NBER WORKING PAPER SERIES

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Working Paper 19620
http://www.nber.org/papers/w19620

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
November 2013

We thank the UCLA Ziman Center for Real Estate for providing generous support. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 19620
November 2013
JEL No. H23,H4,R48

ABSTRACT

At political boundaries, local leaders often have weak incentives to reduce polluting activity because the social costs are borne by downstream neighbors. This paper exploits a natural experiment set in China in which the central government changed the local political promotion criteria and hence incentivized local officials to reduce border pollution along specific criteria. Using a difference in difference approach, we document evidence of pollution progress with respect to targeted criteria at river boundaries. Other indicators of water quality, not targeted by the central government, do not improve after the regime shift. Using data on the economic geography of key industrial water polluters, we explore possible mechanisms.

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1 Introduction

River pollution represents a classic negative externality that spills across political boundaries. The source region generates emissions that pollute the river but most of these social costs are borne downstream. The affected region bears the costs of pollution but enjoys few or none of the benefits of polluting. In cases ranging from Western Europe to China the result has been high levels of water pollution at political boundaries (Cai *et al*., 2013; Sigman 2002, 2005; Sandler 2006). The empirical literature on transboundary river pollution documents a significant free-riding effect along inter-jurisdictional rivers.[1]

Coasian bargaining offers one pathway for mitigating externalities. However, in China it is prevented by the absence of a regional negotiations mechanism.[2] A second way for free riding to cease at river boundaries is for local officials to be motivated to take costly actions to mitigate pollution. In China, the central government has recently provided strong incentives for local officials to take costly actions.

[1] Sigman (2002) compares pollution in domestic and international rivers. She finds that stations immediately upstream of international borders have higher levels of BOD (Biochemical Oxygen Demand) than similar stations elsewhere. Gray and Shadbegian (2004) find different effects on air and water pollution of being near the Canadian-United States border. On the water pollution side they observe more BOD discharges and fewer inspections near the border. Using toxics release inventory data from 1987 to 1996, Helland and Whitford (2003) show that facilities' emissions into the water are systematically higher in counties that border other states. Sigman (2005) finds that free riding gives rise to a 4% degradation of water quality downstream of authorized US states, with an annual environmental cost downstream of 17 million US dollar. In China, Cai *et al*. (2013) document that water-polluting production activities are approximately 30 percent greater in the most downstream county of a province.

[2] The local governments in China are independently authorized by the central government. Generally, the multiregional affairs are coordinated by the central government. In Chinese political culture, regional negotiation is not encouraged since it weakens the governance of the central government. The riparian provinces usually competed with each other to seek resolutions from the central government rather than dialogue and cooperation with other provinces (Tyler, 2006).

In this paper, we investigate how China's central government's regime shift in evaluating local officials for promotion affected water pollution dynamics. China's rivers cut across political jurisdictions. We document that at the baseline there is evidence of free riding. In 2005, the central government changed the rules of the game and provided local officials with strong incentives to reduce specific indicators of water pollution along rivers that flow within. For local officials, who sought to be promoted within the Chinese political promotion system, compliance with these new environmental targets motivated them to cease free riding at boundaries.

We document evidence supporting this claim based on a difference in difference approach using pollution data from 499 stations located in China's major seven rivers during the years 2004 to 2010. We find that the COD (Chemical Oxygen Demand) decreases significantly starting in 2005 when China's central government started to tie officials' promotion chances to this indicator of environmental quality. Furthermore, the COD measures at the province boundary stations decrease faster than at stations located inside the province. We test for the association between urban leader's attributes and indicators of pollution abatement effort at boundaries. We posit that younger governors have greater career concerns because of their longer future planning horizon.

Such water pollutants as petroleum, lead, mercury, and phenol are more harmful than COD for public health. Unlike in the case of COD, these water pollution measures do not decline more at the transboundary stations. This is relevant because these criteria were not chosen to be part of the objective performance criteria for evaluating the effectiveness of local officials. Thus, local officials with career concerns had no incentives to seek to improve their location's pollution based on these criteria.

The paper's final empirical contribution is to explore the mechanisms through which the COD progress might be taking place. The pulp and paper industry is the major COD producer. Using plant level industrial data, we explore the economic geography of this industry relative to the location of rivers. Since the implementation of the target based environmental policy, new pulp and paper firms are less likely to be locating close to rivers.

The remainder of this paper is organized as follows. Section 2 discusses relevant points about China's river geography. Section 3 describes some features of China's recent environmental protection efforts. Section 4 presents a model to convey the spatial free rider problem. Our empirical strategy and our data are described in Section 5. Section 6 discusses our findings. Section 7 offers insights about how urban officials may use their power to achieve pollution improvements. Section 8 concludes.

2. The Geography of China's Major Rivers

All ancient civilizations flourished in the river basin. They are nurtured by rivers, since rivers, as a natural resource, have been used as a source of water, for obtaining food, for transport, as a source of power, and as a means of disposing of waste. Chinese civilization originated in various regional centers along both the Yellow River and the Yangtze River valleys in the Neolithic era, and the Yellow River is said to be the cradle of Chinese civilization. Even today most of Chinese major cities locate along rivers. The basins of China's seven major river systems occupy 44% of the nation's total territory and serves 88% country's population (World Bank, 2007).[3] Among them, the Yangtze River and the Yellow River are the third-longest and sixth-longest river in the world.

Our research focuses on ten river systems listed in *China Environmental Yearbooks.* Besides the seven major river systems, our sample also includes three regional river systems in southeast, southwest and northwest China. These river systems are all cross-provincial and managed by the China central government. It sited many monitoring stations along these rivers and monitors the hydrological attributes and water pollution. The pollution data in our sample are generated from these monitoring stations.

To measure the increasingly serious river pollution, China's central government invested in a significant expansion of its monitoring station system in 2004. Many new stations were built and started to provide data. Our sample collects the pollution data from 499 monitoring stations from 2004 to 2010 as shown in Figure 1.

[Insert Figure 1 about Here]

As shown in Figure 2, cross-provincial rivers connect several different jurisdictions together. Upstream regions often locate polluting enterprises close to the border, so the river's discharge is carried into downstream regions. The average COD level reported at these provincial boundary stations is 10.49 mg/L in 2005. This average is much higher than the 7.04mg/L average reading from stations located within the territory of a single province.

