Pollution Discharge and Treatment in China: Implications for Environmental Governance

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Summary

Pollution control in China has attracted the world's attention, and the Chinese central government has responded by setting ambitious environmental targets for all 31 regions. Can a vast country such as China, with centralized policymaking but idiosyncratic local implementation capacities and drastic regional disparities in wealth, reduce pollution across the country? An analysis of economic-environmental data from year 1998 to 2005 indicates that the institutional capacity of local environmental protection bureaus has both strong pollution-discharge-reducing and pollution-treatment-enhancing effects, but only in the regions better developed economically. Thus, the Chinese central government needs to enhance the environmental governance capacity in the country's less-developed regions, especially because highly polluting industries are migrating into these areas.

Key words

Environmental governance, institutional capacity, regional disparity, Asia, China, development.

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Introduction

It is generally assumed that environmental protection agencies are maximizers of social welfare and that their political will and institutional capacity are adequate for solving environmental problems. Researchers, especially those who subscribe to the Environmental Kuznets Curve (EKC), argue that levels of economic development determine levels of pollution (Grossman & Krueger, 1995; Stern, Common, & Barbier, 1996). If this is the case, people of the developing countries and the areas adjacent to them will have to live with environmental degradation for a rather long period of time before their income rises to a level capable of changing the situation. Because of this, the international community is paying close attention to environmental issues in countries that are going through fast industrialization processes.

China, as a country that has been experiencing both rapid economic growth and tremendous environmental damage, faces pressure to clean up its environment not only from the international community but also from inside the country itself. Over the past 30 years or more, China has established a comprehensive governance system for protecting the environment (Ferris & Zhang, 2003; Jahiel, 1998; Qu, 1991). However, scholars and official reports by the OECD and the World Bank still attribute the severe pollution in China largely to a lack of governmental capacity for strategic planning and the failure to implement environmental laws and policies (Economy, 2004; Jahiel, 1997; Lieberthal, 1997; Ma & Ortolano, 2000; OECD, 2006; Richerzhagen & Scholz, 2008; Sinkule & Ortolano, 1995; The World Bank, 2001).

Recent cross-country studies point out that governance plays an important role in controlling levels of pollution, but in these studies, governance is measured either by a subjective evaluation of corruption or with the aggregated governance index generated by the Transparency International (Dasgupta, Hamilton, Pandey, & Wheeler, 2006; Lopez & Mitra, 2000; Welsch, 2004). The actual efforts made by environmental protection agencies have rarely been considered. Anecdotal evidence shows that the will and capacity of environmental protection agencies are critical to environmental enforcement and thus environmental outcome (Lo & Fryxell, 2003; Lo & Tang, 2006). Because it is a vast country with its wealth unevenly distributed among regions, China is a good case for examining the nexus between development, governance, and environment.

This article addresses the following question: in China's context, given regional disparities in income levels and pollution, what effects does environmental governance have on pollution discharge and treatment? The answers to this question have immediate and far-reaching implications, especially because the international community closely monitors pollution in China, and the Chinese central government promulgated ambitious environmental targets in the 11th Five-Year Plan instituted in 2005.[1] In that plan China intends by 2010 to reduce its energy use per 10,000 RMB GDP by 20 percent and to reduce the total discharge of chemical oxygen demand (COD) and sulfur dioxide (SO_2) by 10 percent (Government of China, 2006). Specific targets for each of the 31 regions have been established and have been made a high priority in the evaluation system of government officials.[2] Thus, a good understanding of the factors that impact pollution discharge and treatment is important, particularly given the ambitious targets set in the 11th Five-Year Plan.

To answer this question, our study is divided into four major parts. First, we discuss the relationships between pollution discharge, income, and governance, most particularly in relation to the institutional capacity of the environmental agencies. Next, using previous institutional analysis of government agencies, we analyze the key tasks performed by environmental protection bureaus (EPBs) and propose a strategy for measuring institutional capacity of local EPBs in China. After examining regional disparities in terms of income level, pollution level, institutional capacity of the environmental protection bureaus, monetary investment in pollution abatement and control, and capacity of industry to protect the environment, we establish an empirical model that distinguishes the components of the problem and then estimate the effects of income and governance on pollution discharge and treatment in China from 1998 to 2005. Finally, we consider implications of our research and make certain policy recommendations for environmental governance in China.

Theoretical and Empirical Work

In light of the hump-shaped relationship between per capita income and pollution found by Grossman and Krueger (1995) and others, Henri De Groot et al. raised the question of whether a similar relationship can be detected in China (De Groot, Withagen, & Minliang, 2004). Using data from 1982 to 1997 that covers 30 regions,[3] they built various econometric models to estimate the effects of per capita income on gross wastewater, gross industrial waste gas, and gross industrial solid waste discharge. They used two dependent variables— per capita pollution (if it is consumer driven) and pollution discharge per unit of production (if it is production driven)—to examine how income impacts pollution. They found wastewater discharge (gross, per capita, and per unit gross regional product) decreases as per capita income increases. For both industrial waste gas and industrial solid waste, only intensity (per unit gross regional product) decreases, while both gross and per capita discharge increase as per capita income goes up. In their analysis, the effects of per capita income on the discharge of a pollutant were the same for all the 30 regions they examined.[4] This seemed to suggest that regions in China might follow a similar trend of pollution emission as the country develops over time. We take exception to this argument and will come back to it later.

In addition to showing the correlation between income and pollution emissions and developing policy tools and measures to mitigate pollution, researchers have also been looking for factors that have an impact on pollution. Governance was found to be one important factor determining pollution levels. López and Mitra analyzed the effect of governance on environmental quality. Their findings showed that corruption leads to pollution above a socially optimal level for any level of per capita income (Lopez & Mitra, 2000).

Welsch (2004) argues that corruption has both direct and indirect effects on pollution. If environmental protection agencies are corrupt, they will not enforce environmental regulations as stringently as they should, which leads to more pollution. Furthermore, corruption reduces prosperity and thus, according to the Environmental Kuznets Curve, affects pollution. Using six indicators of ambient air and water pollution for 106 countries, Welsch found, summing up both direct and indirect effects that corruption led to more pollution.

Using monitoring data managed by the WHO for one air pollutant, suspended particulate matter (SPM), in 170 cities from 1986 to 1999, Dasgupta et al. (2006) estimated the effects of governance on SPM concentration. The authors found the conventional EKC model was insufficient. They therefore constructed an extended EKC model, including the Transparency International (TI) corruption index, the WHO atmospheric vulnerability index, and the percentage of discharge of seven industries that account for at least 90 percent of global emissions of major air and water pollutants. Their study found that although the level of SPM concentration still increased significantly with GDP per capita, higher quality of governance could reduce SPM concentration significantly. Their study assumed that all the factors had the same effects in all the countries studied. In their sample, the values of TI corruption index ranged from 0.7 to 9.8, with richer countries tending to have higher TI corruption index values. There is reason to believe, however, that the effects of these factors vary according to level of economic development. We will discuss this factor in Chinese context later on.

Although scholars have argued the importance of governance for determining environmental quality, they have not found a powerful instrument for measuring this factor. Some studies assert that governance should mainly be measured by level of corruption. Others include variables such as civil and political freedom (Barrett & Graddy, 2000), democratic participation (Harbaugh, Levinson, & Wilson, 2002), and literacy (Torras & Boyce, 1998). These factors are important, but they only partially reflect the quality of environmental governance.

