownership with regards to environmental accountability and pollution abatement efforts, and how these will in turn emulate in provincial emission levels.  Chapter 3 concludes with the hypothesis, which is based on the empirical literature and theory outlined in the previous sections of the chapter. Chapter 4 consists of discussion and motivation for the chosen data and methodology, after which the benchmark models and testing processes are outlined in detail. In Chapter 5, the regression results from the benchmark models are presented and comprehensively analyzed, followed by further extensions to the models. Chapter 6 includes discussion of the main findings and concluding remarks of the study.

## CHAPTER 2: BACKGROUND

### 2.1 CURRENT STATE OF THE ENVIRONMENT

The most recent water quality survey conducted by the Ministry of Water Resources in China reported that 41.2% of water from lakes, 35.8% of water from rivers and 76.8% of water from groundwater wells failed to meet national water quality criteria (Zhou, Tan, Guo and Zhang, 2015). Furthermore, most polluted rivers occur in the northeast of China, in areas of high population density and most under pressure from rapid urbanization (World Bank Report, 2014). Air pollution is also more severe in areas which have undergone rapid urbanization over the recent decades. In fact, only eight out of the seventy-four Chinese cities classified as "large" met international air quality standards in 2014, as reported by Ministry of Environmental Protection statistics (The Economist, 2015).

If the environmental statistics weren't dire enough, China's pollution problems have also led to copious second-order effects. Environmental pollution has multilaterally imposed numerous social and economic costs throughout the nation as long-term effects of China's rapid growth trajectory. Environmental degradation is a serious, yet often a neglected, topic of concern in developing and emerging economies like China, where economic momentum is pursued at the cost of societal and environmental wellbeing. Economic growth that puts the rest of the country off-balance is unsustainable in the long run- a fact that is often overlooked in the earlier stages of economic development. To put matters into perspective, at the end of the twentieth century it was estimated that air pollution from the process of coal burning lead to approximately 50000 premature deaths and 400000 new cases of chronic bronchitis annually in 11 of the largest cities in China, and resulting health costs exceeded urban income as much as 20 percent (Hughes, 1997). In a country like China where, on average, one third of the total population live and work in urban cities and heavy industry accounts for majority of GDP, uncontrolled air and water pollution is naturally to affect a large segment of society (Cai, Chen and Gong, 2016). A WHO report estimated that a quarter of the total Chinese population, primarily residing in rural areas, lack access to safe drinking water, and what is more, water pollution-related sicknesses are claimed to be the root cause of approximately 100000 annual deaths in China (World Bank, 2007).

The WHO claims that some improvements have taken place since the 1990s, but much remains to be done: costs associated with environmental pollution, in the form of premature deaths, lost work days and pollution clean-up projects to name a few, were estimated to total approximately 3 percent of China's gross domestic product (GDP) in 2008, not accounting for costs associated with the loss of vital resources and ecological destruction (World Bank, 2007). The current environmental situation represents the failure of the CCP to address environmental problems early, the enforcement gaps which arise from differing interests and priorities between different levels of government, and lastly, the lack of environmental accountability and incentives to reduce pollution on the enterprise-level.

## 2.2 ECONOMIC RESTRUCTURING SINCE 1978

Ever since 1978, when China first initiated its opening up policy and economic reforms, the era of central planning has gradually diminished and domestic production has increasingly been driven by market forces- namely by demand. The share of state-owned enterprises in the Chinese economy has declined gradually and various ownership forms have emerged, from which the most dominant are state-owned enterprises (SOEs), collective-owned enterprises (COEs), private-owned enterprises (POEs) and foreign-funded enterprises (FFEs). The first steps towards a market economy took place through bottom-up movements in some of the most rural areas of China, initiated by individuals who saw opportunities and pursued them. As a result of the Household Responsibility System (HRS), which was initiated in 1978, agricultural production experienced considerable productivity gains during the 1980s and released millions of excess farmers to seek opportunities elsewhere (Nee and Opper, 2012). The pool of off-farm labour found employment in township-village enterprises (TVEs), most of which were collectively-owned and a dominant form of employment and economic growth during the so-called “hybrid” years, until private firms took over in the mid-1990s as a result of greater market and competitive pressures. Most of the old TVEs were unable to survive in the growing market economy and transformed predominantly into private enterprises. (McMillan and Woodruff, 2002; Jin and Qian, 1998; Naughton, 2007).

While China’s private sector has grown rapidly since the mid-1990s and fuelled the country’s economic growth, China’s state-owned enterprises underwent considerable large-scale reforms in 1995 and have been of diminishing presence ever since. In the years between 1978 and 1993, the SOE share of total industrial output decreased from 78 to 43 percent; many SOEs were loss-makers and fiscal burdens to the government budget, wasting sizable portions of state resources and financial credit (China Statistical Yearbook, 1994; Cao, Qian and Weingast, 1999). In 1995, the local governments recognized the need to take reformative action against the SOEs, in attempt to further facilitate and expedite economic growth. They introduced what can be referred to as “privatisation Chinese style”, influenced by the distinct federal structure in China. The expression “grasping the large and letting go the small” was used to describe the process, in which small SOEs were privatised and substantial crowds of excess workers were laid off at the city level. It has been argued that Chinese-style federalism is what made SOE reform rather successful and mitigated potential social dissension in China (Cao et. al, 1999).

For the purpose of this study, it is also important to note that the regions differ in terms of their industrial ownership compositions; some administrative regions, such as Shanghai and Beijing, have historically had a higher share of SOEs, where as other provinces, such as Guangdong and Zhejiang, have a greater share of private and foreign enterprises (Nee and Opper, 2012; Chiu and Lewis, 2006). Furthermore, economic reform has progressed unevenly across China, showing in different levels of GDP per capita, in openness to foreign capital and in different levels of private sector involvement. For example, Guangdong was set up as an economic "testing ground" by the Chinese government in the early years of reform, to observe how market forces would acclimatize in the nation (Adhikari and Kirkpatrick, 1992). Differences in cross-provincial ownership compositions and degree of private sector involvement are important in light of the present study, as without such variation, it would be impossible to determine causality between industrial ownership and environmental performance.

Figure 2.2 below depicts the changes in gross industrial output contribution of SOEs, COEs, POEs and FFEs during 2000-2010. Prior to the year 2000, statistics on private enterprises are inconsistently reported, as they are grouped in either "non-state enterprises" or under "enterprises of other type of ownership" in the China Statistical Yearbook.

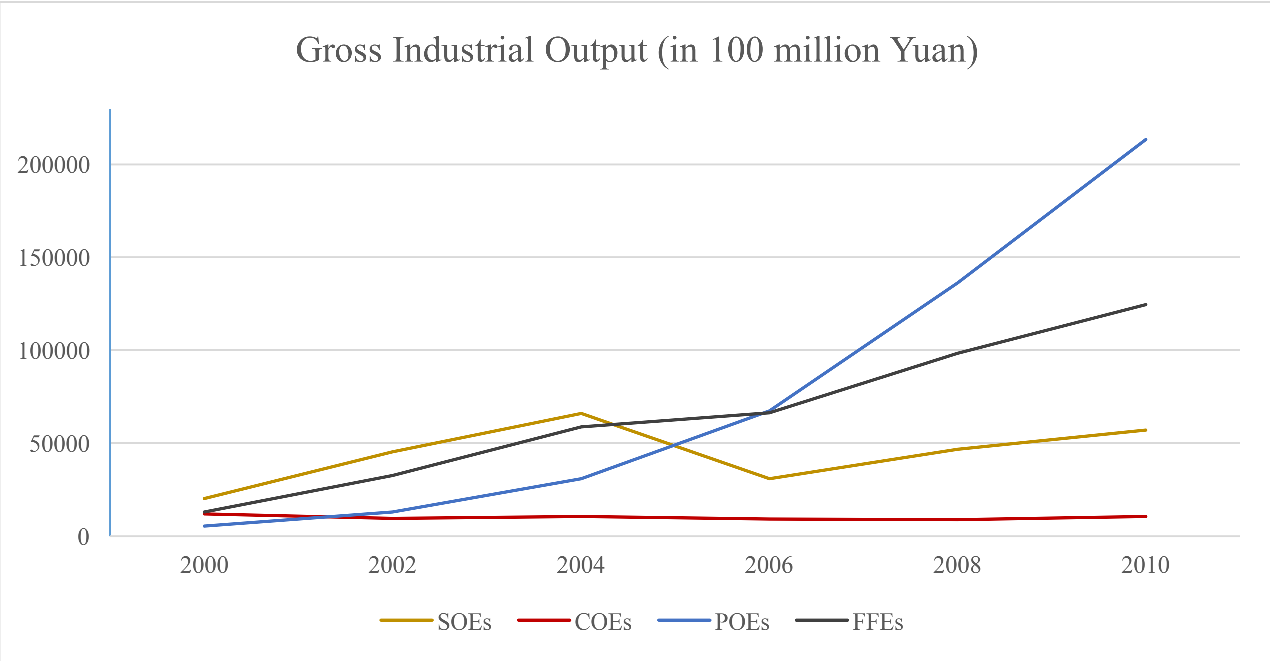


**Figure 2.2: Gross Industrial Output of Enterprises 2000-2010.**

The gross industrial output of SOEs, FFEs and POEs were growing overall during the 10-year period, but domestic POEs were growing at a much faster pace than the other ownership types. Figure 2.2 presents a period of rapid growth in China, fuelled by domestic private and foreign enterprises. Furthermore, we can observe a diminishing contribution of COEs, which began in the late 1990s. In fact, between the years 1998 to 2000 the total industrial contribution of COEs decreased by 73% (China Statistical Yearbook, 2001; China Statistical Yearbook, 1999). At the turn of the century, collective enterprises were no longer competitive against private enterprises, and many even transformed into private enterprises, which explains their comparatively small economic contribution from the year 2000 onwards (Naughton, 2007).

## 2.3 INDUSTRIAL EXPANSION AND ENVIRONMENTAL REGULATION

In the initial years of economic reforms, the primary goal for the CCP was to pursue economic growth at any cost, which has reflected in the current state of China's environment (Wang, 2008). China has experienced large-scale privatisation over the last three decades, but has the shift from a public towards a private economy occurred at a reduced or increased cost on the environment? Market reforms in China have brought great increases in level of competition, profit incentives and overall economic productivity, as resources are often more efficiently used under private sector forces (Fisher-Vanden, 2003; Galal and Shirley, 1994). Fisher-Vanden (2003) claims that "eliminating state-directed allocation of capital is likely to result in higher carbon emission although the carbon intensity of these countries is likely to be lower". In other words, further market reforms may lead to a less carbon-dependent industry and higher tertiary sector contribution, but higher carbon consumption is also needed before reaching that threshold.

In terms of private sector development, one side of the debate supports the view that greater private sector presence leads to increased investment in more efficient and environmentally cleaner technology, and same goes for increased foreign presence, in which foreign firms from developed countries introduce more advanced technology and managerial methods, with better recognition of environmental externalities (Talukdar and Meisner, 2001; Lin, Moon, Yin, 2014). However, another view holds that multinational companies (MNCs) are often criticised for selecting "pollution haven", or countries with weak institutional enforcement, in which to produce at lower costs (Lin et. al, 2014). This side of the debate further supports the view that private sector pursues growth at the cost of environment, by avoiding expenditures arising from environmental regulations and standards.