[Insert Figure 2 about Here]

To better monitor the water quality in China's rivers, the central government sites monitoring stations both inside the province and at the borders of the two provinces. The

[3] They are included Songhuajiang River, Liaohe River, Haihe River, Yellow River, Huaihe River, Yangtze River, and Pearl River.

types of monitoring stations are shown in Figure 2 with different marks. In our sample, 127 monitoring stations are located at the provincial boundary out of 499 total stations.

3 The Water Pollution Policy Regime Shift

China's pollution challenges are well known (see Zheng and Kahn 2013). For decades, the powerful central government has prioritized economic growth to raise the nation's material wellbeing. Hundreds of millions of people have exited poverty but extreme environmental degradation has taken place as China has relied on an industrialization growth strategy and relying on coal for power generation and heating (Vennemo *et al*., 2009, Chen *et al*., 2013).

The nation's high pollution is also related to its unique management and political system. China runs a target-based vertical control system, where the central government ranks local governors' performance and then decides the promotion of local governor directly (Xu, 2011). This evaluation system had traditionally placed heavy emphasis on economic growth statistics (Li and Zhou, 2005). Such incentives discourage local governors from enforcing environmental regulations (Jia, 2013). Local governors also tend to have a short term perspective focused on economic growth, over long term green goals, because they expect that their tenure as governors will be short as they advance in the hierarchy. As a result of this incentive system, local officials have sought to attract high polluting factories to their area. Public health research has documented that industrial pollution has caused severe health problems such as "cancer villages" (Ebenstein, 2012).

Facing this critical situation, China's central government has taken steps to mitigate pollution externalities (Landry 2008; Zheng and Kahn, 2013; Zheng *et al*., 2013). The essence of the new implemented environmental policy is to tie the discharges of major pollutants with the promotion of local governors. In this sense, the central government is explicitly acknowledging the principal-agent problem that it does not fully observe local officials' efforts to reduce pollution.

The implementation of the new environmental policy had two stages. First, the outline of the 11th Five-Year Plan (FYP) in 2005 announced the binding target that national COD and sulfur dioxide discharges must decline. To encourage localities to comply with the national policy, the central government announced that it would impose administrative demerits or removal from office for leaders at sub-national level who failed to meet the pollution targets. The 11th FYP set environmental targets as a mandatory requirement for local governments and provided no wiggle room for poor performance on these environmental criteria.

To ensure the effectiveness of its chosen policies across China's territorial administration, in 2007, the central government announced that the COD and sulfur dioxide reduction targets had to be attained by the end of 2010 and should be incorporated into the responsibility contracts signed with local governments at various levels. More importantly, the central government announced that local official performance with respect to the COD and sulfur dioxide reduction would outweigh all other achievements of the local governors.[4] Local governors therefore have been incentivized to meet these emissions targets.

[4] All provinces reached this green goal by the end of 2010.

When China's central government shifted its environment policy, it also paid special attention to the transboundary pollution to try to limit free-riding.[5] The central government emphasized that upstream regions are also required to take responsibility with respect to the pollution experienced in downstream regions. The central government also authorized the downstream provinces to report the source regions to the central government in the event of poor water quality.[6]

4 An Analysis of Local Official's Response to the Policy Regime Shift

China's central government sets an environmental target and encourages local governors to achieve it under the new environmental policy regime. China's new environmental policy links the promotion probability of local governors to pollution levels. The local governors cannot be promoted if they fail to achieve the target but the local governors' promotion chances are still tied to total output produced. Upstream regions also consider the pollution level in the downstream regions. Once the station in the downstream region fails to achieve the target given by central government, the upstream region's leader also cannot be promoted.

Under this new policy regime, local governors are aware that they face a significant challenge in reducing transboundary pollution because they cannot costlessly

[5] China's water pollution problems easily can transcend the provincial boundaries. The severe transboundary water pollution incidents occurring one after another in recent years are a striking reflection of the problem. In November 2005 a spill of toxic chemicals poisoned the Songhua River, the largest tributary of Amur. As an estimated 100 tons of benzene, aniline and nitrobenzene entered the Songhua River, several Chinese and Russian cities downstream from the spill were forced to shut off their water supplies as toxic reached them. A report from UNEP can be found at: http://www.unep.org/PDF/China_Songhua_River_Spill_draft_7_301205.pdf.

[6] The Chinese document can be found on the website of China government: http://www.gov.cn/gzdt/2008-07/11/content_1042367.htm.

contract with their neighboring local governor.[7] The optimal strategy of local governors is to increase effort and reduce pollution activity more at borders because of their uncertainty about their neighbors' effort. The net effect of this policy is to encourage the local officials to work together and cease the free-riding effects at provincial boundaries.

We present a simple analysis to show the underlying logic how the new pollution control policies in China discourage free-riding at transboundary borders. As shown in Figure 3, we discuss a river crosses the border of two provinces, and there are two monitoring stations within the province and one station at the border. To simplify our model, we assume that three industry parks are located near the monitoring stations. The local governors locate dirty industry into different parks; and the different parts of the river will be polluted by the dirty industry close to them.

The pollution level of each station is decided by the dirty industry in the neighbor industry park, and also impacted by the upstream. We assume that the water is clean before it comes to station 1. The pollution level at station 1 is

$$P_1 = D_1, \tag{1}$$

where D_1 is the total dirty industry in industry park 1. Assume the distance between each station is L; and the decay rate of pollution is λ. The pollution level of station 2 is

$$P_2 = D_2 + D_1 e^{-\lambda L}. \tag{2}$$

And the pollution level of station 3 is

$$P_3 = D_3 + D_2 e^{-\lambda L} + D_1 e^{-\lambda 2L} \approx D_3 + D_2 e^{-\lambda L}, \tag{3}$$

where $e^{-\lambda 2L} \approx 0$.

[7] Promotion is a competition among local leaders. Coordination between competitors is difficult.

Before the new environmental policy is implemented in China, Province A will locate more dirty industry in industry park 2, i.e. the border of two provinces. The upstream region free rides downstream. Recent empirical work supports this claim (Cai, Chen and Qing 2013).