Recent studies have addressed the institutional capacity of environmental agencies, that is, their ability to carry out environmental policies. Schwartz (2003) evaluated the state capacity of 10 Chinese provinces and their compliance with environmental policies. In examining the potential causal relationship between state capacity and compliance, Schwartz illustrates the central role of state capacity in environmental policy compliance. Li and Zusman (2006) have attempted to measure the institutional capacity of local EPBs in China directly and have examined its effects on pollution discharge. Using a cross-sectional data set covering all 31 regions in the year 2002, Li and Zusman found that local EPBs with greater human capital (though, in this study, not necessarily greater financial resources) would enforce regulations more rigorously. However, their study reported these efforts did not necessarily lead to cleaner air or water because of other contingent factors that vary the result. On the basis of their work, this article seeks to develop a strategy for measuring the institutional capacity of local EPBs and for evaluating its impact on pollution in China.

Measuring the Institutional Capacity of Local Environmental Protection Bureaus

We have adopted the analytical framework by Li and Zusman (2006), in which the institutional capacity of government agencies is defined along the following five dimensions: potential capacity, capacity to pick up signals, capacity to balance interests, capacity to implement policies, and capacity to learn and adapt. We relied on environmental yearbooks to formulate composite indicators, and then identified indicators for each dimension and developed a strategy for measuring the institutional capacity of local EPBs in China. The standardized information-collection protocol of the environmental yearbooks makes cross-region comparison possible. The reason to focus on EPBs at the provincial level and below is because the structure of environmental governance in China makes local EPBs primarily responsible for implementing environmental policies and enforcing environmental regulations.

Potential capacity is defined as the entire administrative and organizational stock of financial and human resources owned by a local EPB for the performance of its duties. Ideally, the budget size of a local EPB can best quantify its financial resources. However, it is impossible to get the information from official statistics, especially for a long time span. As a consequence, some studies use per capita GDP or fiscal revenue as proxies. Because income level has been identified as an important factor determining pollution and because it will be included in econometric models later on, adding per capita GDP or fiscal revenue to the model will not provide any new information to the strong correlation already found between per capita GDP and income (see Table 1). We assumed, therefore, that EPBs in economically better-developed regions where people have a higher per capita income would have more financial resources. For human resources, we considered both quantity and quality, including the average number of staff and the percentage of environmental protection professionals on staff.

[Table 1 is about here]

Table 1. Correlation Test for Per Capita GDP and Income

	(1)	(2)
	Disposal income (urban population)	Disposal income (rural population)
Per capita GDP	0.28	0.15
	(31.75)**	(44.28)**
year	415.1	-32.91
	(13.43)**	(2.77)**
Constant	-825,994.37	67,029.11
	(13.35)**	(2.82)**
Observations	240	240
R-squared	0.88	0.90

* p < .1; ** p < .05; *** p < .01

The capacity to pick up signals is reflected in the collecting, processing, and reporting of relevant information. For a local EPB, picking up signals means identifying big emitters (that most often are big users of resources and energy), discerning which are compliant and which are noncompliant polluters, acknowledging efforts made to clean up, and deciding what follow-up actions to take. Thus, information is necessary regarding: (1) resource and energy use, (2) pollution discharge, and (3) pollution treatment. The strategy for quantifying this is to count the percentage of nonempty cells in the corresponding tables in the environmental yearbooks.

Besides ad hoc public protests, there are three major institutionalized channels through which the public can express their views and protect their interests. They can visit or send letters to the government officers themselves, or members of the People's Congress (hereafter PC) and of the People's Political Consultation Committees (hereafter PPCC) to act on their behalf. The capacity of a local EPB to balance interests is reflected in its responses to public letters or visits and proposals brought up by PC or PPCC members. Response by local EPBs to industry is not included because business community in China is powerful, and they have been given favorable treatment by all levels of government in China. In the context of environmental protection, it is the government's capacity to respond to public interests that can make a difference in society. Thus a local EPB's capacity to balance interests is measured by the percentage of public letters/visits and the number of proposals from members of People's Congress being processed.

The ultimate purpose of environmental policy implementation and enforcement is to prevent and control pollution. But not all policies are equally effective. To ensure content validity of the indicators for the capacity to implement policies, we will, in the next section, review key tasks performed by local EPBs and select those items most useful for preventing and controlling pollution.

The capacity to learn and adapt is difficult to define and measure because organizational learning itself is an unsettled topic. Investment in research projects by a local EPB indicates its willingness to learn and adapt. Although not a perfect measure, the average funding size of projects reflects the efforts made to improve and adapt. In this exercise, therefore, we measure capacity to learn and adapt by the local EPS's average funding size of environmental R&D projects.

Key Tasks Performed by Local EPBs

Since the promulgation of the first trial version of environmental protection legislation—PRC Environmental Protection Law of 1979, the Chinese government has adopted a variety of policy instruments to prevent and treat pollution (see Table 2).[5] Overall, four different types of policies have been adopted: preventive measures, direct regulation, incentive mechanisms, and voluntary approaches.

[Table 2 is about here.]

Table 2. Environmental protection policy instruments in China

Category	**Environmental protection policy instruments**
Preventive	Three synchronizations; Environmental Impact Assessment; Cleaner production; Circular economy.
Direct regulation I (administrative)	Discharge permit; Limited time treatment; Firm closure/stoppage/merge/conversion.
Direct regulation II (economic)	Pollution levy/Pollution discharge fee.
Incentive mechanism I (economic)	Tradable emissions permit.
Incentive mechanism II (information)	Color rating & disclosing of environmental performance of firms; Disclosing important pollution sources.
Incentive mechanisms III (political)	Comprehensive evaluation of city environmental protection; Environmental responsibility system; Environmental protection model city; National model eco-park; Environmental protection model township/village; Eco-village.
Voluntary approaches	Nationally environmental friendly enterprises; ISO14000.

Source:

page 10517 in W. Li, "Environmental Governance: Issues and Challenges," *Environmental Law Reporter*, Vol. 36, No. 7 (2006), pp. 10505-10525.

Preventive Measures

The "three synchronizations" policy finds its statutory basis in Article 6 of the Environmental Protection Law of 1979. It requires facilities to design, install, and operate pollution prevention and treatment equipment. The design needs the approval of local EPBs. Local EPBs monitor construction projects. Without verification and permission from the local EPB, completed facilities cannot be put into use. Implementation of the three synchronizations scheme is reported regularly in China environment yearbooks. Since its inauguration, the three synchronizations have been effective in ensuring that new pollution sources invest in pollution abatement and control.

The Environmental Impact Assessment (EIA) Law was enacted in October 2002 and became effective in September 2003. Before that legislation, the 1989 Environmental Protection Law subjected projects with potentially negative environmental effects to environmental impact assessment before seeking approval from local Development and Reform Commissions. The 1998 Ordinance of Environmental Management for the Construction Projects prescribes three different levels of assessment in proportion to the potential environmental impact of the proposed project. But these policies were not strictly implemented. With a view to better prevention of pollution, the EIA law specifies in more detail the content of the environmental assessment: it should include: (1) identification and analysis of potential environmental impacts, (2) possible measures to prevent or control the identified impacts, and (3) an assessment of the feasibility and costs of the possible corrective measures. The State Environmental Protection Administration (SEPA) conducts nationwide checks on the implementation of EIAs and publishes the results in Environmental Yearbooks (OECD, 2006). Moreover, in recent years EIAs have become a useful tool for both the public and top-level SEPA officials to halt development projects that may have harmful environmental implications in the long term.[6]

The Cleaner Production Promotion Law was enacted in June 2002 and became effective in January 2003. It seeks to shift from "end-of pipe" pollution control to pollution prevention through various integrated and comprehensive approaches that occur earlier in the production process. It is not mandatory, however, for industry to adopt cleaner production measures. The Standing Committee of the National People's Congress (NPC) has passed the Law on Circular Economy (Draft) in August 2007, and it is expected to be formally promulgated by the NPC in 2008. Both measures call for changes in the behavior of numerous producers and consumers. To mobilize the wide range of actors, both pieces of legislation need to be supplemented with incentive mechanisms such as subsidy schemes or favorable tax treatment.