Avoidance of pollution abatement efforts and lack of environmental accountability is an unfortunate commonality in emerging and transition economies with underdeveloped institutions and insufficient governmental enforcement, occurring within firms of all ownership types (Talukdar and Meisner, 2001). Provincial governments and local pollution control agencies certainly play a substantial role in influencing factory-level emissions, but it all depends on enforcement. The tolerance for environmental externalities varies across China, as provinces place different priority and importance on tackling environmental pollution (Lo, Fryxell and Wong, 2006). What is more, in provinces with stricter enforcement, many industrial enterprises have already taken great steps in transforming their production methods and investing in cleaner, and more modern, technology, but this also varies amongst individual enterprises, with ownership being a considerable affecting factor. (Daspugta et. al, 1997).

The CCP has shown genuine commitment in tackling both air and water pollution in recent years, and pollution abatement has been a top agenda in the last three five-year plans constructed by the Chinese government (Dasgupta et al., 2001). Furthermore, the CCP has recently focused on better law enforcement and improving existing property rights policies, and thereby directly addressing the problem of weak institutions and deficient managerial incentives to engage in pollution control measures (Jiang et. al, 2014). However, enforcement gaps between local and national governments have arisen, as a result of “pervasive “pro-growth” local government priorities, the weak administrative capacity of environmental agencies themselves, and relatively weak levels of societal support for a cleaner environment”, as claimed Lo, Fryxell and Wong (2006). Although various pollution control efforts, such as the Pollution Discharge Levy System, have been exhausted since the 1980s in China, enterprises continue to lack incentives to control their emissions. As a result, Chinese heavy industry plants have weaker pollution control measures, on average, than in other parts of the world, as reported by a recent World Bank report (Jiang et al., 2014). This sheds light on the central government, which continue to fail in appropriately implementing environmental regulation policies which could incentivise enterprises to become more environmentally conscious (Jiang, Lin and Lin, 2014; Florig, Spofford and Xiaoying Ma, 1995).

# CHAPTER 3: THEORIES ON OWNERSHIP AND ENVIRONMENTAL ACCOUNTABILITY

The concept of ownership is both interesting and crucially important in the context of business in China, especially due to the characteristics embodied by China’s economic and political environment. As a transition economy, China’s private sector has rapidly emerged and flourished over the last three decades, but the state remains ever-present in most sectors of the economy. In assessing the implications of enterprise ownership on the environmental performance of China’s provincial economies, it is important to understand the incentive structures as well as the role of budget constraints within enterprises of different forms of ownership. Furthermore, it is necessary to understand apparent enforcement gaps that arise between different levels of government, and how firm ownership may further affect enforcement.

### 3.1.1 THE ROLE OF PROPERTY RIGHTS AND BUDGET CONSTRAINTS

Prior economic literature concludes that there are notable efficiency and productivity differences between enterprises operating under different ownership forms, which may also be reflected in environmental performance. However, empirical literature is rather inconclusive in determining a dominant form of enterprise ownership in terms of environmental performance. Property rights, such as the right to use a good or the right to appropriate profits and losses, are a key factor in shaping the incentive structures and profitability of enterprises, and may explain possible differences in environmental performance across various enterprise ownership forms. That is, understanding the role of property rights can help explain the economic incentives involved in adopting pollution abatement measures, depending on the specific form of enterprise ownership. The intuition behind this is rather trivial: individuals respond to rewards and punishments when making decisions and taking certain actions, and without exclusive property rights, these elements do not hold. This is for the fact that with property rights come incentives; so that when an enterprise owner invests funds into cleaner technology, for example, they will not reap the potential rewards of that unless they own the exclusive rights to that good. As such, a firm manager may likely lack the incentives to make optimal decisions which may affect the long-term profitability and sustainability of their economic activities (Boardman and Vining, 1989; Demsetz, 1967).

SOEs operate under soft budget constraints, by which they are owned and backed by the Chinese state, operating to fulfill production quotas set by the government. The Chinese financial system continues to be dominated by state-owned banks, in which SOEs generally have direct access to state bank credits and resources. Furthermore, it is essentially impossible for SOEs to go bankrupt, as the the government can simply bail them out in case of financial difficulty. However, the managers of SOEs are not entitled to exclusive property rights, but are only in possession of the right to use a good and the right to make decisions that relate to the formal and material alterations of the good (Demsetz, 1967). That is, managers of state-owned firms cannot claim rewards and punishments as private owners do, but it also means they carry no responsibility for losses, as the government instills funds to the firm in the case of financial difficulty. More importantly, SOE managers may lack the incentives to seek efficient production methods for profit expansion, as they are not entitled to the profits (Kornai, 1986). Entrepreneurs generally act on profit-maximizing incentives, but when the rewards and constraints are missing, as in the case of SOE managers, they purely produce to meet government-set quotas.

With exclusive property rights, private firm owners respond to presented incentives and they place value in maximizing the value of their property. As such, they seek to optimize their investment opportunities and efficient production capacities, as the potential profits can be used in whichever way they wish (Shleifer, 1998; Demsetz, 1967). In other words, private investors want to maximize the value of their property. This is especially true when the right to sell is employed, as an entrepreneur will be motivated to invest more to increase the value of the sale. However, when faced with a hard budget constraint, expenditures are conditional on past, present and and future revenues, and entrepreneurial actions drive expansion (Kornai, 1986). Hard budget constraints generally involve a level of risk-aversion, so that Chinese POEs may be hesitant, or even unable, to go for risky investments, as they are not backed by the state. The state neither provides the private businesses with start-up capital nor tax redemptions, and access to scarce resources are often blocked for private investors. Due to political favouritism and institutional embeddedness, many SOEs receive pollution exemptions, while POEs are most likely to be financially constraint in meeting emission quotas. This reflects in low performance in achieving emission targets overall, in both Chinese POEs and SOEs (Pan, 2011). However, investing in modern technology is likely to reflect in better environmental performance and higher efficiency, which are both in the best interest of a private owner if they arise alongside profit gains (Jiang, Lin and Lin, 2014). In addition, Coasian theory claims that exclusive property rights are likely to be negatively associated with pollution and other negative externalities arising from the process of production (Coase, 1960), which would imply that private enterprises have vested interests in reducing pollution in the long run.

### 3.1.2 Arguments for State-owned Enterprises

China has taken great steps in public sector reform. In just over 10 years since wide-scale SOE reforms were initiated in 1995, the remaining SOEs have seen dramatic efficiency increases and greater awareness for social responsibility (Luo, Qian and Ren, 2015). Despite being "embedded" with the state and often criticized for receiving lenient legal restrictions than their private sector counterparts, Chinese SOEs have been found to be very receptive towards governmental regulations (Cui and Jiang, 2012); Luo et al., 2015). However, this is widely debated in existing empirical literature and there also appears to be apparent differences between the social responsibility and environmental performance between large and small SOEs. Namely, large SOEs tend to outperform smaller SOEs in environmental, political and economic goals (Li and Chan, 2016; Luo et al., 2015).

In a panel data study covering 13 years and 118 industrial enterprises, Lee (2009) found that due to higher external pressure to reduce pollution, SOEs internalized waste and emissions more effectively than non-public enterprises. In developing countries, and as also partly found in China, SOEs and COEs generally take more social responsibility for their production processes. That is, SOEs take social accountability at a more national level, whereas COEs internalize externalities that may threaten social welfare at a local community level (ibid). However, these are likely to differ amongst areas characterised by different level economic prosperity, as COEs have been found to outperform SOEs in environmental performance in areas with higher GDP per capita (Wang and Jin, 2002). Although the private sector may be more efficient in terms of resource allocation than the state, they may be less likely to internalize environmental costs arising from their production activities, especially because costs associated with pollution abatement can be extensive and internal funds for such projects may not exist (Eiser, Reicher and Podpadec, 1996).

In addition to social welfare commitment of Chinese state-owned firms, a number of economic studies (e.g. Wong et al., 2006; Farh, Zhong and Organ., 2004) have reported that environmental participation and ethical citizenship is perceived stronger amongst the employees of Chinese SOEs, in comparison to their private sector counterparts. As such, the environmental performance of individual firms may partly be influenced by the environmental attitudes of the employees working within the enterprises, and vice versa. An explanation for this, as claimed by Farh et al. (2004), could be that SOEs are not solely profit-driven and bankruptcy is an unlikely threat, which is also acknowledged by the employees. As SOEs are owned by the state and not under threat from the forces of market competition, they are economically secured to instill funds into welfare-inducing investments, such as pollution abatement and employee safety (Chun, 2009). Furthermore, in order to achieve political recognition and advocacy, SOE managers seek to achieve social objectives, such as better environmental protection, together with economic goals, i.e. meeting production quotas, which reflects in the actions and attitudes of their employees as well (Luo et al., 2015).

### 3.1.3 Arguments for private enterprises

In a study conducted by Talukdar (2001), which investigated 44 different developing countries during the period 1987 to 1993, it was found that the degree of private sector involvement, as represented by the sector's output value share of total GDP, was significantly and negatively correlated with carbon dioxide emission levels. This would imply that increased privatisation has beneficial effects on the environment and pollution abatement efforts. Wang and Wheeler (2003) found supporting results in the case of China: with specific focus on wastewater discharge and industrial ownership, factories under state-ownership polluted more than private enterprises. Jiang et al., (2014) also confirm with their findings on the Chinese manufacturing sector, that SOEs emit a higher level of SO2, wastewater and soot than FFEs and POEs. This may give an indication of the level of technology adopted by enterprises operating under different ownerships structures. As SOEs are generally older in China, they tend to have outdated and heavily polluting machinery, whereas private firms are more likely to invest in cleaner and more advanced technology in efforts to achieve efficiency gains, as represented by increased returns to production (Kikeri, Nellis and Shirley, 1992). Private enterprises work under profit-maximizing incentives and face harder budget constraints than their state-owned counterparts, but short-term costs associate with pollution abatement efforts are likely to yield long-term financial gains, especially when also taking into account growing consumer demand for environmentally sustainable production. Finding the most efficient and sustainable means for production is also a way to remain competitive within the Chinese domestic and export market, and as such, investments in cleaner technology and pollution abatement may not only profitable but obligatory (Wang, 2015).

Contradictory to what Farh et al. (2004) reported on the environmental attitudes of Chinese SOE employees, Chun (2009) surveyed 472 employees from seven different energy companies in the Shanxi province and found that employees working SOEs had significantly poorer attitudes towards the environment than employees working in POEs. Furthermore, Chun reported that "employees working for SOEs had significantly lower scores on all the four values: conservatism, self-enhancement, self-transcendence, and openness to change", which goes against the body of existing literature that supports the claim that SOE managers and employees take greater accountability for social objectives, such as environmental protection.

Furthermore, although FFEs continue to rank higher in environmental performance than Chinese POEs, the domestic private sector enterprises match their foreign competitors in technology investments and ISO14000 certifications (Lu and Chan, 2016). Greater foreign presence, through technology spillovers, and domestic technological upgrading are likely to further compress the size of the technology gap, which may in turn manifest in lower pollutant emissions and economic growth stemming from the private sector (ibid).

