UNIVERSITY OF CALIFORNIA SAN DIEGO

Corporate Concentration and Air Pollution Governance in China

A dissertation submitted in partial satisfaction of the
Requirements for the degree Doctor of Philosophy

in

Political Science and International Affairs

by

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2018

The Dissertation of Deborah Jane Seligsohn is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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University of California San Diego

2018

DEDICATION

To my mother
Ann D. Seligsohn
who sparked my interest in the world

and
in memory of my father
Walter I. Seligsohn
whose words I still hear in my head every time I write

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LIST OF ABBREVIATIONS

AQSIQ	Administration of Quality Supervision, Inspection and Quarantine
CCP	Chinese Communist Party
CDU	Crude distillation facility
CEMS	Continuous Emissions Monitoring System
CNOOC	China National Offshore Oil Corporation
CNPC	China National Petroleum Corporation
CO_2	Carbon dioxide
DPF	Diesel particulate filter
DV	Dependent variable
EIA	Environmental impact assessment
EPA	Environmental Protection Agency (United States)
EPB	Environmental Protection Bureau
FGD	Flue gas desulfurization
GDP	Gross domestic product
Genco	Power generation company
GHG	Greenhouse gas
GW	gigawatt
HHI	Herfindahl Hirschman Index
IV	Independent variable
MEP	Ministry of Environmental Protection
MLR	Ministry of Land and Resources
MOE	Ministry of Energy

MPI	Ministry of Petroleum Industry
NBS	National Bureau of Statistics
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NO_x	Nitrogen oxides
PM 2.5	Particulate matter of less than 2.5 microns
SASAC	State-owned Assets Supervision and Administration Commission
SCR	Selective catalytic reduction
SEPA	State Environmental Protection Administration
SERC	State Electricity Regulatory Commission
SETC	State Economic and Trade Commission
SINOPEC	China Petroleum and Chemical Corporation
SO_2	Sulfur dioxide
SOE	State-owned enterprise
SPC	State Power Corporation
SDPC	State Development Planning Commission
ULE	Ultra-low emissions
USEIA	United States Energy Information Administration
VOC	Volatile organic compound

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ABSTRACT OF THE DISSERTATION

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Overall air quality in China has improved for six consecutive years (Krotkov et al 2015). A little-studied aspect of pollution control in China is that the source of air pollution is dominated by heavy industry and that improvements have varied by sector. In my dissertation, I assess how corporate governance and competition policy has proven to be a useful tool for improving environmental compliance. Through case studies using both large N statistical analysis and in-depth interviews, I provide an empirical story that substantiates that as energy sectors have become more competitive, the Chinese government is able to impose stricter air quality standards and to enforce them more effectively. Monopolies avoid regulation through their control of information and of market supply of an essential commodity. By contrast, if

the government breaks the monopoly, suppliers compete not just to sell product but also on compliance in order to gain permits and other government-issued advantages.

Chapter 1 Introduction: Corporate Concentration and Corporate Capture

Air pollution in China has become notorious, but what was little noticed was that just at the moment when public attention was most focused on air pollution, with the first of the major public outcries about an "air-pocalypse"[1] – an extreme poor air pollution event lasting days – in 2012, air pollution in China had already peaked and was on the decline (Krotkov et al. 2015). Total air pollution in China, as measured by satellite, actually peaked in 2011. When pollution levels are many times the World Health Organization recommended levels, as was the case in China, a single year's drop is not sufficient for the public to notice (Greenstone and Schwartz 2018). Policies to turn around the air quality problem had actually been initiated years before. It takes years to retool entire industries. Regulation needs to be adopted, enforcement organized, equipment manufactured, retrofits designed and the actual equipment installation staggered to avoid shortages. Thus, the question that needs to be addressed is what helped China to turn the corner and start to regulate air pollution well before the public became concerned?

To begin to answer that question it is worth taking a look at the decline in sulfur pollution, one of the major pollutants from both coal and oil. As seen in figure 1, sulfur began its now considerable decline in 2007, long before the public outcry about air pollution began. The key to the decline was a change in power sector regulation that forced the installation of flue gas desulfurization (FGD) equipment in China. That first change was not enough, and we

[1] Jamil Anderlini, "A Year in a Word: Airpocalypse – China is Getting Airy Ambitions," *The Financial Times* (December 30, 2013). https://www.ft.com/content/a5553e6a-671f-11e3-a5f9-00144feabdc0 and Jonathan Kaiman, "Chinese Struggle Through 'Airpocalypse' Smog," *The Guardian* (February 16, 2013). https://www.theguardian.com/world/2013/feb/16/chinese-struggle-through-airpocalypse-smog Both articles introduce the term to their readers as a new portmanteau word among internet users.

do see a rise in sulfur from 2010 to 2011. We then see a further decline as even tougher standards in the power sector, and ultimately in the oil and gas sector, as well, forced even more considerable equipment upgrades. Those 2011 regulations were sufficient to ensure a

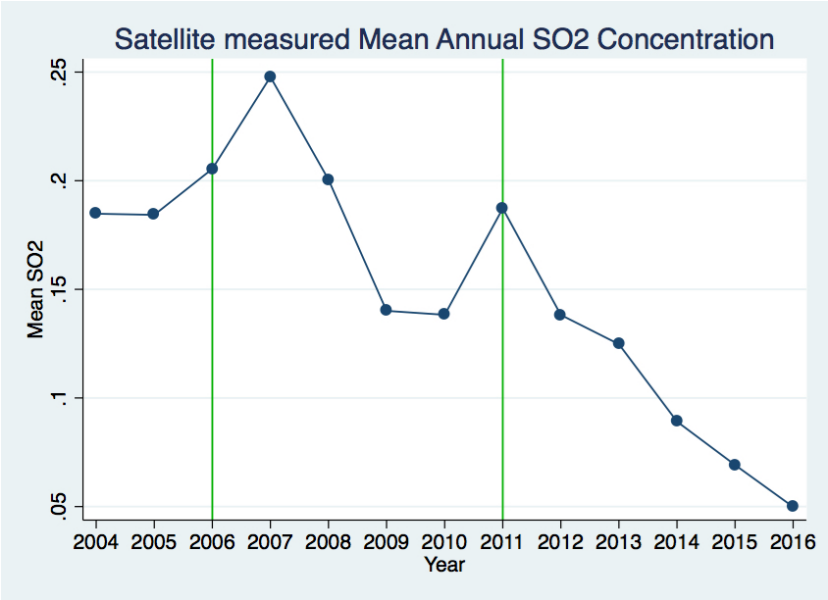


Figure 1: Annual Average Atmospheric Sulfur Concentration

peak in all forms of air pollution. While still hardly clean today, China is now on a trajectory toward clean air.[2]

High levels of pollution were to be expected. Public goods provision is a challenge in any society, because the market alone will undersupply. But this challenge is magnified in an autocracy, where we can expect the government to be unresponsive to public opinion, to prefer to supply private goods to the ruling coalition rather than public goods (Olson 2000, Bueno de Mesquita et al 2005), and that to the extent that the Chinese government does care about the public, it would perceive its interest to be in producing development and economic gains at all costs (Li and Zhou 2005, Guo 2007, 2009). The environmental literature has

[2] Steven Lee Myers, "A Blue Sky in Beijing? It's not a Fluke, Says Greenpeace," New York Times (January 11, 2018). https://www.nytimes.com/2018/01/11/world/asia/pollution-beijing-declines.html

therefore focused on China's past failures (Shapiro 2001, Economy 2011) or how to muster outside groups to influence environmental change (Ho 2001, Stern 2010, Tan 2014, Li et al. 2017, Dai and Spires 2018, Teets and Almen 2018, Wang 2018). The literature acknowledges, however, that these groups to date are weak, and in many cases (Teets and Almen 2018) their influence may be waning. Thus, the interesting question is not so much how China got to where it was in 2011, with horrendous air pollution blanketing not just its cities, but much of its populous countryside, but how it has been able to turn this ship around.

China's recent progress in curbing air pollution, therefore, presents a puzzle. How has an autocratic government significantly reduced air pollution, with one major pollutant (sulfur dioxide or SO_2) peaking in 2007, and another in 2011 (nitrogen oxides or NO_x, Krotkov et al 2016)? Strikingly, these trends predate the very public air-pocalypse events of 2012-2013 and have taken place not just in the small number of cities with civil society organizations but throughout the country. A critical change has been industry structure, which has shifted from single state monopolies to competitive state-owned enterprises (SOEs). This dissertation shows how as a competitive sector, even state-owned, provides government with leverage to strengthen regulations and enforce them.

A striking and to date overlooked aspect of Chinese pollution abatement has been how it has proceeded industrial sector by industrial sector. The history of the Chinese bureaucracy is one of separate industrial bureaucratic fiefdoms, which in many cases were simply reorganized from ministries into state-owned enterprises (Naughton 1992). Given this history it might be intuitive that the Chinese state would need to conquer these fiefdoms one by one. But most literature focused on Chinese pollution and the environment has instead focused on other components of governance, specifically on the role of local government and variation

among localities, on the attributes of individual firms, including their ownership, or on the role of civil society and non-governmental organizations.

This dissertation looks instead at the structure of industry itself. While localities perform differently, this geographic variation itself occurs within in specific sectors. Air quality improvements between 2005 and 2011 relied almost entirely on improvements in the power sector (Schreifels et al 2012), and pollution abatement in the power sector has continued through the present to be a major contributor to overall improvements. Laggards as well as leaders have been defined by their sector. As air quality improvements have continued they can be traced the adoption and enforcement of new industry-specific standards. Moreover, these improvements extend across types of ownership, including in large part the state sector that is assumed to be toughest to reform. To a significant extent environmental change is by nature sector-specific, because any improvement begins with a tightening of standards, most of which are highly technical and written for the sector in question. Only once there are tough standards can the government start to enforce meaningful compliance.

Sectoral change is, thus, critical to understanding environmental enforcement. The Chinese story of the last forty years has been one of massive change in industry structure associated with economic reform. Firstly, industry became corporatized. Corporate interests were separated from ministerial interests, and a regulatory state was introduced. These measures were not necessarily complete, but they were both significantly different from the pre-1978 nature of government-run industrial enterprises in China, and they continued to transform over the course of the reform period, providing for considerable variation in the nature of sectoral industrial structure. The reform period began with very little competition. This was due to not only to the ministry structure that managed from the top, including state

planning, but to the way the Chinese government had assigned industrial enterprises to separate geographic areas that generally did not operate or complete outside their home region, both as a matter of policy and due to limited transportation. Reform brought the opportunity for greater competition as enterprises could reach across geographic boundaries, transport improved, and the central government decided to break up some monopolies. At the same time the number of players was also often reduced through government action, both forced mergers and the forced closures of small, often inefficient enterprises.

Industrial structure is thus one of the major variables at play in Chinese industrial behavior. As these industries have faced a regulatory state they have done so within specific structural arrangements that have varied over time and location. This is especially true of the largest polluting industries – power and oil and gas. Moreover, the Chinese state has traditionally interacted with industries as groups – whether through trade associations or ministerial consultative processes. The structure of the industry was, therefore, critical to the structure of the relationships. In considering how regulation has been brought into effect, both the legal infrastructure and subsequent enforcement, we need to consider how the state interacted with the regulated industries. Fundamental to this consideration is whether the state is captured by industry.

Capture has long been recognized as a critical issue in whether governments regulate firms effectively. In the Chinese case, there has been a general assumption that SOEs have more political power with government than private firms (Lorentzen et al 2013, Y Wang 2015, Eaton and Kostka 2017) and therefore more easily avoid government regulation. However, ownership seems unlikely to be the critical variable when we consider that the heavily state-owned power sector dramatically increased its compliance with air pollution

regulations since 2005, while other state-owned sectors, such as oil and gas, were much slower to improve. Rather than simply looking at state-ownership or the size of companies, an approach that speaks much more directly to the mechanism involved in state capture is to focus on the level of concentration within the industry. A heavily concentrated industry with just a few players is more effective at influencing government, not just through coordinated lobbying, but by controlling information (Cai 2015). Supply and cost information is particularly critical for government regulation of the energy sector, because the public is sensitive not just to pollution, but even more to cost and to shortages.

This dissertation contributes both to our understanding of autocratic governance and to the problem of environmental regulation in transition economies. It adds to the public goods literature on China by moving beyond the village level to thus far less explored large-scale industry (Tsai 2007, Xu and Yao 2015). It adds to the literature that considers effective governance separate from elections (Norris 2012). It moves beyond a story of simple regulatory capture (Y Wang 2017, Eaton and Kostka 2017) to find that a capture model in an autocracy can encompass a full range of strategic behavior by both regulator and polluter. It will add to our understanding of environmental regulation by exploring how industrial structure critically affects this power dynamic, and the tools that companies use to try to control the state, most critically the risk of energy shortages.

State Capture:

When there is no dividing line between government and firms, we can expect no effective regulation. When the functions are separated, we can expect a much more complex relationship, where regulatory capture involves efforts by firms to shape regulation to gain a

competitive advantage. The Chinese case involves changes over time in industrial structure as state owned firms were corporatized and firm entry and exit became more fluid. This offers an excellent opportunity to test how changes in industrial structure affect the implementation of environmental regulation.

The theory that state regulatory systems will be captured by the industries they regulate is well-established within the political science literature. In the classic Stigler-Peltzman model there is a balance between the votes from the public (for regulation) and the private payoffs from regulated industry, either to simply avoid regulation or to shape regulation to benefit incumbents (Stigler 1971, Peltzman 1989). Alternative theories emphasize the power of legislatures to shape regulatory bodies (Carrigan and Coglianese 2011) and the interests, including prestige, of the regulatory bureaucrats themselves (Carpenter 2014). Nevertheless, if we apply the Stigler-Peltzman model directly to an autocracy, we would derive an expectation of complete capture, as there are no voters to counteract the influence of business (Hellman et al 2003). This expectation of complete capture aligns the general expectation that autocracies fail to supply public goods like clean air. When ministries directly administered factories in China in the pre-reform period, we saw this result in full, with essentially no environmental regulation.

Despite the structural change in the 1990s to firms with independent management structures, political analysis has focused more on the relationship between government actors. The interaction between the center and localities was described as fragmented authoritarianism (Lieberthal 1995, Saich 2010) with the different levels of government engaged in constant negotiation (Lieberthal and Lampton 1992). If local governments support central policy, as in the development of the auto sector, for example, the argument then is that

this fragmented approach can lead to effective government-business coordination (Thun 2006). But the story is different when business and local governments might both be concerned about the costs of compliance. Fragmented authoritarianism applied to environmental policy led first to a large literature arguing that local governments were essentially incapable of implementing central policy (Economy 2011, Harris 2004, Shapiro 2001, Kostka 2014, 2016). It also led to arguments that the essential corrective was civil society, whether through civic, often collaborative means (Ho 2001, Xie 2011, Teets 2013) or a more legalistic approach (Stern 2010, A Wang 2013, X Wang 2016, Tan 2014). However, the argument for civil society was essentially an argument that environmental change would need to wait as government has continued to constrain the development of non-governmental organizations and the legal system. Yet, we have seen improvements despite increasing autocracy and weak civil society.

Since regulatory capture depends on the political behavior of firms, Occam's Razor suggests where we have seen capture in the past we should look carefully at firm behavior. The roots of firms' influence on government policy go back to the pre-corporatized days. As Lieberthal and Oksenberg (1988) described in their classic study of Chinese policy-making, the expectation in the Chinese system was that bureaucracies would advocate for their own interests. When these very ministries get turned first into single monopolistic firms and then broken up into competing firms the expectation that government will consult with them does not change, as Pearson (1997) shows in the 1990s. Kennedy (2005) brings in more firm-specific behavior, documenting active lobbying by the firms in the manner that one would expect from a business interest, distinct from a bureaucratic interest. Interestingly enough for our case, he sees the environment as an area where lobbying did not occur. As I'll discuss

below, this is likely due to the years in which he collected his data, right after the breakup of the power sector.

Increasingly literature has found a more complex system than simply fragmented authoritarianism. As Shih (2008) argues with regard to the financial system, when the central government wants to achieve a goal, it has tools at its disposal. Similarly, Landry (2008) details how the central government uses the personnel system to manage its decentralized bureaucracy. These are important tools, and indeed we have seen how the Chinese central government has used everything from green finance (Bai et al 2014) to personnel decisions (A Wang 2013, Zheng et al 2014) to plan targets (Kostka 2014) to attempt to improve environmental quality.

A Model for Environmental Regulatory Relations:

When government wishes to increase air pollution abatement, the major interaction is between government and firms. Building on the consideration of government capture (Y Wang 2017, Eaton and Kostka 2017) and business lobbying practice (Kennedy 2005) I posit that industry structure is the key variable that explains (1) at the national level when key pollution standards where drafted and adopted, and (2) at the provincial level when and where abatement takes place.

The main actors in the model are:

Government, specifically, the standard-setting and environmental regulatory apparatus. In China this consists of the Ministry of Environmental Protection (MEP), which enforces environmental laws, and drafts and enforces standards and regulations and the

General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), responsible for the overall standard-setting process. Standard-setting is the complex and essential step needed before any law can be implemented and enforced. MEP has the lead in setting overall air quality standards, but the achievement of air quality goals requires industry-specific emissions and product standards. These industry-specific standards generally involve detailed work within industry-connected research organizations, as well as input from MEP, before they are ultimately approved at the State Council level. Moreover, the standards review process involves input from a variety of stakeholders, crucially including industry representatives, but also technical experts and government officials. Environmental enforcement is more exclusively the responsibility of MEP through provincial and local bureaus. Enforcement includes both regularly monitoring air pollution emissions and sanctioning any emissions in excess of allowable limits and reviewing environmental impact assessments (EIAs), a critical step in receiving permits for new facilities.

Large industrial sectors face additional regulations from a range of ministries, including the National Development and Reform Commission (NDRC), the National Energy Administration (NEA), the State Electricity Regulatory Commission (SERC, for power only), the Ministry of Land and Resources (MLR) among others. Critical constraints include permitting for new pipelines and facilities, operating licenses, prices (set by NDRC) and the electricity dispatch rules (set by SERC), which determines the priority order for taking power onto or off the grid. Thus, energy companies have complex relationships with a range of regulatory actors.

The government has varied interests. Clearly, as with any government its own survival is paramount. In establishing its strategy for maintaining power, the government prioritizes

social stability and economic growth. Nonetheless, environmental protection has become a much larger part of its overall strategy. In 2006 "Energy Efficiency and Environmental Protection" was named a National Policy (国策), one of only three such policies.[3]

Firms. The actors that must comply or find strategies for avoiding regulation. Firms in China vary in terms of their ownership, from state-owned, to foreign-invested to private. For the most part heavy industry is state-owned, and this is particularly true of the energy sector. Oil companies are entirely state-owned, and more than 90% of power generation is also state-owned. In fact, the percentage of non-SOE in the power sector has declined in recent years.

Chinese firms have a number of interests, of which perhaps the greatest is survival. SOEs can be restructured by government decree, generally with larger firms ordered to absorb smaller ones. Thus, there is often a premium for increasing market share and ensuring in the case of a merger that the firm be the larger of the entities in the merger.

Beyond surviving, generating both revenues and profits confers great benefits to the firm and its managers, both for their personal benefit and to help them in their quest for promotions within the Chinese system. SOE managers are promoted within the government's bureaucratic system. While many managers spend years within a single SOE, some move between companies and government. Moreover, top SOE directors regularly move from SOEs to ministry or provincial leadership.[4] Profits and revenue are important, because of the priority

[3] The other two are Reform and Opening, the comprehensive transformation of the Chinese economy that began with Deng Xiaoping in 1979, and Family Planning, the famous "one child policy," described recently by the journalist Mei Fong as "China's most radical social experiment." Given the effort that has gone into implementing the first two policies, it seems reasonable to assume that by naming this third policy the government signaled its interest in protecting the environment.

[4] For example, Li Huangpeng, former Chairman of China's largest power company, Huaneng, moved from that position to Party Secretary in Shanxi province.

on economic growth. But beyond these two, compliance with government policy and priorities can attract central government attention that benefits an enterprises' leaders.

While the idea that more concentrated industries are better able to overcome the **collective action** problem (Olsen 1965) is not new, I suggest that there are three additional reasons why less concentrated industries are more likely to (1) face higher air pollution-related standards, and (2) comply with those standards.

1. Monopolies and monopolistic competitors have greater capacity to **control information**, leaving the state in a difficult situation where it cannot predict the impact of regulatory changes (whether they be changes in standards or enforcement). If the government is ignorant of the true costs and capabilities of an industry, it will be less likely to enforce stringent regulation. While government bureaus can be well informed about the level of pollution, they may be ignorant of true energy supply, pollution abatement capacities and costs, and the true risk of shortages – even in markets with state ownership. If the industry can stand together in obstructing a regulation, either at the standard-setting or the enforcement point, the government may be unable to determine whether the regulation is too costly or not. But if one company breaks rank, it provides the government with extremely valuable information, namely that the regulation is not cost prohibitive. If the company actually implements the regulation, even more information can be gained, about how much time equipment procurement and installation took, and how difficult the regulation is to implement. The companies' public or government-directed dividends may provide even more information as to whether the abatement program is really too costly.

2. **Government risk aversion to energy shortages**. Most pollution derives from the burning of fossil fuels. Regulating pollution from energy sources presents a challenge to

regulators in that the public is highly sensitive to supply (in a way that would not be the case, for example, with the textile or steel industry). Moreover, in many countries at least some key energy sources (electricity commonly, and often natural gas and motor fuels) are subject to price controls. In China all of these are controlled. Figure 2 shows how the combination of monopoly and price controls are likely to lead to shortages. A monopolist prefers to supply where marginal cost equals marginal revenue, but the monopolist's price is determined by the demand curve (price and quantity shown by the green lines on the figure). The government's controlled price is lower, and the amount the public would like to buy at that price is determined by where that much lower price intersects the demand curve. The monopolist, however, sets its supply by where that lower price intersects with its marginal cost curve. The result is the large gap shown on the x axis, between the price-controlled supply and the price-controlled demand.

