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Water Pollution Progress at Borders: The Role of Changes in China's Political Promotion Incentives†

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At political boundaries, local leaders 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 thus incentivized local officials to reduce border pollution along specific criteria. We document evidence of pollution progress with respect to targeted criteria at province boundaries. Heavy metal pollutants, not targeted by the central government, have not decreased in concentration after the regime shift. Using data on the economic geography of key industrial water polluters, we explore possible mechanisms. (*JEL* D72, O13, O18, P25, P28, Q25, Q53)

River pollution represents a classic negative externality that spills across political boundaries. The source region generates emissions that pollute the river, but social costs are borne downstream. In cases ranging from Western Europe to China, empirical studies have documented significant free riding along interjurisdictional river boundaries (Cai, Chen, and Qing 2013; Sigman 2002, 2005; and Sandler 2006).[1]

Coasian bargaining offers one pathway for mitigating such externalities. Due to the absence of binding international law between nation-states, negotiated solutions can be difficult to achieve even when there are only a few actors (Dinar 2006; Lipscomb and Mobarak 2013; Sigman 2005; and Wolf 2007).

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[1] Sigman (2002) compares pollution in domestic and international rivers. She finds that stations immediately upstream of international borders have higher levels of biochemical oxygen demand (BOD) than similar stations elsewhere. Gray and Shadbegian (2004) find that near the Canadian-United States border BOD discharges are higher and that fewer inspections take place. Using Toxic Release Inventory data from 1987 to 1996, Helland and Whitford (2003) show that facilities' water emissions are higher in counties that border other states. Sigman (2005) finds that free riding gives rise to a 4 percent degradation of water quality downstream of authorized US states. Lipscomb and Mobarak (2013) exploit a Brazilian natural experiment in which county borders are redrawn frequently and consequently changes strategic polluting behavior around borders. They conclude that solutions to cross-boundary spillovers require active regulatory involvement by upper-level governmental officials.

A second way to discourage free riding at rivers that cross political boundaries is to motivate local officials to take costly actions to mitigate pollution. In the recent past, water pollution levels have been elevated at political boundaries in China. Using the Hebei province as a case, Duvivier and Xiong (2013) find that dirty firms are more likely to set up in border counties than in the interior area. Cai, Chen, and Qing (2013) document that water-polluting production activities are approximately 30 percent greater in the most downstream county of a Chinese province. They discuss the mechanisms behind the "downstream effect" based on the agglomeration of dirty firms in specific counties.

In China, the central government has recently provided strong incentives for local officials to take costly actions. 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. Local officials, who sought to be promoted within the Chinese political promotion system, were motivated to take greater efforts to reduce water pollution in order to achieve compliance with these new environmental targets.

We document evidence supporting this claim based on a difference-in-differences approach using water pollution data from 499 stations located along China's major seven rivers during the years 2004 to 2010. We find that chemical oxygen demand (COD) decreased significantly after China's central government started to tie officials' promotion chances to this indicator of water pollution in 2006.[2] Furthermore, the COD levels at the province boundary stations decrease faster than at stations located inside the province. We test whether there are greater water pollution reductions in upstream locations administered by younger leaders. Such leaders may have greater incentive to meet COD targets due to their long-term career goals.

Water pollutants such as petroleum, mercury, and phenol are more harmful than COD for public health. Unlike the case of COD, these water pollution measures do not significantly improve at boundary 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 who harbored ambitions for promotion had weaker incentives to devote effort to improving water quality, based on these criteria.

The paper's final empirical contribution is to explore one mechanism through which the COD progress might be taking place. The pulp and paper industry is a major COD producer. Using plant level industrial locational data, we document that new pulp and paper firms are less likely to be locating close to rivers.

The remainder of this paper is organized as follows: Section I discusses China's river geography. Section II describes some features of China's recent environmental

[2] COD is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia (Tchobanoglous and Schroeder 1985). It is commonly used to assess the general health of a river. Higher COD is associated with an increased bacterial count and organisms in the water.

protection efforts. Section III introduces our data, while Section IV reports our empirical results. Section V presents evidence on industrial dynamics near provincial boundaries and Section VI presents our conclusions.

I. Monitoring Pollution along China's Major Rivers

Rivers, as a natural resource, are essential for human civilization. They have been used as a source of water and of power, as well as a means for providing transport, obtaining food, and 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 China's major cities are located along rivers. The basins of China's seven major river systems occupy 44 percent of the nation's total territory (World Bank 2007).[3] Among them, the Yangtze River and the Yellow River are the third-longest and sixth-longest rivers in the world.

Our research focuses on ten river systems listed in the *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 are managed by the Chinese central government, which locates many monitoring stations along these rivers. The pollution data in our sample are generated by these monitoring stations.