It is also imperative to acknowledge that enterprises have different influences on local and national politics, depending on their ownership structure. For instance, in the case of China, SOEs and COEs tend to have stronger environmental bargaining power with local governments and environmental agencies (which are often government-owned) in terms of complying to environmental standards and avoiding potential pollution fines (Wang and Wheeler, 2003; Wang and Jin, 2007). In many cases, SOE managers have stronger political authority than local environmental agencies, in which case they may be able to avoid pollution abatement costs, resulting in an incentive problem in cutting emissions. The same goes for COEs, which are owned by the community and are therefore connected with the local political environment (Wang and Jin, 2002; Wang and Jin, 2007). This also explains the familiar correlation between environmental problems within many developing countries and the rent-seeking activities of the countries' politicians and enterprises (Wang, 2015). In contrast, POEs tend to have lower bargaining power and more pressure to comply to environmental standards. In terms of pollution monitoring and regulation, the incentive for enterprise managers to cut emissions is highly correlated with the authorities' ability to detect non-compliance as well as general tolerance for non-compliant behaviour. This is especially true for POEs, due to the exclusivity of property rights and higher incentive range (Dasgupta, et al., 1997).

### 3.2 Hypothesis

This study explores the relationship between the composition of industrial ownership in a provincial economy and its repercussions on the environmental state of the province, with specific focus on the emission of sulfur dioxide and wastewater deemed unsafe for discharge. In light of previous empirical literature, and particularly motivated by the incentive structures of private and public enterprises, this study employs the following testable hypothesis:

H1: *"With all else being equal, a higher share of public sector involvement, and thus a lower* *private sector involvement, will result in higher levels of SO2 and wastewater emissions on average in China."*

Although there exists some evidence indicating that SOEs take great social responsibility in their production decisions and are more receptive towards environmental regulations, a considerably larger share of empirical evidence supports the opposing side of the debate, thus further motivating the aforementioned hypothesis. It is imperative to acknowledge, however, that the prior literature, which lay the foundations for the theoretical framework used in the present study, are primarily based on firm-level studies. As such, the results obtained from enterprise-level studies on ownership and environmental performance may, or may not, be replicable on a macro-economic perspective.

# CHAPTER 4: METHODOLOGY

## 4.1. DATA

Various editions of Chinese Provincial Statistical Yearbooks (2001-2011), obtained from the China Statistical Database, are used for the collection of data for all contained variables of the model. The province-specific yearbooks are published on an annual basis and are presently the most thorough and detailed sources of Chinese data. All administrative regions in China publish their own yearbooks, which differ slightly in terms of content and structure, but they typically contain 24 chapters, ranging widely in data from common economic indicators such as GDP per capita to more specific data, such as volume of noise pollution. Due to limitations in data availability for environmental indicators, Hebei, Jilin, Guangxi, Hainan and Tibet are excluded from model testing, leaving a total of 26 provinces. For similar data inconsistency reasons, the time period used for model testing is limited to ten years, covering the period between 2000 and 2010. A consequence of having to drop five observation units (i.e. the provinces and autonomous regions with inconsistent environmental data) is that the collection of data used in the present study is a balanced panel, in which each cross section observation (i.e. province) has the same time period, t= 1, 2,…,10. Balanced panels are generally preferred in panel data testing, due to their ability to reduce noise arising from individual heterogeneity (Hsiao, 2003).

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| **Administrative regions included in the study:** | *Beijing, Tianjin, Shanxi, Inner Mongolia, Liaoning, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang* |

## 4.2 VARIABLES

### 4.2.1 DEPENDENT VARIABLES

This study investigates the relationship between public versus private sector involvement on two different pollutants, sulfur dioxide and unsafe wastewater. As such, it is necessary to have two models for each pollutant:

*(1) Volume of Sulfur Dioxide Emissions*

*(2) Volume of Industrial wastewater considered "unsafe" for discharge*

Annual sulfur dioxide and "unsafe" wastewater (WW) emission volumes are collected from the yearbook respective to each year and each province (e.g. SO2 emissions for year 2003 in Guangdong province are collected from the 2004 edition of the Guangdong Statistical Yearbook). The chapter including various environmental statistics can be found in all the yearbooks for all the provinces included in the present study. Both pollutant emissions are reported in 10000 tons, from which the total annual emission is divided by the population in order to derive *per capita* emission levels. Using per capita values controls for unwanted population size effects, as a greater population is likely to be correlated with higher levels of SO2 and wastewater emissions.

The motivation for investigating SO2 and toxic WW emissions is not only the fact that they are potentially the most problematic forms of pollution, in terms of discharge volume, in China, but they are also the most consistently reported pollutants in the provincial statistical yearbooks. The benefits of including different pollutants as dependent variables in two separate regressions allows for better investigation of the effects of ownership. Namely, including two pollutants allows us to compare and analyze possible ownership differences, e.g. whether ownership has a stronger correlation with one of the pollutants and why this may be. Furthermore, although the level of sulfur dioxide and wastewater emissions are likely to be positively correlated, the volume of each pollutant can vary considerably depending on geographical and industry-specific differences.

### 4.2.2 The main independent Variable

The main independent variable, the share of SOEs in a provincial economy, is constructed by obtaining the number of SOEs above a designated size and dividing it by the total amount of industrial enterprises above a designated size in that respective province. As reported in the statistical yearbooks, "above designated size" refers to enterprises with total business income exceeding or equaling 5 million Yuan annually. The provincial yearbooks report SOE data more thoroughly than data on private enterprises, and as such, SOE share will be used in the model as the main independent variable and not the share of POEs. In fact, in some provinces enterprise data was categorized as "state" and "non-state" prior to the year 2007 (e.g. Beijing Statistical Yearbook), with no indication of how much domestic POEs comprise of the "non-state" total. The reason for better reporting of SOEs could be state-bias in favour of the public sector, better transparency within the enterprises, and also the fact that they have historically been around longer than private firms in China. The total amount of industrial enterprises above a designated size, in a given province, is composed of the total number of SOEs, COEs, as well as FFEs and POEs, which are often a joint number. The share of COEs, especially after the year 2000, is very minor in all provinces. For the interest of this study, a smaller share of SOEs can be interpreted as a larger private sector presence. Ideally, the ownership share would be constructed as a share of total economic contribution in a provincial economy. However, this data is not available for all provinces between the years 2000-2010. The share of SOEs from the total amount of industrial enterprise units serves the same purpose, especially since the enterprises are all above a designated size- therefore excluding very small businesses with small economic and pollution contributions from the total.

### 4.2.3 Control Variables

When investigating China's environmental pollution and economic development trends, it is of upmost importance to acknowledge apparent regional differences and avoid assumptions of cross-provincial homogeneity. China has an expansive territory, spreading over 9.5 million square kilometres of land, with considerable regional variation in economic, geographical, social and environmental conditions (China Statistical Yearbook, 2011). In order to isolate ownership effects, it is important to control for various confounding factors, which are likely to not only be correlated with pollutant emissions but also with industrial ownership.

***GDP per capita and GDP per capita squared***

GDP per capita does not only indicate how well the economy is doing overall, but it takes into account individual income, which is a better representation of the level of development than total provincial GDP. The eastern, coastal provinces of China enjoy a higher level of economic development, as indicated by GDP per capita, and greater foreign direct investment (FDI) presence, whereas majority of western provinces lag behind in terms of economic development (China Statistical Yearbook, 2011). GDP per capita is included as a control variable in the model, as it is likely to be related with pollutant emission volumes as well as industrial ownership structure. For example, a province with greater private sector involvement is likely to enjoy a higher level of GDP per capita (Hull, 2009). The causality may also be reversed, so that private investors establish businesses in provinces with higher levels of GDP per capita and economic activity. A squared GDP per capita term is included because the level of income is likely to have a non-linear relationship on SO2 and wastewater pollution, as theorized by Grossman and Krueger (1994) with the Environmental Kuznets Curve (EKC) hypothesis. As such, different levels of income may have different effects on environmental pollution.

***Level of Human Capital***

Improvements in human capital have been found to have a positive effect on the environmental quality in developing countries like China (Jun, Zhong-kui and Peng-fei, 2011). Daspugta and Wheeler (1996) also found a positive correlation between citizen complaints and the level of human capital in Chinese provinces; more specifically, they found that areas with high illiteracy rates had fewer citizen complaints than areas with a higher level of human capital, indicating that this share of the population is unaware of the environmental problems and the consequences of such problems. Societal pressure is a significant driver of environmental protection, and without such pressure, enforcement of environmental standards is likely to be weak (ibid.). As the level of human capital may reflect in the pollution abatement efforts of provincial governments and enterprises, it is important to control for it in the econometric modeling. More importantly, industrial ownership and the level of human capital may be correlated. For example, SOEs may have more skilled labour than in POEs, since working in SOEs has traditionally been more attractive for skilled labour, where wages and social insurance tend to be higher (Nee and Opper, 2012). However, greater private sector presence is also likely induce tighter labour market competition, which motivates individuals to pursue higher education. The number of secondary school graduates is used as a proxy for human capital level in a given province. This number varies greatly across Chinese provinces, not only in line with the provincial population but also with the level of development. The number of secondary school graduates is divided by the total provincial population, in order to derive *secondary school graduates per capita* and to rule out size effects.

***Level of Technology***

The level technological sophistication is likely to provide an indication of the overall level of development, income and foreign capital presence in a specific province (Findlay, 1978). In light of the present study, it is likely to be correlated with not only total SO2 and WW emission levels but also with the industrial ownership factor. More advanced technology is likely to be more efficient and cleaner, resulting in higher returns but at a lower cost on the environment. Furthermore, as SOEs are likely to be older and arguably less incentivized to invest in better machinery, a higher SOE presence (or a lower private sector share) may be correlated with an overall lower level of technology in a given province (Kikeri et al., 1992). The "number of patent applications granted" is used as a proxy for the level of technology, which is then also divided by the total provincial population to obtain *patents per capita*. The use of patent data as a proxy for technological innovation is frequently observed in empirical studies (Watson, Jonstone and Haščič, 2009; Verbeek, Debackere, Luwel, Andries, Zimmermann and Deleus, 2002). Patent applications are generally consistently reported, even in countries like China with weaker and less transparent statistical reporting, and are an easy measure for the level of technology, which is more abstract.

***Volume of Road Traffic***

In studying the causes of pollution, and especially atmospheric pollution, road traffic is a plausible factor to consider. Although industry accounts for a majority of the atmospheric pollution in China, vehicle exhaust emissions are also a considerable culprit, especially when taking into consideration China's large population and land size (Lu, Streets, Zhang, Wang, Carmichael, Cheng, Wei, Chin, Diehl and Tan, 2010). Cross-provincial road traffic volumes range appreciably in China; car ownership and vehicle traffic is positively correlated with land area and negatively correlated with competent public transportation systems (Xu and Lin, 2016). It is also reasonable to assume that higher provincial car ownership and vehicle traffic signals a higher level of economic development, which can be seen higher volumes of freight traffic and people commuting to work. There could also be possible discrepancies in vehicle and transportation use between public and private enterprises. For example, as private enterprises tend to be more cost-efficient and financially conscious, they may look for ways to reduce costs associated with freight transport, such as combine transportation destinations and plan better routes to save on petrol costs (Fisher-Vanden, 2003; Kikeri et al., 1992). The variable is constructed by taking the total volume of passenger and freight traffic in a given province, and dividing it by the provincial population. Deriving a *per capita* term eliminates population size effects, as a larger population also indicates a larger volume of passenger traffic.