Direct regulation

Under the Discharge Permit System, established according to the estimated regional environmental assimilative capacity, EPBs issue permits that limit both the quantity and concentration of pollutants in an enterprise's wastewater discharges and air emissions. SEPA provides guidance to provincial EPBs on how to calculate the total environmental assimilative capacity. However, this guidance is not backed up by binding procedures. Permits for air pollutants usually cover only SO_2. The number of water pollutants regulated by permit varies by locality. Local EPBs currently have flexibility in developing their own environmental permit systems. In October 2007, SEPA drafted national guidelines on pollution discharge, but they are currently undergoing stakeholder consultations, and a date for enactment of these guidelines has not yet been set. The guidelines are likely to provide enterprises with a single environmental permit that integrates the three synchronizations. Also, the draft SEPA guidelines require EPBs to make information on discharge permits available to the public.[7]

Under the "Limited Time Treatment" rules, local EPBs can command a noncompliant entity to treat the pollution and ensure full compliance within a limited time period (see Environmental Protection Law, Article 29). But the law is vague and fails to specify what constitutes the "severe pollution" that triggers limited time treatment requirements or sanctions should the entity fail to treat the pollution satisfactorily. These important decisions are left to the discretion of the government. Since this is issued as an order, enterprises usually purchase or install pollution-abatement equipment. Enforcement officers take it as an indication of good faith when enterprises comply. Yet it seems like good faith but actually then the process stops and nothing is ultimately corrected.

For enterprises that fail to comply within deadlines, the last resort for a local EPB is to seek an order from its local government to suspend or shut down their operation. For enterprises controlled by the central government, any stoppage or closure has to be approved by the State Council. Closure/stoppage/merger/conversion orders are always issued when inspection campaigns or other environmental campaigns are conducted. For example, during the campaign to clean up the Huai River, the local EPBs as well as their local governments were required to close the 15 different types of highly polluting small factories along the Huai River. SEPA publishes annual statistics on how many facilities are inspected, how many orders issued for limited time treatment, and how many enterprises temporarily or permanently closed.

Since 1981, pollution levies/pollution discharge fees have been a major environmental policy tool for stimulating pollution prevention and control. Article 28 of the 1989 Environmental Protection Law stipulated that polluters pay a fee for a single pollutant discharge that exceeds national standards even though the enterprise might have several other polluting discharges over the national standards. This is the largest amount of pollutant discharged by the polluter. However, the pollution discharge fees were so low that it was economically rational for polluters to pollute rather than to treat pollution. In addition to this, EPBs gradually came to rely on pollution discharge fees to fund to meet their administrative and salary needs. Consequently, the original regulatory goal was not met. The State Council therefore enacted the 2003 Ordinances on Collecting and Managing Pollution Discharge Fees to enhance the deterrent effect of this policy instrument and to deal with the problem of goal displacement.[8] Although local EPBs are still responsible for collecting pollution discharge fees, the power to allocate the funds has been turned over to finance bureaus at or above the county level. In addition, these funds are earmarked for environmental protection usages. The separation of pollution discharge fee collection from appropriation has the potential to correct misaligned interests. Moreover, a discharge fee is assessed on any pollution discharge, regardless of whether it exceeds national standards or how large it is in comparison with other discharges. And the rate of pollution discharge fee is indexed to the discharge amount, with a higher rate assessed for amounts that exceed national standards. Despite these changes, it is still cheaper for polluters to pay for pollution discharges instead of taking pollution prevention and treatment measures. According to one account, the operating cost of wastewater treatment in one highly polluting industry is around 1.2-1.8 RMB/ton. The fixed investment in wastewater treatment facility is 100 million RMB for the 150ton/day alkali-recycling equipment used in the paper and pulp industry. But the maximum fine on wastewater discharge is 100,000 RMB, and hence it is a rational choice to pay the fine rather than treat the pollution (Yang & Ge, 2006).

Incentive mechanisms

Although SEPA has been advocating a SO_2 emissions trading scheme in China since 1999, the inadequate monitoring and weak methodological basis for determining emission and effluent limits are major impediments in its implementation. Tradable emission permits for SO_2 have been tested in only a few cities, such as Nantong, Jiangsu province, as experiments to inform future scale-up initiatives. The most recent one took place in Tai Lake, when SEPA and Jiangsu province decided to allow enterprises around the lake to trade their water pollutant discharge permits. They hope firms that can treat water pollution at a lower cost will be encouraged to treat more pollution by gaining profits from selling their discharge permits.[9]

There are also incentive mechanisms that encourage government officials to include environmental factors when pursuing regional economic development. Model cities/townships/villages for protecting the environment, nationally recognized eco-parks, and "eco-villages" are measures designed to honor municipalities that consider environmental factors in their land-use planning and economic decision-making. But comprehensive evaluations of city environmental protection and environmental responsibility systems ensure only that minimum consideration has been given to the environment by the leadership of municipal governments.

By making the environmental performance of industries public, informational incentive measures aim to reward good performance and put pressure on bad performers. This tool works on the premise that industries are concerned about the reactions of residents in nearby neighborhoods, consumers, investors, and business partners. However, the industries themselves decide how they will respond to public reactions about their environmental information. A color rating system and environmental performance disclosure began in China in 1999, with mixed results. In April 2007, SEPA published national implementation guidelines on how to rate and disclose industrial environmental performance, and individual municipalities are encouraged to make specific policies tailored to their local conditions.[10] As a measure, Article 17 of the Cleaner Production Promotion Law 2002 encourages local governments at the provincial level to regularly publicize significant polluters—enterprises whose discharges exceed national standards. The list is intended to spur the public into urging specific enterprises to undertake cleaner production. Although specifically aimed at promoting cleaner production, disclosing significant sources of pollution may potentially lead to improved compliance and enforcement due to increased public scrutiny.

Voluntary approaches

Voluntary industry efforts to improve environmental performance have been very limited in China. Examples of voluntary measures currently taking place in China include ISO14000 and its associated EMS (Environmental Management System), the prestige of being named a nationally environmentally friendly enterprise by SEPA, and negotiated agreements with public authorities on improving resource/energy efficiency through cleaner production. ISO14000 is largely limited to enterprises that have integrated with the global market. Other than these items, there is no documentation on negotiated agreements concerning resource/energy efficiency between individual enterprises and local EPBs or on voluntary reporting of environmental performance by publicly listed companies (Chan & Welford, 2004).

In July 2007, SEPA acknowledged there was a the coordination problem: without concerted efforts by other government agencies and actors that deal with economic development, it is impossible to clean up industry. In consequence, SEPA, together with the People's Bank and the Banking Industry Supervision Commission, issued a policy note. They initiated a "green credit" movement, which called upon the financial section to check the environmental performance of borrowers and deny noncompliant enterprises access to credit.[11] In a very recent news report from *Ta Kung Pao*, the deputy minister of SEPA, Pan Yue has evaluated the new "green credit" scheme six months after its implementation. The scheme has not been as successfully implemented as expected. His reasons are the following, (1) small and medium enterprises do not access credit through banks but directly from the public; (2) there is information asymmetry between borrowers that are polluting enterprises and financial institutions; (3) implementation guidelines are lacking on how to evaluate the environmental risks of borrowers; and (4) under the current scheme, financial institutions do not have incentives to participate in the "green credit" movement. [12]

We can see, therefore, that the Chinese government has adopted a variety of environmental policy instruments. Not all of them are equally effective in controlling pollution. For example, the pollution levy, the charge on pollution discharge, is small compared with costs of pollution treatment. Consequently, it has not helped reduce pollution. To develop valid measurements of the institutional capacity of local EPBs in China, we therefore include the following three items in the indicator system: the EIA, the three synchronizations, and firm closure/stoppage/merger/conversion. Table 3 provides the list of proposed indicators for measuring the institutional capacity of local EPBs in China.