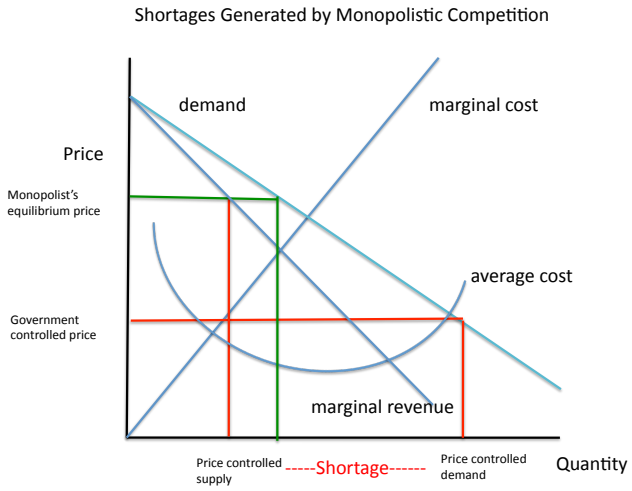


Figure 2: Monopolies Under Price Controls Generate Shortages

While the specifics will vary depending on the nature of the curves and the difference between the controlled price and the monopoly price, the likelihood of shortages presents an opportunity for producers to manipulate the market in order to make the government leery of imposing any policy (such as environmental regulation) that might increase costs and thus lead by this logic to more shortages. Producers will be aided in using this strategy if they are able to overcome the collective action problem and control information that makes it difficult for the government to independently evaluate both costs and risks, especially if there have been shortages in the past.

3. **SOEs compete for government favors**. Missing from the literature is the fact that SOEs compete with each other. How fierce this competition is will depend as in any market system in significant part on the number of players. The managers of these companies directly benefit from the company's success and thus will compete with other companies, especially if

the number becomes larger than provides for easy collusion or if no single firm dominates the market. Given the level of government regulation, not only with regards to emissions, but also permitting, dispatch rules for power (the rank order in which the grid buys power from generating companies) and other market-related rules, compliance in one area may help a company gain government advantages in another regulated area. Companies' interest in future permits, access to grid networks, and other benefits, means that both sides of this negotiation can be strategic.

Four key assumptions of the model

1. *Pollution abatement is costly.* This study examines regulation of traditional air pollutants, such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulates and other airborne chemicals like mercury or volatile organic compounds (VOCs). While specific cost data is not available for all these pollutants, data is for the majority and the theory applies to all. Removing these pollutants from fossil fuel processing or burning requires an active process, equipment and the energy to run that equipment, as well as disposal of the waste material from treatment. These processes cost money both for equipment and operations, as much as 5-10% of both capital and variable costs. This analysis does not apply to pollution mitigation or environmental protection that maybe costless or cost-saving, such as for example, reducing carbon dioxide (CO_2) emissions by increasing energy efficiency. If the investment is costly, once one takes into account the time value of money (something often not done when arguments are made that various environmental interventions are costless), then companies need to weigh the costs (and potential benefits – such as political benefits) of compliance with the costs and cost-savings of non-compliance. Thus, absent any political benefits, companies

will prefer to avoid regulation. They also will have a hierarchy of preferences for avoiding expensive compliance:

A. No or low regulation. The least risk circumstances for a company are when they are able to be in compliance and not have to face expensive abatement costs.
B. Regulatory noncompliance. If the company can avoid expensive changes, it will obviously be interested in doing so, but failing to comply with regulatory codes is obviously riskier than the absence of such codes. While a local government might ignore a regulation in the short term, the company would face the risk that enforcement could change at some later date, because of a change in local preferences or national-level supervision.

2. *All else being equal government prefers cleaner air to dirty*. This is a simple assumption. It does not argue that the government will always work actively to achieve clean outcomes, but simply that if it required no effort the government would prefer cleaner to dirtier air. This assumption is agnostic as to causality and to where air pollution falls on the government's priority list. The preference could be due to leaders' preferences, mid-level and local officials' preferences (those that administer the environmental protection system) or a response to pressure from the public. It also may be quite low on the government's list of priorities. The assumption seems reasonable, since almost all countries have some clean air regulations, regardless of whether they are enforced. It does not mean that governments are not also rent seeking.

3. *Companies are strategic*. Companies seek business success, but doing so may include both profits and market share. Complying with government regulations may be a strategy for gaining future benefits. This is particularly true in China where major state-owned companies

are not particularly dependent on short-term fluctuations in their stock market valuation. They have relatively little equity listed. The domestic stock market is not considered a source of true information on value. And they tend to list only a fraction of their company, generally selected prime assets on an international exchange. Thus, their business strategy is more focused on domestic relations, even if some of these relationships are costly.

4. *Governments regulate many aspects of company behavi*or. This model is based on an assumption that governments are concerned not just with environmental behavior, but are involved in market behavior, as well. At a minimum, this includes having some sorts of rules on competition – whether it is to encourage competitive sectors or to allow for monopolies. Moreover, the full implications of the model occur where there are price controls. The interaction of these multiple regulatory pressures drives the ultimate outcome. While this assumption limits the external validity of this study to some extent, large energy companies always face some types of government permitting regulation, and price controls are common in many countries.

This model of firm-government interaction examines a complex interaction involving multiple regulators with multiple goals. At a minimum we have two regulators – one setting prices and another setting allowable pollution levels. In fact, we have other regulators involved in permitting and industry control. The savvy firm can manipulate the incentives of these multiple regulators to free itself from onerous requirements. But this ability will be more likely if the firm's market power is greater, collective action is feasible, the government is ignorant of the firm's true capacity and the firm's production is a government priority. In contrast, government can be savvy and manipulate incentives to increase firm compliance,

and this effect will be greatest in sectors where companies are competitive and active in seeking government favors.

My **theory** to be tested in this dissertation is that industrial concentration affects the relationship between companies and government. More concentrated industries are able to use their market power (in particular their tendency to create shortages of a key input into economic health and consumer well-being) to make a risk-averse government unlikely to push costly changes in their behavior. Conversely, governments can take advantage of business competition to promote competition for compliance to gain future regulatory advantage. Using the power and oil and gas sectors I will test three hypotheses:

H_1: Sectoral emissions standards will be tougher when a sector becomes more competitive.
H_2: Once a sector becomes competitive companies will find collective action difficult, and there will be opportunities for some to defect.
H_3: Air pollution from a sector will be greater in localities that have more concentration in that sector.

The plan for this dissertation is as follows. In **chapter 2** I provide a history of China's major fossil fuel consuming sectors, the power and oil and gas industries. The independent variable throughout this dissertation is the degree of concentration of the relevant industry. The chapter thus describes the changes in structure of the two sectors under study. The history of each begins with monopoly as a dedicated ministry, which is then corporatized in the 1990s. But then the two sectors diverge, with the power sector broken up in 2002 and competition introduced to the oil and gas sector only very recently. Moreover, in the power

sector, I also find subnational variation that provides a useful mechanism for cross-provincial comparison.

Chapter 3 uses qualitative methods to examine power sector standards. The sector expanded from one company to five in 2002; by 2008 the market share of the top 5 had dropped to 45%. This change in concentration corresponded to the major changes in regulatory standards. Using in-depth interviews with regulators, company officials, and plant managers, I find that increased competition provided regulators with leverage.

Chapter 4 uses large N quantitative analysis to consider variation in the power sector at the provincial level. While standards are national, enforcement falls to local and provincial bureaucracies. The Chinese sector is essentially divided into regional power grids, creating the opportunity to consider each province's industrial concentration and power-sector related emissions independently. I calculate standard measures of industry concentration from a dataset of more than 13,000 power plant units in China to derive a level of power sector concentration for each province-year and measure its influence on power sector specific emissions. I find the more competitive the industry in a province, the greater the emissions reductions.

Chapter 5 uses qualitative methods to consider standards in the Chinese oil and gas industry. The key standard in question was a new fuel quality requirement for heavy vehicles that the Chinese government had slated to go into effect in 2010, but which was repeatedly delayed. The standard took effect in 2015, only after the Chinese government allowed new competition into the industry. Through interviews with key players, I find that small firms behaved strategically in demonstrating they could meet higher emissions standards as a way to gain import permits.

Overall, I find that it is critical to consider the political relationships between major polluters and government if we are to understand pollution regulation. I also find that we need to consider not just firm-level characteristics, but the structure of industries to understand how players behave. Even in an autocratic state with state-owned enterprise dominated sectors, my results indicate that companies compete with each other and that competition can be used by government to promote regulatory aims. Some companies will use regulatory compliance to gain a competitive edge, which creates an opportunity for government regulators.

Chapter 2 A Brief History of China's Major Fossil Fuel Consuming Sectors

Energy is not simply another industrial sector, it is the fuel by which all of industry and society runs, and it was recognized as such from the founding of the People's Republic. From the outset the state priority on production led to centralized and protected state monopolies, and a strong connection between energy leadership and national leadership. The major energy companies' beginnings as ministries and their imperfect and incomplete corporatization is fundamental to how they act today and the difficulties involved in imposing outside standards. Moreover, environmental regulation does not occur in a vacuum. These energy companies are regulated first and foremost as producers of a key input into the production process, and in recent years also as a generator of profits to their government owner. To understand the relationship between the contemporary state and these energy companies it is necessary to understand the origins and evolution of their tangled relationship.

Prior to 1949, the modern energy production sector was tiny, and what little modern industry did exist, such as a very nascent oil and gas industry, had been limited by the near constant state of conflict China experienced in the decades leading up to 1949 (Kambara and Howe 2007). When the Chinese Communist Party (CCP) came to power, China produced only 120 thousand tons of oil per year (2400 barrels/day, Lim 2010). That is less than 1 million barrels in an entire year. By contrast, in 2014 China consumed more than 500 million tons of oil per year (or more than 10 million barrels per day), and more than 200 million tons, or about 40% was produced domestically (NBS). Coal consumption grew equally dramatically from production of less than 32.4 million metric tons in 1949 (Peng 2009) to approximately 4 billion tons of coal in 2014 (NBS).\In contrast to the oil story, domestic

production continues to be responsible for 93% of consumption. Approximately half of that coal today goes into the electric power industry, which continues to rely on coal for more than two-thirds of its production. Total electricity output in 2014 was 5600 terawatt-hours, generated from 1370 GW of installed capacity (NBS), making China the world's largest electricity market. Again, the rise from 1949 is staggering. At the time China had only 1.85 GW installed capacity in the entire country (Fridley and Lu, 2016).

Growth itself would hardly be surprising. Indeed, US installed capacity in the same period grew from 65 GW to 1074 GW[5]. But while both are impressive, the earlier Chinese figure is essentially that of a pre-industrial society. The new government's challenge was to create an energy industry that could generate economic transformation. This endeavor was central to the development project of the Chinese state.

Longstanding features of the Chinese energy sector

As a major state priority, several features have been constants across energy sources and technologies over the years. Two remarkably consistent tendencies have been the focus on supply issues and a marked preference for centralization. At the same time the sector has seen a near constant debate between those who wished to go it alone and those who sought more foreign cooperation, technology and investment.

Since the People's Republic started out with insufficient energy production to supply an industrializing economy, ensuring adequate supply was a paramount goal from 1949 onward. This generally led to greater focus on upstream production than on downstream

[5] 1949 data, Rocky Mountain Institute, accessed June 9, 2018. https://www.rmi.org/insights/reinventing-fire/reinventing-fire-electricity/research/ 2016 data, Energy Information Administration, *Electric Power Annual*, released December 7, 2017. https://www.eia.gov/electricity/annual/

development or on coordination along the supply chain. These issues range from the overwhelming emphasis on oil exploration rather than refinery development and distribution to the difficulties in coordinating between the coal pipeline and the complex electricity industry (generation, transmission and distribution). It also has meant that until recently supply-side solutions to problems have received greater attention than demand-side approaches even for an issue like conservation that might appear to be more related to demand (Zhou and Yang 2015).

A second feature of the system in many ways grows out of this priority on augmenting and ensuring energy supply. From the outset energy policy was never entrusted to the localities. It was more highly centralized at the national level than most sectors outside of direct military goods despite multiple waves of policy change. While thanks to Maoist notions of self-reliance much of Chinese industry was fractured and administered by localities even before markets were introduced in the reform era, this was not the case with the energy sector. Given both its high priority and the legacy of Soviet-introduced practices in the 1950s (Kambara and Howe 2007) it was highly centralized under specific functional ministries well into the reform era. Despite Chinese planners' recognition of the advantages in most industries of introducing competition to increase supply and quality, to control cost, and to foster innovation, planners were reluctant to let go of central inputs into the rest of the economy. There are multiple aspects, including production, distribution and pricing, as well as of course different fuels and production methods. Planners have allowed more flexibility in some of these areas than others, as will be addressed in the discussion of fuel types below. But overall the level of control has remained much higher than is the case for industry in general, even other priority industries.

While the supply focus and central control were constants, the views toward international engagement in the sector changed multiple times and were often the subject of heated debate within the leadership. The 1950s were the heyday of international assistance, with the Soviets involved in advising on all aspects of Chinese energy development. Their withdrawal was the great shock that began China's long go-it-alone phase, but their influence lingered in two significant ways. Firstly, they contributed the central planning institutional structure that dominated the energy industry through 1979 and, while attenuated, continues to have an influence. Secondly, the shock of the Soviet departure, the ensuing desperation to find domestic oil, and the subsequent discovery of the Daqing field became one of the formative stories of the Chinese Communist Party's success in governance. It formed the ethos around self-reliance and led to the formation of the "oil clique," which in its dominance and then its recent fall has had disproportionate influence in Chinese politics until the present day.

The debate over international involvement reemerged in the reform era, and foreign participation, particularly in offshore oil development, became important and mutually profitable. From the vantage of hindsight, however, the more striking aspect of foreign involvement in recent decades, especially in terms of project development as opposed to equipment manufacture, is how little long-term influence it has had. The Chinese energy industry continues to be dominated by SOEs, and the percentage of foreign ownership in the sector today is lower than it was in the late 1980s.

Industry Structure

Energy has been dominated by national level management, and its evolution is charted in figure 3. The key elements of the government-dominated system were the Planning and

Economic Commissions that set targets and prices and coordinated policy among ministries under the State Council, and ministries that ran each of the main energy types. As can be seen from the figure, how these responsibilities should be divided was the subject of periodic rethinking as the complexity of managing multiple sources under one bureaucracy or the difficult of coordinating separate bureaucracies caused government leadership to rethink the optimal structure. Other than during the first five years of the People's Republic, the main variation was whether there was one fossil fuel ministry or separate ministries for coal and petroleum, with the latter more dominant, and similarly whether power and water resources were merged or separate with the merged model prevailing.

The major initial challenge, and the logic that came to dominate energy planning, was to increase supply. With such low initial production levels, capital for expansion would need to come from the central government, and the entire infrastructure for producing energy and supplying it to users needed to be developed. All energy sources were administered by centralized ministries, but the degree of actual central control even in the earlier period, and then when control was reduced during the reform period varied considerably.

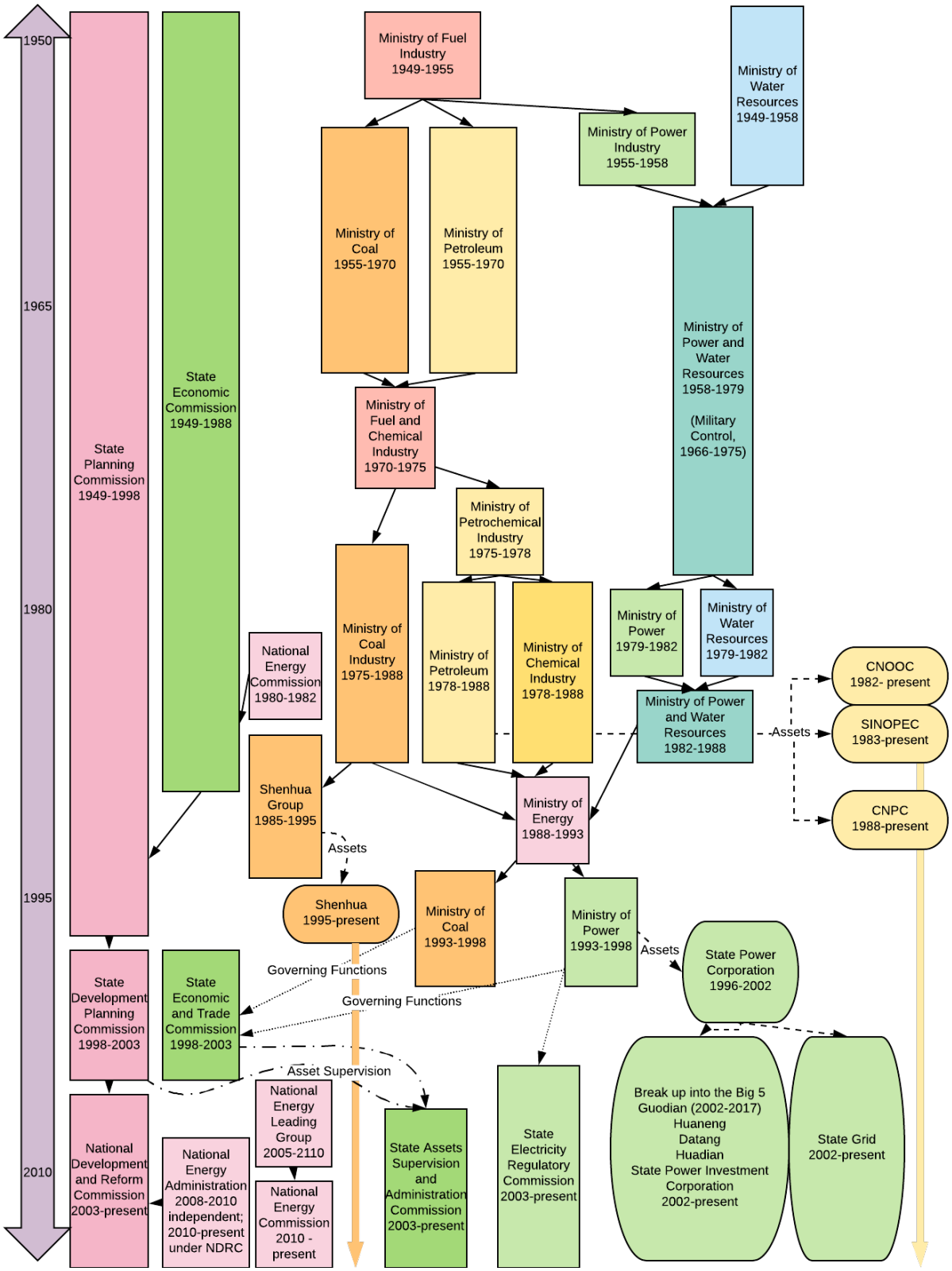
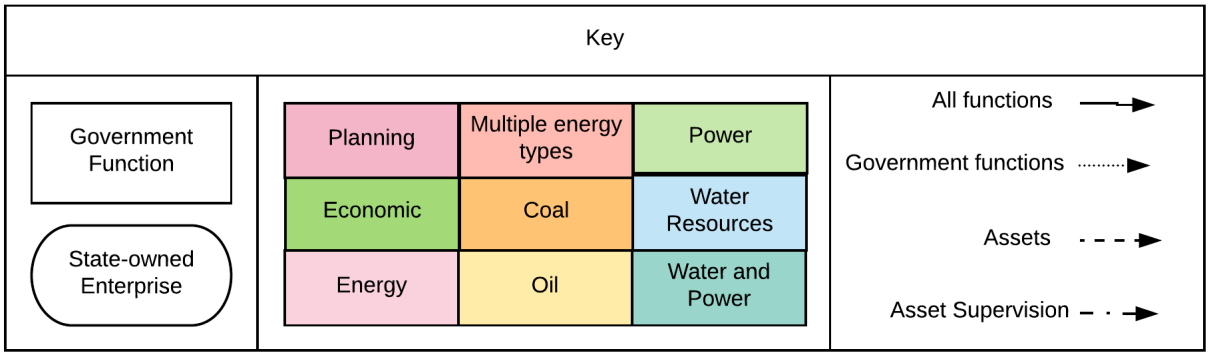


Figure 3: Chinese Energy Organization Over Time



Sources: Andrews-Speed 2012, Chiu and Lewis 2006, Downs 2008 and 2017, Kambara and Howe 2007, Lieberthal and Oksenberg 1986 and 1988, Lim 2010, Mackerras et al. 2003, Xu 2016, David Reid, "China just approved the world's largest power company with more than 225 gigawatts of capacity," CNBC, Aug. 28, 2017 https://www.cnbc.com/2017/08/28/china-approves-merger-of-guodian-and-shenhua-to-create-worlds-largest-power-company.html, and Ruining Hou, "State Council Organizational Reform Plan Announces the Energy Bureau will be under NDRC administration," 侯瑞宁， "国务院机构改革方案公布 能源局仍由发改委管理，" jieman.com, March 13, 2018.