***Legal Situation***

Controlling for the legal situation in a province accounts for much of the disparity between provinces with stronger legal structures and provinces with weaker law-governing institutions. This is of interest in light of the present investigation, because stronger law enforcement and better institutions are connected with better pollution abatement measures within enterprises and higher environmental accountability (Talukdar and Meisner, 2001). If environmental laws and standards are enforced, enterprises will face more pressure to meet them, as failure to do so will result in punishment in the form of fines, prosecution, subsidization cuts and event factory shut-downs. Intuitively, provinces with stronger legal institutions are also likely have more private firms, as their property rights will be better protected. A statistic that can give an indication of the legal situation within a province is the number of practicing lawyers. Thus, the number of full-time and part-time qualified lawyers are used as a proxy to represent the legal situation within a given province. The total number of lawyers is divided by the population in order to derive lawyers per capita.

***Level of Urbanization***

China has experienced rapid urbanization since reforms were initiated. The level of urbanization, varying largely across provinces, is a major source of pollution and reflects the state of economic and social development (Ponce de Leon Barido, and Marshall, 2014). A high level of urbanization implies that a large amount of the provincial population resides and works in urban areas. These densely populated urban areas, in turn, become increasingly more constrained by human activity, as can be seen from higher use of resources, higher volumes of waste, congested traffic, increased business activity, construction work, etc. (Huang, Zhou, Lee, Bao, Zhao, Fung, Richter, Liu, and Zheng, 2013). A higher level of urbanization places a considerable amount of pressure on the environment, not only from the loss of resources through deforestation, but also on the atmospheric environment from increased traffic and densely-located factories, as well as on soil and ground water from the discharge of wastewater from human and industrial use (Ponce de Leon Barido and Marshall, 2014). Furthermore, the private sector, which is the primary source of employment growth in China, may be correlated with the level of urbanization, as many private enterprises will be located in urban areas, close to their competitors and business partners. As such, the growing private sector will consume increasingly more job-seeking migrants, resulting in higher urbanization figures (Kanamori and Zhao, 2004). The provincial percentage of non-agricultural population is used as a proxy for the level of urbanization, as urbanization figures were inconsistently reported across provinces. Using non-agricultural population as a proxy for urbanization is common practice in existing literature, especially in studies focusing on China (Zhu, 1999; Wu, Findlay and Watson, 1994).

***Share of Heavy Industry***

China's legacy as the "factory of the world" was achieved at a high cost on the environment. Coal-burning factories have been labeled as the biggest contributors to SO2 emissions in China (Dasgupta et. al, 1997). Furthermore, from the process of industrial production, toxic heavy metals are released into wastewater. However, it is actually agricultural production which accounts for roughly 50% of total water pollution, as claimed by the China's Ministry of Environmental Protection. The ministry adds that the agricultural sector is the largest contributor to Chemical Oxygen Demand (COD) and ammonium (NH4), which are some of the main toxic elements of wastewater in addition to heavy metal content (The World Bank, 2012). Although industrialization and environmental quality are found to exhibit a negative relationship, the correlation may not be as clear with all pollutants. However, it is also important to note that the rural areas which rely more on agricultural production are more likely to have underdeveloped wastewater infrastructure and low treatment rates for toxic chemical elements, and this will in turn affect the pollution statistics as well (ibid).

In light of the present study, it is important to control for heavy industry share because of its clear connection with SO2 and WW pollution, and due to the apparent cross-provincial differences in the industry composition of economic output. For example, the province of Liaoning has been known as the nation's centre for heavy industry, much of which depends on coal-based energy and old, polluting machinery. Beijing, on the other hand, represents China's capital with the most effective emission levies and lowest pollution intensity within its industry (Daspugta et al., 1997). There also lie potential connections between ownership and the share of heavy industry, as some of the worst-polluting heavy industry giants are SOEs. The variable for heavy industry contribution is constructed by diving the heavy industry gross output value from the total gross output value of industry above designated size, expressed in units of 100 million Yuan.

### 4.2.4 DESCRIPTIVE STATISTICS

This section will offer an overview of the dataset used for the present study, with key statistics on the entire sample. The dataset includes a total of 286 observations on the 26 Chinese provinces for the years 2000 to 2010. Table 4.2.4 contains the key statistics on the contained variables.

**Table 4.2.4: Summary statistics of variables**

| Variable | Obs. | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| ***dependent variables*** | | | | | |
| *SO2 per capita* | 286 | 0.0183243 | 0.0106157 | 0.0051954 | 0.0579729 |
| *WW per capita* | 286 | 21.71877 | 27.75927 | 4.123975 | 196.4318 |
| ***Main independent variable*** | | | | | |
| *SOE share* | 286 | 0.155533 | 0.1533492 | 0.0047026 | 0.684375 |
| ***Control Variables*** | | | | | |
| *GDP per capita* | 286 | 19044.47 | 14873.13 | 2759 | 76074 |
| *GDP per capita*$^2$ | 286 | 5.83e+08 | 9.77e+08 | 7612081 | 5.79e+09 |
| *Graduates per capita* | 286 | 0.020799 | 0.0056332 | 0.0098283 | 0.0447431 |
| *Patents per capita* | 286 | 0.0002424 | 0.0005275 | 0.0000118 | 0.0057036 |
| *Lawyers per capita* | 286 | 0.0001455 | 0.0001681 | 0.0000249 | 0.0011691 |
| *Traffic Per capita* | 286 | 18.09598 | 17.30157 | 2.5875 | 112.9085 |
| *Urbanisation level* | 286 | 0.3858651 | 0.1616715 | 0.143412 | 0.820432 |
| *Heavy Industry Share* | 286 | 0.7184193 | 0.1032654 | 0.4199997 | 0.941125 |

As indicated by Table 4.2.4, there is considerable variation in all of the time series, in which some observations take on very small values (as indicated by sample minimum) and some take on considerably larger values (as indicated by sample maximum), thus further motivating the use of logarithmic transformations for all variables. The substantial variation in the sample values also highlights the large disparities between the 26 administrative regions, which makes China an interesting case to study in panel data analysis. For example, the province with the highest share of SOEs (out of the total industrial enterprise total) has been Qinghai with 68%

and 13% in 2000 and 2010 respectively, where as Jiangsu and Zhejiang have had the highest share of privately owned firms during the ten-year period. The highest levels of GDP per capita are found in Shanghai while the lowest are found in Guizhou, where even in the year 2010, GDP per capita was merely 13119 Yuan. Lowest levels of urbanization, as indicated by share of non-agricultural population, are found in Guizhou and Yunnan, and the highest unsurprisingly in Shanghai. Heavy industry accounted for as much 94% of total industrial output, which is the sample maximum, in Qinghai, while heavy industry accounted for only 42-54% of total industrial output in Fujian between the years 2000 and 2010.

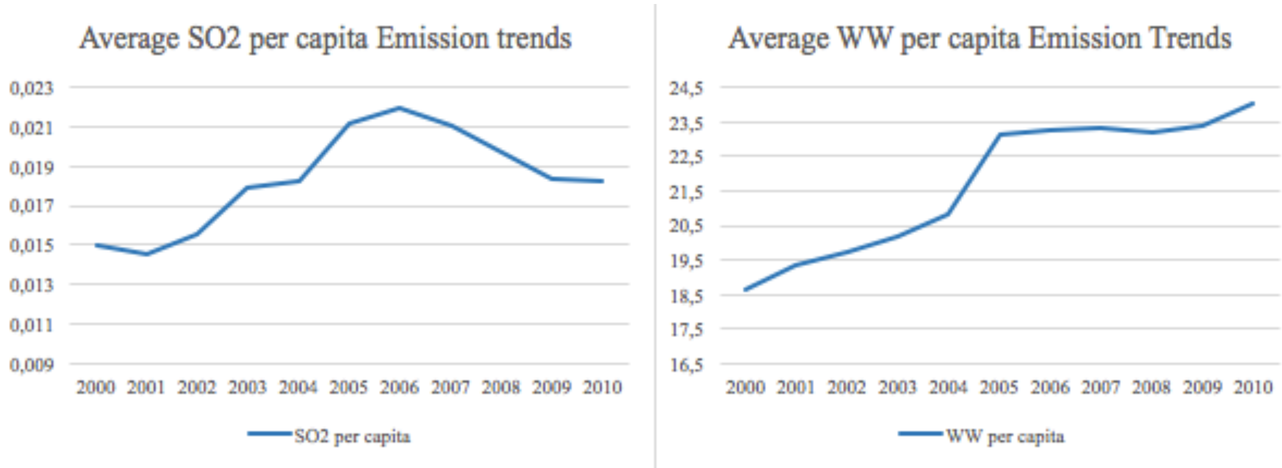


**Figure 4.2.4: SO2 and WW emissions in China 2000-2010**

Figure 4.2.4 graphs the cross-provincial SO2 and WW emission averages by year during the period 2000-2010, in which we can see a continuously increasing trend in toxic wastewater emissions and a non-linear trend for SO2 emissions overall. The highest levels of SO2 emissions per capita were found in Ningxia and lowest in Fujian, while the highest levels of toxic WW discharge per capita were observed in Zhejiang and lowest in Guizhou. However, the same does not apply when population size is unaccounted for.

As can be seen from the summary statistics table, there is considerable variation for all time series in the sample. It is also likely that some variables are moderately correlated, which may culminate into a multicollinearity problem. Multicollinearity results in abnormally large standard errors and distorts parameter estimates, which makes for difficult interpretation of individual effects (Wooldridge, 2009). To eliminate the possibility of multicollinearity amongst the contained variables, variance inflation factor (VIF) test is conducted prior to model estimation. The results of the VIF test confirmed multicollinearity to not be an afflicting problem within the group of variables used in the present study. The results of the VIF tests can be found in the Appendix, along with a correlation matrix of the included regressors.

## 4.3 ECONOMETRIC TESTING

The present study adopts annual panel data from 26 Chinese provinces over a 10-year period. The main advantage of using panel data, as opposed to cross-sectional or time series data, to study the effects of ownership on pollution, is the larger amount of data points and observations available, which consequently increases the overall degrees of freedom and decreases the presence of possible collinearity amongst the set of control and independent variables. As a result, the model is more efficient (Hsiao, 2003). Furthermore, as China has been developing at a very rapid rate, it is important to include a time dimension that captures the changes that have occurred over a 10-year period. Furthermore, including 26 provinces as separate observation units, as opposed to running a time series model on just China, allows us to account for individual heterogeneity, or province-specific effects; this is especially important in the case of China, as each province resembles an average country in size and in GDP. There are also considerable differences amongst the provinces in terms of the role and attitude of the provincial government towards pollution abatement, industry structure, private-sector involvement and more, which are certainly important in light of the focus of this study.