[Table 3 is about here]

Table 3. Proposed Indicators for Measuring Institutional Capacity of Local EPBs in China

Indicator	Definition & Measurement
Potential capacity	
Financial resources	Budget size of a local EPB
Quantity of human resources	Average number of staff of a local EPB
Quality of human resources	Percentage of environmental protection professionals on staff of a local EPB
Pick up signals	
Capacity to collect, process, and report information	Ability to collect and report data on (1) resource and energy use, (2) pollution discharge, and (3) pollution treatment. Measured by the percentage of nonempty cells in corresponding tables in Environmental Yearbooks.
Balance interests	
Respond to public concerns directly	Percentage of public letters and visits being processed
Respond to public concerns directly	Percentage of public letters and visits being processed
Respond to public concerns through their representatives	Number of proposals from members of people's congress
Implement policies	
Implement EIA	EIA implementation rate
Implement three synchronizations	Three synchronization implementation rate
Implement firm closure/stoppage/merge/conversion	Number of firms being closed, stopped, merged, or converted
Learn and adapt	
Fund and conduct environmental research projects	Average funding size of environmental R&D projects

To come up with an index of the institutional capacity of local EPBs, all the indicators are weighted equally, for the existing theoretical and empirical literature does not give preference to one indicator over another (Esty & Cornelius, 2002). To allow cross-region and cross-year comparison for all the 31 regions in China, we normalize their index values by year.

We now turn to discuss regional disparities in terms of level of economic development, pollution, and the capacity of government and industry to control pollution. This is followed by econometric models that separate out and estimate the effects of environmental governance, along with conventional factors such as income, on pollution discharge and treatment in China.

Regional Disparities in China from 1998 to 2005

It has been widely acknowledged that China is an unevenly developed country. For the years from 1998 to 2005, we understand a region to be economically better developed if its per capita GDP is above the same year national average; otherwise, it falls into less-developed category.[13] Regions that are economically better developed are listed in Table 4 in descending order by their per capita GDP. From 1998 to 2005, only Heilongjiang and Inner Mongolia were in and out of the list. All the other nine regions that appeared in the category of better-developed regions remained the same. Except for Beijing, the capital of China, the better-developed regions are all located along the east coast.

[Table 4 is about here]

Table 4. Regions with per capita GDP above national average in 1998 and 2005

Ranking	1998	1999	2000	2001	2002	2003	2004	2005
1	Shanghai	Shanghai	Shanghai	Shanghai	Shanghai	Shanghai	Shanghai	Shanghai
2	Beijing **	Beijing **	Beijing **	Beijing **	Beijing **	Beijing **	Beijing **	Beijing **
3	Tianjin	Tianjin	Tianjin	Tianjin	Tianjin	Tianjin	Tianjin	Tianjin
4	Zhejiang	Zhejiang	Zhejiang	Guangdong	Zhejiang	Zhejiang	Zhejiang	Zhejiang
5	Guangdong	Guangdong	Jiangsu	Zhejiang	Guangdong	Guangdong	Guangdong	Jiangsu
6	Fujian	Fujian	Fujian	Jiangsu	Jiangsu	Jiangsu	Jiangsu	Guangdong
7	Jiangsu	Jiangsu	Guangdong	Liaoning	Liaoning	Fujian	Fujian	Shandong

8	Liaoning	Liaoning	Liaoning	Fujian	Fujian	Liaoning	Shandong	Liaoning
9	Shandong	Shandong	Shandong	Shandong	Shandong	Shandong	Liaoning	Fujian
10	Heilongjiang*	Heilongjiang*	Heilongjiang*					Inner Mongolia*

Table 5 indicates rapid economic growth in both better- and less-developed regions. However, better-developed regions have become even relatively richer in 2005 than they were in 1998. Per capita GDP of the better-developed regions was 61.7 percent more than that of less-developed regions in 1998, but 63.1 percent more in 2005. Per capita income of urban residents[14] in better-developed regions was 30.5 percent higher than that of less-developed regions in 1998, but 36 percent higher in 2005. The t-test results indicate the differences are statistically significant at a 1 percent significance level.

[Table 5 is about here]

Table 5. Economic Performance of Economically Less and Better Developed Regions

	Per capita GDP		**Per capita income**	
	1998	**2005**	**1998**	**2005**
National mean (yuan)	7329.90	16019.83	5581.55	10916.2
Mean (econstat=0, yuan)	4824.05	10323.84	4870.15	9237.29
Mean (econstat=1, yuan)	12592.17	27981.41	7004.34	14441.91
Percentage (mean[1-0]/mean[1])	61.69%	63.10%	30.47%	36.04%
t-statistics[1]	(4.53)***	(4.67)***	(3.74)***	(4.25)***

Note: Both per capita GDP and per capita income are in consistent price.
* p < .1; ** p < .05; *** p < .01

Regional performance on environmental governance, the institutional capacity of local EPBs (government capacity), and the number of environmental professionals employed by an enterprise (business capacity) are reported in Table 6. It is clear that the government capacity of better-developed regions was slightly higher (but this rate was statistically significant) than the government capacity of less-developed regions in both 1998 and 2005. However, no statistically significant difference was found in terms of business capacity either in 1998 or 2005.

[Table 6 is about here]

Table 6. Environmental Governance of Economically Less and Better Developed Regions

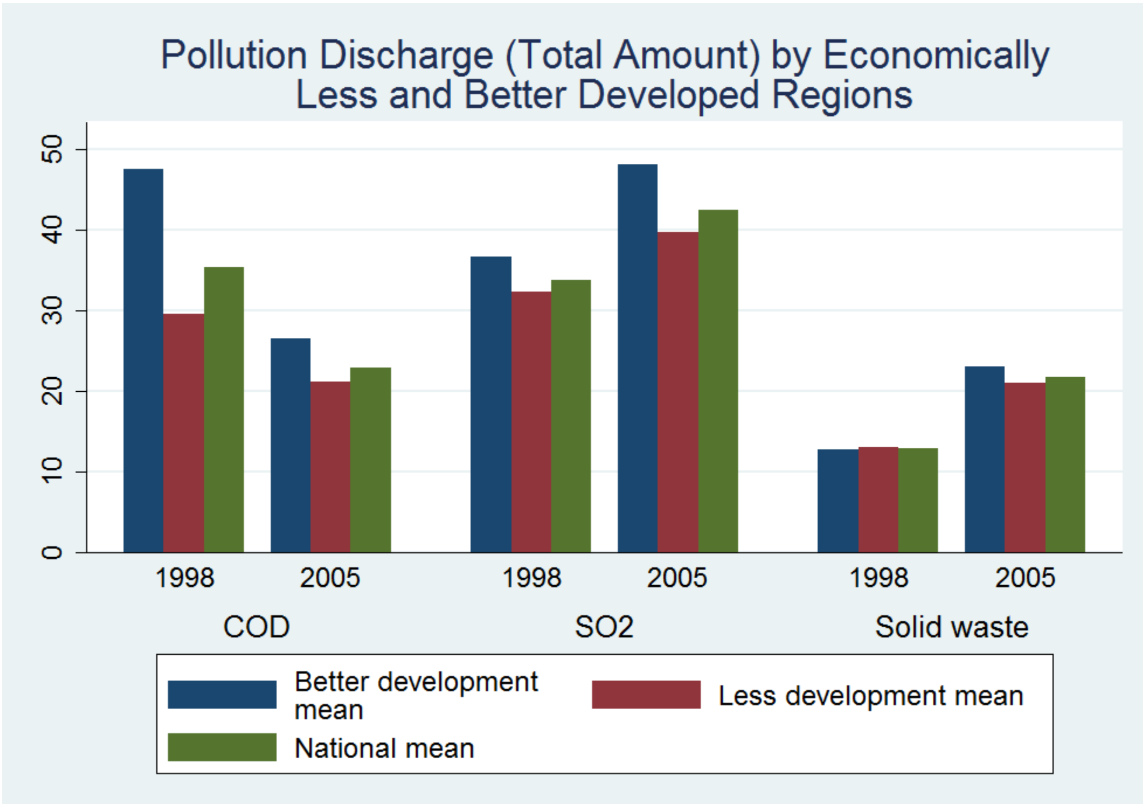
	Government capacity		**Business capacity**	
	1998	**2005**	**1998**	**2005**
National mean	60.10	61.18	59.73	59.84
Mean (econstat=0)	59.34	60.51	58.72	59.37
Mean (econstat=1)	61.62	62.60	61.85	60.80
Percentage (mean[1-0]/mean[1])	3.70%	3.35%	5.06%	2.35%
t-statistics	(3.01)**	(2.51)**	(0.87)	(0.40)