Figure 3 (continued): Chinese Energy Organization Over Time

Coal: China's Most Plentiful Resource

Coal was obviously the most plentiful energy type in the ground, and thus not the all-consuming concern for China's energy planners that oil, which we'll discuss below, was, but there was a large need for investment in new mines and much higher production to fuel ambitious for developing heavy industry and the power sector. Thus, after a brief period when all fossil fuel energy was run from a single ministry, coal was administered separately by the Ministry of Coal from the mid-1950s through the 1980s and then again through much of the 1990s. However, coal was the first fuel source to be opened up to local initiative in 1979, and in 2002 became the only sector to have prices decontrolled. State management for the coal

sector was varied from the beginning with actual state management at the central, provincial and local level, including the township and village level, depending on the size of the mine. Distribution was also somewhat decentralized, with the central government controlling distribution from the nationally-owned mines, but with governmental distribution managed for the other mines at the same level as was ownership. During the centrally-planned period, the central government was responsible for 90% of investment in the coal sector, yet the share of production from sub-national level mines gradually grew even before the sector was opened up. By 1980 provincial and local mines accounted for approximately 40% of total production. Despite considerable growth, lack of fuel continued to be a major constraint on industrial production, however. Factories were idled as much as 30% of the time. The basic supply problem had not yet been solved. (Aden et al. 2008, Peng 2009)

The industry changed rapidly after 1979, when township and village mines were first allowed to sell coal on the market. Prior to reform local coal mines had not been able to sell coal outside their own locality. Once the market was opened up, local initiative blossomed, with the number of mines increasing tenfold during the 1980s from some 10,000 to a peak of around 100,000 by 1991. The relationship with state mines changed as well, with a shift from planning to contracts, called the General Contract system, in 1982. While the national level contract with the Ministry was essentially a plan, and each mine then had a production contract with the Ministry. Production boomed, growing from 635 million tons in 1979 to over 1 billion tons by 1990, and then to some 4 billion tons today (Peng 2009, NBS 2015). As a result, coal availability per se was no longer a constraint on development, although China

continued to face coal transport bottlenecks with most of the supply in the north and west and demand heaviest along the east coast.[6]

The rapid expansion in local mines led to an equally rapid growth in coal mine deaths (He and Song 2012). While mine deaths from state-run coal mines actually peaked around 1979, even though production continued to rise, deaths from local mines grew rapidly through the 1990s. The central government responded to the wildly unsafe and poorly managed small coal mines by periodically requiring closures or mergers. These were difficult to enforce and actually led to major unreported output in the late 1990s. (Aden et al 2008, Tu 2011)). The number of small mines during the 1990s fluctuated between 80,000 and 100,000 (Andrews-Speed 2012). By the early 2000s, the Chinese government became much more concerned about coal mine deaths, passing the Work Safety Law in 2002, and then steadily closing down small mines (Hu and Song 2012, Wei et al. 2016). As a result, total mine deaths actually peak in 2002 (Cui et al. 2012), and the total number of small mines is driven down to around 10,000 by the end of the decade (Tu 2011). In addition to mine safety, the Chinese government was also concerned with the ecological damage surrounding poorly-run local mines[7] and increasingly with overcapacity (Caldecott et al. 2017). As mines became more efficient[8] and China decided to cap total coal consumption at no more than 4.1 billion tons per year starting in 2020,[9] these small mines became unnecessary.

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[6] Muyu Xu and Josephine Mason, "Perfect Storm: China's Blizzard Exposes Flaws in Rail, Coal Policies," *Reuters*)February 2, 20180. https://uk.reuters.com/article/us-china-weather-railway-commodities-ana/perfect-storm-chinas-blizzard-exposes-flaws-in-rail-coal-policies-idUKKBN1FN06H

[7] David Stanway, "Undermining China: Towns Sink after Mines Close," *Reuters (*August 13, 2016). https://www.reuters.com/article/us-china-coal-environment-idUSKCN10P03V

[8] Mechanized mining grew from 30% to over 90% during the Reform period (Wei et al 2016).

[9] "China to Cap Coal Consumption at 4.1 Bln Tonnes by 2020," *Xinhua* (January 17, 2017). http://www.xinhuanet.com/english/2017-01/17/c_135990689.htm

While small mines launched the reform era, large state-owned mines are now the norm. Other than the Shenhua Group, as discussed below, these have been entirely managed at the provincial or local level since 1998 (Peng 2009). A major goal for policymakers was to mechanize the mining process, making it safer and more efficient. Modern equipment and methods needed to be sought internationally. The first corporatized reform was the establishment of the China Coal Import and Export Corporation, in 1982, which in addition to trade functions, also was to be the partner for foreign investors (Peng 2009). But foreign investment turned out not to be such a major part of the Chinese coal sector. The largest joint venture, the $650 million Antaibao project with Occidental, was inaugurated with great fanfare in 1986, with then Vice Premier Li Peng attending the launch. But just six years later Occidental pulled out losing its entire $250 million investment as it failed to find a buyer.[10] The Chinese coal industry found they could purchase the equipment they needed.[11] In fact, because of the size of the domestic market and growing energy demand, China was well on the way to creating the world's largest coal company, Shenhua.

The Shenhua Group was established as a separate centrally-administered coal-producing unit with captive rail in 1985. It was then corporatized in 1995 (Peng 2009). In

[10] John F. Burns, "Occidental Begins China Coal Project," *The New York Times (*July 3, 1985). https://www.nytimes.com/1985/07/03/business/occidental-begins-china-coal-project.html and Helen Berg, "Occidental Signs Contract with China for Antaibao Pullout Coal Mine Stake Given Away?" JOC.com (July 7, 1991). https://www.joc.com/occidental-signs-contract-china-antaibao-pullout-coal-mine-stake-given-away_19910627.html

[11] Over time international manufacturers have tended to set up joint ventures in China to produce equipment for the world's largest market. See for example, Caterpillar. "Cat Signs 5-Year agreement with Chinese Energy Corp," *Construction Equipment* (November 8, 2017). https://www.constructionequipment.com/cat-signs-5-year-agreement-chinese-energy-corp; Rajesh Kumar Singh and Brenda Goh, Caterpillar Drives Sales on China's New Silk Road, *Reuters* (March 4, 2018). https://www.reuters.com/article/us-caterpillar-china-b-r/caterpillar-drives-sales-on-chinas-new-silk-road-idUSKBN1GG146 Despite the increasing capacity of Chinese companies to produce quality equipment, the U.S. Department of Commerce continues to see equipment sales in higher technology areas as a good opportunity for international companies. See https://www.export.gov/article?id=China-Mining-and-Materials

2017 it produced 295.4 million tons and traded 443.8 million tons of coal, which made it the world's largest coal company, but still a producer of less than 10% of China's output. Shenhua still sees its success as tightly tied with coal, describing itself as having a vertically integrated business with a "coal-based industrial chain,"[12] but it has moved aggressively into the power sector since that sector was opened up. With its merger with the power company Guodian in 2017, Shenhua has become the world's largest power company.[13]

The coal industry, thus, was the earliest to experience competition, and even with consolidation in recent years, it still has many players in the market. The largest problem throughout the reform period has been small, unregulated operators, and the government has reduced that portion of the sector dramatically since the early 2000s. At the same time the sector has operated with free prices since 2002. Even though the power sector, its largest customer, is still price controlled, the coal sector has been able to produce to meet demand. The fundamental problem of lack of supply has long since been resolved, and in fact, coal output peaked in 2014 (NBS Statistical Communiques, 2015-2017).

Power: Critical Engine of Growth

Electric power is a much more complex commodity than coal. While the main job in coal production is to safely dig it out of the ground and put it on a train, electricity generation

[12] China Shenhua Energy Company Limited, *Annual Report* (2017). http://www.csec.com/shenhuaChinaEn/Report2017/201803/38cab167e8cb410cae5f48c626964754/files/01ecd9ec2d92427986b3793ea4fbf03c.pdf Peabody data from statista.com. Comparison to second largest company (according to Peng 2009, is Peabody data from statista.com http://www.csec.com/shenhuaChinaEn/Report2017/201803/38cab167e8cb410cae5f48c626964754/files/01ecd9ec2d92427986b3793ea4fbf03c.pdf

[13] China is Creating the World's Largest Power Company," *Bloomberg News* (August 28, 2017). https://www.bloomberg.com/news/articles/2017-08-28/china-approves-guodian-shenhua-group-to-merge

requires safe and effective infrastructure, the steady supply of fuel, effective generation and a transmission and distribution network to deliver the electricity to the end users. Because the focus of this dissertation is on how industrial structure affects air pollution, I will not discuss distribution (which does not generate pollution) in detail, but it is worth noting that despite serious allegations of poor corporate governance in the transmission and distribution sector,[14] the monopoly grid companies, State Grid and the much-smaller Southern Grid, have been highly successful in delivering electricity to both industry and the public. Improvement in electricity access was a largely achieved during the early years of the reform era, before the restructuring of the power sector. In 1978 almost half the population lacked access to power. By 1997 those without access had dropped to less than 5% of the population, and by 2010 to a half a percent. This is an extraordinary achievement when compared to any other developing country, especially those with large, dispersed rural populations (Zheng 2004, Bhattacharyya and Ohiare 2012).

As with other forms of energy, the major focus in power development has been on the need for greater supply. As it continuously grappled with demand that far exceeded supply, power planners debated how to proceed. Two questions emerged multiple times. The first was about what fuel source to emphasize for supply – coal or hydropower. The second was how much and what type of foreign involvement would be useful.

In recent years China has diversified its fuel sources in the power sector considerably, with rapidly growing and world-leading development in nuclear, solar and wind power. In 1949, however, there really were only two choices for power generation – coal and

[14] Patti Waldmeir and Gabriel Wildau, "China Graft Probe Uncovers Falsified Revenues at Large SOEs" *The Financial Times* (June 28, 2015). https://www.ft.com/content/91b7855c-1d85-11e5-ab0f-6bb9974f25d0

hydropower. Moreover, even in 2017, 90% of China's power generation came from fossil fuels and hydropower, the vast majority from coal and hydro (see figure 4). Thermal power production is comprised almost entirely coal, with a tiny fraction from China's very limited quantity of natural gas. Nuclear, solar and wind are all growing rapidly, but from very small bases, and these sources are quite recent.

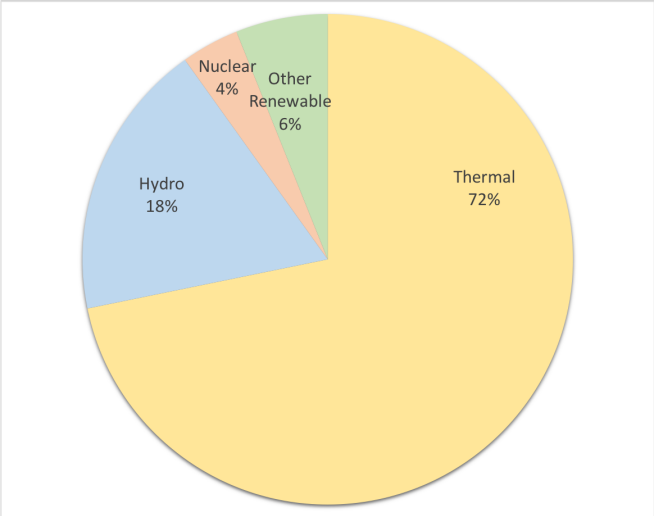

Figure 4: Total Electricity Output, 2017

Source: National Bureau of Statistics, Statistical Communique, February 28, 2018

The debate throughout the 1940s through the 1990s was about what proportions of limited investment capital should go to coal-fired power plants or to hydropower projects. Coal-fired power plants were cheaper and faster to build, but more expensive to run, dependent on the supply of coal, and are of course polluting. Hydropower projects are either quite small, in which case they were basically left to local government, and not a major part of this analysis, or if large, involve long-term and expensive investment and the major human and financial cost of relocating significant populations, but then are relatively cheap to run, do

not require transport or production of fuel, provide for flood control and irrigation, and offer development opportunities especially in China's southwest. Hydropower does also have environmental risks, but these are quite different from the very visible soil, water and air pollution associated with coal mining and burning (Lieberthal and Oksenberg 1988). Moreover, while one might expect that the safety argument would be against coal, especially given China's history of mine accidents, the People's Republic also had a history of spectacular dam disasters that were even more politically salient (Shapiro 2001).

As a result of these conflicting priorities the ministries were repeatedly restructured (figure 3) with power and water resources combined when the central government wished a greater emphasis on hydropower and separated when the quick and dirty coal advocates were in ascendancy (Lieberthal and Oksenberg 1988).

The power sector also had to grapple with how much to rely on foreign assistance or technology for its development. As with coal mining, the 1950s were marked by large-scale Soviet assistance, and the withdrawal of Soviet advisors did indeed end of the first boom period in energy production (Liu et al. 1992). Nevertheless, the real barriers to further expansion at the time appear to have been in large part due to domestic political circumstances – the Great Leap Forward and the Cultural Revolution – since the electricity growth rate had picked up by the late 1970s before there were further opportunities for foreign cooperation. However, by the beginning of the reform period, there was severe unmet demand for power and an increasing concern with the poor quality of Chinese infrastructure. The Chinese government sought multiple foreign inputs (Tan and Seligsohn 2010, Zhou and Zhang 2010, Watson et al. 2015). It was interested in equipment purchase, such as turbines for major dams purchased from the West. But for many technologies it wanted the technology

transferred, including for coal-fired generation and for nuclear plants. It also pursued international investment in power plants. While technology transfer was highly successful, with China becoming the world leader in producing many power generation technologies, investment turned out to be far less important. In fact, as with the coal industry, the interest in foreign investment declined over the reform era as Chinese financial resources increased and the major SOEs chose to invest heavily in expansion (WEPP data, as used in chapter 4).

The push and pull between the coal advocates and hydro advocates continued through the 1980s, but by the 1990s, the approach became what might best be called an "all of the above" strategy. With major efforts to build dams, plus ever larger coal-fired power plants, the Chinese power sector was focused on growth. Despite this effort, electricity supply continued to be a major issue until well into the 11th Five Year Plan (2006 – 2010).

China's industrial ministries corporatized over the 1990s, a slow and incomplete process (Naughton 2015). The first effort to push greater accountability in improving output came with this change in administrative structure. In 1996, the grid and generation functions of the old Ministry of Power devolved to an SOE, the State Power Corporation (SPC). SPC continued to provide a fully integrated power service – generation, transmission and distribution – for all national-level power production, which included all large plants. There were small locally managed plants that served local markets, especially small hydro that was responsible for much of the improvement in rural electricity access (Peng 2009). However, there was no competitive market in any aspect of the power sector. Regulatory functions were separated out, first to the Ministry of Power, but then to the State Economic and Trade Commission (SETC), a relatively short-lived planning organ.

The change to a single national corporate structure, however, failed to provide the spur needed to meet demand. By the early 2000s with the economy growing rapidly electricity shortages were worsening (Cunningham 2008). At the same time, there was a distinct global trend toward energy market deregulation, including separating component functions and promoting competition. Deregulation had begun in developed countries in the late 1980s, but by the 1990s had been implemented in a number of developing countries and was being actively promoted by international development organizations (Jamasb and Pollitt 2000, Jamasb 2006).

In late 2002, the Chinese government, through a State Council decision, made the most significant change to the sector since initially imposing central control in 1949. It broke the State Power Corporation into five generating companies and two grid companies. This was essentially a partial decoupling. Transmission and distribution were still together under the grid companies, which had monopoly coverage of their areas. Moreover, each provincial grid essentially manages the power within its province without a real interprovincial market. However, genuine competition among the generating companies or gencos was introduced (Zeng et al 2016). The goal was to increase output, and environmental goals did not feature in the State Council's decision. (Yeh and Lewis 2004, Xu and Chen 2006).

The Big 5 gencos as they came to be known were not in a secure position. The reform also allowed for new entrants into the market, most of which were also state-owned. The big five saw their market share drop precipitously from almost 100% in 2003[15] to 45% by 2008. Since then their share has remained relatively stable, rising as high as 50%, but dropping back again to 45% (Pollitt et al 2017). The loss of Big 5 market share was driven mainly by new

[15] Small local hydropower plants had never been controlled by the central ministry in any meaningful sense.

provincial entrants, but some new national companies also engaged. Nuclear energy is run by dedicated nuclear specialty companies, and, as noted above, Shenhua, the giant coal company, has become a major power producer. The national picture encompasses considerable provincial variation as some provinces authorized many companies, while others focused on developing their own regional giant, such as Zheneng in Zhejiang province, and Yudean, in Guangdong, which today invest not just in their home provinces, but in others, as well.

While the 2002 reform precipitated the largest power plant building boom in world history, the Chinese government has continued to be concerned about efficiency. Today's inefficiency is caused by overcapacity, but there have been various issues with plant and grid management throughout the history of this reform. As a result, there are constant rumors that the Chinese government is going to force some of the firms to merge, in an attempt to gain efficiencies from size.[16] In a forced merger, the larger company usually winds up gaining the upper hand. Therefore, Chinese power companies have been particularly interested in expanding market share, and thus seek new permits to build and operate. This need for permits gave the Chinese government some leverage in its efforts to force new standards and standards compliance. Compliance was one strategy for gaining favor for new permits.

Oil and Gas: Defining Communist Success

The oil and gas sector has been particularly central to the CCP's self-presentation and its power structure. In 1949 China had limited productive domestic oil and gas resources and also limited knowledge of the true size of China's potential. While China actually had an

[16] See Lucy Hornby, "China's Consolidation Push Turns to Sprawling Power Sector; Beijing Targets Coal-Fired Electricity Producers for Mergers," *The Financial Times* (June 14, 2017).

ancient gas industry in the Sichuan basin, extending back at least as far as the Tang dynasty and perhaps much earlier (Kambara and Howe 2007, Ma 2017), there had been very limited development prior to 1949. There were several modest oil fields developed in the Chinese Northwest during the 1930s, and the Japanese also established a modest shale-oil production facility in Liaoning, when it was under their control (Kambara and How 2007). However, all these efforts were modest, and China was a net importer of oil both prior to 1949 and throughout the 1950s. In the 1950s China was heavily dependent both on oil from the Soviet Union and on Soviet experts that to assist in developing an indigenous industry. There was some success in identifying new fields, in particular the Karamay field in China's far west, and the cooperation fostered highly beneficial knowledge transfer to the fledgling Chinese oil industry (Kambara and Howe 2007).

The break with the Soviet Union was of considerable importance throughout the energy sector, but nowhere was it as searing as in the oil and gas sector. While Chinese production had grown thirty-fold over the 1950s, it still was able to meet only 40% of civilian demand and 20% of military demand (Ling 1975, Kong 2010). Thus, the Soviet pull-out was devastating. But essentially concurrently in 1959 the Chinese discovered oil in what was to become its largest oilfield, Daqing, in the Northeast (Ling 1975, Kambara and Howe 2007). The Daqing discovery meant that China was well on its way to becoming self-sufficient in oil production and then became from the 1970s to the early 1990s, an oil exporter. Daqing alone produced over 1 million barrels/day in its heyday, and even in recent years when considered a mature field with declining output, it produced 800,000 barrels/day in 2015 (USEIA 2015).

The Daqing experience was transformative for the Chinese oil industry and beyond. It fed directly into this ongoing debate about whether to be self-reliant or to look for

international cooperation. Daqing became a powerful argument for the primacy of self-reliance. Daqing was not only a critical tool for China's industrialization, but a symbol for the nation. The slogan from the Cultural Revolution, "In industry, learn from Daqing," became a point of pride that extended well beyond the denunciations and recriminations that ended that turbulent period. After all, while the corresponding slogan about the mythical commune Dazhai turned out to be a fraud, Daqing was a genuine achievement and for many years was one of the largest oil-producing fields in the world. Moreover, Chinese geologists, having made the case to Mao that they should move the focus of their oil exploration from the West to the East, had a string of further discoveries, in particular Shengli and Liaohe fields in the Bohai Basin, that, while not as large as Daqing, were important producers. By the 1980s, these other oilfields were producing half of China's considerable output (Kambara and Howe 2009).

But even in the 1970s it had become clear to many in the oil sector that going it alone would only enable the Chinese industry to move so far. Daqing's technical approach, learned from the Soviets, while maximizing early production, likely damaged total long-term oil recovery (Lieberthal and Oksenberg 1988). Moreover, further oil development potential was widely believed to be offshore, where the Chinese had no expertise, and international technology was constantly improving. The Chinese already had made small steps in the early 1970s by importing some equipment and engaging in some oil service contracts. After a hiatus in the mid-1970s when politics turned against international cooperation, it heated up at the end of the decade, culminating in the 1979 decision to allow equity investment (Lieberthal and Oksenberg 1988).

The Chinese government then chose to move the partnership-seeking portion of the oil business into a separate entity, its first corporatized oil company, the China National Offshore Oil Corporation (CNOOC, Feng et al. 2013). CNOOC developed into a highly successful joint venture company with partnerships with most of the major oil companies. While the initial excitement about the South China Sea paid off only modestly, today their partnered production offshore in the Bohai Gulf constitutes two-thirds of China's total production (USEIA 2015). While onshore partnerships, particularly in the Tarim Basin, never delivered anticipated results (Kambara and Howe 2007), oil and gas remains the area where Chinese companies are most active in forming partnerships, more recently by partnering with majors in third countries. Chinese oil companies continue to seek partnerships for access to both technology and large project management skills (Downs 2010). Beyond partnership activities Chinese companies actively purchase international equipment and hire international oil service companies.

Foreign cooperation continues to be focused on upstream development, and that has now extended to China's quest for overseas resources. China's international acquisitions have been related to both energy security, especially diversifying supply, and acquiring technical expertise (Downs 2010).

This focus on upstream development led to a refinery sector that was for the most part too small for optimal output and poorly equipped (Kambara and Howe 2007, Ma et al. 2012). The lack of emphasis meant that Chinese refineries were able to purchase equipment from overseas, but with underinvestment they have been relatively slow to upgrade. This focus has begun to change only very recently. There are now some Chinese international downstream

refinery investments, in places like Laos and Kazakhstan.[17] International companies have sought greater access to China's refinery and distribution market for decades, but thus far have little other than a minority share in a few facilities.[18]

The result of the lack of high level interest in downstream is not just underinvestment. It has also left SINOPEC relatively unfettered to determine standards and policies on its own, as will be discussed in chapter 5. It has also meant that the fundamental problems Chinese refineries face with free world market oil prices for their imported inputs and price controls at the pump have never been fully addressed.