The central government requires the pollution level of each station reduces to μ of the initial level and $\mu < 1$ after a fixed period under new policy regime.[8] Local governors can either invest in new technology or reduce the dirty industry's scale of production in order to meet the environmental target. To simplify, we assume that the technology is constant and governors improve environmental quality through reducing the scale of dirty industry production.[9] The local governors can choose between three strategies. They can reduce their dirty industry to μ proportion of the initial level; or a bit higher than μ, $\mu + \delta$ of the initial industry level; or a bit lower than μ, $\mu - \delta$ of the initial industry level. The local governor faces a tradeoff over the scale of the dirty industry. Such industry raises total output. However, the pollution from the dirty industry will make them more likely to fail to achieve the environmental target; and this will hurt their career prospects.

At station 1, the optimal strategy of local governor is to reduce the dirty industry in industry park 1 to μD_1. And the pollution reading will be

$$P_1^n = \mu D_1. \quad (4)$$

Local governor has the maximum output; meanwhile it is also can fulfill the environmental requirement.

[8] China's central government set $\mu = 90\%$ during the years 2006-2010.
[9] We also can discuss that local governors reduce pollutants discharge through improving technology. The results are as same as above discussion. Local governors will invest more on the industry at the province border.

At station 2, if the local governor of province A reduces the dirty industry to μ, he can achieve the environmental target at station 2. But since the behavior of local governor in province B is uncertain. If he/she locates a bit more dirty industry in industry park 3, perhaps the local leader in province A will fail to be promoted. The local governor in province A will choose a lower dirty industry $\mu - \delta$ in the boundary. Lower dirty industry gives governor a greater likelihood to achieve the environment target at stations 2 and 3, although it reduces the output and the probability of promotion slightly. Overall, the pollution level at station 2 is

$$P_2{}^n = (\mu - \delta)D_2 + \mu D_1 e^{-\lambda L}. \quad (5)$$

Comparing equation (1), (2), (4) and (5), pollution at the boundary monitoring stations declines in absolute and relative terms.

5 Data and Empirical Strategy

The water pollution datasets used in our analysis are obtained from the *China Environmental Yearbooks* published in various years. Our sample covers eight water quality indicators at 499 stations between 2004 and 2010 with a sample size of 3,377 individual observations. It is an unbalanced panel sample since some stations do not report data in certain years. However, the missing observations are rare, representing less than 3% of the sample. They are Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), and the densities of Oxygen (DO), Hydronitrogen (NH), petroleum, lead, mercury, and phenol, respectively. All of these eight water pollutants capture general forms of anthropogenic pollution and could travel reasonably far downstream causing significant spillovers at many monitoring stations on domestic rivers.

Data quality is a major concern in China environmental studies.[10] The statistical data is often manipulated by China authorities since the data is related to the performance evaluations of local governments (Chen *et al*., 2013). Our study avoids these issues. First, the monitoring stations in our sample are all run by the central government. Local governments have limited influences on these stations. Second, our paper focuses on the difference between stations within the province and at the boundary. There is no motivation for the central government to only modify the data of one specific category of stations.

The additional explanatory variable included in our study is the city's GDP level. These data are from the *China Statistical Yearbook for Regional Economy* published in various years. Summary statistics of the water pollution indicators and control variables are presented in Table 1.

[Insert Table 1 about Here]

This paper investigates transboundary water pollution dynamics as a function of centralized environmental policy. For each type of pollution, we estimate a multivariate regression of the form

$$PL_{i,t} = \beta_s BD_i \times Year_t + \rho Year_t + \gamma X_{i,t} + \mu_i + \varepsilon_{i,t} \qquad (6)$$

[10] In most of the papers discussing China's water pollution, water quality data are either directly collected from the local/national monitoring stations (*e.g*., Yin *et al*., 2005; Wang *et al*., 2008) or collected via field work (*e.g*., Ma *et al*., 2009). Using Shenzhen as a case, Wang *et al*. (2004) show that satellite image data after calibration and correction for atmospheric effects can serve as another means of estimating water quality.

where $PL_{i,t}$ is the water pollutant outcome in station i at year t; BD_i is the boundary dummy equal to 1 if station i is located on the provincial boundary and 0 otherwise[11]; $Year_t$ is a vector of year dummies; μ_i is a vector of station dummies; $\varepsilon_{i,t}$ is the error term. $X_{i,t}$ is a vector of control variables. In our study, the GDP of the city in the river basin is included as a control variable to allow for the fact that the scale of economic activity varies across different stations.[12]

In equation (6), β_s is the coefficient of our interest and 2004 is selected as the base year. β_s can be interpreted as a difference in difference estimate (Meyer, 1995) that captures annual change (compared to the base year 2004) in water pollutant discharges in a boundary station relative to similar stations elsewhere.

As we discussed earlier, China's recent environmental responsibility scheme is the key tool that the central authorities use to incentivize local officials to achieve green goals of concerns. However, it does not mean that all local governors will be induced to exert effort and resources in ways commensurate with the preferences of the central government. Since meeting the green goal raises the local leader's career prospects, those who are young should be more enthusiastic about attaining the green target laid down by the central government.

Since the *Decision to Build a Retiring Scheme for Senior Cadres* (1982) ruled out reappointment of civil servants after the age of 65, age has become a critical variable determining turnover (Li and Zhou, 2009). To maintain position stability of leadership term, the *Temporary Regulations on Terms of Cadre of China Communist Party and Government* (2006) further regulated that each term of provincial governors and Party

[11] The *China Environmental Yearbooks* report whether a station is a provincial boundary one. We double checked this definition using the coordinates of each station based on its address.
[12] At the borders, we average the two neighbor cities' economic variables.

secretaries should not be longer than 5 years. These norms serve as powerful tools to guarantee the relatively young leaders reach leadership positions. Thus, when a leader approaches the age of 60, the chances of promotion diminishes quickly even if he/she is capable. We hypothesize that young local leaders are more eager to fulfill the COD discharges cut target since they have a longer career horizon. We posit that border pollution will fall much faster if both sides of the border are led by younger governors.

To test this leaders hypothesis, we collect detailed biographical information on chief governors and chief provincial party secretaries, from several publicly accessible sources including the internet services *China Vitae*[13] and individual biographies. The data allow us to establish the month and year in which they were born and took/left office.