* $p < .1$; ** $p < .05$; *** $p < .01$

In order to examine differences in pollution discharge and treatment, we consider the following three major pollutants: industrial chemical oxygen demand (COD, a major water pollutant), sulfur dioxide (SO_2, a major air pollutant that causes acid rain), and solid waste. Figure 1 illustrates that less-developed regions have witnessed a faster increase in pollution discharge and that the burden of pollution has been shifting from better to less-developed regions as time has gone by. In 1998 the better-developed discharged 37.79 percent (statistically significant) more COD compared with less-developed regions, but only 20.37 percent (not statistically significant) more in 2005. No significant differences have been found between the two groups in their total amount of industrial SO_2 or solid waste discharge.

[Figure 1 is about here]

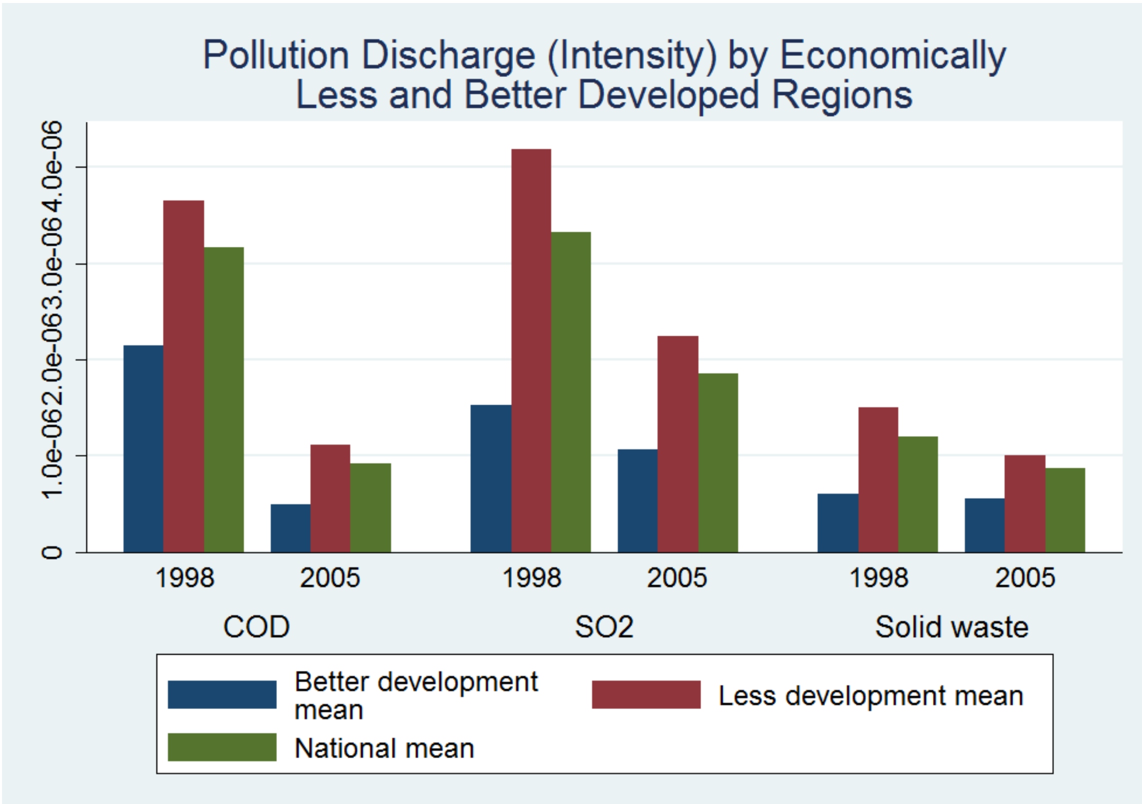
Figure 1. Pollution Discharge (Total Amount) by Economically Less and Better Developed Regions



If we divide the total amount of pollutant discharge by the gross product of a region, we obtain the intensity of pollution discharge. As shown in Figure 2, less-developed regions experience much more intensive pollution than better-developed regions. The intensity of COD discharge was 69.77 percent and 1.26 times, SO_2 1.74 percent and 1.11 times, and industrial solid waste 1.49 times and 82.17 percent higher than that of better-developed regions in 1998 and 2005 respectively.

[Figure 2 is about here]

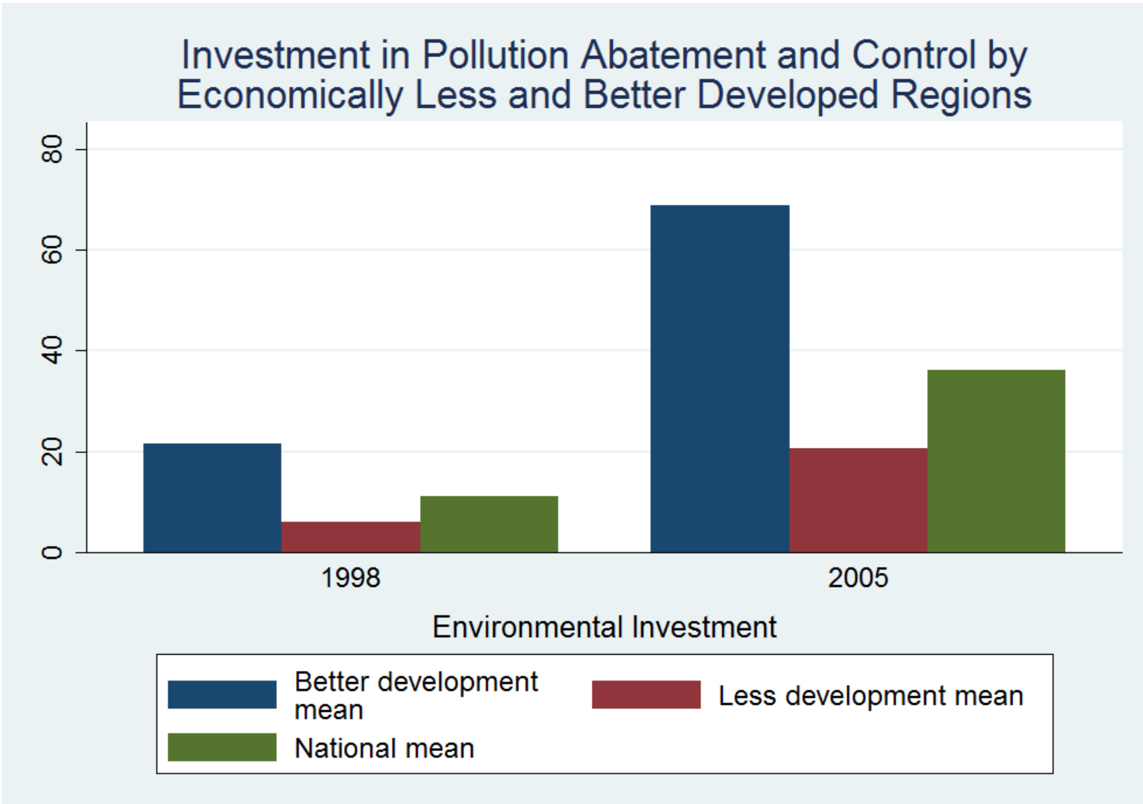
Figure 2. Pollution Intensity in Economically Less and Better Developed Regions