Perhaps the largest impact of the focus on upstream development and the glorification of the "victories" at Daqing and other oilfields, was the political elevation of the oil clique. From the outset, oil production was a top priority given maximum attention by the Chinese leadership (Lieberthal and Oksenberg 1988, Jiang 2012). The oil clique (or petroleum faction 石油派) developed in the Daqing field in the early 1960s around the head of the project, Yu Qiuli (Lim 2010). Factions are an important part of Chinese politics (Nathan 1973, Shih 2008), but few factions have sustained through generations. The oil clique did not face its ultimate downfall until the fall of Zhou Yongkang in 2012-2015.[19] Zhou had risen through the ranks at CNPC before becoming Party Secretary of Sichuan and Minister for State Security. He continued to be closely associated with CNPC, and in his wake CNPC was particularly

[17] "Lao-Chinese joint venture building Laos' 1st oil refinery," Xinhua, August 3, 2017. http://www.chinadaily.com.cn/business/2017-08/03/content_30345084.htm. Zheng Xin, "China-Kazakhstan oil refinery put into operation," *China Daily*, June 30, 2017. http://www.chinadaily.com.cn/business/2017-06/30/content_29951399.htm

[18] "Saudi Arabia seeks downstream Asia-Pacific investment," Argus Media, March 20, 2017. https://www.argusmedia.com/pages/NewsBody.aspx?id=1426082&menu=yes

[19] Rumors began to circulate in early 2012, but Zhou was not ultimately charged until 2015. Damian Grammaticas, "Damaging Coup Rumours Ricochet Across China," BBC News (March 22, 2012). http://www.bbc.com/news/world-asia-china-17476760 The actual 2015 charges are cited in Wedeman 2017.

hard hit in the anticorruption campaign.[20] While the oil clique's influence varied somewhat over time, one of the major impacts was that the Chinese government was often responsive to the oil companies, rather than the other way around (Downs 2010). While the real dominance in national politics came from CNPC and its commitment to a self-reliant upstream-focused policy, the oil companies as a group were highly influential and often immune to outside pressure.

The corporatization of the petroleum industry occurred in three stages. First, CNOOC as discussed above, was created to act as the joint venture partner for offshore oil development in 1982. This could best be described as an effort to benefit from foreign investment and technology while also ensuring that foreign investors were fenced in and didn't have access to the crown jewels, the major onshore fields. Second, in 1983, SINOPEC was formed, moving all of the downstream assets from the Ministry of Petroleum Industry (MPI) to the new company. Third, in 1988, MPI simply became the China National Petroleum Corporation (CNPC, Kong 2010). In theory, MPI's governance functions moved to the Ministry of Energy (MOE), but MOE's staff had come from the Ministry of Power and Water Resources, while the MPI staff went to CNPC. I served as the US government's point person in Beijing on energy issues in 1991-1993, and CNPC officials were still using their ministerial ranks and titles, and never deferred to MOE.

[20] Hu Shuli, "Action on CNPC Signals Beijing's Resolve to Hit Corruption Hard," *South China Morning Post* (September 5, 2013). http://www.scmp.com/comment/insight-opinion/article/1303360/action-cnpc-signals-beijings-resolve-hit-corruption-hard. Du Juan, "Anti-corruption Campaign Moves Forward at CNPC," *China Daily* (October 10, 2014). https://www.chinadaily.com.cn/bizchina/2014-10/10/content_18716815.htm. "The Chinese Oil Sector: Beijing's Latest Anti-Corruption Target," *Stratfor Worldview* (September 10, 2013). https://worldview.stratfor.com/article/chinese-oil-sector-beijings-latest-anti-corruption-target

The Chinese government then reorganized the oil sector again in 1998, moving some refinery assets to CNPC, essentially those connected to their major oilfields, and moving some oilfields to SINOPEC, in order to create two vertically integrated oil companies. The two companies continued to operate, however, very much in parallel, since they generally faced robust demand and government-controlled prices. Prices were adjusted according to the world market price, but they were not able to compete on price (Lin and Jiang 2011).

The Evolution of a Corporate Regulatory Structure

The Chinese government always had a regulatory structure above the ministerial structure that managed the specific energy sources. Traditionally, the key organizations were the Planning Commission and the Economic Commission. This structure both evolved as the companies became corporatized, and also had to add new functions, specifically the management of state assets, which became the State-owned Assets Supervision and Administration Commission (SASAC).

Importantly, these national level organizations never had much influence in the standard-setting process that will be described in the subsequent chapters. That process involved interaction between the ministries and the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), which will be described in greater detail in the next chapter. As a result, when these companies lost power through competition, they did not have an obvious sponsor at the higher level to turn to for assistance.

From Planning to Development and Reform

The most powerful organization in the era of the planned economy was the State Planning Commission. As its title would suggest it was in charge of developing plans. This included the plans for energy development, determining the specific projects that would be built and setting their timelines (Lieberthal and Oksenberg 1988). The Planning Commission then was reorganized into the State Development Planning Commission (SDPC) in 1998, and then finally into the National Development and Reform Commission, since 2003 (see figure 3).

Regardless of the name change, the NDRC has continued to be in charge of drafting the all-important energy portions of the five year plan as well as the subsidiary energy sector five year plan, both of which set targets for the sector (N. Zhou et al. 2010, Andrews-Speed 2012). Its approval continues to be required for all large-scale projects, which includes powerplants, refineries, oilfield development and pipelines (Magee 2006, Kang et al. 2012). It also designs and administers a growing number of energy programs, ranging from energy efficiency to solar power (N. Zhou et al. 2010, Kang et al. 2012, Zhang and He 2013). The NDRC also sets prices for electricity and oil products (Lin and Zhang 2011, Zhang and He 2013).

The direction of project planning has shifted some since the days of the Planning Commission. Many projects are initiated by provincial or local governments, and then require the approval of NDRC, as opposed to being part of a plan initiated by the central Planning Commission. While provinces often try to evade NDRC approval by breaking up projects into smaller packages (Kang et al. 2012), this is possible in an area such as a wind or solar farm, where the design involves the aggregation of smaller units. It is not possible for large unit

facilities, like coal and nuclear power plants and oil refineries. Thus, NDRC continues to have significant control. Moreover, in recent years NDRC has exerted considerable control through its closure orders. The requirement to close plants is set out in the five year plans, and the actual requirements are set out either as targets to the provinces or as lists of specific plants to close by NDRC (Price et al. 2011).

While the market now plays a much more important role especially in individual and even company choices, NDRC in many ways has more concentrated power than the old Planning Commission. The Planning Commission had to contend with ministries, but over the years a number of functions have shifted from the ministries either directly to the Planning Commission and then the NDRC or to the SETC or National Energy Administration (NEA) and then were subsequently absorbed into the NDRC. While NDRC is much more interested in output than in environmental goals, it does not have a strong interest in maintaining monopolies. Its own authority is clearly greater when there are multiple companies to compete for its permits. In each case as will be discussed, there are clear non-environmental goals that NDRC believes will be met by increasing competition.

Managing State Assets

Perhaps the most significant change with corporatization is that the state needed to develop institutions for managing its own assets. The state has separate functions as a regulator and as an owner, and it took some time for that differentiation to be recognized and institutionalized. In 2003, the State Assets Supervision and Administration Commission (SASAC) was established, and SASAC represents the state's interests as owner for key central SOEs. These include the big five power companies, the three major oil and gas

companies and the two largest coal companies.[21] Thus, a large number of the significant incumbents in the cases detailed in the next several chapters are under the direction of SASAC. One important rising competitor in this arena, Shenhua, is also SASAC-managed. However, many of the competitors that enter the space are not. Provincially-owned SOEs, like Zheneng and Yudean that have been aggressive competitors in the power sector, discussed in chapter 3, and the small teapot refiners that will be discussed in chapter 5, are outside the purview of SASAC, and hence of direct central government control of their assets. The ownership interests for many of the rising competitors is at the provincial and local level.

SASAC was established to improve corporate governance and to focus government ownership on areas of government priority and comparative advantage (Naughton 2015). As discussed previously energy has been a top state priority consistently. Moreover, these firms have been among SASAC's most consistently profitable assets. Naughton (2015) reports that the big three oil firms are among SASAC's top four earners and that Shenhua is generally also in the top ten in earnings. While SASAC is supposed to manage these firms as a shareholder, in fact the firms have a great deal of independence, both because of the legacy of their previous bureaucratic power and because their leadership tend to be high-ranking party officials in their own right (Downs and Meidan 2011, Liao 2014). The energy firms have been particularly profitable for SASAC, presumably one of its major interests as the asset owner. However, despite the fact that their profitability has relied to a significant extent on their traditional near monopoly positions (Naughton 2015), as we will see in this analysis SASAC has not been particularly successful in protecting these firms from outside competition. While the Chinese government's traditional concern has been whether these firms should face

[21] SASAC companies 2010 and 2013 list from Barry Naughton.

international competition on their home turf, what we will see in the energy sector is that domestic competition from other SOEs can be at least as effective if not more so.

The background, therefore, of the effort to set pollution standards, were strongly independent industries, operating under state planning, but only loosely under state ownership, who were habituated to demand that exceeded their ability to supply, and hence a heavy emphasis on increasing supply at all costs. The industry had corporatized by the early 2000s, but what it would mean for governance was not yet clear.

Chapter 3 The Setting of Meaningful Power Sector Standards

As discussed in Chapter 2 the national-level Chinese power sector expanded from one company to five in 2002. After the power sector break up, provincial power companies could compete nationally: they were no longer restricted to their home province. At the same time new companies, like the coal company Shenhua could also enter the power market. As a result, by 2008 the market share of the top 5 had dropped to 45%. This change in concentration corresponded to the major changes in regulatory standards. Using in-depth interviews with regulators, company officials, and plant managers, I find that increased competition provided regulators with leverage.

Before testing this hypothesis that greater competition led to tougher standards, we first need to understand the nature of the regulatory apparatus that designed, set and implemented the standards. Thus, to understand where the standards fit in we first need to understand the Chinese environmental regulatory structure.

The Evolution of Environmental Regulation

Environmental regulation evolved concurrently with changes in industrial structure. Although the first Environmental Protection Law coincided with the launch of the reform era in 1979, the environmental agencies of the 1980s and 1990s, the National Environmental Protection office (1974 or 1978, depending on reports, through 1982), the Environmental Protection Bureau (1982-1984), and the National Environmental Protection Agency (1984-1998), had very little enforcement power. The first environmental regulatory agency was established in 1998, the State Environmental Protection Administration (SEPA). The

organization did not reach ministry (the Ministry of Environmental Protection or MEP) status until 2008.[22] Environmental policymakers had been arguing for greater pollution regulation since at least the early 1990s. Indeed, China's first National Environmental Protection Agency Administrator Qu Geping spoke out not just internally, but published internationally, on the subject (Qu 1992). However, prior to the 2000s they had little power and relied heavily on the initiative of the small minority of local governments that wished to push some kind of environmental protection agenda (Mol and Carter 2006). That approach was highly limited, because the group that chose that agenda were self-selecting and unlikely to rely heavily on polluting industry for their income and jobs.

The essence of change within the environmental bureaucracy over the past two decades has been a move toward more formal strength and authority and away from a highly varied and inconsistent system, under which local bureaus were more responsive to local government and adapted their own regulatory and implementation strategies to local requirements (Jahiel 1998). Since 2006 clear national policy has emerged. Environmental staffing increased, environmental targets were stiffened in the five-year plans and added to individual cadre performance evaluation, and local environmental bureaus no longer

[22] On March 13, 2018, at the National People's Congress, the ministry was again restructured as part of a larger State Council Restructuring and became the Ministry of Ecology and Environmental Protection (生态环境部). The core air pollution governance remains unchanged, but the new ministry has greatly expanded powers with new and much more clearly demarcated responsibilities for water pollution and land protection that will increase its ability to govern energy polluters. The most far ranging change is likely to be gaining the responsibility for governing climate change from the National Development and Reform Commission (NDRC), which had previously controlled climate policy as part of its energy governance and since the mid-2000s as a separate policy area. In the future, these changes will increase the new MEEP's capacity to control energy polluters. The research for this dissertation was completed in 2017, and thus I will use MEP as the name for the ministry. "国务院机构改革方案," (State Council Restructuring Plan), March 17, 2018. http://www.gov.cn/guowuyuan/2018-03/17/content_5275116.htm and Tianjie Ma, "China Reshapes Ministries to Better Protect Environment," *China Dialogue* (March 12, 2018). https://www.chinadialogue.net/article/show/single/en/10502-China-reshapes-ministries-to-better-protect-environment

depended directly on revenue from pollution discharge fees (which counterproductively encouraged maximizing discharge) for their operating revenues. In other words, there has been a move away from the fragmented form of authoritarianism to a more uniform and complete bureaucracy (Turiel et al 2017, A. Wang 2013). Yet, these changes did not result in across the board improvements. Instead, pollution reductions have occurred industry by industry and pollutant by pollutant.

High-quality environmental outcomes require continuous monitoring. Clean air and clean water do not result from punishment that occurs after regulatory breaches. The fundamental work of environmental enforcement is to prevent these breaches in the first place. This requires near constant surveillance, because polluters will seek opportunities when unobserved to cut corners and increase the amount of pollution. Air pollution emissions in both China and the United States are regulated not by the occasional complaints of the public but by Continuous Emissions Monitoring Systems (CEMS) on all major facilities (Schreifels et al, 2012) that operate 24/7. Chapter 4 provides further details on monitoring and enforcement.

Setting New Power Sector Standards

The case study in this chapter addresses the establishment of power sector standards that constrain emissions and require active abatement from power companies. SEPA approved the first constraining air pollution standards for the power sector in 2003. The critical step for the government was putting a "hard target" for this pollutant (sulfur dioxide) in the 11th Five Year Plan (which began in 2006).

In this case we examine a single sector with change over three distinct time periods:

Pre-2002: A single, monopoly power provider.

December 2002: A split into the Big 5 national-level power providers.

2003 – 2008: Rapid increase in number of providers. The Big 5 drop from 100% to 45% of market share with ability to operate nationally.

2008 – present: Relative stability in total market share by Big 5, but new large players begin to compete with them aggressively.

As discussed in the previous chapter, the goal of the power sector breakup was unrelated to environmental issues. Instead policymakers' goal was to increase electricity capacity and reduce shortages. Increasing competition did achieve this policy goal. After growing at 5 or 6% a year, growth in power sector jumped to 9% in 2003 and averaged 11.5% over the next decade (see figure 5). Indeed, at its most prodigious, in 2006 and 2007, China was adding new power capacity at a rate of 17-18% a year. This was the period that introduced the notion that China was adding two power plants a week, and indeed it was true.

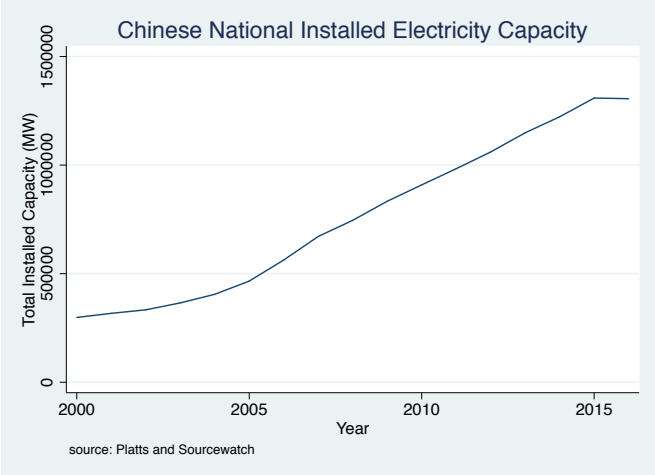

Figure 5: Installed Power Capacity in China, 2000-2015

The Standard-setting Process

Chinese standards are overseen by the AQSIQ. As its wide-ranging name implies, AQSIQ covers a broad range of functions, including the types of standards set by governments around the world, such as health, safety and environmental standards, as well as more technical performance standards that in many countries, including in the United States, are set by private bodies. As the apex organization, AQSIQ does not have the technical expertise for setting these standards itself, but instead works with other ministries and dozens of standardization research institutes to design the specifications and coordinates a system of hundreds of technical committees and tens of thousands of experts that are consulted in this process (Suttmeier et al 2006).

Suttmeier et al describe the Chinese system as involving four "tiers" of standards: compulsory, industry, local and enterprise. "These compulsory standards include regulations for processes and products, accounting, hygiene and safety, and environmental protection." The standard-setting process examined in this dissertation is of this top tier of national-level compulsory environmental standards, and it will include two distinct types: emissions standards for the electric power industry, and product standards for the oil and gas industry (since it is the composition of the petroleum product that determines the emissions, as will be discussed further in chapter 5). From these compulsory national standards dozens of technical standards for machinery and processes are derived, some of which are national, but many more of which are industry standards, written by the same standards institutes, but requiring lower levels of approval. All standards require AQSIQ approval – as the standard-setters I spoke with emphasize, the definition of a standard in China is that it contains the AQSIQ seal and a number issued by AQSIQ – but further approvals are determined by which tier the

standard lies on and among national standards, the breadth of its impact. Some national standards are approved at the ministry level, but others, are approved by the State Council. Given the complexity of coordinating across ministerial domains (China's fragmentary authoritarianism), if enforcement will require cross ministerial cooperation, State Council approval, and hence buy-in, is essential.

The power plant emissions standards that changed the trajectory of China's overall pollution levels were drafted by two research institutes operating in partnership – MEP's China Environmental Science Research Institute, and the Guodian Environmental Research Institute. Guodian is one of the big five power companies. When the power ministry was broken apart into companies, different research institutes that had previously reported to the ministry were assigned to different major power companies where they continued to serve the industry as a whole. Guodian's think tank is located in Nanjing, a fair remove from the politicking of the capital and by all accounts has relatively little to do with Guodian management. The standards are drafted by both institutes; however, Guodian, which has the real technical expertise in power plant equipment, takes the lead in writing the first draft. They go through a series of comment periods. These include advisory committee meetings, involving MEP officials, industry and technical experts (academics and researchers), about forty members total. For more recent standard setting, specifically the 2011 standards, there was also a public comment period. This was unlikely to have occurred during the previous standard setting, but though I spoke with a number of people involved with the 2003 standards, none remembered specifically what public comments were acquired. Now that comments are required, the institute documents and addresses each one. This is quite similar

to US rule-making procedures, with the important difference that neither the comments nor the Institute's responses are available to the public.

The Standard-setting timeline

Standards are established and then reviewed on a regular schedule. In general, interlocutors at several standards institutes said they try to review standards every five years. Each time they seek outside input and consult with their technical committee and then develop drafts.

The discussion below details the changes made to Chinese power sector emissions standards over the course of the period 2002 through 2016. The power sector case involves change over time. The time line below (Figure 6) combines the changes in the independent variable (in green, the level of concentration at the national level), with the changes in the dependent variable, the standards themselves (in red), with other key policy events (in black).

The expectations of the Stigler-Peltzman model is that when industry structure is more monopolistic it will be able to "capture" regulators completely leading to extremely lax regulation. This was essentially the story during the entire pre-reform period, where government itself was the producer and had no incentive to police itself. Once the industry is split up, government will be less open to pure dominance by the industry. However, regulation then offers a second attractive capture option for the regulated industry. If there are new players in the marketplace, regulation then creates the opportunity Stigler showed in his original analysis for companies to influence regulations in ways that create barriers to entry by increasing costs for competitors. The expectation, therefore, is that over time, some companies will start to find a competitive advantage in environmental regulation.

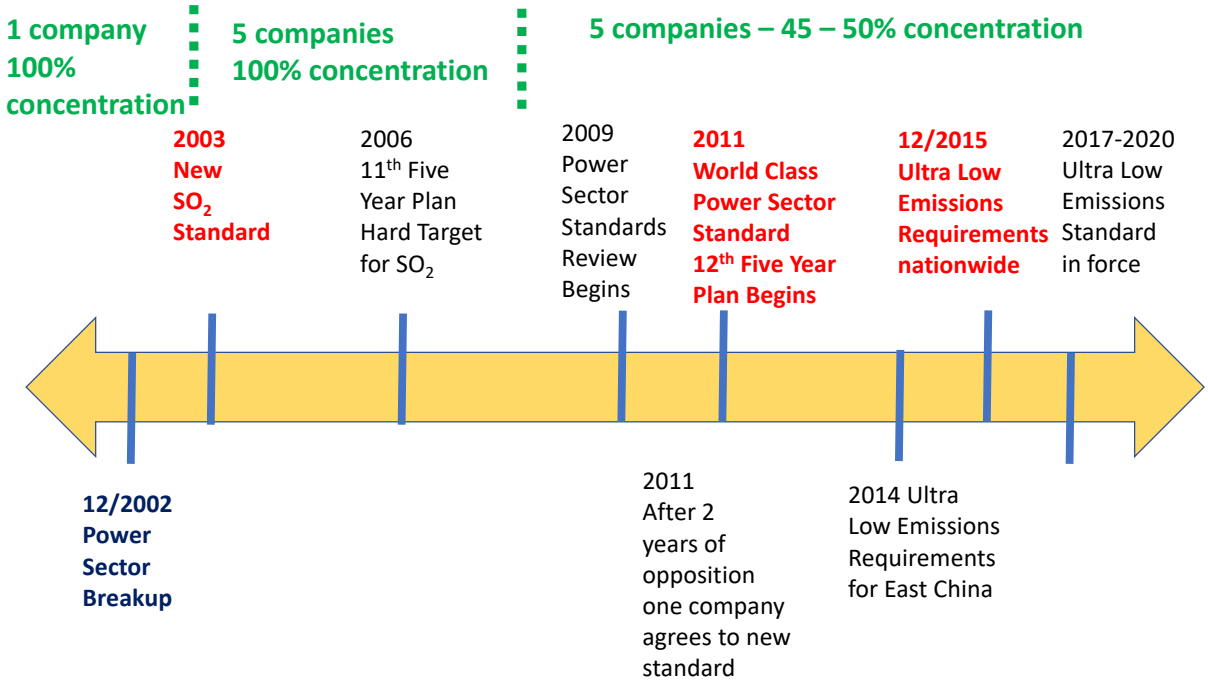

Figure 6: The Standard-setting Timeline

The 2003 Standard

Chinese environmental officials had been interested in raising emissions standards for years (Qu 1992). The power sector is critical to air pollution regulation, since it is the largest single user of coal in a heavily coal-reliant country. In detailed interviews with environmental regulatory officials, they emphasized that they had been looking for an opening, and the breakup of the power sector at the end of 2002 provided the opportunity. MEP introduced the first strict standards, with the first limits on SO_2, a major pollutant from coal, in 2003. A comparison of standards over the four time periods discussed is in table 1 below. The measurements are in terms of concentration in the smokestack emissions. The key points for our purposes is the magnitude of changes that take place in each time period. As you can see

upper limits on sulfur (which varied by size and location of plant) were cut by more than 5/6 in the 2003 standards, and subsequent reductions were equally large.