We divide the provincial leaders by age into two groups, "young" (60 or less) and "old" (over 60).[14] Then we partition all transboundary stations in our sample into three subsamples based on the above information. In group A, the provincial leaders on both sides are "young". In group B, at least one of the provincial leaders on each side is "old" (or "young"). In group C, both provincial leaders of the neighboring provinces are "old". We then can capture the promotion effect by examining and comparing the coefficients for the year dummies specified in the following equation.

$$COD_{i,t} = \beta_M Year_t + \gamma X_{ijt} + \mu_i + \varepsilon_{it} \quad (7)$$

It is expected that other things being equal, the year dummy coefficient of group A should exceed that of group C in absolute terms.

[13] See http://www.chinavitae.com/
[14] In our sample the average age of a governor is 57.6 years and that of a party secretary 58.6.

6 Empirical Results

This section presents our results testing the free riding hypothesis as we examine water pollution dynamics at boundary monitoring stations after the 2005 environmental policy shift. Since the promotion criteria only target COD pollution, we posit that only this criterion should improve while others should not be affected.

Table 2 summarizes our key results for COD. We report two estimates of equation (6). Our benchmark regression is displayed in Column 1, and the subsequent columns provide robustness checks when extra control variables are included. As expected, in column 1 of Table 2, the coefficients of the interaction terms (defined as year dummies multiplied by the indicator of whether the station is at a boundary) are all negative and large in absolute value. These interaction terms only become statistically significant after the year of 2006. The magnitude of the interaction terms increase in every year except for 2007.

[Insert Table 2 about Here]

As shown in Table 2's column (2) both economic growth and per capita income are estimated to increase COD concentrations.[15]

In our next set of results, we report placebo regressions where we focus on other measures of water pollution, some of which are more important to public health than COD that the government chose not to use as performance criteria.[16] Table 3 reports the results when the dependent variable is represented in turn by the other seven measures of

[15] By 2010, the COD discharge reduction target had been surpassed and an overall 13.3% reduction had been achieved.

[16] COD is the total measurement of all chemicals in the water that can be oxidized that are mainly generated by industry activities. It is a feasible and easy test to identify this water pollution.

water pollution. The coefficients of the interaction terms are never negative and statistically significant and in one case the coefficients are positive and statistically significant. This indicates (in the case of DO) that water pollution on this criteria increased at the boundary station over time. Judging from Table 3 it appears that China's recent environmental target-based responsibility scheme only promotes good neighbor behavior in the COD case no matter how harmful other pollutants might be for human health and ecosystem.

[Insert Table 3 about Here]

As we discussed above, younger local officials have the greatest career concerns. In Table 4, we test for differential water pollution progress as a function of local officials' attributes. As expected, compared with other cases, if leaders on both sides of the boundary are "young", the COD concentrations in the transboundary sites were more quickly reduced.[17] As shown in Table 4, achieving the green goal mattered more for the political fortunes of Party secretaries but not those of governors. These results suggest that performance-based rewarding or punishment is actually a feasible tool to promote interest alignment between central and local leaders.

[Insert Table 4 about Here]

7 Exploring the Mechanisms: The Location of Pulp and Paper Plants

[17] Note that although both provincial Party secretaries and governors are evaluated, it is primarily the leading cadres (*i.e.*, Party secretaries) who are more affected by the environmental target-based responsibility system.

Local governors can influence the location and scale of dirty industry production through using their administration power. They can shut down and move away the dirty industry to improve environmental quality.

In China, local governments have a monopoly on land development and the power to zone land to decide what industrial activity goes where. For example, to encourage eco-industrial initiatives, China initiated the pilot construction of Eco-Industrial Parks in 2001 and established the Standard for Sector-Integrate Eco-Industrial Parks (SSEP) in 2009. According to the SSEP, industrial value added per unit of COD discharged within the EIPs must not exceed 1 kg/Yuan (the national average in 2009 is 3.26 kg/Yuan).[18]

COD, the target pollutant set by China central government, is mainly discharged due to industrial production. The pulp and paper industry is responsible for a very large share of total industrial COD emissions (see Laplante and Rilstone, 1996; Gray and Shadbegian, 1998). Using data from 2004 to 2008 from the China Statistical Yearbook and the China Environmental Statistical Yearbook, in Figure 4 we plot each industry's share of total industrial COD emissions on the vertical axis and the industry's share of total industrial output on the horizontal axis. The pulp and paper industry stands out as an enormous outlier. While its share of output is roughly 2.5% it produces 32.6% of total industry COD. Given this fact, we focus on the economic geography of where these plants cluster over time.[19]

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[18] See details: http://www.sepa.gov.cn/info/bgw/bgg/200907/W020090701557555441134.pdf. It is the official document from China's government.

[19] Paper production can be divided into five major manufacturing steps: 1. pulp production, 2. pulp processing and chemical recovery, 3. pulp bleaching, 4. stock preparation and 5. paper manufacturing. All of these steps require a large volume of water. After the pulping stage is complete, residual matter remains which are usually released directly into rivers. Production costs are higher if a pulp & paper firm is further from a river where it is required to meet tougher emission standards, install higher-capacity (more expensive) pollution control equipment, incur higher operating costs, and perform more frequent maintenance. In China, many of the thousands of pulp mills are located in regions close to forests. These

[Insert Figure 4 about Here]

Using data from the China Annual Survey of Industrial Firm 2005-2008, we identify the new pulp and paper plants each year and calculate the distance (Measured by Kilometer) between them and the nearest river monitoring station. We divide all plants into two groups. One group includes the new pulp and paper plants that opened between 2003 and 2005 when the central government had not implement the new environmental policy while the other group includes the new pulp and paper plants opened between 2006 and 2008 when the policy is implemented.

Figure 5 shows the kernel density function of each set of pulp and paper plants' distance to the nearest provincial boundary monitoring station. Most of the new pulp and paper plants from 2006 to 2008 located further from the boundary station. Figure 6 shows the kernel density of pulp and paper plants' distance to the nearest non-provincial boundary monitoring station of both groups. The figure shows the locations of pulp and paper plants relative to non-boundary station have similar trend before and after the implementation of environmental policy. Together, these figures highlight that new pulp and paper plants are locating further from the provincial border while within provinces there are no discernible migration patterns for this polluting industry.