### 4.3.1 UNIT ROOT TEST

Intuitively, the present model is likely to have non-stationary variables, as certain data exhibits a time trend (e.g. growing number of private firms over time). A stationary model, with no predictable trend and constant statistical properties, is required for appropriate panel data estimation (Verbeek, 2004). In order to test for non-stationary time series, the Lewin-Lin-Chu (LLC) test is performed on all variables. The null hypothesis states that the time series has a unit root, and failure to reject the null implies non-stationary time series. By the augmented specifications of the test, the LLC test also assumes a common autoregressive (AR) parameter for all panels, by which all panels homogeneously either contain or do not contain a unit root for a specific variable.

After running the LLC test on all time series in the model, the results indicate that for five variables (WW emissions, GDP per capita, lawyers per capita, road traffic volume per capita and patents per capita) the series were non-stationary. As such, rejection of the null was possible with the remaining five variables: SO2 emissions, secondary school graduates per capita, share of heavy industry, urbanization level and SOE share. However, as most of the series were close to having a unit root and are likely to be highly persistent, thus exhibiting unit root-like behavior, it is best to treat the entire model for non-stationarity.

### 4.3.2 BENCHMARK MODELS

The results of the LLC tests confirmed that half of the contained variables were non-stationary, thus containing a unit root, while the remaining five were somewhat close to containing a unit root. A common way to treat non-stationary data is to to transform a series into *first differences.* If first differencing is enough to transform the non-stationary series into a stationary series, the series is said to be "integrated of order one" (Verbeek, 2004). Such is the case with the variables used in the present study, as running the LLC test on the first-differenced variables confirmed all series to be stationary.

To investigate the effects of industrial ownership on sulfur dioxide and toxic wastewater emissions, this study estimates the following baseline models:

$$(1)\ \Delta \ln(\mathrm{SO2pc})_{it} = \alpha_i + \beta_1 \Delta SOE_{it} + \beta_2 \Delta X'_{it} + \beta_3 YEAR + \varepsilon_{it}$$

$$(2)\ \Delta \ln(\mathrm{WWpc})_{it} = \alpha_i + \beta_1 \Delta SOE_{it} + \beta_2 \Delta X'_{it} + \beta_3 YEAR + \varepsilon_{it}$$

Models (1) and (2) are two-way fixed effects (FE) models, based on first differences, where Δ represents the first difference, and $\ln(SO2\_pc)_{it}$ and $\ln(WW\_pc)_{it}$ are the dependent variables across time (t= 1,….10) and provinces (i= 1,….,26). Constant $\alpha_I$ is the province-specific fixed-effect, and $SOE_{it}$ is the independent variable of interest at time *t* and cross-section unit *i*. X is a vector of control variables, containing *GDP per capita* and *GDP per capita$^2$, secondary school graduates per capita, patents per capita, road traffic per capita, lawyers per capita, share of non-agricultural population* and *share of heavy industry,* at time *t* and cross section *i.* Variable *YEAR* is further included in the model as a dummy variable to control for any time effects on the dependent variable and $\varepsilon_{it}$ is the error term which captures effects unexplained by the contained explanatory variables. Within this model, the natural logarithm has been applied to all contained variables, apart from the year dummy.

Next stage in the econometric testing includes making the model dynamic by including a lagged dependent variable. A lagged dependent variable as a regressor is likely to account for much of the serial correlation that would otherwise exist in the error term. The following regressions are adjustments to model (1) and (2), in which one-year lagged per capita sulfur dioxide ($ln(SO2pc)_{it-1}$) and wastewater emissions ($ln(WWpc)_{it-1}$) are included on the right-hand-side of the equation:

$$(1)\ \Delta \ln(SO2pc)_{it} = \alpha_i + \beta_1 \Delta\, ln(SO2pc)_{it-1} + \beta_2 \Delta\, SOE_{it} + \beta_3 \Delta\, X'_{it} + \beta_4 YEAR + \varepsilon_{it}$$

$$(2)\ \Delta \ln(WWpc)_{it} = \alpha_i + \beta_1 \Delta\, ln(WWpc)_{it-1} + \beta_2 \Delta\, SOE_{it} + \beta_3 \Delta\, X'_{it} + \beta_4 YEAR + \varepsilon_{it}$$

# CHAPTER 5: RESULTS

This chapter presents the main findings from the econometric testing of the models outlined in Chapter 4. The results are analyzed and various robustness tests will be carried out.

## 5.1 BENCHMARK RESULTS

Table 5.1 below displays the results of model (1), (2), (3) and (4), in which a two-way fixed-effects approach, based on first differences, is employed. Model (3) and (4) are dynamic FE models, in which a lagged dependent variable is included as a regressor.

**Table 5.1 Benchmark Results**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dep. Var. | Ln(SO2pc) | Ln(WWpc) | Ln(SO2pc) | Ln(WWpc) |
| *Lagged Dep. Var,* | - | - | -0.1235* | -0.1840** |
| | | | *(0.0612)* | *(0.0551)* |
| *SOE share* | 0.0091* | -0.0044* | 0.0157** | -0.0061* |
| | *(0.0082)* | *(0.0112)* | *(0.0074)* | *(0.0149)* |
| *GDPpc* | 4.5942* | 0.8234* | 5.9765* | 0.0383* |
| | *(0.2715)* | *(0.2602)* | *(.3216)* | *(0.2334)* |
| *$GDPpc^2$* | -0.2309** | -0.0527** | -0.2990* | -0.0158* |
| | *(0.1333)* | *(0.1328)* | *(0.1581)* | *(0.1201)** |
| *Graduatespc* | -0.0144* | 0.0042 | -0.0057* | 0.0068 |
| | *(0.1647)* | *(0.2208)* | *(0.1745)* | *(.2117)* |
| *Patentspc* | 0.0185 | 0.0346 | 0.0145 | 0.0562 |
| | *(0.0391)* | *(0.0810)* | *(0.0460)* | *(0.0800)* |
| *Lawyerspc* | 0.1037 | 0.1514 | 0.1044 | 0.1607 |
| | *(0.0891)* | *(0.0931)* | *(0.1209)* | *(0.1130)* |
| *Trafficpc* | 0.0157* | 0.0428 | 0.0252* | -0.0305 |
| | *(0.0281)* | *(0.0490)* | *(0.04662)* | *(0.0494)* |
| *Urb* | -0.1353 | -0.1595 | -0.5014 | -0.4182 |
| | *(0.1931)* | *(0.1061)* | *(0.4164)* | *(0.2531)* |
| *Heavyind* | 0.1305* | -0.0444 | 0.3205* | -0.3546 |
| | *(0.2562)* | *(0.2198)* | *(0.4416)* | *(0.3365)* |
| *Constant* | -0.0626* | 0.0163 | -0.0055 | 0.0215 |
| | *(0.0368)* | *(0.0425)* | *(0.0354)* | *(0.0524)* |
| R-squared | 0.3363 | 0.1040 | 0.3627 | 0.1437 |
| Observations | 260 | 260 | 234 | 234 |

Period and cross-section fixed effects.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
All variables are logged to generate desired linearity in parameters and for clearer interpretation of results.

In Models (1) and (2) the dependent variables *ln(SO2pc)* and *ln(WWpc)* are regressed on the independent variable of interest, *SOE share*, as well as on the set of eight control variables, as previously explained in section 4.2.3. Furthermore, the first-differences of all contained variables have been obtained prior to running the regressions. The components of Models (3) and (4) are identical to the components of Models (1) and (2), along with the inclusion of lagged dependent variables, $ln(SO2pc)_{it-1}$ and $ln(WWpc)_{it-1}$. The interpretation of first-differences is rather different from levels, but transforming all variables into logarithmic form makes for easier analysis. Econometrically, the difference of the natural logarithm of a variable is approximately equal to the growth rate of that series, so that the coefficients in table 5.1 indicate the effect on the dependent variable of a one-percent increase in the explanatory variable.

The independent variable of interest, *SOE share*, is statistically significant in the first non-dynamic models. That is, a greater share of SOEs, and thus a smaller share of private-sector involvement, is correlated with higher SO2 emission levels, as indicated by Column (1). Surprisingly, the effect is the opposite in the case of toxic wastewater emissions, where a lower SOE presence, or equally a higher share of private-ownership, is correlated with higher emission levels. In models (3) and (4), the independent variable, *SOE Share,* is statistically, and it again exhibits a negative relationship with wastewater emission and a positive relationship with SO2 emissions. Greater private sector involvement, as indicated by a smaller SOE share, is likely to be negatively related to atmospheric pollution of SO2, as suggested by models (1) and (3), and positively related to toxic wastewater discharge, as suggested by models (2) and (4). As such, the models imply that private enterprises may perform better in terms SO2 emissions in comparison to their state-owned counterparts, but not in terms of WW emissions.

Although the remaining variables are only control variables and are not entirely relevant to the focus of this study, it is worth mentioning some of their coefficients briefly. The variables for GDP per capita and GDP per capita squared are statistically in all models. *GDPpc* is significant at a 10% level in all models, and positively correlated with SO2 and WW emissions. On the other hand, $GDPpc^2$, exhibits a positive sign, meaning that there may exist an "income threshold" at which GDP levels are no longer associated with higher pollution. This has been studied in previous economic literature and also theorized by Grossman and Krueger (1994) with the infamous EKC hypothesis, which states that income and pollution exhibit a positive relationship at earlier stages development, and then turns negative once an economy has developed up to an income threshold. So provinces which are still at earlier stages of development may experience higher levels of SO2 and WW emissions, and provinces which are at higher levels of development are likely to be more dependent on the tertiary sector, which in turn pollutes less than primary and secondary sectors.

The volume of road traffic per capita, *Trafficpc*, is statistically significant in the case of SO2 emissions, in which higher road traffic volumes are associated with higher levels of SO2 in the atmosphere. However, *Trafficpc*, lacks statistical significance in the case of WW emissions. This relationship is rather intuitive, as vehicle fumes affect the atmospheric environment more than aquatic environments through toxic wastewater discharge. Similarly, the share of heavy industry, *heavyind*, is statistically significant and positively correlated with SO2 emissions, but negatively associated with WW emissions. This is in line with existing literature, which has identified manufacturing and agricultural industries as the biggest culprits of toxic WW emissions (China Ministry of Environmental Protection; The World Bank, 2012).

To shed more light on the inclusion of dynamic models, the current values of the dependent variable, $ln(SO2pc)_{it}$ and $ln(WWpc)_{it}$, are negatively associated with the respective one-year lagged variables in both models (3) and (4). Although a fixed-effects model with first-differenced variables occurs with a high risk of autocorrelation in the error term, transforming such a model in to a dynamic one has potential drawbacks as well. In addition to reducing the overall sample size, including lagged dependent variables (LDVs) is criticized in econometric literature for the reason that they may suppress the explanatory power of the other regressors. As such, LDVs may distort the results and incorrectly “dominate” over the influence of the other variables (Achen, 2001). Whilst it is important to acknowledge the concept of “dominant lagged variables”, the inclusion of $ln(SO2pc)_{it-1}$ and $ln(WWpc)_{it-1}$ appear to be statistically supported. After adding the LDVs onto the right-hand-side of the models, none of the coefficients collapsed into insignificant values. In fact, it appeared to do the exact opposite for most variables. Furthermore, the explanatory power, or the R-squared, increased in both models from 33.6% to 36.3% and 10.4% to 14.4% respectively. As for the LDVs, they are both statistically significant in Model (3) and (4), exhibiting a negative relationship with both pollutants. This may strike as surprising at first, but the negative effect could be explained by potential governmental initiatives to tackle high pollution figures. To add, as suggested by Model (3) and (4), past year’s SO2 and WW emissions have a negative effect on the current emissions, which could be explained by higher societal pressure and stronger governmental enforcement of pollution abatement efforts.