Table 1: Chinese Power Plant Air Quality Standards

	PM (m/m3)	SO_2 (m/m3)	NO_x (m/m3)	Mercury
Pre-2003 1996 Standard	200-3300	-	-	-
2003 Standard	200-600 (2005)	1200-2100	650-1500	-
	50-200 (2010)	400-1200		-
2011 Standard	30	100-400	100-200	0.03
Ultra-Low Emissions 2015	10	35	50	0.03

Sources: GB13223-1996, 2003 and 2011 Standards, MEP announcement: "全面实施燃煤电厂超低排放和节能改造工作方案" 2015

Prior to 2003 only regulatory costs had been calculated, and the power sector had estimated the total cost of controlling SO_2 as RMB 2 hundred billion (or about $24 billion at the 2003 exchange rate). In 2003 regulators for the first time took into account both costs and potential benefits, enabling them to compare the equipment and operating costs to the potential health and ecosystem benefits. The process was as described above. The standards institutes developed drafts and consulted with their advisory committee. Company representatives comprised the major share of advisory committee members, but at the time the power sector was distracted by their reorganization and despite earlier opposition were quiet

(according to my interlocutors and as previously documented by Kennedy 2005). One regulator described company opposition as the difference between an open hand (the Big 5) and a closed fist (the previous monopoly). It is easier to bend the hand, he said as he pulled back a finger to show how easily separated the fingers in an open hand are. They also likely thought they could fall back to the secondary strategy of avoiding implementation, and indeed in 2004 and 2005 there was little implementation.

However, MEP pushed to have "hard" (i.e. enforceable) SO_2 targets added to the 11th Five Year Plan at the beginning of 2006 and was successful. Once the new standards were incorporated into the Five Year Plan document as emissions targets that could not be met without the addition of FGD equipment, local governments began to enforce, and the power sector was forced to comply. The next chapter will address the relationship between industrial structure and local enforcement. The critical point here is that the stricter standards were the necessary first step without which new Five Year Plan goals and enforcement would have been meaningless. This demonstrates firstly why companies will always prefer loose standards to strict so as to avoid this threat of future enforcement, and how the opportunity to drive new standards through a divided and disorganized sector was critical to future enforcement success.

As shown in figure 7, power sector SO_2 emissions then rapidly decline. These controls were indeed costly, as power plants had to install and then operate FGD equipment.

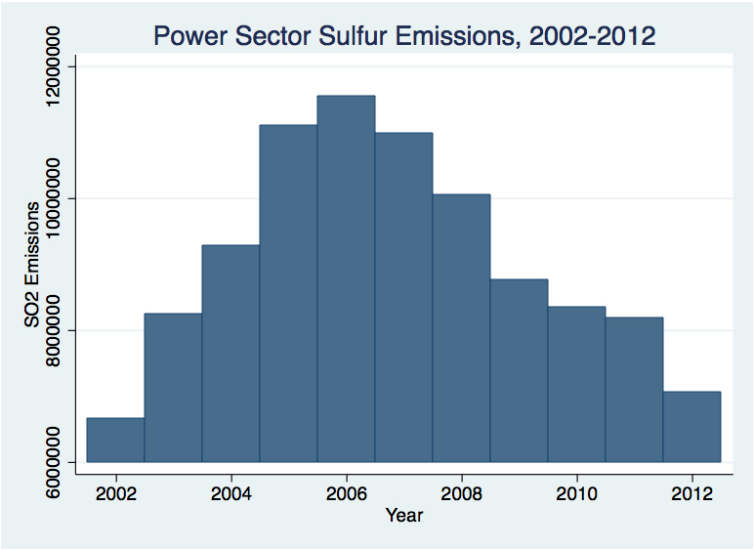

Figure 7: National power sector sulfur emissions 2002-2012

Sources: Chinese Environmental Statistical Yearbooks, 2002-2012

The 2011 Standard

The 2003 standard came up for review in 2009, close to the standard-setters' five-year timetable. The standards drafters looked both at the progress that had been made under the previous standard, which by 2009 had been fairly well implemented, and the continuing challenge of air pollution and decided to go for an even more ambitious standard. In interviews, my interlocutors said that they base their standards from the needs described in the five year plan, which in this case would have been the 2006 11th Five Year Plan. But if we look at the actual standards in both 2003 and in the next standard that they began to draft in 2009, in each case they actually anticipated what would then be in the next five year plan (in 2006 and 2011). The consultation process for the targets in the 12th five year plan began with a review of the previous plan in 2008, quickly followed by intensive work on new targets (Seligsohn and Tan 2011). Thus, by 2009 the institutes drawing up new standards had a

reasonable sense of what the likely overall pollution targets would be. Drafting a standard is essentially taking the overall pollution targets and translating them into specific technical requirements for emissions controls on individual facilities.

The standards drafted during 2009 were equivalent to those in the United States and Europe. This was an ambitious step for a Chinese organization to take since Chinese officials and experts generally argued both internationally and at home that they couldn't be expected to meet the standards of the wealthy west. Matching US or European standards was an expensive choice. It required adding both a new FGD, at the same cost as the first one, and even more expensive equipment for NO_x removal, the most commonly used of which is called Selective Catalytic Reduction (SCR).

The industry began the consultations very much opposed to the new standards. In fact, those involved said opposition was much stronger than it had been in 2003. However, as illustrated in figure 5, the industry was in a very different position from its period of initial break-up. Between 2003 and 2008 the Big 5's market share had dropped to 45%, and these companies were seeking to regain market share. The large companies that are included in national-level consultations initially made the standard argument that as a developing country China should not be held to the same standards as the U.S. or Europe, but the standard-setters had come to take environmental carrying capacity seriously. They explained to a meeting of top power industry leaders that the United States actually had more land and fewer power plants than China. So even with the same standard, China was going to experience a greater negative environmental impact at both the per capita and per hectare level. At this point the advantage of a more varied industry, and the difficulties involved in collective action emerged. As I predict in H_2 one company defects: My interlocutors said one major company's

leader responded to the drafters, saying he understood the argument for stricter standards and could agree with it. This particular company had already taken the lead on several "green" power plants, positioning itself as environmentally conscious. Once one major agreed that they could afford to implement the higher standards, the rest of the industry, especially the other large firms represented in consultations, could no longer argue effectively that the expense was too great. Thus, the government was able to use division within the industry to reveal information on true costs and to enlist support for needed air quality controls.

The advantage for the leading power companies of acquiescing to the higher standard was twofold: Firstly, especially for the company that initially agreed to the new standard it set them up as a cooperative player when seeking additional government permits and other advantages. Secondly, in line with Stigler's model, it added costs to building new power plants that were more easily borne by incumbents and the larger companies that are represented at these consultative meetings than by the smaller provincial players who don't attend.

The Ultra-Low Emissions Standard

The 2011 standards are the last set of official standards established for the power sector in China, and thus the final implementation deadline for these new standards, July 1, 2014, might seem like the end of this story. But instead, power plants all across China are in the process of installing still more expensive equipment. Costs in pollution abatement are not linear. As the amount of pollution left to be abated becomes more and more diluted in the exhaust stream, the costs increase at an ever more rapid rate. That had been the industry's

concern with the new sulfur standards in 2011. But in by 2014 companies within the industry proposed new and more difficult to implement requirements.

Experts in the industry, and especially in the standard-setting bureaucracy emphasized to me over and over that technically the Ultra-Low Emissions requirement (ULE) is not a standard. This differentiation is based on two critical tissues. The first is essentially bureaucratic. It was never approved by AQSIQ and issued a number, and thus for the standard-setting bureaucracy it isn't a standard, full stop. But while that sounds like a paperwork issue, the second reason is substantive and crucial. There are no technical standards attached to the requirement, and so it could never have been submitted for a number. A true standard involves technical specifications for how to meet the standard. And, in fact, the major reason why there are no technical specifications is because there was insufficient research to determine both how to meet the standard consistently and how to measure it accurately at scale when this standard was adopted.[23]

In fact, when Greenpeace examined data from 12 of the first 26 ULE plants, they found most were out of compliance at least some of the time. While some of the problem may have been equipment that was turned off, in some cases results are relatively close to but do not meet the requirement, which may well be because either the abatement or the

[23] The issue is the permissible amount of pollution in the exhaust stream is highly diluted, because it is so low. Standard stack monitoring has a larger error margin, which makes measurements at these low levels inaccurate. There certainly is lab equipment that can measure these levels accurately, but when the Chinese set the standards, they did not have a cost effective solution for industrial use.

measurement equipment is inconsistent at these very low levels, the two issues flagged by experts in my interviews.[24]

The idea behind ULE was a proposal to produce a coal-fired power plant whose emissions would be as clean as a natural gas plant. The entire coal to electricity process could not be as clean as gas: coal mining and transport have a heavy environmental impact, coal plants require more water for cooling, and the sulfur and ash captured at the plant need to be disposed of – a major waste management challenge. The idea was simply that the air pollution emissions could be kept within the level of a natural gas plant with increased use of pollution abatement equipment. Natural gas plants produce high levels NO_x – even more than coal-fired plants do. Thus, the 2011 standards, which added tough standards for NO_x for coal-fired power plants, took care of equivalence for that pollutant. But natural gas typically would produce no SO_2 and very little direct particulate (NO_x and SO_2, as well, become PM 2.5 particulates once in the atmosphere). So ULE's intention was to add much stricter controls for both SO_2 and particulate pollution. This meant adding a great deal of expensive equipment to achieve results that had never before been tested. The 2003 and 2011 standards used off the shelf technology demonstrated as effective in most developed countries. Achieving ULE results required breaking new ground.

The first companies that sought to build under the ULE concept were in Eastern China. Shanghai and its environs had imposed a ban on new coal-fired power plants even before a ban in the Beijing, Shanghai and Guangzhou areas became national policy under the

[24] Greenpeace China, "新闻摘要: 国内 12 家'超低排放'燃煤电厂的实际排放情况调查," "News Summary: Investigation of Actual Emissions of 12 Ultra-Low Emissions Coal-Fired Power Plants in China," (December 16, 2015). http://www.greenpeace.org.cn/ultra-low-emission/

September 2013 National Air Pollution Action Plan.[25] As early as 2012 a Shanghai company proposed a ULE plant, but it was never approved. The following year the largest company in neighboring Zhejiang province, Zheneng, took up the ULE concept and received provincial permission. That plant, Jiaxing Unit 8, was completed in 2014.[26]

The original idea behind ULE was to gain permission to build more coal-fired plants in areas that had already placed moratoria. The strategy was to argue with local governments that these ULE plants were just as clean as gas. But the concept rapidly spread to a program of retrofitting existing power plants, as well. The leader in retrofitting was the Shenhua group, the world's third largest coal company and the largest in China. With the opening up of the power sector after 2002, Shenhua became a major power generator and serious competitor to the Big 5. Not only are coal-fired power plants more profitable than gas, a major motivator for all of the power companies in their coal advocacy, but Shenhua also had a direct interest in both using and selling its coal. Shenhua's first retrofit was completed by the summer of 2014 and by the end of the year the company claimed 5 units completely retrofitted with one maintaining emissions no higher than a natural gas plant.[27]

Shenhua's 2013 annual report discusses environmental protection as a major risk factor for a coal company, but it is only in 2014 that the term ULE first gets introduced. Interest clearly ramped up fast, as the title of the 2014 annual report was *Embracing a Green Future with Ultra-Low Emission.* Without the pressure to improve environmental outcomes it

[25] "国务院关于印发大气污染防治行动计划的通知,"国发【2013】37 号，"大气污染防治行业计划。"
[26] "国内首套超低排放脱硫装置在浙能嘉电投运," The first domestic ultra-low emissions and desulfurization equipment was put into operation at ZNEC," *Zhejiang News* (July 4, 2014).
[27] China Shenhua Energy Company Limited, *Embracing a Green Future with Ultra-Low Emission, 2014 Annual Report*. Lin Huocan, "Shenhua Takes Lead in Ultra-Low Emission Technology," *China Economic Net* (June 16, 2016).

is unlikely that power companies would have chosen ULE. But while there was environmental pressure, the push from government initially wasn't for ULE.

The ULE approach was originally opposed by the MEP, and indeed MEP officials at every level hastened to remind me that it isn't an official standard, but rather a set of regulations approved by the NDRC, then issued jointly with MEP and then State Council approval, but with no connection to the Standards Administration. MEP officials had two objections. Firstly, standards were already high in the power sector and the cost curve for further abatement was steep. Improving reductions in other sectors would yield more cost-effective results. Secondly, as discussed above, it was not clear that the requirements could be met or measured consistently.[28] However, MEP was under considerable pressure from NDRC and the power sector to agree to ULE. Both power executives and energy planners preferred the costs of new equipment to limits on new coal-fired power plants and pressure to use more expensive and scarce natural gas. Environmental officials described there being "pressure" to agree to this new requirement. While they did not say so explicitly, one can imagine that arguing against a tougher standard would have been difficult within the State Council when all of MEP's other advocacy was for additional air pollution controls.

Once ULE was introduced, policy change snowballed. The requirements were first announced for new power plants in the East under the September 2014 *2014-2020 Coal-fired electricity energy savings and pollution reduction upgrade and transformation action plan*.[29]

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[28] This information comes from multiple interviews, but cost-benefit analyses showing the high cost of ULE were also published, such as Shi Rui, Wang Peihua, Yang Qian, Zhao Heng, "A Cost Analysis of Ultra Low Emissions Power Plants," "燃煤电厂"超低排放"成本效益分析," *China Atmospheric Network* (January 19, 2016).

[29] "煤电节能减排升级与改造行动计划（2014—2020 年)," "Energy Efficiency and Pollution Abatement Plan for Upgrading and Retrofitting Coal Fired Power Plants, 2014-2020," Ministry of Environmental Protection (September 2009). http://www.mep.gov.cn/gkml/hbb/gwy/201409/W020140925407622627853.pdf

Throughout 2015 Zheneng, Shenhua and a number of the Big 5 companies built new ULE units and retrofitted older units to ULE standards. Especially in the east companies used an early ULE upgrade to try to ensure they would be given permits for additional units.

ULE provided the two pioneers in this space several advantages. ULE for new units was a way to keep coal viable in the prosperous but polluted eastern provinces that were already taking active measures to reduce coal plant construction. In addition, both companies were also quite prosperous themselves, and forcing expensive retrofits would make them more competitive than some of their smaller provincial counterparts. While Zheneng's base was in the very wealthy eastern province of Zhejiang, much of its expansion has taken place in far western Xinjiang. Xinjiang is both rich in coal and had a fairly poor record of upgrading its powerplants. Similarly, Shenhua has expanded its powerplants particularly in the areas of its coal mining base in Inner Mongolia and nearby provinces. For both companies strict adherence to tough environmental standards provided an advantage over competitors that had been more long-established locally and might otherwise have better connections with local government.

The September 2014 plan required ULE for all new plants in the east, but requirements for the rest of the country were a bit vague. The central region was required to build new plants to ULE "in principle," while those in the western region were "encouraged." Similarly, retrofits were required by 2020 for the eastern region, but the plan was unclear on expectations for the rest of the country, simply encouraging them.

But by the following year the requirements became much tougher. On December 11, 2015, NDRC and MEP with State Council approval issued the *Work Plan for Complete Implementation of the ULE and Energy Savings Retrofit Program for Coal-Fired Power*

Plants.[30] This work plan explicitly sped up implementation for the entire country, moving the retrofit implementation date up to 2017 for the east, 2018 for the central region and 2020 for the west, and making these dates mandatory.

The speed of implementation and the stringency of the requirements surprised people in the coal-rich and far less affluent north central and western regions. Government and company officials in several of these provinces expressed to me concern about the cost of these abatement technologies, even while as good Party members they said they were sure they would comply. Given the large capital costs, however, the ultimate result of these standards seems likely to advantage their competition. In fact, the expectation would be that these additional requirements would lead to greater concentration. While the Big 5 also expressed their commitments to implementation,[31] Shenhua, the prime mover behind the new regulations, has already acquired one of the Big 5, Guodian, as discussed in chapter 2. Thus, over the course of the power sector's transformation we have seen capture move from a strategy of regulatory avoidance to one where powerful companies can drive regulatory changes that benefit them at the expense of their less powerful rivals and will likely lead to even greater concentration over time.

[30] "全面实施燃煤电厂超低排放和节能改造工作方案," http://www.mep.gov.cn/gkml/hbb/bwj/201512/W020151215366215476108.pdf?COLLCC=2058847079& This regulation was linked to an MEP announcement, "关于印发《全面实施燃煤电厂超低排放和节能改造工作方案》的通知," "On Disseminating the Work Plan for the Full Implementation of Ultra-Low Emissions and Energy Savings Retrofits of Coal-fired Power Plants," No. 164 (2015). http://www.mep.gov.cn/gkml/hbb/bwj/201512/t20151215_319170.htm?COLLCC=2058847079&

[31] "五大发电集团超低排放晒成绩单 五专家热议," "The Big 5 Power Companies' Progress in ULE," China Atmospheric Network (May 16, 2015).

Chapter 4 How Corporate Concentration Influences Enforcement

From the previous chapter, we know that increasing industry competition contributed directly to the government's ability to adopt tougher emissions standards. While standards are set at the national level, enforcement falls to local and provincial bureaucracies. Thus, looking at the provincial level gives us a better picture as to whether concentration directly affects implementation in a large N panel study.

The Chinese power sector is essentially divided into regional power grids, creating the opportunity to consider each province's industrial concentration and power-sector related emissions independently (Jia 2017). The number of companies in each province varied considerably over time as some provincial companies became large and powerful, other small local units only loosely connected to the national grid either were shut down or absorbed by larger companies, and the Big 5, who originally each had been allotted plants mainly in a specific geographic area, began to compete for projects throughout the country. Thus, I analyze provincial-level data to test H_3 whether when provinces are less concentrated provinces they reduce their SO_2 more effectively than when they are more concentrated.

Enforcing Emissions Standards

Enforcement takes place at the local level, and the approach strengthened considerably after 2006. The key air pollution standards for a fossil fuel-fired power plant apply to the emissions stream. As shown in Table 1 (chapter 3), in China these are set as concentration levels. Prior to 2006 local Environmental Protection Bureaus (EPBs) needed to use the laborious practice of collecting and testing samples. Given the workload these were conducted

relatively rarely and often on a schedule. While fines were relatively low, they actually were an essential part of the EPB's budget.

After 2006 these power plants were mandated to install CEMS and they were integrated into both monitoring and tariff payment systems (Schreifels et al 2012). While fines were moved into general revenue, changing the incentive for their use from revenue generation to enforcement, they still were not that expensive. The key enforcement mechanism involved the pollution abatement surcharge that power plants were allowed to charge the local grid company if they ran their equipment. At first the CEMS was connected to the local EPBs, who were supposed to monitor whether the equipment was operating and inform the grid company, but environment officials quickly realized that this was both inefficient and not fully effective. Instead they connected the CEMS directly to the local grid. The EPBs continued to monitor emissions, and in fact, the emissions information is available at all levels of the environmental bureaucracy. But the grid company itself became a part of the enforcement machinery.

If equipment was properly monitored, the system became almost self-enforcing (Figure 8). Power plant executives told me that they would lose money if they didn't receive the surcharge, because as one energy expert said to me: "Their whole profit is built into the surcharge." The base rate was designed to simply cover costs. The grid company, on the other hand, would closely monitor the power plants' CEMS operations, because it stood to make additional money if it didn't pay the surcharge. The grid's electricity charges to customers are not based on the cost of the electricity it purchases, but like the rates to the power plant, set by the Price Bureau under the NDRC (Yang 2006). EPBs still have a key role in monitoring the equipment itself, which they do by a combination of monitoring the CEMS data that streams

into their offices 24/7 and inspection visits to the plants to ensure that the equipment hasn't been tampered with. The actual equipment is kept by the local EPB under lock and key.

The result was that after 2006 provinces and localities had access to an effective enforcement approach, but as we'll see below, there was still variation in how effectively enforcement was carried out. In this chapter we will examine how corporate concentration affected provinces' actual implementation of the standards.