[Insert Figure 5&6 about Here]

We recognize that pulp and paper plants may differ with respect to their scale of operations. Local officials concerned about pollution impacts should care more about larger plants. In results available on request, we find that the employment weighted non-parametric kernel distributions look quite similar to the unweighted distributions

regions are also punctuated by numerous large rivers, which can be tapped to provide the sizable energy needed to grind timber into pulp and paper presented in Figures 5 and 6. The new pulp and paper plants locate significantly further away from the boundary stations during the 2006 to 2008 period. This suggests that the local governors put more effort in reducing the boundary pollution under China centralized environmental policy as they restrict pulp and paper plants from locating close to the boundary.

8 Conclusion

Free riding at political boundaries causes significant social costs for people who live on the other side of the boundary. This paper has studied how changes in the performance criteria used for evaluating Chinese government officials incentivized them to exert effort to reduce pollution externalities.

China's recent environmental target responsibility system creates new rules of the game that incentivize local governors to increase their effort to reduce water pollution at political boundaries. Those local governors who seek to rise in the government's power structure recognize that high pollution levels will reduce their promotion chances.

We find evidence consistent with the hypothesis that local governors have responded to the new promotion rules by taking more effort to reduce water pollution at political boundaries.[20] Our study also points out a fault of the current system. Local governors focus on the environmental measures set by central government rather than a broader set of water criteria that might be more relevant for public health (see Tables 2

[20] The central government cannot distinguish between the sources of transboundary pollution, and will thus hold both sides responsible. The upstream regions devote more effort due to their uncertainty about their neighbors' efforts.

and 3). In a principal-agent model, the agent will focus on those criteria that he knows he is being evaluated on and will tend to shirk on other output targets (Holmstrom and Milgrom 1991). Future research should investigate the local quality of life impacts and the economic incidence of these pollution reductions.

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Table 1
Descriptive Statistics

Year	COD	BOD	DO	NH	Petroleum	Lead	Mercury	Phenol	GDP Growth	GDP per capita
2004	8.76	7.64	7.09	2.58	0.17	0.01	0.04	0.01	0.14	1.28
	(15.47)	(21.39)	(2.63)	(6.07)	(0.48)	(0.02)	(0.14)	(0.03)	(0.03)	(0.94)
2005	7.96	6.70	7.18	2.44	0.14	0.01	0.04	0.01	0.14	1.44
	(13.03)	(16.75)	(2.11)	(5.82)	(0.34)	(0.02)	(0.06)	(0.03)	(0.04)	(1.05)
2006	7.68	6.93	7.05	2.34	0.12	0.01	0.04	0.01	0.14	1.64
	(13.96)	(17.87)	(2.06)	(5.45)	(0.27)	(0.02)	(0.14)	(0.04)	(0.02)	(1.21)
2007	7.05	6.09	7.25	2.30	0.12	0.01	0.03	0.01	0.15	1.87
	(10.81)	(14.99)	(2.03)	(5.68)	(0.37)	(0.02)	(0.10)	(0.03)	(0.03)	(1.38)
2008	5.90	4.52	7.31	1.97	0.08	0.01	0.03	0.01	0.14	2.10
	(7.50)	(7.76)	(1.89)	(4.90)	(0.14)	(0.01)	(0.03)	(0.05)	(0.04)	(1.52)
2009	5.09	3.80	7.55	1.78	0.07	0.00	0.03	0.00	0.13	2.34
	(5.41)	(5.68)	(1.80)	(4.58)	(0.13)	(0.01)	(0.05)	(0.01)	(0.03)	(1.68)
2010	4.82	3.72	7.60	1.57	0.06	0.00	0.03	0.00	0.14	2.67
	(4.89)	(6.47)	(1.66)	(4.14)	(0.10)	(0.01)	(0.03)	(0.01)	(0.02)	(1.94)
Total	6.75	5.63	7.29	2.14	0.11	0.01	0.03	0.01	0.14	1.91
	(10.97)	(14.29)	(2.05)	(5.28)	(0.30)	(0.01)	(0.09)	(0.03)	(0.03)	(1.50)

Note: This table shows the descriptive statistics of 8 water quality measurements in our data. They are Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), and the densities of Oxygen (DO), Hydronitrogen (NH), Petroleum, Lead, Mercury, and Phenol, respectively. The control variables GDP growth rate and GDP per capita are also summarized here. Standard deviations are in parentheses.

Table 2
The Determinants of COD Water Pollution Levels

Independent variables	(1)	(2)
Boundary × 2005 Year Dummy	-1.689	-1.675
	(1.320)	(1.319)
Boundary × 2006 Year Dummy	-2.851**	-2.823**
	(1.324)	(1.323)
Boundary × 2007 Year Dummy	-2.134*	-2.077*
	(1.261)	(1.258)
Boundary × 2008 Year Dummy	-2.462*	-2.371*
	(1.282)	(1.279)
Boundary × 2009 Year Dummy	-3.389**	-3.264**
	(1.370)	(1.367)
Boundary × 2010 Year Dummy	-4.075***	-3.912***
	(1.425)	(1.424)
2005 Year Dummy	-0.376	0.000
	(0.429)	(0.000)
2006 Year Dummy	-0.451	-0.440
	(0.550)	(0.429)
2007 Year Dummy	-1.141***	-0.586
	(0.359)	(0.549)
2008 Year Dummy	-2.206***	-1.368***
	(0.427)	(0.372)
2009 Year Dummy	-2.833***	-2.530***
	(0.451)	(0.450)
2010 Year Dummy	-2.885***	-3.262***
	(0.471)	(0.491)
GDP of River Basin		0.627***
		(0.187)
Station dummies	Yes	Yes
No. of observations	3377	3377
R^2	0.731	0.732
F- statistics	2.25**	2.08*

Notes: (1) ***, **, * indicate significance at the 0.01, 0.05, and 0.1 levels, respectively. (2) Heteroskedasticity robust standard errors are in parenthesis. (3) The H0 hypothesis of F-Statistics is that the coefficients on the interacted term between boundary and 2006-2010 year dummies are jointly equal to 0.