Both better and less-developed regions in China face the challenge of abating and controlling pollution, even though the severity of the environmental degradation and the capacity to address it varies from region to region in China. Figure 3 indicates that both better and less-developed regions have increased their investments in pollution abatement and control since 1998. However, better-developed regions have invested significantly more financial resources than less-developed regions in both 1998 and 2005.

[Figure 3 is about here]

Figure 3. Investment in Pollution Abatement and Control by Economically Less and Better Developed Regions



From Figure 3 it is clear to see that better-developed regions have more resources and a greater capacity to protect the environment, while at the same time they are burdened with much lower pollution intensity than regions that are less developed. A question that follows naturally is how better and less-developed regions compare in treating pollution. Table 7 reports the outcomes of pollution treatment for the following four indicators: (1) percentage of industrial wastewater discharge meeting standards, (2) percentage of municipal wastewater treated, (3) percentage of SO_2 discharge being treated, and (4) percentage of solid waste reuse. Although better-developed regions performed better almost across the board, less-developed regions have been catching up in the treatment of industrial pollution. Still, however, they are far behind in controlling pollution from municipal sources. In 1998 and 2005, better-developed regions had 19 percent and 10 percent respectively more industrial wastewater discharge meeting standards compared with less-developed regions,; 8 per cent less but 5 percent more SO_2 being treated; and 36 percent and 28 percent more solid waste being reused. Regarding municipal wastewater, better-developed regions treated 5 percent more than the less developed in 1998 and 27 percent more in 2005.

[Table 7 is about here]

Table 7. Pollution Treatment by Economically Less and Better Developed Regions

	Industrial Wastewater Discharge Meeting Standards		Municipal Wastewater Treated		SO_2 Discharge Treated		Solid Waste Reuse	
	1998	2005	1998	2005	1998	2005	1998	2005
National mean	0.56	0.86	0.14	0.37	0.22	0.39	0.47	0.62
Mean (econstat=0)	0.50	0.83	0.12	0.28	0.25	0.37	0.35	0.53
Mean (econstat=1)	0.69	0.93	0.17	0.55	0.17	0.42	0.71	0.81
Mean(1-0)/Mean 1	27.34%	10.75%	27.50%	49.05%	-43.35%	13.56%	51.05%	34.42%
t-statistics	(3.95)***	(2.22)**	(0.89)	(5.10)***	(0.81)	(0.62)	(4.54)***	(3.29)***

* $p < .1$; ** $p < .05$; *** $p < .01$

Having illustrated the divide between economically better- and less-developed regions regarding economic status, environmental governance, and pollution discharge and treatment, we now analyze the impact of economic and institutional factors on pollution by devising econometric models.

Separating Out and Estimating the Effects of Income and Environmental Governance on Pollution in China

In an attempt to go beyond a descriptive account of environmental governance and pollution, researchers have been searching for a better understanding of the nexus between development and pollution so as to craft effective policy instruments for achieving a cleaner environment. By devising econometric models, we seek to separate out and estimate the effects of conventional factors such as income as well as environmental governance—measured by the institutional capacity of local EPBs—on pollution discharge and treatment in China. We use the total amount of discharge and treatment of COD, SO_2, and solid waste as our dependent variables. For independent variables, besides using income and environmental governance, we create a dummy variable (econstat) to distinguish the two classes of regions because of the significant disparities we have observed. We expect income and environmental governance to have different effects on pollution discharge and treatment in regions at different developmental stages (see Table 8, where we list the variables included in the econometric models).

[Table 8 is about here]

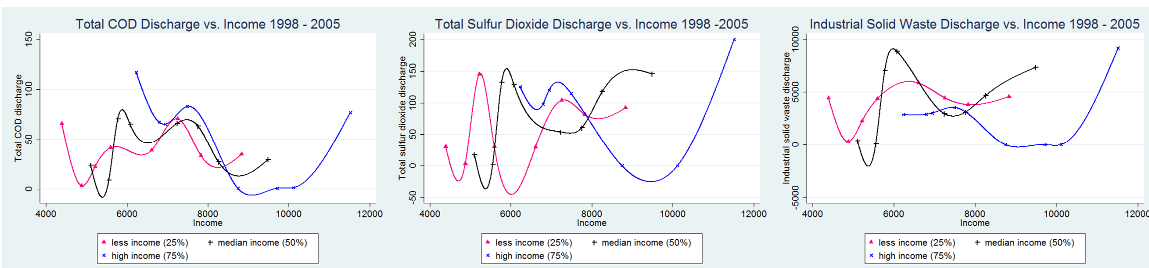
Table 8. Variables in Econometric Models

	Description
Dependent Variable	
Pd1	Total amount of COD discharge
Pd2	Total amount of sulfur dioxide discharge
Pd3	Total amount of solid waste discharge
Pt1	Percentage of wastewater discharge meeting standards
Pt2	Percentage of municipal wastewater treated
Pt3	Percentage of SO2 treated
Pt4	Percentage of solid waste reuse
Independent Variable	
income	Per capita income of urban population
capt_g	Institutional capacity of local EPBs
capt_b	Number of environmental professionals employed by an enterprise
econstat	Dummy variable indicating if a region is economically advanced

Theoretically, there are three ways to assess how income makes an impact on pollution: scale effect,[15] intensity effect,[16] and structural (or composition) effect.[17] Economists tend to argue that for any country or region, preferences for better environmental quality and more stringent environmental enforcement occur only after income rises to a certain level. It may be true in a cross-country setting where no strong central authority is in charge, and any country can make decisions on development and environment on their own. However, in China, which has a strong central government that enacts environmental laws from above, local governments are not totally free to balance economic and environmental considerations. When the coastal regions started to develop in the 1980s, economic development overshadowed environmental considerations. However, when inland regions attempted to develop in the early years of the new century, they have been constrained by more stringent environmental standards and more aggressive environmental enforcement. Figure 4 illustrates that pollution reduction occurred in poor regions (the bottom 25 percent) at a much lower income level than it did in rich regions (the top 25 percent). This partially verifies our hypothesis that income and environmental governance to have different effects on pollution in economically better and less-developed regions.

[Figure 4 is about here]

Figure 4. Pollutant Discharge vs. Income in China 1998-2005



The following econometric models are proposed here to separate out and estimate the effects of income and environmental governance on pollution for all the 31 regions in China from year 1998 to 2005.

Model 1-3: Pollution discharge vs. income and environmental governance

$$\ln pd_{ij} = \alpha_{i0} + \alpha_{i1} \ln income_j + \alpha_{i2} \ln capt\_g_j + \alpha_{i3} \ln capt\_b_j + \alpha_{i4} \ln(econstat_j \times income_j) + \alpha_{i5} \ln(econstat_j \times capt\_g_j) + \alpha_{i6} \ln(econstat_j \times capt\_b_j) + \alpha_{i7} time + \varepsilon_{ij}$$

Another four models have also been constructed to analyze the relationships between treatment of industrial and municipal wastewater, sulfur dioxide, and solid waste in the 31 regions from 1998 to 2005.