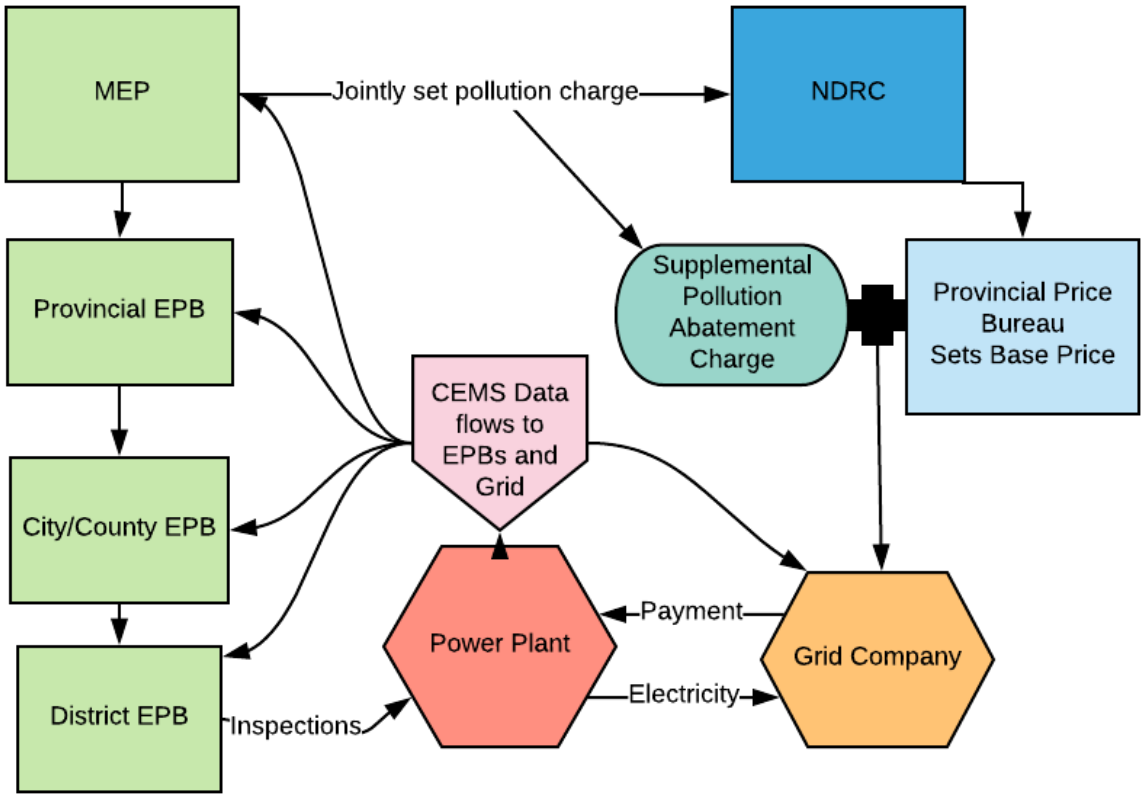

Figure 8: : Continuous Emissions Monitoring and Electricity Generation and Sales

Independent Variables

Corporate Concentration

Our Independent Variable (IV) of interest is the industrial concentration level. We can now calculate it by province-year as a Herfindahl Hirschman Index (HHI) for the power sector. The HHI takes into account the market share of all players in the market by adding the squares of the percentage shares of all the companies in the market – a higher number indicates a more concentrated market, and the range is from 1 to 10,000.

In most sectors subnational studies of the effect of industrial concentration would be difficult to conduct because companies buy and sell across provincial boundaries. Thus, it would not be that clear how their corporate influence would affect a specific provincial government, since presumably both producing and consuming provinces would have interests. However, the Chinese power sector is unusual, in that very little power, especially fossil fuel-generated electricity, is sold across provincial boundaries. Power generation is both the largest single source of air pollution in China and the sector that has faced the strictest standards and most regulation. Firms sell power at controlled prices to a single grid in each province, and while that grid is owned by one of the two higher-level grid companies in the country – State Grid or Southern Grid - in practice each grid is managed at the provincial level. Thus, in a practical sense industrial concentration within the electric power market varies by province. While at the national level the power sector is relatively competitive, concentration levels in provinces varies from highly competitive to highly concentrated. Regulatory requirements are set nationally, but implementation is at the local and provincial level.

Using data on over 13,000 power plants in China,[32] I have used the installed capacity per company to calculate HHI numbers for each province-year. While an ideal HHI for corporate concentration would use firm revenue, this is not available in the Chinese power sector. Installed capacity, however, is a reasonable proxy, given that prices are fixed and during the years covered by this dataset utilization rates were fairly high. This data is collected both by a commercial concern and an NGO. The Chinese government does not publish such data. As a result, it is subject to collection error. I have tried to correct for this by comparing all the available lists of power plants and conducting web searches with the aid of research assistants to attempt to disambiguate duplicates, questionable figures and other errors. Because all the data was collected after 2009, the ownership data for earlier years may overstates the number of firms in the industry in earlier years, which works against the hypothesis by reducing variation. Despite these limitations, figure 9 below shows the range of numbers over the 2002-2012 time period. The blue lines represent each province, while the red line shows the national trend.

The HHI varies a great deal in all the provinces from year to year. The variation by year is driven by the rapid changes in the Chinese power market. New entrants were coming into provinces and building plants, existing firms also built plants, and old plants were being regularly shut down. There was also some buying and selling of old power plants, shifting ownership between companies.

[32] The data on powerplants comes from the World Electric Power Plant database compiled by Platts, and updated through 2016, cross-referenced with the coal-fired open source database maintained by Sourcewatch, and checked through 2017 updates.

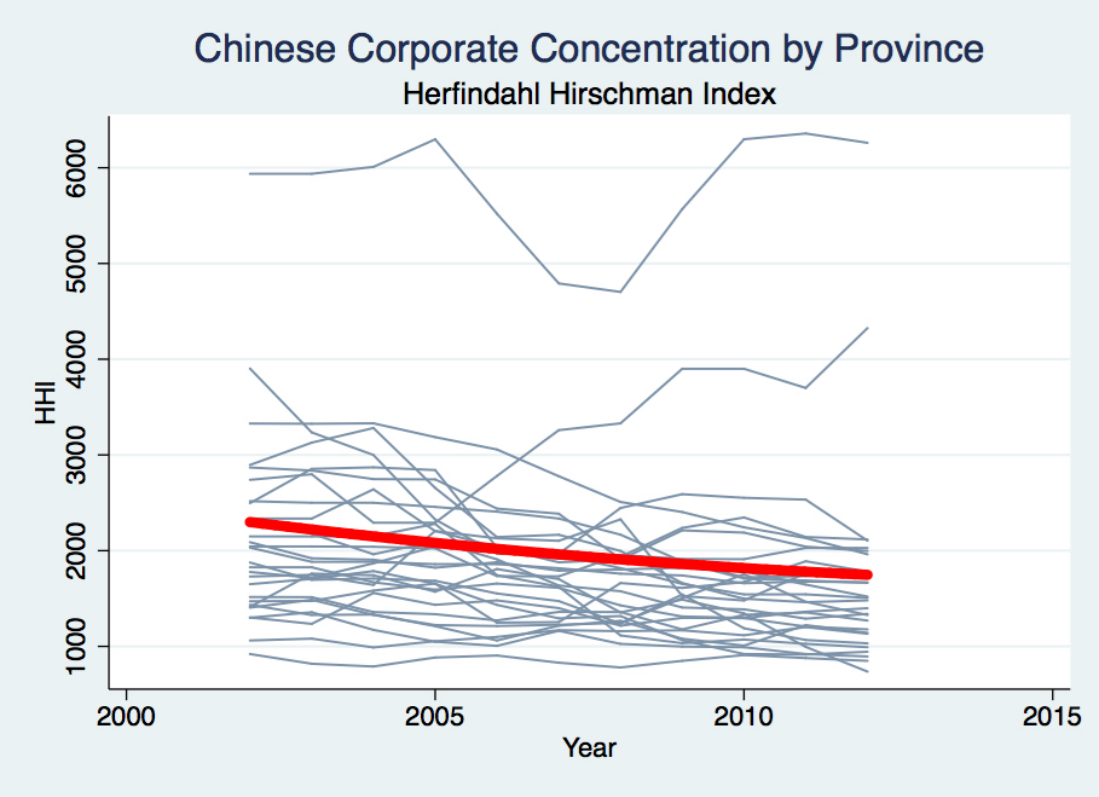

Figure 9: Provincial Herfindahl-Hirschman Index

Sources: World Electric Power Plants, Platts, 2009-2016, Sourcewatch, 2015-2017, and independent media searches, 2015-2017.

Additional Controls

In addition, I have controlled for the most likely alternative explanations for provincial variation. The first category is economic, and I have controlled for both economic growth and the percentage of industry in GDP. Industry is particularly important because it is the largest source of air pollution, especially in most of China. While much attention is paid to vehicles, ownership numbers outside of a few of the wealthiest cities are quite low, whereas China's GDP is more heavily weighted toward industry than most developed and developing economies.

A second key alternative hypothesis is political influence and political connections, in other words whether connections between the province and the center drive outcomes. The effect could either be that close connections insulate the province and allow for more flouting of rules or that close connections incentivize provincial leadership to want to adhere more closely to central government policy. To control for either case I have added variables for Party Secretary membership in the Communist Party Politburo and Central Committee. I tested for Provincial Governors, as well, but very few are members of these bodies.

Dependent Variable

Air Pollution Mitigation

The Dependent Variable (DV) is air pollution mitigation in the power sector. I specifically look at SO_2 abatement here, because Five Year Plan goals for SO_2 begin in 2006, while controls for other pollutants begin only in 2011. I am not able to disaggregate enforcement from compliance. I cannot say with this data whether an outcome is due to greater vigilance on the part of the province or greater compliance on the part of the companies. However, while performance improves over time in all provinces, it does not do so uniformly. To give a sense of the variation in pollution levels around the country, figure 10 maps average annual sulfur concentrations by province for the year 2010, after several years of decline. Levels are still quite high, especially in northern and eastern China.

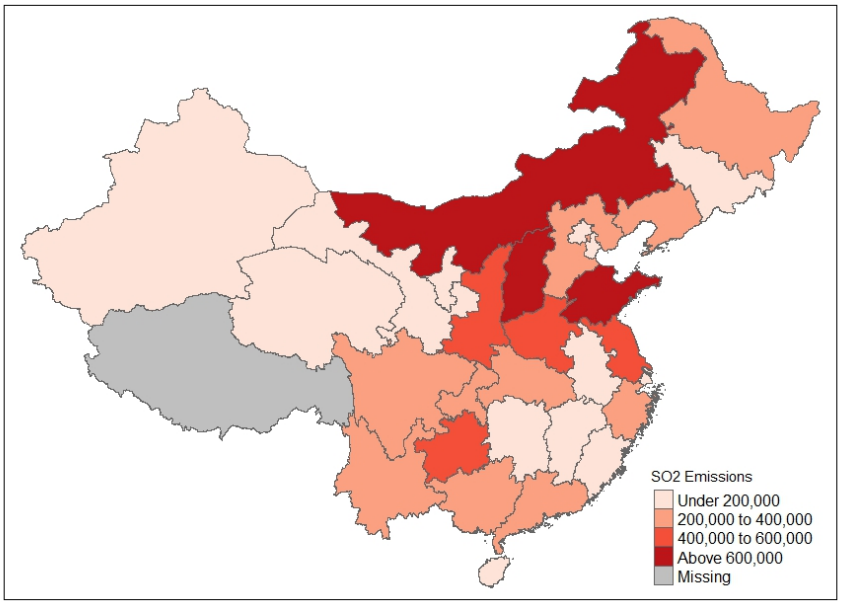

Figure 10: Average annual sulfur dioxide emissions by province, 2010

Source: Chinese Environmental Statistical Yearbook, 2010

Emissions have generally improved across all of China, but the amount of improved has varied considerably, as has the peaking year. The variation is driven both by the number of coal-fired power plants and the amount of pollution abatement equipment used. During this period of rapid growth in the power sector it was not uncommon for a locality to close a small plant, but then open a plant ten to twenty times larger. As a result, even if the plant were then abating 90% of its emissions (as one would expect to comply with the 2003 standards) or 95-98% of sulfur emissions (to comply with the 2011 standard), total emissions in the locality might not fall or might fall only slightly. The constant addition of new plants, retrofits of older plants and closure of still gives the locality a number of tools for controlling emissions – including licensing decisions, enforcement of retrofits and enforcement of closures. Thus, progress is uneven and quite variable, and there is considerable variation in the tons of sulfur

emitted each year in each province. Figure 11 shows the variation in sulfur emissions by province. The national trend is again shown in red while provincial emissions are in blue.

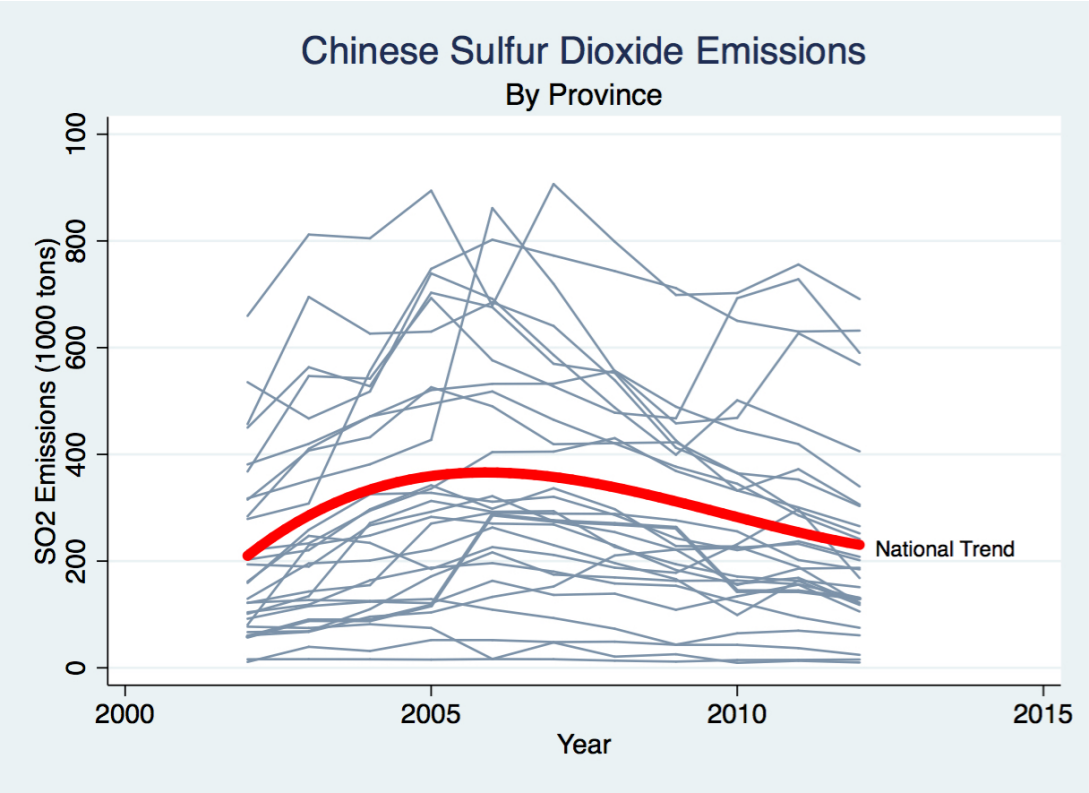

Figure 41: Provincial Sulfur Emissions from the Power Sector

Source: Chinese Environmental Statistical Yearbooks, 2002-2012

Results

Using the percentage of sulfur removed from the emissions stream as the dependent variable and HHI as the independent variable, I run a random effects model (following a Hausman test). I run five different versions of the model, using year fixed effects, a dummy for the policy change with the 2007 beginning of implementation of the 11th Five Year Plan, controls for political connections to the central government (whether the Party Secretary is on

the Politburo or Central committee) and economic controls (GDP growth and percentage of industry in GDP). The model is significant at the 95% level with year and provincial random effects and shows that less concentration leads to greater emissions reductions. With economic controls added, the model still shows the correct direction and similar magnitude, and is significant at the 90% level. Moreover, the effect size is important and consistent, for a 1 percent increase in industrial concentration results in a 5% reduction in the amount of sulfur removed from the emissions stream.

Table 2: Influence of Corporate Concentration on Sulfur Abatement 2002-2012

	(1)	(2)	(3)	(4)	(5)
Log HHI	-5.631*	-13.22*	-5.509*	-5.161+	-5.161+
	(2.773)	(3.681)	(2.804)	(2.946)	(2.946)
Five Year Plan		43.83*			50.73*
		(1.673)			(2.565)
Party Sec in Politburo			-5.454	-8.836	-8.836
			(5.226)	(5.783)	(5.783)
Party Sec CC member			-3.711	-6.065	-6.065
			(4.552)	(4.988)	(4.988)
Party Sec Alt CC member			-3.283	-5.266	-5.266
			(4.883)	(5.431)	(5.431)
Per capita GDP growth				-27.83+	-27.83+
				(15.28)	(15.28)
Percentage Industry				-0.517+	-0.517+
				(0.296)	(0.296)
_constant	50.96*	111.9*	53.79*	126.1*	75.37*
	(21.17)	(27.83)	(21.27)	(22.02)	(22.62)
Year RE	Yes	No	Yes	Yes	Yes
Province RE	Yes	Yes	Yes	Yes	Yes
N	326	326	326	297	297

Standard errors in parentheses
+ $p < 0.10$, * $p < 0.05$

These results thus are in line both with the theory and with the results of the qualitative case study. The fact that GDP is also important is to be expected. We know that pollution abatement tends to increase with GDP increase, but that fact does not explain the mechanism.

The importance of industry concentration is that it helps us understand how government is actually able to increase enforcement. Using divide and rule strategies government becomes more effective. Figure 12 below shows the marginal effects of the main

variables using model 5. The figure shows significance at the 95, 90, 80 and 70 percent level. As can be clearly seen our key variable is significant at the 90% level even when the control variables are taken into account. The model includes all three of the political controls, and as can be seen in Table 2 they yield similar, non-significant results. For simplicity, I include just one, whether the party secretary is in the central committee.

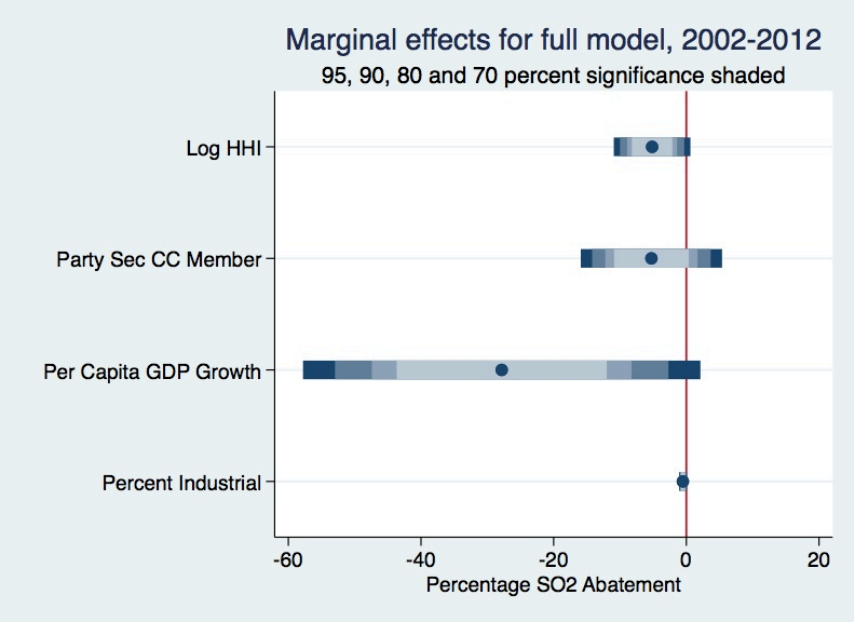

Figure 2: Marginal Effects of Full Model

Robustness Checks

One concern that might be raised with the previous analysis is that the enforcement mechanism as discussed above changed in 2006 with the installation of CEMS and then its connection directly to the grid companies. To address that concern I duplicate the models for 2006 – 2012. This offers both the advantage that it is under one mandated enforcement regime and that the HHI data is more accurate for this period, because the ownership records I can

access were closer to contemporaneous. The results in table 3 below are all statistically significant and show a somewhat larger effect. Interestingly in this more recent modeling neither per capita growth nor percentage industry in GDP are statistically significant, highlighting the importance of government-industry relations, which are affected by industrial structure, rather than simply economic resources, as critical the provinces' ability to regulate effectively.

Table 3: Influence of Corporate Concentration on Sulfur

	Percent SO_2 Abatement				
	(1)	(2)	(3)	(4)	(5)
HHIlog	-8.609*	-17.87*	-8.334*	-7.666*	-7.666*
	(3.758)	(5.197)	(3.788)	(3.838)	(3.838)
FYP		36.42*			51.48*
		(3.233)			(2.565)
SecPolitburo			-7.777	-9.447	-9.447
			(5.975)	(5.989)	(5.989)
SecCCmemb			-7.393	-7.376	-7.376
			(4.963)	(4.908)	(4.908)
SecACCmemb			-5.109	-5.529	-5.529
			(5.517)	(5.461)	(5.461)
pcgrowth				-2.204	-2.204
				(18.93)	(18.93)
pctind				-0.634	-0.634
				(0.386)	(0.386)
_cons	136.8*	153.6*	141.5*	143.9*	92.39*
	(27.72)	(38.97)	(27.70)	(28.32)	(29.06)
N	210	210	210	210	210

Standard errors in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$

To give a sense of the marginal effects of the inputs into the model I again provide a graph of marginal effects (figure 13). In this model the key independent variable, the electric power industrial concentration is significant at the 95% level.

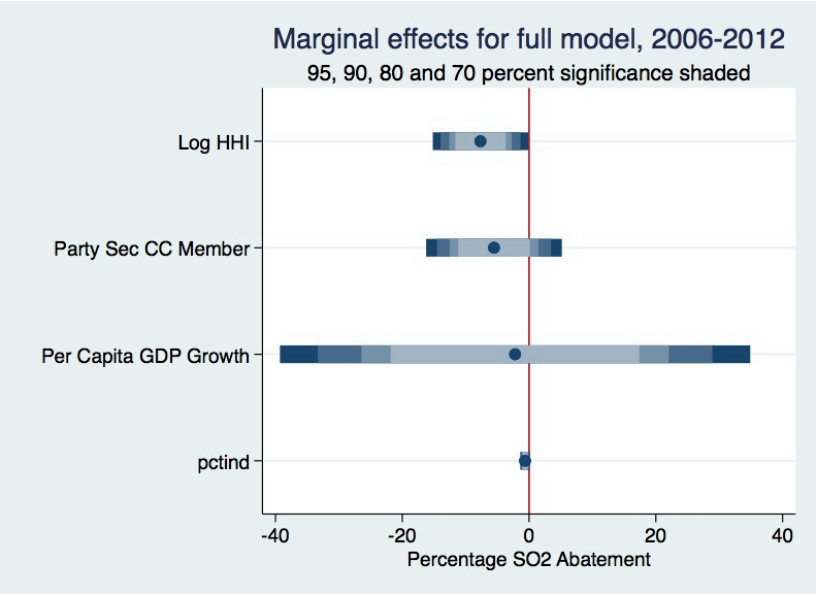

Figure 13: Marginal Effects for the 2006-2012 Period

A second concern, and one that can't be tested in the same model is public opinion. The notion that public views are a key point of pressure in shaping government is widely assumed in public discourse to be the case though rarely tested. There is little evidence that in an autocratic state the general public has a mechanism for influencing environmental outcomes (Seligsohn et al 2018), but some case studies have suggested such an input in the policy process (Li 2011). Thus, it seems important to test for the effect. Most measures of public participation are not very useful for examining provincial level effects, because the actors are quite concentrated, generally in the wealthy east. For example, Figure 14 provides a map of public interest NGOs in 2013, and as can be seen most are either concentrated in developed enclaves along the east coast or in nature-rich areas of the west.