Table 3
Water Pollutants and their Determinants

Independent variables	BOD	DO	NH	Petroleum	Lead	Mercury	Phenol
Boundary × 2005 Year Dummy	0.325	0.036	0.246	0.028	0.003	0.125	0.033
	(1.140)	(0.176)	(0.394)	(0.036)	(0.012)	(0.100)	(0.049)
Boundary × 2006 Year Dummy	-1.238	0.128	-0.372	-0.003	-0.010	0.076	0.041
	(1.088)	(0.171)	(0.348)	(0.029)	(0.008)	(0.114)	(0.046)
Boundary × 2007 Year Dummy	0.227	0.154	0.111	0.013	-0.004	0.026	0.050
	(1.055)	(0.176)	(0.358)	(0.034)	(0.013)	(0.096)	(0.039)
Boundary × 2008 Year Dummy	0.910	0.197	-0.305	0.026	0.003	0.112	0.123
	(1.094)	(0.172)	(0.353)	(0.030)	(0.008)	(0.095)	(0.076)
Boundary × 2009 Year Dummy	0.063	0.418**	-0.132	0.008	0.010	0.080	0.020
	(1.137)	(0.185)	(0.373)	(0.031)	(0.009)	(0.091)	(0.046)
Boundary × 2010 Year Dummy	-0.519	0.511**	-0.387	-0.024	-0.002	0.092	0.015
	(1.197)	(0.200)	(0.421)	(0.034)	(0.009)	(0.094)	(0.046)
2005 Year Dummy	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
2006 Year Dummy	-1.060	0.077	-0.187	-0.032	0.000	-0.089	-0.012
	(0.777)	(0.100)	(0.153)	(0.021)	(0.005)	(0.090)	(0.013)
2007 Year Dummy	-0.541	-0.014	-0.151	-0.049**	-0.009*	-0.074	-0.012
	(0.838)	(0.101)	(0.153)	(0.021)	(0.005)	(0.106)	(0.015)
2008 Year Dummy	-1.612**	0.099	-0.203	-0.044*	-0.006	-0.144	-0.034***
	(0.807)	(0.102)	(0.153)	(0.024)	(0.010)	(0.095)	(0.011)
2009 Year Dummy	-3.281***	0.143	-0.396***	-0.085***	-0.021***	-0.162*	-0.042***
	(0.833)	(0.108)	(0.141)	(0.023)	(0.005)	(0.094)	(0.012)
2010 Year Dummy	-3.966***	0.327***	-0.614***	-0.085***	-0.030***	-0.161*	-0.054***
	(0.926)	(0.116)	(0.164)	(0.024)	(0.006)	(0.094)	(0.014)

GDP of River Basin	-3.890***	0.337***	-0.724***	-0.086***	-0.030***	-0.169*	-0.059***
	(0.958)	(0.123)	(0.180)	(0.025)	(0.005)	(0.098)	(0.014)
Stations dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	3377	3377	3377	3377	3377	3377	3377
R^2	0.711	0.799	0.882	0.585	0.749	0.399	0.468
F- statistics	1.44	2.37**	1.02	0.96	1.55	0.67	0.79

Notes: (1) ***, **, * indicate significance at the 0.01, 0.05, and 0.1 levels, respectively. (2) Heteroskedasticity robust standard errors are in parentheses. (3) The H0 hypothesis of F-Statistics is that the coefficients on the interacted term between boundary and 2006-2010 year dummies are jointly equal to 0.

Table 4
COD Water Pollution at Provincial Boundaries

Independent variables	All	Province's secretaries			Province's governors		
		Young vs. Young	Young vs. Old	Old vs. Old	Young vs. Young	Young vs. Old	Old vs. Old
2005 Year Dummy	-2.043	-3.562*	3.072	0.053	-4.153	-0.163	0.074
	(1.272)	(1.864)	(1.986)	(0.492)	(4.055)	(1.248)	(0.582)
2006 Year Dummy	-3.255***	-5.749**	-0.516	1.595	-5.814	-0.532	0.754
	(1.256)	(2.410)	(1.051)	(1.404)	(3.556)	(1.119)	(0.740)
2007 Year Dummy	-3.200**	-8.776***	-1.214	1.507	-3.851	-1.634	1.960
	(1.290)	(3.219)	(0.785)	(1.809)	(2.597)	(1.357)	(1.661)
2008 Year Dummy	-4.566***	-14.442***	-1.138	-0.178	-6.939***	-2.336	0.339
	(1.329)	(4.727)	(0.883)	(2.193)	(2.581)	(1.469)	(0.958)
2009 Year Dummy	-6.088***	-18.227***	-2.730***	-0.426	-8.359***	-4.524**	0.179
	(1.454)	(5.647)	(0.916)	(2.394)	(2.744)	(1.766)	(1.156)
2010 Year Dummy	-6.789***	-19.785***	-3.360***	-0.675	-8.796***	-3.838***	-4.124
	(1.546)	(6.497)	(1.053)	(2.732)	(2.794)	(1.240)	(2.956)
GDP of River Basin	-0.275	12.318**	-0.627	-2.804**	1.803	-1.906*	-2.873
	(0.782)	(5.850)	(1.342)	(1.251)	(1.284)	(1.114)	(5.093)
Station dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	858	290	374	194	292	350	216
R^2	0.761	0.878	0.804	0.905	0.910	0.786	0.922
F- statistics	6.90***	2.38**	3.18***	0.56	2.80**	2.43***	0.74

Notes: (1) ***, **, * indicate significance at the 0.01, 0.05, and 0.1 levels, respectively. (2) Heteroskedasticity robust standard errors are in parentheses. (3) The H0 hypothesis of F-Statistics is that the coefficients on the interacted term between boundary and 2006-2010 year dummies are jointly equal to 0.