## 5.2 ROBUSTNESS TESTS

The robustness of the results obtained from the benchmark models in 5.1 are tested by subgrouping provinces by different criteria and by the inclusion of a lagged independent variable. The dynamic models (3) and (4) will be used hereafter to test for robustness, as the inclusion of lagged dependent variables improved overall estimation results.

### 5.2.1 SUBGROUPING BY NORTH AND SOUTH

The first supplementary analysis includes subgrouping provinces by whether they belong to "North" or "South" China, in order to examine whether further differences exist regionally. Figure A in the Appendix shows the exact regional categorization used to conduct this supplementary testing. After subgrouping, each region category consists of 13 administrative regions, which eliminates the threat of a smaller sample bias arising from unequal division.

The primary motivation for dividing the sample into northern and southern provinces lies in the apparent geographical and climatic differences between the two regions. During the years 2000-2006, SO2 emissions increased by 85% in North China, while South China only experienced a 28% increase. While both figures are high enough to cause concern, the considerably high emission growth in the North can be explained by a higher concentration of power plants and coal reserves in Northern China (Lu et. al., 2010). The entire power industry is highly regulated in China and many power plants have at least some share of state-ownership, which is a reason for why we can observe many SOEs in the North. Furthermore, coal consumption for heating and electricity is also the highest in North China, where winters are long and cold (Bradsher and Barboza, 2006).

In contrast, the provinces of South China revealed higher levels of toxic WW discharge per capita. This could be explained by larger agricultural and manufacturing sectors, both of which have been identified as biggest culprits of unsafe wastewater discharge. Furthermore, the share of population living in urban areas is on average higher in the south than in the north, thus exhibiting in higher levels of household wastewater originating from densely populated areas.

**Table 5.2.1a Estimation Results for SO2 after Subgrouping by "North" and "South"**

| | "North" | "South" |
|---|---|---|
| Dep. Var. | Ln(SO2pc) | Ln(S02pc) |
| *Lagged Dep. Var.* | -0.1392 | 0.0844 |
| | *(0.0847)* | *(0.1167)* |
| *SOE share* | 0.0317** | 0.0196* |
| | *(0.0129)* | *(0.0161)* |
| *GDPpc* | 12.346** | 2.839* |
| | *(4.4436)* | *(2.186)* |
| *$GDPpc^2$* | -0.6096** | -0.1253* |
| | *(0.2213)* | *(0.1007)* |
| *Graduatespc* | -0.6682* | -0.2272* |
| | *(0.3529)* | *(0.1165)* |
| *Patentspc* | 0.0026 | 0.0167 |
| | *(0.0511)* | *(0.0762)* |
| *Lawyerspc* | 0.0578 | 0.1439 |
| | *(0.0891)* | *(0.1485)* |
| *Trafficpc* | 0.0316* | 0.0213* |
| | *(0.0470)* | *(0.0267)* |
| *Urb* | -0.3976 | -0.40079 |
| | *(0.8876)* | *(0.4588)* |
| *Heavyind* | 0.6993* | 0.2292* |
| | *(1.467)* | *(0.4267)* |
| *Constant* | -0.0153 | 0.0525 |
| | *(0.0494)* | *(0.0380)* |
| R-squared | 0.4575 | 0.4860 |
| Observations | 117 | 117 |

Period and cross-section fixed effects.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
All variables are logged to generate desired linearity in parameters and for clearer interpretation of results.

Tables 5.2.1a and 5.2.1b display the regression results for regional SO2 per capita emissions and regional WW per capita emissions respectively. The independent variable of interest, *SOE share,* is statistically in both models estimating SO2 emissions. In the model for Northern provinces, *SOE share* takes on a value of 0.0317, which is significant on a 5% level, where as in the South, *SOE share* takes on a value of 0.0196, which is significant on a 10% level. This implies that, a larger public sector share (out of the total industry total) is positively correlated with SO2 emissions in both regions, but more strongly so in the North. More specifically, a one-percent increase in the SOE share results in a 0.03% and 0.02% increase in the volume of SO2 emissions in the North and South respectively, as suggested by the results in Table 5.2.1a. For toxic wastewater emissions, on the other hand, *SOE Share* took on a negative value in both regions and was statistically significant on a 10% level. This implies that a higher private sector share, in comparison, is correlated with higher WW emissions in both the North and the South, but more strongly so in the Southern provinces.

**Table 5.2.1b Estimation Results for WW after subgrouping by "North" and "South"**

| | "North" | "South" |
|---|---|---|
| Dep. Var. | Ln(WWpc) | Ln(WWpc) |
| *Lagged Dep. Var.* | -0.2640* | -0.1267 |
| | *(0.1377)* | *(0.0894)* |
| *SOE share* | -0.0020* | -0.0127* |
| | *(0.0099)* | *(0.0422)* |
| *GDPpc* | -3.920* | 5.811* |
| | *(4.4436)* | *(2.853)* |
| *$GDPpc^2$* | 0.1705* | -0.2898* |
| | *(0.0750)* | *(0.1656)* |
| *Graduatespc* | 0.0369 | -0.0048* |
| | *(0.2545)* | *(0.3174)* |
| *Patentspc* | 0.0026 | 0.1188 |
| | *(0.1511)* | *(0.1299)* |
| *Lawyerspc* | 0.1521 | 0.0859 |
| | *(0.2932)* | *(0.1324)* |
| *Trafficpc* | -0.0381 | 0.0129 |
| | *(0.0415)* | *(0.1280)* |
| *Urb* | 0.7285* | 0.4766* |
| | *(0.3572)* | *(0.2198)* |
| *Heavyind* | -0.4409 | -0.2583 |
| | *(0.8356)* | *(0.6833)* |
| *Constant* | 0.0538 | -0.0323 |
| | *(0.0648)* | *(0.0793)* |
| R-squared | 0.2665 | 0.1426 |
| Observations | 117 | 117 |

Period and cross-section fixed effects.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
All variables are logged to generate desired linearity in parameters and for clearer interpretation of results.

### 5.2.2 Excluding Municipalities

Mainland China has a rather complex political geography, in which the country is not just divided into 31 provinces, but some of the administrative regions are classified as autonomous regions and municipalities. Although the municipalities and autonomous regions are considered hierarchically equal to the 22 provinces, they differ considerably in other aspects. A detailed discussion of the political differences of the geographical units is beyond the scope of this study, but it is of interest to exclude municipalities from the model as a robustness test, in order to investigate whether they may have distorted the benchmark results. The four municipalities, namely Shanghai, Beijing, Tianjin and Chongqing, are geographically, politically and economically very different from the other provinces and autonomous regions in mainland China. The municipalities are under direct administration of the Chinese central government and are considered "higher status" cities, equally ranked with provinces (china.org.cn).

Furthermore, they have a high standard of living, as can be interpreted from GDP per capita figures, and are markedly smaller in land area than the other administrative regions.

**Table 5.2.2 Estimation results with municipalities excluded**

| | (3) | (4) |
|---|---|---|
| Dep. Var. | Ln(SO2pc) | Ln(WWpc) |
| *Lagged Dep. Var.* | -0.1600* | -0.1896 |
| | *(0.0817)* | *(0.0589)* |
| *SOE share* | 0.0194** | 0.0076 |
| | *(0.0087)* | *(0.0094)* |
| *GDPpc* | 6.0491* | 0.0497* |
| | *(4.4430)* | *(3.576)* |
| *$GDPpc^2$* | -0.3116 | -0.0236 |
| | *(0.2209)* | *(0.1928)* |
| *Graduatespc* | -0.0016* | -0.0244* |
| | *(0.1898)* | *(0.2371)* |
| *Patentspc* | 0.0474 | 0.0518 |
| | *(0.0573)* | *(0.1154)* |
| *Lawyerspc* | 0.0720 | 0.1951 |
| | *(0.1438)* | *(0.1456)* |
| *Trafficpc* | 0.0058* | -0.0319 |
| | *(0.0357)* | *(0.0609)* |
| *Urb* | 0.5106 | 0.3387 |
| | *(0.4252)* | *(0.2803)* |
| *Heavyind* | 0.2116* | -0.4032 |
| | *(0.8356)* | *(0.3808)* |
| *Constant* | -0.0165 | 0.0344 |
| | *(0.0401)* | *(0.0563)* |
| R-squared | 0.4189 | 0.1630 |
| Observations | 117 | 117 |

Period and cross-section fixed effects.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
All variables are logged to generate desired linearity in parameters and for clearer interpretation of results.

Table 5.2.2 depicts results obtained from model (3) and (4) with the four municipalities excluded from the sample. Overall, the SO2 model had higher explanatory power than the WW model, as indicated by a higher $R^2$ value, and also more statistically significant individual regressors. For the model predicting SO2 emissions, the explanatory power of *SOE share* as a single regressor increased from a value of 0.0157 in the benchmark model to 0.0194 after the four municipalities were excluded. That is, the independent variable of interest was positively and significantly associated with SO2 per capita emissions, but not with WW per capita emissions. In fact, for the WW per capita model, *SOE share* was no longer statistically significant. Another interesting finding, although not relevant to the research question at hand, is that *GDPpc* was statistically significant and positively correlated to SO2 and WW emissions, but $GDPpc^2$ was no longer statistically significant. A potential reason for this could be the fact that when the more economically developed municipalities are excluded from the sample, the sample is no longer sufficient to capture the effects of a higher level of income.

### 5.2.3 Subgrouping by Legal situation

The benchmark results revealed that, a larger public public sector share, or in contrast a smaller private sector share, is positively correlated with SO2 emission levels and negatively correlated with the emission of toxic WW. Strong legal institutions are likely to be associated with better pollution abatement efforts, as when laws are enforced on all levels of the government, enterprises face higher pressure to comply to pollution standards and environmental laws. Although the proxy representing the legal situation in a province, *the number of full-and part-time lawyers*, failed to deliver statistically significant results in all models, it is of interest to categorize the group of 26 administrative regions into provinces with "Above Average" and "Below Average" legal situation. The categories are constructed by taking the cross-provincial mean value of *lawyers per capita* and then dividing the sample group into provinces that fall below the average (i.e. "Below Average") and provinces that fall above the average (i.e. "Above Average") (See Figure B in the Appendix for exact categorization).

From the results obtained from the benchmark models, it is reasonable to hypothesize that, in provinces with better legal situations, the relationship between the share of private sector involvement on total SO2 emissions will exhibit a stronger negative effect than provinces with weaker legal situations. In other words, the *SOE share* would take on a value that is below its respective coefficient in the benchmark model. In terms of WW emissions, it can be expected that in provinces with better legal situations, *SOE share* will take on a "weaker negative" value, but potentially a larger negative value in provinces with weaker legal institutions.