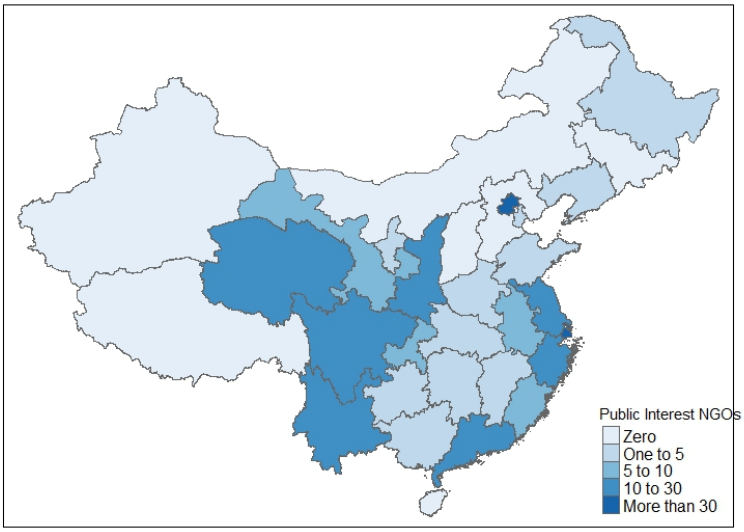

Figure 14: Public Interest NGOs in China, 2013

Source: Shieh and Brown-Inz, China Development Brief, 2013

As can be seen in the above map, many of the most coal rich areas, such as Inner Mongolia and Shanxi, as well as Hebei, the province that surrounds Beijing and provides the capital with a particular pollution headache, have no public interest NGOs at all, and provinces like Shandong, where power growth has been particularly large in recent years, have less than 5. By contrast, the largest number are in China's capital, and many of the other provinces with large numbers are western provinces with many NGOs devoted to wildlife protection, and wealthy southern and eastern provinces that rely more on light industry.

NGOs present another problem in that they are not possible to use in panel data, since we don't have annual numbers. However, we can look at complaints to EPBs, which the Ministry compiles and reports each year. Unfortunately, in 2011 they changed the way they reported the numbers, so that we do not have a continuous time series. So to test whether complaints have an impact on pollution abatement, I have tested this model separately, using

only data from 2002 to 2010. As can be seen in Table 4 the complaints only show up as significant in one of the 5 models, and the effect size varies and is quite small. In the one model that shows significance, the average total number of complaints received by a province in a year (4301) would have changed sulfur emissions by 2 percentage points, but in the other models, the effect size is much smaller. If we add GDP to the model, which seems critical, not only is the effect not significant, but the effect on emissions would be only .05 percentage points.

Table 4: Effect of complaints on pollution abatement

	Percent SO_2 Abatement				
	(1)	(2)	(3)	(4)	(5)
Letters_Air	0.0000953	0.000494*	0.0000904	0.0000130	0.0000130
	(0.000105)	(0.000124)	(0.000106)	(0.000108)	(0.000108)
FYP		38.49*			40.01*
		(1.505)			(4.004)
SecPolitburo			1.379	1.470	1.470
			(6.332)	(7.586)	(7.586)
SecCCmemb			3.173	3.264	3.264
			(5.692)	(6.859)	(6.859)
SecACCmemb			4.151	5.824	5.824
			(5.994)	(7.297)	(7.297)
pcgrowth				-29.48	-29.48
				(19.41)	(19.41)
pctind				-0.462	-0.462
				(0.313)	(0.313)
_cons	9.414*	9.730*	6.378	68.29*	28.28*
	(2.501)	(2.234)	(6.022)	(8.209)	(9.083)
N	264	264	264	235	235

Standard errors in parentheses
$^{+}$ $p < 0.10$, * $p < 0.05$

Looking at a map of where complaints are made, we can see why complaints do not play the major role (figure 15). Public complaints are strongest in wealthy regions, which, if

one looks back at figure 7, are not where we find the largest amount of emissions. Thus, overall, there simply isn't much connection between public concern and the actual magnitude of the problem, providing a signal for government as to where they have an engaged public,

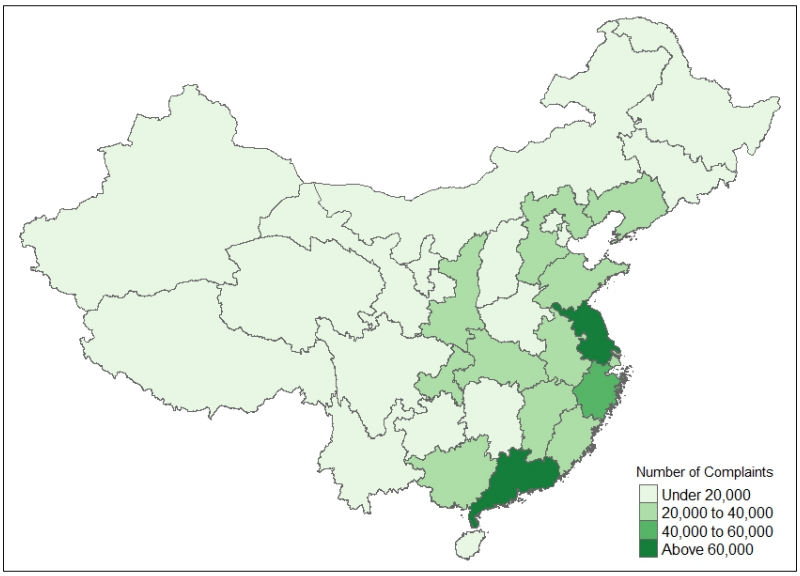

Figure 15: Total Number of Air Pollution Complaints by Province, 2010

but not as to where the mitigation problem is greatest. By contrast, the CEMS program provides the direct input needed.

Source: Chinese Environmental Statistical Yearbook 2010.

Conclusion

Thus, we can see from this chapter that provincial governments clearly faced capacity issues – greater wealth led to better abatement – but they also could be benefited or harmed by industrial structure. When provincial governments could avail themselves or more options for electricity supply, they were better able to implement China's increasingly tough regulatory standards. The changes in standards were critical, as were improvements in policy and

technology, but we still find significant variation. To implement provincial and local governments needed to be able to rein in industry and still ensure an adequate electricity supply. That required confidence that they could control the sector, which was easier with more players involved.

Chapter 5 Getting to Euro 4: Breaking the Oil and Gas Duopoly

China's oil and gas industry has a different history and structure from the power sector, and yet the introduction of competition turns out to have been crucial, and in this case connected, to driving environmental improvements. Given the ease of transporting oil products and the typical size of refineries, the oil and gas industry has never had the type of provincial markets that the power sector has maintained. Thus, the key questions need to be examined at the national level. In addition, while both sectors have been high priorities for the central government and reformed later than most other sectors (Andrews-Speed 2012), the oil sector has always been special. As discussed in chapter 2 the oil sector has had particular political salience for the central government. Concern about supply has loomed large for planners, and success in the sector was formative to the CCP's narrative of its own success. Oil is also, of course, tied to global markets much more directly than the power sector. The global oil market has historically been particularly volatile, and since 1994 China has been a net oil importer. Given this complexity and risk, the Chinese government has been exceedingly cautious in altering its structure.

There has been no similarly dramatic action like the power sector break-up, but when we look at the sector we find that significant competition has been introduced into the sector in the past five years. The change was subtle. While dominated by the oil majors, the Chinese government allowed small, locally-owned refiners, particularly in Shandong province. This competition always existed, but it was on an uneven playing field. The small refiners, known as teapots, were unable to import oil directly and could only purchase from the majors. This

meant their initial oil purchase price was always higher than the nationally-owned SOEs. Changing these policies in 2015, as we will see, fundamentally altered the market.

The Vehicle Emissions Challenge

The oil sector is critical not only for its input into the economy, but for its concomitant contribution to China's air pollution woes. After coal-fired power plants the single largest source of pollution in China is transportation (Kahn and Zheng 2016). While China, fairly unusually, uses about half its coal outside the power sector, those applications are diffuse and require separate technologies and regulatory approaches. Electric power was the obvious place to start a pollution control effort, but especially with the 2008 Beijing Olympics experience, it was clear both that vehicle emissions controls were necessary, and that regulation needed to be much broader than simply in urban hot spots (T. Wang et al. 2010, Zhou et al. 2010, Chen et al. 2013, Zhang et al. 2016). Reducing vehicle emissions, a major part of Beijing Olympics pollution control, had clear and measurable air quality and health improvements.

Regulating vehicle emissions is more complex than that for power sector, essentially because vehicles are a non-point source. With power plants, the regulator can, as shown in chapter 3, continuously monitor actual, real-time emissions. The result is that the specific mix of technology and fuel choice can to some extent be left up to the power plant managers. A plant can choose to use lower sulfur content coal, for example, and require less sulfur removal from the exhaust stream, or it can choose the reverse. While in China, which does not produce coal with such a low sulfur content that FGD can be avoided, FGD is in fact mandated, the regulator basically has only to focus on the emissions stream. By contrast with vehicles it

would be impossible for the regulator to monitor real-time emissions on the road. As a result, vehicle emissions are governed by technology specifications. Moreover, it is insufficient to simply specify the technology required in the vehicle. The fuel needs to be formulated to meet the needs of the pollution abatement equipment on board the vehicle, a regulatory system known as an "auto-oil" program (Yue et al. 2015). Most consumers are aware of the phase out of leaded gasoline, which the Chinese achieved in 2000 (Gallagher, 2003, Q. Li et al. 2012), but as pollution abatement has become more stringent, the fuel used in the vehicle has also needed to be of higher quality, containing fewer impurities and burning more cleanly.[33] Gasoline and diesel are both much more complex chemically than either coal or natural gas. While for both coal and natural gas there is one specific molecule that acts as the fuel, and anything else is an impurity, gasoline and diesel are complex solutions of hydrocarbons formed through multiple processes in a refinery (Song 2003). Fuel standards entail requirements for and limits on multiple chemicals, both content derived from the original crude oil and additives, to ensure a cleaner and more efficient burn (U.S. Department of Energy 2009). These requirements also vary seasonally. Typically temperate countries like China and the United States have separate standards for summer and winter.[34] Cleaner fuels require more processes at the refinery, many of which require additional equipment as well as the additional cost of running this equipment.

[33] United State Environmental Protection Agency, "Gasoline Standards; Gasoline Sulfur," accessed May 6, 2018, https://www.epa.gov/gasoline-standards/gasoline-sulfur

[34] Clifford Atiyeh, "The Vapor Rub: Summer versus Winter Gasoline Explained," *Car and Driver*, October 12, 2017. https://www.caranddriver.com/news/the-vapor-rub-summer-versus-winter-gasoline-explained

SINOPEC Dominates Standard-setting

The standard-setting process in China begins with the ambient air quality standard, which the MEP then translates into the required vehicle standard. The vehicle standard is then the basis for determining the fuel quality required. MEP has the lead in drafting both ambient air quality and vehicle standards with the actual standard issued jointly with AQSIQ.[35] The fuel standard, by contrast, while required to be derived from the vehicle standard, is actually drafted by SINOPEC's own research institute, the Research Institute of Petroleum Processing (RIPP). On paper this may appear similar to Guodian's Environmental Research Institute's drafting for the power sector, but in fact the two sectoral research institutes operate quite differently. As discussed in chapter 3, Guodian's research institute is tucked away in Nanjing, at a significant remove from Guodian's Beijing headquarters, and operates as a resource for the entire power sector rather than specifically connected to a single company. By contrast RIPP is on SINOPEC's Beijing campus and integrated into its business activities. SINOPEC's website describes RIPP as "subordinated to SINOPEC Corporation," and its main functions as "the development and application of petroleum refining technologies."[36] Thus, standard-setting is not a major part of the overall institute's work. And yet, the institute's standard-setting role is enormously powerful.

[35] Information on the standard-setting process comes from both interviews in China and information provided by transportpolicy.net, a collaborative website of the International Council on Clean Transportation (ICCT) and DieselNet, that provides comprehensive information on most national vehicle and fuel standards, including China's.

[36] http://www.sinopec.com/listco/en/about_sinopec/subsidiaries/research_institutions/20161109/news_20161109_403866876515.shtml, accessed May 7, 2018.

One key indicator of the difference in power is that while for power sector standards MEP's own research institute acts as the coordinator and secretariat, RIPP is the actual secretariat for all fuel standards, including these crucial environmental standards (Yue 2015).

Since the Chinese first adopted vehicle standards in 2000, they have basically followed the European vehicle regulatory system. The two prevalent approaches to vehicle emissions regulation are the European and the U.S. systems, although Japan and Korea both have distinct systems. The European system is marked by its simplicity. Firstly, it numbers its increasingly stringent requirements by a simple Euro 1 to Euro 6 scale. As a result, it is quite easy for the public to know where a country or city is in terms of relative stringency even if they know little or nothing about the technical requirements of emissions control. Secondly, as the European system progressed from Euro 1 to the higher levels required in recent years (we are now at Euro 6), it combined air quality and greenhouse gas control into a single set of standards, making the system even easier for the general public to understand. The U.S. continues to run its emissions, fuel economy and alternative fuel requirements with separate nomenclature and implementation rules. Many countries around the world, from Indonesia to Argentina, have simply adopted the European system wholesale, including the nomenclature. The Chinese and the Indians basically adopted the European system, but renamed it with their own countries' name first. The Chinese system is generally referred to in English as China 1-6, while in Chinese it is actually simply the national system (国1-6)[37] MEP, however, has worked closely with the U.S. EPA and the state of California on vehicle standards and implementation over more than twenty years, and there are aspects of the U.S. system, with its

[37] Similarly, the Indian system is Bharat 1-6, Bharat being India's official name in its Constitution.

more stringent testing and complex requirements, that MEP prefers. As a result, China 6 is not simply a copy of the Euro 6, but actually is more stringent, and in certain respects its requirements will be as strict as those of California, the most rigorous in the U.S. (Wu et al. 2017).

Effective vehicular emissions control depends heavily on these product standards – the specifications for on-board emissions control equipment and for the fuel that suits that equipment. Reducing the pollution from fuel both reduces pollutants directly by cleaner burning and protects the vehicle's emissions control equipment, since impurities, especially sulfur, damage the equipment, reducing its abatement efficiency. MEP officials report that these product specifications lead to the vast majority of pollution abatement, that the annual pollution checks we are all accustomed to have relatively little effect on overall pollution levels compared to ensuring the fundamental technology is clean.

Lagging Fuel Standards

Clean fuel needs to be available on the market before the roll out of new vehicle technologies to avoid damaging these more sensitive pollution abatement technologies (Wu et al. 2016). Because the Euro or China system employs the same standards numbers for the vehicle and the fuel that means that the China 4 fuel should be available before the China 4 vehicles come on the market. This has proven to be continuously problematic in China, where different cities have phased in these new standards at different times before the standard becomes national, and where the major refinery companies, SINOPEC and CNPC, have insisted that it is difficult to meet higher standards (Yue 2015, Z. Yang 2015). While delays of six months to a year have been the norm, the most dramatic delay was with the adoption of

China 4 diesel standards. These were originally mandated to be implemented in 2010, but after three delays, were finally implemented in 2015. Until 2015 the major refiners, SINOPEC and PetroChina insisted they could not meet the China 4 standard.

The need for a genuinely coordinated strategy increases as the standards increase in stringency. The more sophisticated pollution abatement is expensive and sensitive to damage. By all accounts the real shift occurs between Euro or China 3 and 4. The cost and the required changes are particularly great for the upgrade in diesel quality. At the China 4 level heavy-duty vehicles require SCR and diesel particulate filters (DPF), both of which require the cleaner fuel. In particular the DPF requires that refiners produce diesel with sulfur levels less than 15 parts per million (Z. Yang et al 2015). Although refiners had been slow to deliver other reformulated fuels to the market, the shift from China 3 to China 4 diesel was the only one that involved years of active and successful effort by the refiners to block its adoption.

While transport-related pollution abatement requires a suite of policies ranging from traffic management and overall vehicle number control to mass transit development (Z. Yang et al 2015), vehicle emissions control through on-board equipment and fuel quality are central to the task. Moreover, heavy duty vehicles (essentially trucks and buses) are the major contributors of two of the pollutants of greatest concern, NO_x and PM 2.5. In studies before the China 4 diesel standard was implemented, trucks alone accounted for 76% of NO_x emissions and 73% of PM 2.5 (Wu et al. 2016).[38] Thus, this specific regulatory change is

[38] The best study available to me did not break out sulfur emissions separately, but sulfur emissions are a major component of the PM 2.5 formed in the atmosphere and would be an important contributor to the overall PM 2.5 figure. It is as PM 2.5 that sulfur causes major health damage. NO_x both contributes to PM 2.5, as well, and is separately a health issue.

critical, both from the perspective of our independent variable of concern, the market power of the major refiners, and from the perspective of its actual impact on pollution abatement.

When I began this study I expected the story here would simply be of a concentrated industry blocking environmental protection. But, in fact, the new standards, while delayed, were brought into effect in 2015, and the China 5 and 6 standards have now been accelerated. In interviews with refiners it turned out the Chinese government had introduced competition, just in a more indirect way than was the case with the breakup of the power sector.

The Chinese Refining Sector

Dominated by a Duopoly

The Chinese refining sector has always been dominated by SINOPEC, and it continues to be the nation's largest refiner with almost 35% of total refining capacity in both 2015 and 2016, but that is a substantial decline from almost 45% a decade ago (Jin 2017), and an even more precipitous decline from 1998, when CNPC and SINOPEC traded assets (Downs 2017b). Prior to 1998 SINOPEC, established in 1983, controlled all the national-level state-owned refineries, the downstream portion of the oil industry, while CNPC controlled the upstream portion. The only major change had been the addition of CNOOC in 1982 to manage offshore upstream development, which was essentially a joint venture business. In fact, CNOOC was founded to handle offshore exploration and development precisely because the domestic Chinese oil industry lacked the needed technology. In the 1980s it was an attempt to shelter the domestic industry from foreign interference (Lieberthal and Oksenberg 1986, 1988). Thus, through the 1980s and even through most of the 1990s, even as competition was introduced to many other sectors, oil and gas continued to be a state-planned

sector. The three companies the state established in the 1980s had no overlap in business functions. While CNPC and CNOOC both were upstream developers, they did not compete for development opportunities and for the most part sold their oil in different markets with much of CNPC's oil used domestically, while CNOOC marketed its production overseas. The choice to introduce foreign technology to the upstream exploration and development side of the business reflected the much higher priority placed on supply rather than on quality output. The result was that SINOPEC not only dominated the refinery business, but was left relatively undisturbed.

However, by the late 1990s Chinese state planners became concerned about the inefficiency and lack of competition in the oil business. Their first attempt to address the issue was an asset trade in 1998. SINOPEC gave some refineries to CNPC in return for some oilfields. The idea was to create two competitive integrated oil companies. Unsurprisingly, both companies kept the better assets for themselves. Thus, SINOPEC continued to control the larger more advanced refineries in the country, while CNPC received smaller units (Kambara and Howe 2007). While the sector successfully more than doubled capacity between 2000 and 2016, the Chinese government often found it resistant to policy initiatives, ranging from the fuel quality upgrades of concern here to the expansion of natural gas capacity. The fundamental issue in the refining business is that more modern, efficient and high tech refineries can produce more of the fuels in high demand, particularly higher quality diesel and gasoline (Ma et al. 2012). Crude oil is a mixture of hundreds of different hydrocarbons. Rudimentary refining produces products like fuel oil that used to be used in some small, very dirty power plants that have long since been shut down, as well as

lubrication-type products. Refineries that are somewhat technically more sophisticated can produce some gasoline and diesel, but more technology enables refineries to produce more high quality products including these key transport fuels, by changing molecular structures and removing impurities (Kambara and Howe 2007).[39] Thus, as China's vehicle and aviation fleets grew, policymakers became increasingly interested in seeing the refinery sector expand and become more sophisticated (Walls 2010). While the Chinese government did allow a small portion of the sector to partner with international companies, the major focus was on facilitating upgrades at the two main oil companies. However, these companies had a captive market and were not necessarily interested in expensive upgrades.

An additional challenge for China's refineries has been adapting to imported crude oil. China's indigenous crude was mainly low sulfur "sweet" crude (Walls 2010, Ma et al. 2012). As mentioned previously, in 1994 China became a net importer, and imports have grown rapidly ever since. By 2000 imports constituted over 40% of China's total consumption and by 2015 imports were up to 72% of total consumption. Production has been essentially flat for the past decade, and thus all of the increase in consumption as Chinese society has become wealthier and more mobile has been met by imports (National Bureau of Statistics 2017). Much of China's imported crude is higher in sulfur, both because of the nature of middle eastern supply and Chinese refiners' preference for less expensive product (Kambara and Howe 2007, Leung 2010)

[39] "The Process of Petroleum Refining," Penn State Department of Energy and Mineral Engineering, https://www.e-education.psu.edu/eme801/node/470, accessed April 30, 2018.