Model 4-7: Pollution treatment vs. income and environmental governance

$$\ln pt_{ij} = \alpha_{i0} + \alpha_{i1} \ln income_j + \alpha_{i2} \ln capt\_g_j + \alpha_{i3} \ln capt\_b_j + \alpha_{i4} \ln(econstat_j \times income_j) + \alpha_{i5} \ln(econstat_j \times capt\_g_j) + \alpha_{i6} \ln(econstat_j \times capt\_b_j) + \alpha_{i7} time + \varepsilon_{ij}$$

In the above econometric models, i is the index variable specifying a pollutant ($i = 1,2,3,4$; refer to Table 11 for the description of variables, and j is the index variable specifying a region ($j = 1,2,3,......31$). Taking a natural log transformation of both the dependent and independent variables obtains the elasticity.[18]

Regression results (with autocorrelation corrected) are reported in Table 9 for discharge of COD, SO_2, and solid waste. Generally speaking, the three models fit well with R-square range from 0.13 to 0.65. Specifically, 1 percent of income increase reduces COD discharge by 0.36 percent but increases SO_2 and solid waste discharge by 0.48 and 0.7 percent respectively. On a national average, higher institutional capacity of local EPBs does not lead to less pollution discharge. However, in economically better-developed regions, if government capacity increases by 1 percent, COD, SO_2, and solid waste discharge are reduced by 1.78, 0.19, and 0.18 percent respectively. More environmental professionals hired by an enterprise do not have pollution-reducing effects. Instead, as business capacity increases by 1 percent, COD, SO_2, and solid waste discharge increase by 0.77, 1.01, and 0.95 percent respectively on a national average, while in economically better-developed regions they increase even more.

[Table 9 is about here]

Table 9. Pollution Discharge: Random Effects (autocorrelation corrected)

	(1)	(2)	(3)
	lncod	lnsulfur	lnsolidwaste
Lnincome	-0.356	0.481	0.703
	(3.16)***	(4.79)***	(7.50)***
Ln(econstat*income)	-0.039	-0.067	0.082
	(0.23)	(0.45)	(0.59)
lncap_g	1.013	0.586	-0.160
	(1.68)*	(1.25)	(0.38)
Ln(econstat*cap_g)	-1.780	-0.194	-0.179
	(2.61)***	(0.34)	(0.34)
lncap_b	0.767	1.012	0.946

	(1.25)	(1.94)*	(1.99)**
Ln(econstat*cap_b)	1.959	0.373	0.051
	(2.86)***	(0.63)	(0.09)
Constant	-0.621	-7.117	-1.960
	(0.22)	(2.85)***	(0.86)
R-sq within	0.13	0.36	0.65
R-sq between	0.32	0.12	0.02
R-sq overall	0.33	0.14	0.019
Observations	221	220	221
Number of id	31	31	31

* $p < .1$; ** $p < .05$; *** $p < .01$

Regression results on pollution treatment are reported in Table 10. All models fit well with R-square range from 0.38 to 0.55. Not surprisingly, income does have a significantly positive effect on pollution treatment for all the regions in China. If income increases by 1 percent, industrial wastewater discharge meeting standards will increase by 1.03 per cent; 2.06 percent more municipal wastewater will receive treatment; 0.83 percent more of SO_2 will be treated; and 0.57 more percent of solid waste will be reused. Government capacity, at a national level, does not have positive effects on pollution treatment, with the exception of solid waste reuse. However, the better institutional capacity of local EPBs in economically better-developed regions does significantly improve pollution treatment, with every percent increase in government capacity leading to 1.34, 1.73, and 0.18 percent increase in treatment of industrial wastewater, municipal wastewater, and solid waste respectively. Unfortunately, government capacity does not seem to work in treating sulfur dioxide emissions. The effects of business capacity on pollution treatment are mixed, with positive effects on industrial wastewater, sulfur dioxide, and solid waste but negative effects on municipal wastewater treatment.

[Table 10 is about here]

Table 10. Pollution Treatment: Random Effects (autocorrelation corrected)

	(1)	(2)	(3)	(4)
	lnpt1	lnpt2	lnpt3	lnpt4
Lnincome	1.025	2.062	0.831	0.572
	(8.70)***	(8.59)***	(4.81)***	(10.17)***
Ln(econstat*income)	-0.456	-0.793	0.388	-0.219
	(2.73)***	(2.35)**	(1.51)	(2.55)**

lncap_g	-0.745	-1.344	-0.180	0.242
	(0.98)	(1.21)	(0.21)	(0.73)
Ln(econstat*cap_g)	1.338	1.725	-0.724	0.175
	(2.18)**	(1.48)	(0.73)	(0.47)
lncap_b	0.733	-1.074	1.221	0.213
	(1.63)	(1.09)	(1.37)	(0.63)
Ln(econstat*cap_b)	-0.375	0.064	-0.217	0.346
	(0.74)	(0.06)	(0.22)	(0.92)
Constant	-9.388	-10.267	-12.791	-7.706
	(3.50)***	(2.16)**	(3.05)***	(4.86)***
R-sq within	0.40	0.48	0.38	0.55
R-sq between	0.30	0.24	0.01	0.40
R-sq overall	0.36	0.33	0.017	0.42
Observations	220	213	216	220
Number of id	30	30	29	30

* $p < .1$; ** $p < .05$; *** $p < .01$

Conclusions, Implications, and Policy Recommendations

Our findings indicate that, across the country, as income goes up, the total amount of pollution discharge does not go down but the percentages of pollution being treated does increase. The institutional capacity of local EPBs has both strong pollution-discharge reducing and pollution-treatment enhancing effects for economically better-developed regions. Overall, business capacity does not help reduce pollution discharge or improve pollution treatment. Specifically, this study has the following six major findings:

- Economically less-developed regions experience significantly more intensive pollutant discharge than better-developed regions.
- Although the total amount of pollution remains lower in less-developed regions, it increases at a faster pace than that in better-developed regions.
- Pollution reduction occurs in poor regions (the bottom 25 percent) at a much lower income level than it does in rich regions (the top 25 percent).
- Income does not have pollution-discharge reducing effect in China, but it does have s

significantly positive effect on pollution treatment.

- The institutional capacity of local EPBs has both strong pollution-discharge reducing and pollution-treatment enhancing effects in economically better-developed regions.
- Overall, business capacity does not help reduce pollution discharge or improve pollution treatment.

Besides confirming the findings of previous studies concerning the effects of income on pollution, this study finds evidence for the positive impact of centrally initiated environmental governance on regional pollution reduction in China. These findings are especially relevant given that China has articulated in the 11th Five-Year Plan a striving for pollution reduction, improvement in energy efficiency, and a harmonious society. It is clear that between 1998 and 2005 increased income in China helped improve pollution treatment but did not help reduce the total amount of pollutant discharge (finding 4). This finding implies that economic growth is gained at the cost of environmental degradation. This has been a long-standing issue in China, and other scholars have also identified the unfavorable tradeoffs being made where the environment suffers to achieve economic growth. Tong found, back in 1998–1999, that although government and business elites had high levels of environmental awareness, when they were asked whether they would choose to shut down highly polluting enterprises that are highly profitable, only 50 percent of government officials and 39 percent of firm managers answered yes (Tong, 2007). Tilt analyzed factors affecting environmental enforcement in Futian, an industrial township in rural Sichuan province, and found if a firm constituted a vital revenue source for either the township or the district government, it was less likely to be the target of strict enforcement (Tilt, 2007). Recently, the preferences of some government officials may have changed. In September 2007, in light of water pollution in Tai Lake, the former party secretary of Jiangsu province declared in public that he would sacrifice GDP growth for better environmental quality. That means the municipal governments in Jiangsu may have to refuse some polluting industries that seek to locate in their jurisdictions, even though these industries might bring jobs and revenue. Better-developed regions are becoming selective in which industrial projects they host. However, findings 1 and 2 inform us that there has been a rapid increase in pollution intensity and gross pollution in less-developed regions. It can be inferred that those regions have been accepting highly polluting industries in an effort to develop their economy. It may be unreasonable to expect all the regions, especially the less developed, to drive all polluting industries out of business in five years. What hope is there, then, for a cleaner China? In light of finding 5, it appears that the most feasible and effective solution will be to enhance the institutional capacity of local EPBs.