**Table 5.2.3a Estimation results for SO2 after subgrouping by legal situation**

| | "Above Average" | "Below Average" |
|---|---|---|
| Dep. Var. | Ln(SO2pc) | Ln(SO2pc) |
| *Lagged Dep. Var.* | -0.0982* | -0.1024 |
| | *(0.1198)* | *(0.0876)* |
| *SOE share* | 0.0207* | -0.0189* |
| | *(0.0180)* | *(0.0089)* |
| *GDPpc* | 9.5313* | 2.4237* |
| | *(5.7693))* | *(3.3430)* |
| *$GDPpc^2$* | -0.4399* | -0.1314* |
| | *(0.2590))* | *(0.1707)* |
| *Graduatespc* | -0.8202* | 0.0523* |
| | *(0.4978))* | *(0.1714)* |
| *Patentspc* | -0.0438 | 0.0298 |
| | *(0.0881)* | *(0.0498)* |
| *Lawyerspc* | 0.6784 | 0.0359 |
| | *(0.2427)* | *(0.1571)* |
| *Trafficpc* | 0.0129* | 0.0365* |
| | *(0.0474)* | *(0.0334)* |
| *Urb* | -1.8654 | -0.5180 |
| | *(1.1496)* | *(0.4877)* |
| *Heavyind* | 1.3511* | 0.0239 |
| | *(1.0983)* | *(0.3974)* |
| *Constant* | 0.0674 | 0.0096 |
| | *(0.1306)* | *(0.0347)* |
| R-squared | 0.4821 | 0.4013 |
| Observations | 63 | 171 |

Period and cross-section fixed effects.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
All variables are logged to generate desired linearity in parameters and for clearer interpretation of results.

Table 5.2.3a depicts the results of the SO2 model after subgrouping the sample by legal situation. The independent variable of interest is, as expected, more positively correlated with SO2 emissions in provinces with stronger legal situations. That is, a lower private sector involvement (and thus higher public sector involvement) would result in higher SO2 emissions. This suggests that, in provinces with stronger legal situations, private enterprises have even better environmental performance in terms of SO2 pollution than nationally, when the sample is not divided by the strength of their legal institutions. In provinces with weaker legal situations, however, *SOE share* took on a negative value, in which a higher state-owned share of industrial enterprises (and thus lower private sector share) is associated with lower emission levels.

**Table 5.2.3b Estimation results for WW after subgrouping by legal situation**

| | "Above Average" | "Below Average" |
|---|---|---|
| Dep. Var. | Ln(WWpc) | Ln(WWpc) |
| *Lagged Dep. Var.* | -0.0323 | -0.2127*** |
| | *(0.1745)* | *(0.0576)* |
| *SOE share* | -0.1254*** | 0.0072 |
| | *(0.0317)* | *(0.0098)* |
| *GDPpc* | -6.2054 | 5.2851* |
| | *(5.7693))* | *(4.9446)* |
| *GDPpc*$^2$ | 0.2787 | -0.3095* |
| | *(0.1652)* | *(0.2692)* |
| *Graduatespc* | -0.2057* | 0.0210 |
| | *(0.1886)* | *(0.2429)* |
| *Patentspc* | 0.0048 | 0.0265 |
| | *(0.0654)* | *(0.1145)* |
| *Lawyerspc* | 0.1082 | 0.1552 |
| | *(0.2233)* | *(0.1532)* |
| *Trafficpc* | -0.1289 | 0.0516 |
| | *(0.0553)* | *(0.0687)* |
| *Urb* | 0.4791* | 0.5201* |
| | *(0.7581)* | *(0.2702)* |
| *Heavyind* | 0.6636 | -0.4972 |
| | *(0.8461)* | *(0.4117)* |
| *Constant* | 0.1081 | 0.0016 |
| | *(0.0690)* | *(0.0520)* |
| R-squared | 0.4929 | 0.1795 |
| Observations | 63 | 171 |

Period and cross-section fixed effects.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
All variables are logged to generate desired linearity in parameters and for clearer interpretation of results.

In terms of WW emissions, *SOE share* took on a negative value, as previously in the benchmark model, but only in the sample of provinces with "above average" legal situations, as depicted by table 5.2.3b. In provinces, with "below average" legal situations, the independent variable of interest was no longer statistically significant. More surprisingly, the variable *SOE share* has a much larger negative coefficient in the "above average" sample than in the benchmark model, which again suggests that SOEs have better environmental performance than POEs in terms of toxic WW emissions, and this difference is even stronger in provinces with better legal situations.

It is important to acknowledge that the number of lawyers alone is unlikely to be sufficient to fully capture the legal situation in a province, but it can evidently give a strong indication.

### 5.2.4 INCLUSION OF LAGGED INDEPENDENT VARIABLE

The final extension to the original models involves the addition of a one-year lagged term for the independent variable of interest, *SOE share*, in order to investigate potential effects on SO2 and WW that may occur with a time-lag. The share of SOEs have declined considerably alongside a growing private sector presence throughout China in the last decade; however, more so in some provinces than others. Industrial ownership effects are likely to extend beyond the time scope of one year- that is, the share of private enterprises, or in contrast the share of public enterprises, in the previous year may be correlated with the current emission levels of SO2 and WW. As such, it is of interest to examine this potential relationship. Table 5.2.4 depicts the estimation results of models (5) and (6), which are the benchmark dynamic models (3) and (4) amended with an additional regressor, *Lagged SOE share*. This variable was also first-differenced to correct for non-stationarity, as done with the components of the benchmark model. Atmospheric pollution and wastewater discharge is a relatively direct effect from current economic and structural factors, which is why it is not of interest to include multiple year lags on the independent variable. Furthermore, for the same reason, it is not of interest to include lagged terms for the control variables, especially since most of them are rather slow-changing institutional elements and are not likely to vary considerably in consecutive years.

As can be observed from Table 5.2.4, the current and lagged *SOE share* variable is statistically significant and positively correlated with current SO2 emissions. Although the current variable for *SOE share* has a larger coefficient, the lagged term is statistically more significant, which also argues in favour for its conclusion. In the WW model, neither the current or lagged value of the independent variable are statistically significant, unlike in the benchmark model, where *SOE share* was negatively correlated with SO2 emissions. In other words, by the inclusion of the the lagged independent variable, the current and past share of SOEs no longer had a statistically significant effect on WW emissions in the given model. As can be concluded from the results of model (5), however, is that the share of SOEs in the previous year are positively associated with current SO2 emissions, but current share of SOEs still possess a greater explanatory power. SO2 particles in the have rather life cycles, so the SO2 volumes may not exist in the atmosphere long enough for us to observe lagged effects arising from the production activities of industrial enterprises in the previous year (Lu et al., 2010).

**Table 5.2.4 Estimation results for SO2 and WW with a lagged independent variable**

| | (5) | (6) |
|---|---|---|
| Dep. Var. | Ln(SO2pc) | Ln(WWpc) |
| *Lagged Dep. Var.* | -0.1312** | -0.1867*** |
| | *(0.05982)* | *(0.0559)* |
| *SOE share* | 0.0340* | 0.0098 |
| | *(0.0182)* | *(0.0141)* |
| *Lagged SOE share* | 0.0475*** | 0.0026 |
| | *(0.0099)* | *(0.1100)* |
| *GDPpc* | 6.1646* | -0.0349 |
| | *(3.1935)* | *(2.3476)* |
| *$GDPpc^2$* | -0.3104* | -0.0238 |
| | *(0.1570)* | *(0.1209)* |
| *Graduatespc* | -0.0018* | 0.0083 |
| | *(0.1763)* | *(0.2132)* |
| *Patentspc* | 0.0111 | 0.0579 |
| | *(0.0467)* | *(0.0812)* |
| *Lawyerspc* | 0.0994 | 0.1583 |
| | *(0.1187)* | *(0.1131)* |
| *Trafficpc* | 0.0307* | 0.0277 |
| | *(0.0267)* | *(0.0488)* |
| *Urb* | -0.1268 | 0.1494* |
| | *(0.1816)* | *(0.1168)* |
| *Heavyind* | 0.2285 | -0.1565 |
| | *(0.2784)* | *(0.2051)* |
| *Constant* | 0.0010 | 0.0267 |
| | *(0.0362)* | *(0.0561)* |
| R-squared | 0.3647 | 0.1409 |
| Observations | 234 | 234 |

Period and cross-section fixed effects.
Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
All variables are logged to generate desired linearity in parameters and for clearer interpretation of results.

# CHAPTER 6: CONCLUDING REMARKS

Economic growth that puts the rest of the country off-balance is unsustainable in the long run; yet, far too many countries have pursued economic growth at the expense of the environment during the early stages of development. Neglecting environmental considerations from the onset results in costly long-run effects, including decreased population health and ecological destruction. In developing countries like China, where legal institutions are deficient, the grim truth is that it is often cheaper to pollute than to invest internal funds into environmental clean-up projects and greener machinery in the short term (Hu, Tan and Lazareva, 2014). Pollution fines are not enforced, and it is cheaper for companies to discharge untreated wastewater and harmful atmospheric pollutants than to install and invest in newer and cleaner production equipment and pollution treatment systems (Jiang et al., 2014; Hu et al., 2014). Enterprises lack the incentives to control their emissions, which transmit to large-scale pollution problems, as can be observed throughout China (Florig et al., 1995). It is no surprise that China is the largest SO2 emitter in the world, contributing to 50% of the Asian total and 25% of the global total in SO2 emissions (Streets, Yarber, Woo and Carmichael, 2003; Lu et al., 2010). In addition, untreated, toxic wastewater has been identified as the most problematic environmental issue of today in China, after decades of disregard for wastewater treatment (Hughes, 1997).

China's industry has been recognized as the biggest source of SO2 and wastewater emissions, contributing to 70% and 72% of total emissions of each pollutant respectively (Dasgupta, Wang and Wheeler, 1997). However, empirical literature is inconclusive on how, and whether, the legal status of enterprises affects environmental accountability. Furthermore, to my knowledge, no studies to date have investigated the effects of industrial ownership compositions on provincial-level SO2 and wastewater emissions in China. In a country where private sectors have grown rapidly over the last few decades, it is both relevant and important to investigate whether private sector growth has occurred at the expense of the environment, or whether private enterprises outperform public enterprises in environmental performance.

In answering the focal question of how industrial ownership affects cross-provincial environmental conditions in China, the results of the present study indicate the following: a higher share of state-owned enterprises are positively associated with SO2 emissions, and negatively associated with toxic wastewater emissions. In other words, it suggests that, in provinces with larger private sector shares, SO2 emissions are likely to be lower than in provinces with smaller private sector shares. The opposite is true for wastewater emissions, as the results suggest that total wastewater emissions are likely to be higher the greater the greater the private sector involvement, and vice versa. Although the present paper looked at the relationship of ownership and pollution from a broader perspective, e.g. on a provincial level, the results further imply that POEs have better environmental performance than SOEs in terms of SO2 emissions, but potentially worse wastewater treatment practices than SOEs.