The Quixotic "Teapots"

At the same time China had a legacy of small independent refineries, known as the "teapots." The teapots were originally established by local governments, and while their ownership structure now varies, they continue to be tied to local governments, where they are important economically, and they have never had a direct connection to the central government. More than two-thirds of the teapots are in Shandong province, while the rest are mainly in the northeast, Shaanxi and Guangdong. These local refineries developed in response to specific local geographic or geologic conditions that created opportunities that were not controlled by the central Ministry of Petroleum. The majority are in Shandong's Shengli oilfield, where oil deposits were much more spread out than in China's other oilfields, creating the opportunity to capture oil from leaky pipelines on the one hand, while also needing to mollify local government for the major land losses associated with the oil development on the other. Allowing some local refining helped address local grievances while also reducing the central companies' costs (Downs 2017b).

Once established the teapots proved surprisingly difficult for the Chinese central government to control much less abolish. While the teapots developed to handle miscellaneous crude from China's own production, given China's net importer status and the decline of the older oilfields where these refineries are based, the original need for these scattered refineries has long since disappeared. The teapots were also small and inefficient. Not only did they produce low quality fuel, but they used energy-intensive, dirty processes. An independent national survey in 2010 and 2011 found fuel quality from independent producers varied considerably, but overall was of much poorer quality than that produced by the two majors (Yue et al. 2015). Both the majors themselves and the central government

wanted to shut down the teapots, and some of the very small teapots were shut down in the early 2000s (Kambara and Howe 2007), but since then the remaining teapots successfully allied with local governments to avoid shutdown (Downs 2017b).

Shutting down local refineries appeared to be much more challenging for the central government than closing power plants, and in many ways is more similar to the challenge the Chinese government has had with other heavy industrial sectors like steel. One great advantage of power is that it is by nature distributed. When the central government ordered a locality to close down some old power plants, the locality was still allowed to run and even to build newer, more efficient and cleaner plants. While by 2016 much new power sector construction was cancelled, during the 2006-2010 11th Five Year Plan period when many of the oldest power plants were being shuttered, there was widespread new construction. By contrast there is no need for refineries in every locality. In comparison to the 13000 power units in the country, there are around 200 refineries, and even this number is much larger than optimal. The Chinese government's goal has been to encourage efficient, large refineries. How that goal has related to competition has evolved over time.

The teapots also met a need that Chinese policymakers have yet to find a different solution. When one visits the refineries in Shandong there are miles of tanker trucks lined up to bring gasoline or diesel to independent service stations throughout China. I observed license plates from as far away as Yunnan, well over 2000 km by road. While the majority of service stations in the country, and virtually all in the big cities and other more prosperous routes, are branded stations connected to the majors, the oligopolistic players don't choose to serve less profitable rural or out-of-the-way markets. This is obviously an inefficient and

environmentally suboptimal practice. But the lack of service by the majors has made it harder for the Chinese government to simply close down the teapots.

While the 1998 redistribution of assets signaled some interest in creating competition, the Chinese government's stance toward the teapots was not encouraging for many years. As domestic crude became scarcer, their position became more precarious, because they had no crude oil import rights. Their options were to purchase crude from the majors or from the few other SOE import licensees like Sinochem at a mark-up or to import fuel oil. Either way their costs were higher than that of the majors for producing a substantially lower quality product. Not only were they feeling significant economic pressure, operating at 30-40% of capacity (Jin and Fei 2017), but they were directly targeted for closure. In 2009 NDRC ordered refineries with production below 1 million tons per year or 20,000 barrels/day to close by 2011, and suggested that those between 1 and 2 million tons and those that produced only low end petroleum products should be "guided" to the same goal.[40] By 2011 the 2 million ton or 40,000 barrels/day minimum became NDRC policy, with a requirement that all smaller units be closed by 2013.[41] But as Downs (2017) reports, these instructions as in many other areas where there is local protectionism, did not have the intended effect. Instead firms merged to exceed the production minimums.

At the same time, however, while the two majors' refineries were larger and somewhat more modern, they still insisted they couldn't meet higher fuel quality standards. In particular

[40] National Development and Reform Commission, 发展改革委员会，"在保增长，扩内需中加快淘汰落后产能，推进产业结构调整升级" " Accelerating the elimination of backward production capacity, promoting industrial restructuring and upgrading, while maintaining growth and expanding domestic demand," May 3, 2009. http://www.gov.cn/gzdt/2009-05/03/content_1303018.htm

[41] National Development and Reform Commission, "产业机构调整指导目录 " "Instructions for Industrial Structural Reform (2011)" http://www.gov.cn/gzdt/att/att/site1/20110426/001e3741a2cc0f20bacd01.pdf

they stalled on producing higher quality diesel, the move from China 3 to China 4 (see figure 16). As a result, the standard, originally schedule for 2010 was delayed first to 2012, then 2013 and finally to 2015.

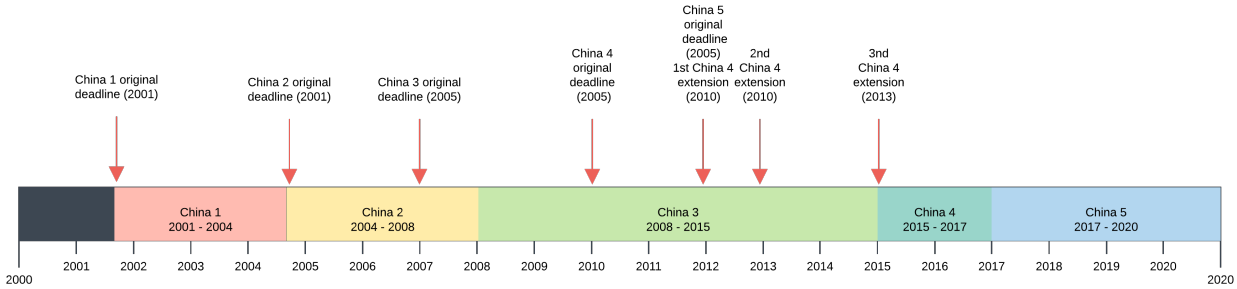

Figure 16: Heavy Duty Vehicle Fuel Standards Timeline

Sources: Z. Yang et al 2015； GB 17691-2001 "Limits and Measurement methods for exhaust pollutions from compression ignition (C.I.) engines of vehicles；" GB 17691-2005 "Limits and measurement methods for exhaust pollutants from compression ignition and gas fueled positive ignition engines of vehicles (III, IV, V);" 中华人民共和国环境保护部办公厅， "关于国家机动车排放标准第四阶段值实施日期的复函" (2010)1390 号; Ministry of Environmental Protection, "Notice on achieving China 4 standards for Compression Ignition engines and light vehicle engines," 中华人民共和国生态环境部环境保护公告， "关于实施国家第四阶段车用压燃式发动机与汽车污染物排放标准的公告,"(2011)92 号, The State Council, People's Republic of China, "China upgrades fuel quality standard for cleaner air," *Xinhua*, December 26, 2016.

Even when the standard was delayed to 2015, the Chinese government, in the form of MEP and even the State Council, had very little information as to whether the oil majors could actually produce higher quality diesel. Not only is the industry a duopoly with what is either an explicit or tacit agreement that SINOPEC continue to take the lead downstream, and CNPC maintains the policy lead upstream, but very little information exists outside of their control. While power plant engineering is taught in dozens of universities run through the

Ministry of Education, and the government draws expertise from these major engineering universities, most oil experts come from a very limited number of universities that until recently were under the control of MPI. Technically today these universities are under the Ministry of Education, but they continue to be managed by the oil companies and there is a considerable revolving door between institutions like the China University of Petroleum and the major companies. Moreover, a search of journal articles in Chinese academic journals related to petroleum technology revealed no authors from RIPP, the key research institute under SINOPEC. Interview subjects outside of RIPP were clear that RIPP controlled information on the costs and technical issues surrounding standards implementation, and that they did not have access to such information.

From interviews in China, there were two other sources for information on costs. The first was the U.S. Environmental Protection Agency (EPA), which had been advocating for what it termed "low-sulfur diesel" since the mid-2000s. EPA advocated low-sulfur diesel not only for heavy-duty vehicles, but also for light-duty vehicles, as well, i.e. cars. The logic behind this is that diesel is superior from a greenhouse gas (GHG) point of view, because it has more heat content than gasoline, so if one could produce diesel vehicles that were as clean as gasoline vehicles, there would be a GHG and local air pollution advantage. As we have seen with the Volkswagen scandal in the US this logic turned out not to work out that well, and to their good fortune the Chinese never had much interest in diesel for passenger cars. Chinese industry was already set up for gasoline vehicles, and they were looking ahead, intending to lead in electric vehicles. However, EPA's advocacy of low-sulfur diesel introduced the concept to Chinese policymakers, and they were interested in using it in traditional heavy duty vehicles. In addition, a transportation NGO said they had given the

Chinese government confidential estimates on the additional costs to refiners of meeting China 4 standards. These outside advocates were important, but as we have seen with the power sector, there is always concern about how information gained outside of China will actually apply to Chinese conditions.

The Teapots See an Opportunity

With essentially a standoff between the MEP, which has been able to convince the State Council to adopt a higher standard, and the oil majors, who continued to say that while they supported pollution abatement in principle, they weren't ready to meet this higher standard, the teapots spotted an opportunity. In 2013 one of the relatively large teapot refineries in Shandong decided to upgrade and demonstrate to the central government that it was able to produce high quality fuel. The China 4 standard had been delayed to 2015, and so the company had plenty of time to upgrade its facilities and show it could meet the new standard. By doing so it also revealed information to the regulators on the real costs of producing higher quality fuel even in China's relatively small refineries when compared to the world norm. If one of these much smaller teapots could do it, why were the majors dragging their feet?

By 2014 other independent companies told me they saw what their neighboring firm had done and decided to follow suit. The result was that several of the teapots were able to produce China 4 diesel in advance of the 2015 target date. They had also expanded their production, and some had closed their smallest and least efficient units. The central government observed the teapots and responded with a strategy that incentivized their compliance not only with the fuel quality standards, but with several other central government

policy priorities. In February 2015 NDRC announced that it would grant crude import quotas to independent refiners that closed all of their crude distillation facilities (CDUs) with a capacity of less than 2 million tons/year or 40,000 barrels/day, adhered to the new fuel quality standards and built CNG or LPG storage.[42] With teapots now in compliance, SINOPEC and CNPC had no hope of asking for another extension for the China 4 standard, and the 2015 deadline was met.

The teapots jumped at the chance to import oil, rapidly pursuing upgrades and seeking import permits. By 2016, 19 refiners had received 1.5 million barrels/day in import permits. The number was cut in 2017, to 1.1 million barrels/day, partly because the teapots had not used all of their capacity in 2016, but also because of their long-running tax avoidance behavior. However, the teapots formally announced they would comply with taxation rules in June 2017, and in November 2017 China's Ministry of Commerce announced a significant expansion in import permits for independent in 2018, totally 2.85 million barrels per day.[43] At the same time the Chinese government was able to get the improvements in diesel fuel quality back on track. Not only was China 4 was implemented nationwide in 2015, China 5 was rolled out nationwide at the beginning of 2017. Some localities, like Beijing and Shanghai, are

[42] The CNG or LPG storage does not relate closely to the other goals. This simply appears to be the central government taking advantage of the opportunity to require policy goals, since it had also faced difficulty in getting oil and gas firms to build sufficient storage.
[43] Irina Slav, "China's Teapots Agree to Play Ball with State-Run Giants," OilPrice.com (June 6, 2017). https://oilprice.com/Latest-Energy-News/World-News/Chinas-Teapots-Agree-To-Play-Ball-With-State-Run-Giants.html, Anjli Raval, "China Strives to Reduce Capacity of 'Teapot' Oil Refineries," *The Financial Times* (Sept. 8, 2017) https://www.ft.com/content/2b6d92cc-946c-11e7-bdfa-eda243196c2c and Tsvetana Paraskova, "China Relaxes Rules for Teapot Refiners," Oilprice.com (Nov. 8, 2017). https://oilprice.com/Latest-Energy-News/World-News/China-Relaxes-Rules-For-Teapot-Refiners.html

already at China 6, which is equal to Europe's top requirement, and the entire country is expected to reach China 6 in 2020.[44]

We have clear evidence that the changes in refining were real: the refineries upgraded their equipment and produced new product. In fact, by 2016 there were press reports about high quality Chinese oil product exports expanding their market and even threatening Japanese and South Korean suppliers.[45] Part of the new rules negotiated in 2017 with the teapot refiners is actually about their export strategy. They are now limited in the quantity of exports allowed.

The teapots have also flourished. Not only are they importing and exporting more oil, but their overall production is up. Their average run rate (the percentage of capacity that they actually use) has moved from 30-40% to 60% or even higher (Downs 2017b)[46]

The Fall of the "Oil Clique"

There is one other aspect of this complex story that we must consider, and that is the fall of the "oil clique" in 2012-2014. Zhou Yongkang, one of the most prominent targets of Xi Jinping's anticorruption campaign, was a product of the oil clique, and was associated with that clique even after he assumed important roles in Sichuan and in the Ministry of State

[44] "China Yuchai Launches 14 New Diesel and Natural Gas Engines to Meet Upcoming National VI Emission Standards," *Green Car Congress* (January 15, 2018) . http://www.greencarcongress.com/2018/01/20180115-chinayuchai.html and Du Xiaoying, "China accelerates upgrade of emissions standards," *China Daily* (February 15, 2016). http://www.chinadaily.com.cn/business/motoring/2016-02/15/content_23490210.htm

[45] "Rival Exporters Fear China's High-Grade Oil Products," *Nikkei Asian Review* (October 14, 2016). https://asia.nikkei.com/Markets/Commodities/Rival-exporters-fear-China-s-high-grade-oil-products and Henning Gloystein, "China CNOOC Exports First Australia-Spec Diesel Cargo," *Reuters* (June 22, 2016). https://www.reuters.com/article/us-china-diesel-exports-idUSKCN0Z80UK

[46] Oceana Zhou and Mriganka Jaipuriyar, "China's Refining Sector Policy Timeline," *S&P Global Platts*, accessed May 8, 2018. https://www.platts.com/news-feature/2018/oil/china-policy/china-refining-policy-timeline

Security (Zhang et al. 2017, Wedeman 2017). With Zhou's downfall, there is clear evidence that the oil majors went through a cautious period, particularly with regard to overseas investment. Downs (2017a) documents a substantial decline of overseas upstream acquisitions in 2015, their virtual disappearance in 2016, and what appears to be a slow resumption of this activity in 2017. Clearly the oil majors were keeping their heads down. But most of the heads that rolled were at CNPC/PetroChina, Zhou Yongkang's home base, and not at SINOPEC. Of the dozen top-level executives Downs finds were investigated for corruption, only one was from SINOPEC, while nine were from CNPC/PetroChina. The "oil clique" was much more closely associated with the upstream activity that had always been central to the Chinese myth (the Daqing Miracle) than to the rather more prosaic downstream refining sector, and Zhou was closely associated with CNPC and never with SINOPEC (Wedeman 2017).

While the anticorruption campaign may have made companies more cautious about investing very large quantities of money at high risk, it is difficult to find a link to the refining activities or those of a research institute under SINOPEC. It is possible that the crackdown made SINOPEC less likely to speak up in opposing the teapots' new import rights, but it did not provide the information the government needed to determine the China 4 standard's feasibility. That information came from the teapots' competitive behavior. The government's logic in increasing competition through the granting of the import rights may well have been political – to keep the majors from being so politically influential – but if that is the case it supports the argument that greater competition leads to greater environmental compliance. The argument given above is that unlike in the power sector where the break-up was exogenous to the environmental result, in the oil and gas sector, the result is endogenous – due to the strategic behavior of both the government and the teapots. The teapots saw an

opportunity to increase their competitive edge by becoming more compliant, and the government responded by increasing competition within the sector in return for the teapots' greater compliance to a suite of regulatory priorities. If the increase in competition is actually exogenous, then the outcome of the increased competition, namely the significant increase in fuel quality, the ease in moving not just to China 4, but then to China 5 without any additional delays (a result that had not occurred since China 2, see figure 14), and the removal of the smaller, more polluting, lower quality units, supports the model in a more straightforward manner.

The Strategic Use of Competition

We, thus, have an example of both the refiners and the government acting strategically in a manner predicted by a Stigler-Peltzman model. We begin with simple monopoly behavior – a monopoly refiner that produces low-quality product for the highest allowable price (prices were always regulated). We have the long-term behavior of both SINOPEC and CNPC to try to reduce competition in the sector (the classic Stigler-Peltzman outcome) by controlling crude import rights. And then we have clever upstarts who seek entrée into the import business by showing they can comply with regulators, and regulators interested in rewarding this behavior. But our final outcome is the expectation that companies in general wish to reduce competition. Since the teapots have entered the import market there has been a spate of mergers.[47] Six Shandong teapots have attempted to form a joint venture,[48] after efforts of a

[47] Nick Cunningham, "International Implications of the rise of China's Teapot Refineries," *The Fuse* (September 14, 2017). http://energyfuse.org/international-implications-rise-chinas-teapot-refineries/
[48] "China Independent Oil Refiners Set Up $5 Billion Joint Venture: Executive," *Reuters* (October 11, 2017). https://www.reuters.com/article/us-china-oil-independents/china-independent-oil-refiners-set-up-5-billion-joint-venture-executive-idUSKBN1CG13Q

larger group of Shandong teapots to respond to competition by creating an "alliance" that was essentially a buyer's club apparently found little success.[49] Most of these efforts are led by the largest of the independent refiners, Shandong Dongming Petrochemical Group, which was also one of the early adopters of the compliance strategy for upgrading to China 4. The net result of compliance looks to be that the largest of the teapots are likely to become long-term viable participants in the oil products market, while their smaller competition is absorbed or driven out of business. While CNPC and SINOPEC have not succeeded in repressing all competition, in the end the compliance strategy is likely to lead to a more consolidated market than what they faced with dozens of teapots entering the import business.

[49] Anjli Raval and Neil Hume, "China's 'Teapot' Oil Refiners Feel the Heat as Competition Grows," *The Financial Times* (September 27, 2017). https://www.ft.com/content/5a78b594-a365-11e7-9e4f-7f5e6a7c98a2

Chapter 6 Conclusion

The regulatory relationship between the Chinese government and major SOEs in the power and oil and gas sectors appears to have changed fundamentally over the past fifteen years. The move from a government-managed, ministry model over time led to competition. With greater competition, the traditional industry stance, that all environmental regulation would be too expensive for these developing country SOEs, became unsustainable. Over time, the Chinese government's regulatory apparatus became established and separate from its ownership institutions. At the same time the government gained increasing access to information about the true costs and benefits of pollution abatement. The transformation starts with the government's appreciation that a more competitive sector is more divided and cannot so easily oppose all regulation. Then a second state is the perception by at least some members of the sector that regulation may give them a competitive advantage. Ultimately this leads to a third stage, where companies that seek a competitive advantage by imposing costs on competitors may actively seek additional regulation. At the same time, these greater costs are likely to ultimately lead to a reconcentration of the industry. Whether it returns to monopoly or oligopoly depends on whether the Chinese government chooses to manage this reconcentration challenge through its monopoly law, something we have yet to see.

In the power sector we see each of these stages operating separately in time. First, the sector is weak, and surprised to see the 2003 standards adopted and then actually enforced. Then we see one defector choose to endorse a government-proposed higher standard in the run-up to the 2011 standard. But ultimately, we see new dynamic players actively promote a new standard that fits their business model but is ultimately likely to damage many of their

competitors. We have already seen one major merger in this new ULE requirement's wake and may well see more in the future.

In the oil and gas sector these stages combine in a more dynamic process. First, we see the duopoly successfully avoid a particularly expensive regulation for five years. Then we see a handful of smaller potential competitors acting strategically, demonstrating they are able to meet this new standard. The government responds strategically in turn, offering all the potential competitors the opportunity for a much more level playing field with the majors in return for meeting these new environmental standards. The net result is real competition with the majors for the first time. Ultimately, this appears to be leading a reconcentration of the industry. A number of these smaller companies have already merged, and others are seeking cooperative arrangements.

While the energy industry can no longer avoid environmental regulation, savvy players are increasingly able to capture regulation to their competitive advantage. Thus far, this type of industry capture also appears to be to the Chinese government's benefit. It appears to have effectively implemented an effective "divide and rule" approach to its energy industries. This has resulted both in higher standards and greater enforcement. But having overcome collective action, the government is still challenged by the strategic approach of powerful players in the industry. First, they competed on compliance, now they actually compete to raise compliance standards and thus the costs to their competitors.

This analysis shows how critically important it is to look at the political relationship between government and firms in China. Firms are by far the most dominant players in the Chinese economy and have far more political standing than civil society. How they behave will be critical not just to the implementation of specific regulatory policies, but to how the

government as a whole functions. They clearly are learning to exert power even in a more complex and competitive landscape.

In analyzing the political relationships of firms, this dissertation also establishes the importance of examining not just firm-specific characteristics, but the structure of a given industry. Firms do not exist in a vacuum, but in relation to each other and to their regulators. Whether or not they are able to engage in collective action, whether they have incentives to compete is largely dependent on the nature of the market they are in. Moreover, given the incentives of the market structure, firms will compete regardless of whether they are state-owned or private. Much of the attention of international observers on Chinese economic reform has been on the degree of state-ownership, an area where China has not chosen to reform as much as many had previously expected. It is, therefore, critical to understand where state-ownership affects firm behavior. The focus on market share above profits is certainly an area where state-ownership affects firm behavior, but in environmental regulation, it seems unlikely that compliance would have increased any faster had the industry been less state-owned.

The experience of the Chinese energy sector suggests that environmental compliance is achievable in an autocracy, and adds to our understanding of how the mechanism operates at the provincial and national level rather than the more studied are of public goods provision in village settings in China. Moreover, this story of safety and health improvements is not limited to air pollution. Over the past decade China has also seen dramatic improvements in mine safety (He and Li 2012), an area where state-owned firms have been able to use compliance as a wedge to drive out less safe private competitors. While the original Stigler-Peltzman model was premised on democratic governance, this paper illustrates how it is

widely applicable to an autocratic context. Firms will use regulation to gain competitive advantage, but governments focused on achieving regulatory outcomes can use firm competition strategically to increase support for regulation.

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