Figure 1
The Spatial Distribution of Water quality Monitoring Stations in China

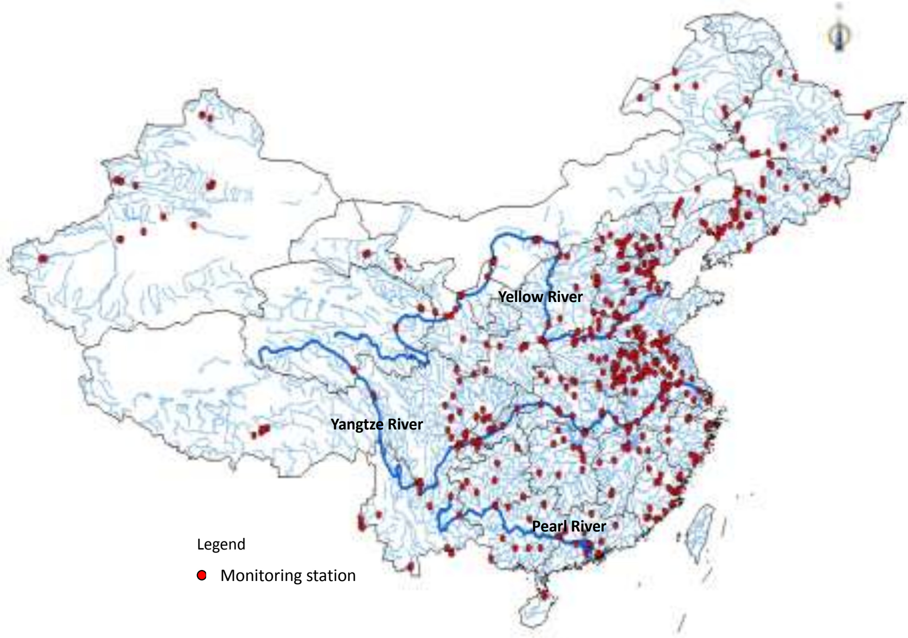


Figure 2
Water Quality Monitoring Across Chinese Provinces

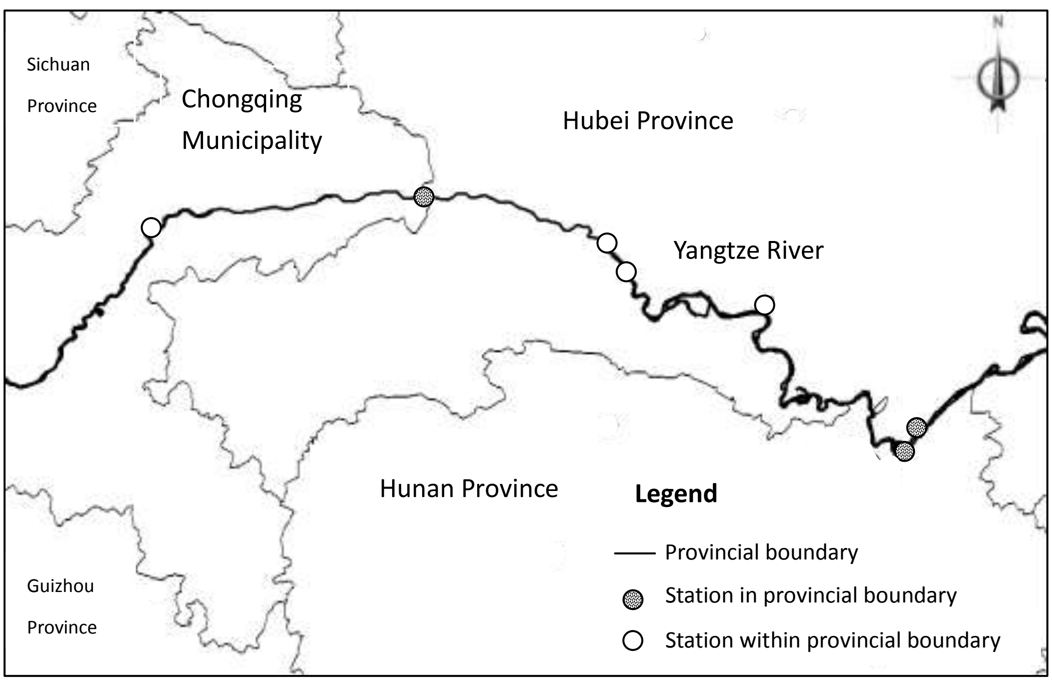


Figure 3

An Illustrative Example of the Causes of Transboundary Pollution

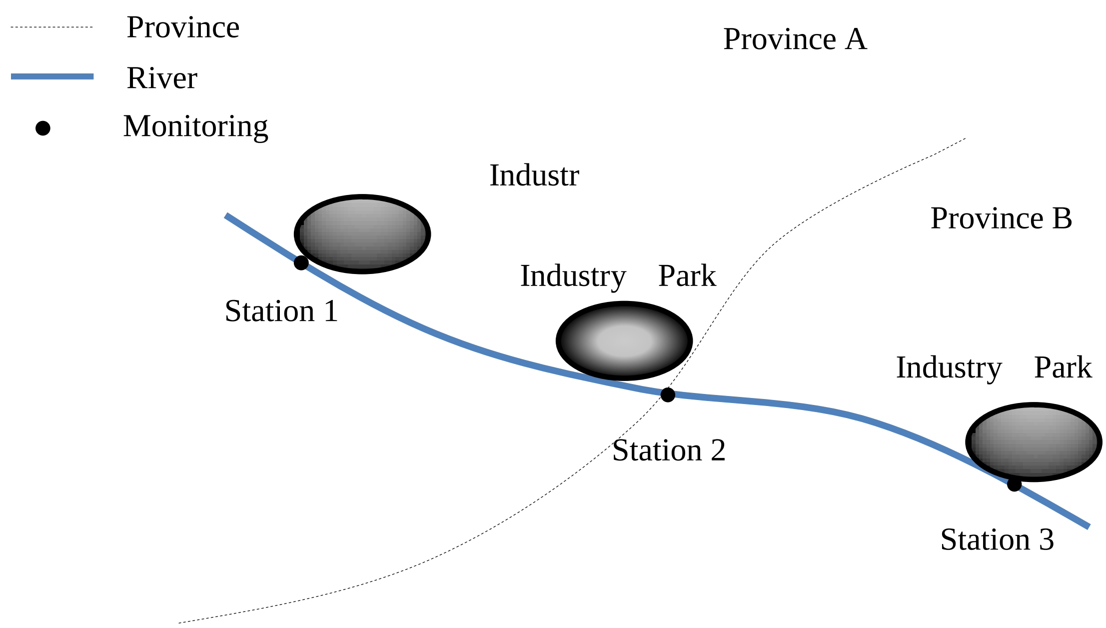
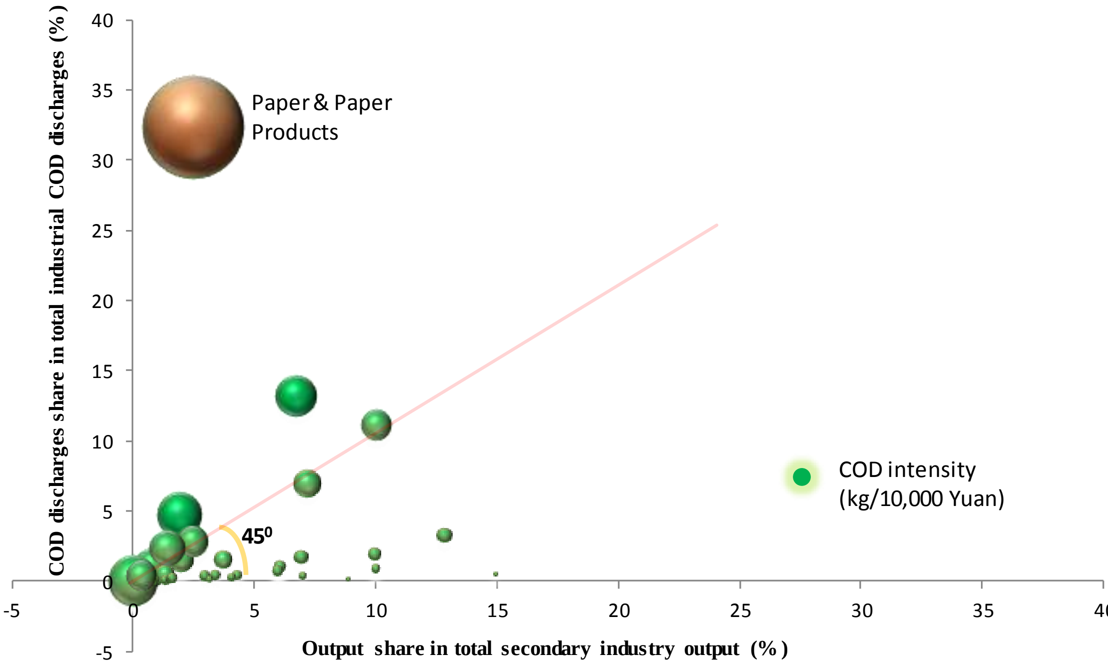