As such, the initial hypothesis was partially confirmed with the results of this paper. The results are, to some extent, in line with the findings of Wang and Wheeler (2003), Wang and Jin (2007), Jiang et al. (2014) and Lu and Chan (2016), whom found SOEs to have worse environmental performance, on a firm-level, than private enterprises in China. Furthermore, the main results were robust to several model extensions, which included subgrouping the observation sample by the quality of the legal situation, as well as splitting the sample into provinces that are geographically located in the north and in the south, by excluding municipalities from the sample completely and by including a lagged independent variable.

Regardless of whether public or private enterprises pollute more, China's current pollution catastrophe calls for better law enforcement and for the improvement of existing property rights policies, thereby directly addressing the problem of weak institutions and deficient managerial incentives in adopting pollution control measures.

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# APPENDIX

## Table A: Results of VIF test

| Variable | VIF | 1/VIF |
|---|---|---|
| *GDPpc* | 48.53 | 0.020605 |
| *GDPpc2* | 47.58 | 0.021017 |
| *Graduatespc* | 1.30 | 0.766455 |
| *Patentspc* | 1.12 | 0.891675 |
| *Lawyerspc* | 1.10 | 0.912689 |
| *Trafficpc* | 1.09 | 0.915987 |
| *Heavyind* | 1.08 | 0.928159 |
| *SOE share* | 1.04 | 0.965956 |
| *Urb* | 1.01 | 0.986452 |

## Table B: Correlation Matrix of contained variables

| | ***SOE share*** | ***GDPpc*** | ***GDPpc2*** | ***Gradpc*** | ***Patentspc*** | ***Lawyerspc*** | ***Trafficpc*** | ***Urb*** | ***Heavyind*** |
|---|---|---|---|---|---|---|---|---|---|
| ***SOE share*** | 1.0000 | | | | | | | | |
| ***GDPpc*** | -0.1339 | 1.0000 | | | | | | | |
| ***GDPpc2*** | -0.1278 | 0.9850 | 1.0000 | | | | | | |
| ***Graduatespc*** | 0.0139 | -0.0536 | -0.1330 | 1.0000 | | | | | |
| ***Patentspc*** | 0.0187 | 0.1141 | 0.1596 | -0.1851 | 1.0000 | | | | |
| ***Lawyerspc*** | 0.0620 | -0.1445 | -0.1048 | -0.0395 | 0.0706 | 1.0000 | | | |
| ***Trafficpc*** | -0.0555 | 0.1782 | 0.2085 | -0.0746 | 0.0421 | 0.1036 | 1.0000 | | |
| ***Urb*** | 0.0201 | 0.0406 | 0.0308 | 0.0734 | 0.0228 | -0.0058 | -0.0198 | 1.0000 | |
| ***Heavyind*** | 0.0784 | 0.1163 | 0.0928 | 0.1220 | -0.1365 | -0.1124 | -0.0682 | -0.0413 | 1.0000 |

## Table C: Benchmark Results with no first-differences

| | (1) | (2) |
|---|---|---|
| Dep. Var | Ln(SO2pc) | Ln(WWpc) |
| *SOE share* | 0.0388*** | 0.0191 |
| | *(0.014)* | *(0.0282)* |
| *GDPpc* | 0.5469* | 2.1319* |
| | *(0.8497)* | *(0.0816)* |
| *$GDPpc^2$* | -0.0200* | -0.0816* |
| | *(0.0385)* | *(0.0871)* |
| *Graduatespc* | 0.1130 | -0.1989* |
| | *(0.1328)* | *(0.2951)* |
| *Patentspc* | -0.0480 | 0.0247 |
| | *(0.0917)* | *(0.0810)* |
| *Lawyerspc* | -0.3893** | -0.0241* |
| | *(0.1879)* | *(0.2720)* |
| *Trafficpc* | 0.1908** | -0.1505 |
| | *(0.0753)* | *(0.0827))* |
| *Urb* | 0.0944 | 0.2874* |
| | *(0.2999)* | *(0.3548)* |
| *Heavyind* | 0.1050 | -0.3968 |
| | *(0.3621)* | *(0.3907)* |
| *Constant* | -10.6841** | -7.6676 |
| | *(4.650)* | *(3.648)* |
| R-squared | 0.5510 | 0.3084 |
| Observations | 286 | 286 |

Period and cross-section fixed effects.
Robust standard errors displayed in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

*Results prior to first-differencing do not account for non-stationary time series, and this results in a spurious regression, in which the results are biased and inaccurate.

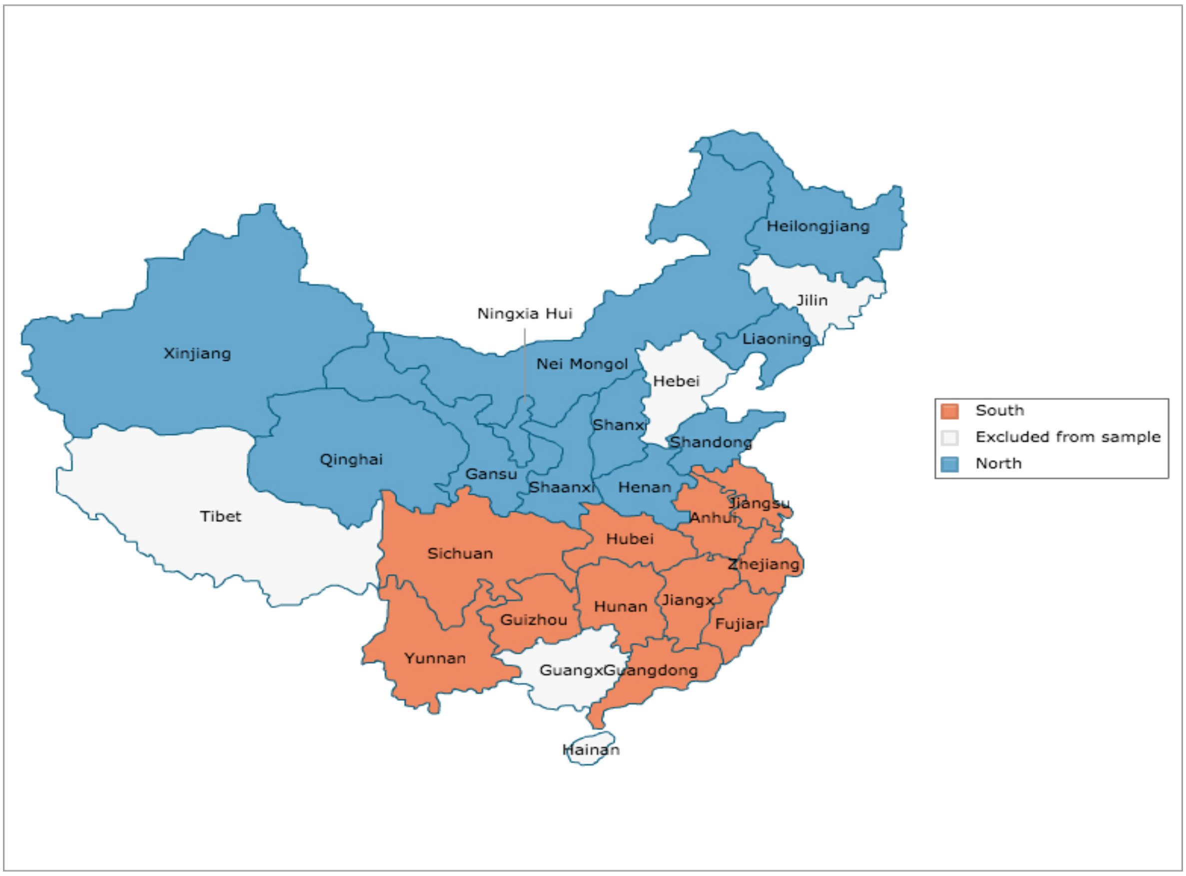


**Figure A: Subgrouping regions by "North" and "South".**

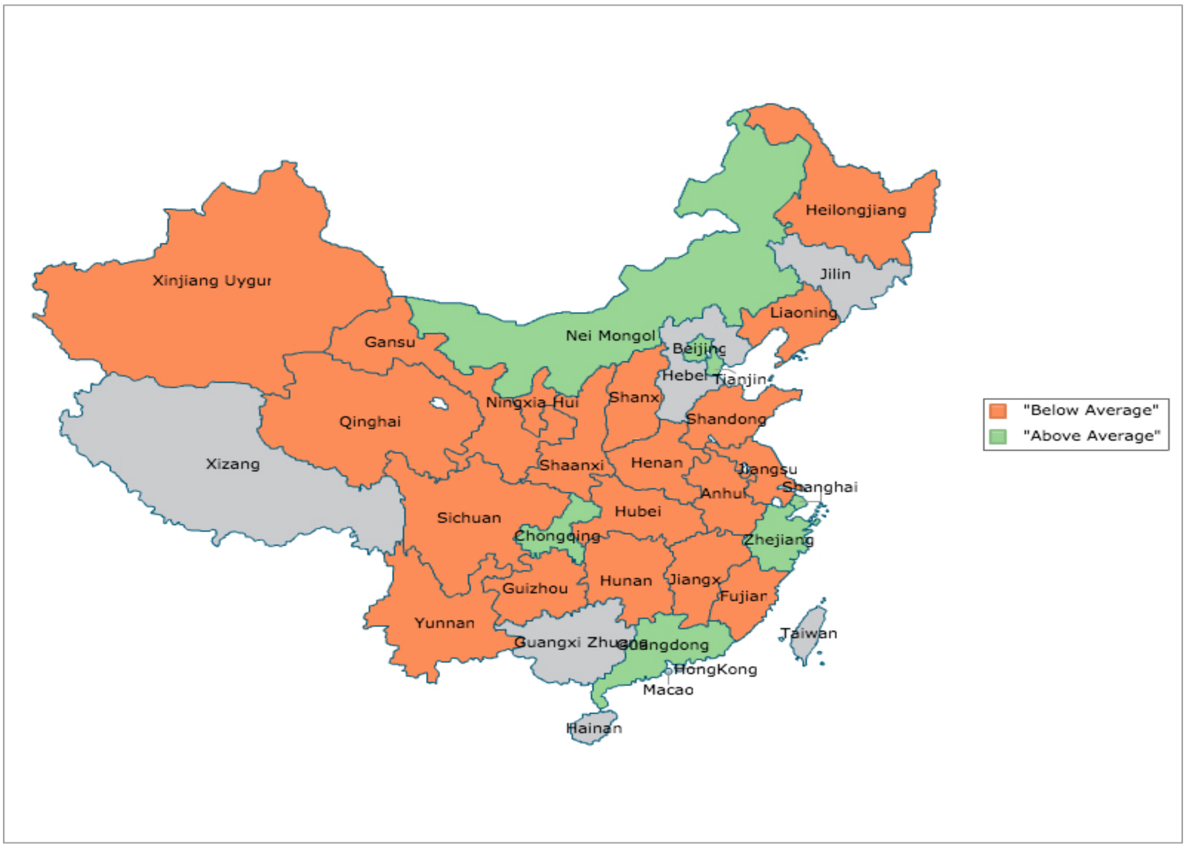


**Figure B: Subgrouping by legal situation**