From finding 5, we can infer that if the institutional capacity of local EPBs in economically better-developed regions is improved, it can significantly reduce pollution discharge and improve pollution treatment. However, we did not observe similar effects for less-developed regions. Jahiel (1997) states that the decentralization of profit retention and economic investment decisions has conferred a tremendous autonomy on localities in determining economic priorities, and this has pushed local EPBs to engage in revenue-generating activities to become self-sustaining. In the Chinese context, EPBs in economically less-developed regions face more acute pressures to sustain themselves than those in the better-developed regions do. As a result, their already limited institutional capacity has to be diverted to income-generating activities that do not serve the purpose of protecting the environment. It may be that what has caused local EPBs in less-developed regions to be ineffective in reducing pollution is simply that they have shirked their duty.

Nevertheless, when compared with rich regions (the top 25 percent), pollution in poor regions (the bottom 25 percent) started to decrease at a much lower income level. We can attribute this to the environmental governance regime set by the central government (finding 3). Were it not for the central government directives, local governments in less-developed regions, given their financial situation, would have continued to pursue economic growth regardless of the cost to the environment. Thus, if the central government continues strengthening environmental regulations and enforcement and builds the institutional capacity of local EPBs, we may expect that EPBs in the less-developed regions will be able to control pollution effectively.

In addition, environmental protection requires concerted efforts from both government and business. As of 2005, the business community of China as a whole has not yet played a positive role in reducing pollution (finding 6). This finding largely confirms the results from other studies. For example, Jahiel (1998) found polluting enterprises, even in the Huai River clean-up campaign, committed to opportunistic behavior, and they reopened their operations soon after regulators left the scene. Thus, China faces the daunting challenge of trying to clean up industries that tend to take advantage of the weak enforcement capacity of the environmental protection agencies. From finding 5, we know the three mandatory measures (EIA, the three synchronizations, and firm closure/stoppage/merge/conversion) have generated good results, at least in the economically better-developed regions. In contrast, we conclude after reviewing the key tasks performed by local EPBs that government incentive schemes and voluntary industry measures have not been effective. The deputy administer of SEPA, Pan Yue has correctly pointed out that among other factors information asymmetry between polluters and other actors in society has impeded efforts to commit to environmentally friendly behaviors. Perhaps enhancing the capacity of local EPBs to pick up signals and create an information-sharing protocol will help ease the problem and stimulate more public and private enforcement actions and a more environmentally responsible industry.

Based on the research findings, we propose the following policy recommendations:

First, translate the commitment to pollution reduction, energy efficiency, and a harmonious society by the Chinese central leadership into efforts for reducing poverty and enhancing the capacity of local EPBs to pick up signals, balance interests, implement policies, and learn and adapt. As a result, higher income and better institutional capacity of local EPBs will lead to less pollution discharge and better pollution treatment.

Second, establish an information-sharing protocol to ease the problem of information asymmetry between polluters and other actors in society. Only with publicly accessible information on the environmental performance of polluters can financial institutions and the public make informed decisions on whether to grant these industries access to credit, to boycott their products, or to file complaints with government. Information provided by local EPBs may induce concerted efforts in society that will lead to a cleaner environment.

To achieve nationwide pollution reduction, the key is to enhance the environmental governance capacity, especially in economically less-developed regions. If local EPBs have a better capacity to pick up signals, balance interests, implement policies, and learn and adapt, we expect China to reduce pollution discharge and improve pollution treatment before their income rise to a certain level. If these things occur, then regional environmental performance should not fall short of the ambitious environmental targets set in the 11th Five-Year Plan.

Notes

1. For example, the threat of global warming is widely acknowledged by the international community. The Netherlands Environmental Assessment Agency announced in June 2007 that China topped the list of CO_2-emitting countries, surpassing the United States by an estimated 8 percent. Hence, China's participation in solving this problem is critical. Information Available online at http://www.mnp.nl/en/dossiers/Climatechange/moreinfo/Chinanowno1inCO2emissionsUSAinsecondposition.html.
2. In State Council Ordinance [2006] No. 70, the State Environmental Protection Administration and National Development and Reform Commission are responsible for allocating individual targets to each province regarding pollution reduction and energy efficiency. Ordinance No. 94 does the same for those cities that are directly controlled by the central government.
3. In 1997 Chongqing was made into a city directly controlled by the center and thus became the 31st region in China.
4. Different intercepts in the models refer to the level of pollution when per capita income is hypothetically equal to zero.
5. At present, there are roughly 22 statutes, more than 40 regulations, approximately 500 standards, and more than 600 other legal norm-creating documents primarily addressing pollution control, natural resource conservation, and management of the environmental stewardship aspects of consumer products ("product stewardship").
6. Just to name a few of EIA cases that have gained wide publicity: Yuanmingyuan case in 2005, Tiger Leaping George Dam case in 2005, and EIA storms called forth by the deputy administer of SEPA, Yue Pan in both 2006 and 2007.
7. Environmental protection agencies tend not to take economic considerations into account within the permit process. However, local governments may interfere if they see important tax-revenue generators or big employers are not getting the permits necessary for them to operate, as there is no institutionalized guarantee to ensure transparency of the permitting process. SEPA published its draft national guidelines on pollution discharge permitting and called for public comments in October 2007. Because there is no transparency, the public may not know that the government has intervened to get permission for a polluting

industry that brings in tax revenue or job. Please refer to the SEPA official document [2007] no. 777.

8. State Council Ordinance No. 369 on Collecting and Managing Pollution Discharge Fees (2 January 2003).
9. Refer to the People's News report on 14 November 2007. Available at the following link: http://finance .people.com.cn/GB/6530094.html.
10. State Environmental Protection Administration Ordinance [2007] No. 35 (11 April 2007).
11. State Environmental Protection Administration Official Policy Note [2007] No. 108 (12 July 2007).
12. Ta Kung Pao, 14 February 2008, p.A4.
13. An economically better-developed region is coded as "econstat=1." An economically less-developed region is coded as "econstat=0."
14. Because the institutional apparatus for dealing with pollution in rural areas is not well developed, people implicitly limit their discussions of environmental governance to urban areas in China. As a consequence we adopt the per capita income of the urban population for our analysis.
15. In a growing economy, emissions tend to increase at given emission intensities and a given industrial structure. See (H. L. F. De Groot et al., 2004).
16. The intensity effect also can be called the technique effect. As economies grow rich, they can afford more advanced and more efficient technologies, which results in lower emission intensities. See (Copeland & Taylor, 2003).
17. A typical time path of the sectoral composition of an economy is one in which countries are initially characterized by a large agricultural sector, followed by a period of industrialization, which is subsequently followed by deindustrialization and a rising service sector. See (H. De Groot, 2000)
18. For example, α_{i1} , can be interpreted as every percentage point increase in income of the j^{th} region will lead to α_{i1} percentage point change in discharge of the i^{th} pollutant in the same region.

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