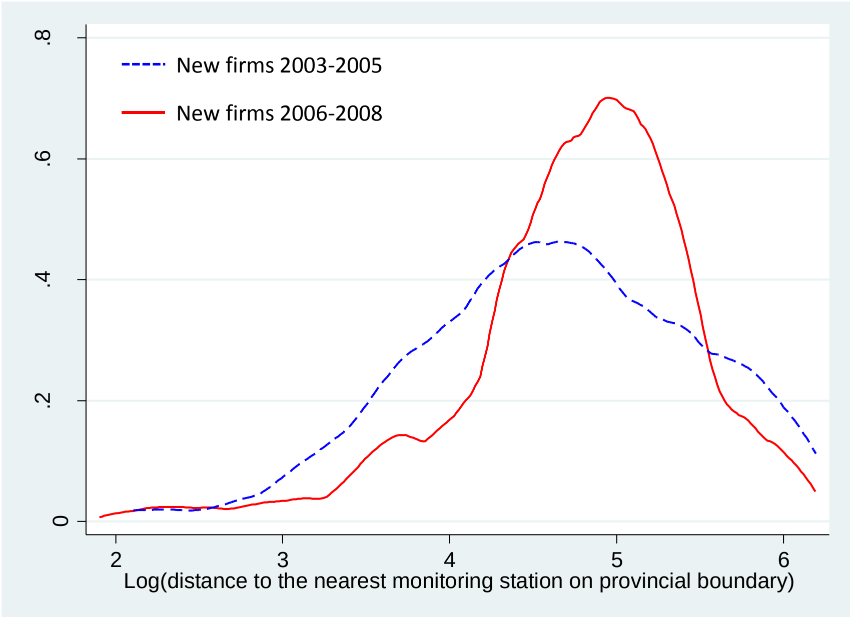
Figure 4
Industrial Output, COD discharges and Pollution Intensity



Data sources: China Statistical Yearbook 2005-2009 and China Environmental Statistical Yearbook 2005-2009

Figure 5

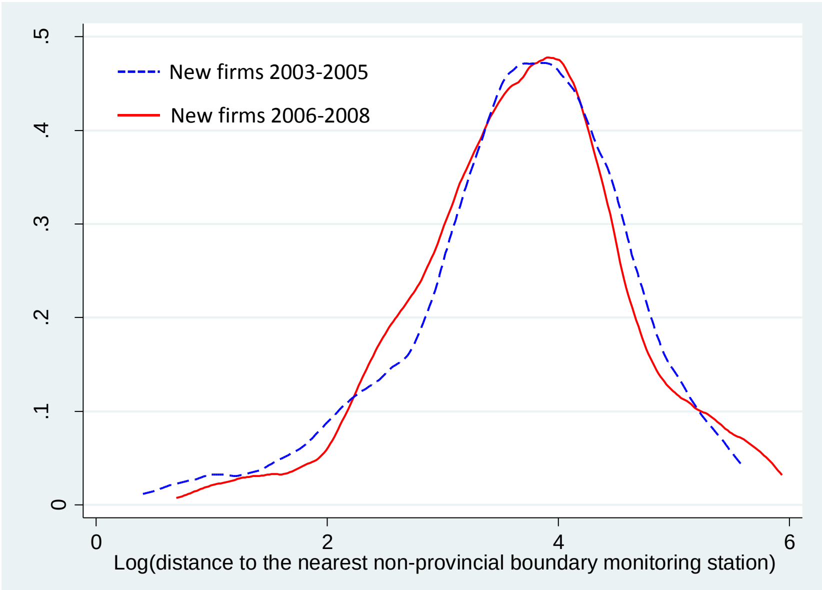
The Kernel Density of the Distance between Pulp and Paper Firms and the Nearest Provincial Boundary Monitoring Station



Data source: China Annual Survey of Industrial Firm 2005-2008.

Figure 6

The Kernel Density of the Distance between Pulp and Paper Firms and the Nearest Non-Provincial Boundary Monitoring Station



Data source: China Annual Survey of Industrial Firm 2005-2008.