To measure river pollution, China's central government invested in a significant expansion of its monitoring station system in 2004. We have collected pollution data from 499 monitoring stations from 2004 to 2010. The locations of these stations are reported in Figure 1.

As shown in Figure 1, rivers cross different provincial boundaries. 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 two provinces. The types of monitoring stations are shown in Figure 2 with different marks. In our sample, 127 (of the total of 499) monitoring stations are located at a provincial boundary. Besides the boundary stations, 136 monitoring stations are located within 30 kilometers of a provincial boundary.

II. The Water Pollution Policy Regime Shift

Upstream regions often locate polluting enterprises close to borders so that pollution is carried downstream. This strategy allows the upstream region to enjoy the benefits of industrial production while not bearing the social costs. Given that China's centralized political system lacks a regional negotiations mechanism, such free riding is a predictable outcome.[4] In the year 2004, the average COD level reported at provincial boundary stations was 12.59 mg/L. This average was much

[3] They include the Yangtze River, Yellow River, Pearl River, Songhua River, Huai River, Hai River, and the Liao River.

[4] Under the Unitary State System of China, local officials are appointed by the central government and exercise their power independently. Multiregional affairs are coordinated by the central government. In the Chinese political culture, regional negotiation is not encouraged since it weakens the power of the central government (Tyler 2006).

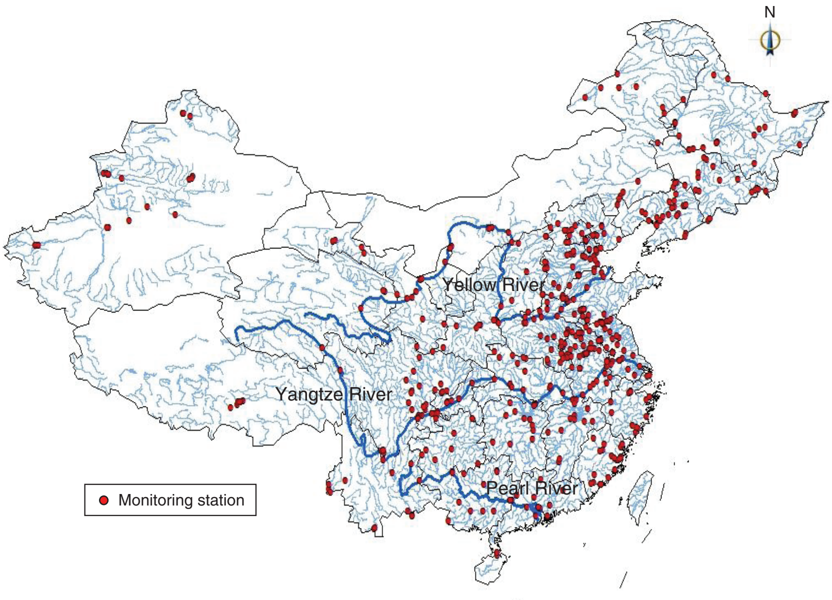

Figure 1. The Spatial Distribution of China's Water Quality Monitoring Stations

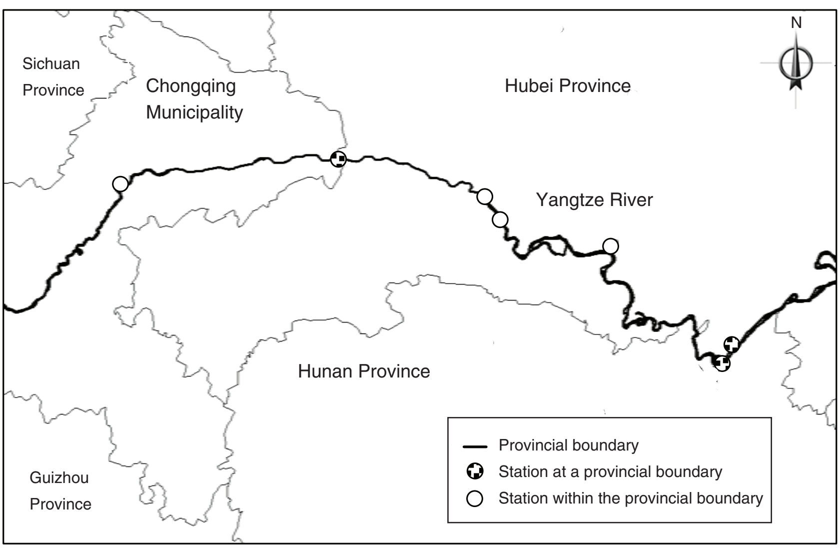

Figure 2. Water Quality Monitoring across Chinese Provinces

higher than the 7.42mg/L average reading from stations located within the territory of a single province. We will use a regression approach to document that this boundary COD differential in the base year is statistically significant. Studies of China's governance structure have noted the close ties between local officials and industry and have conjectured that this inhibits the effectiveness of regulation intended to reduce pollution (Kostka 2014). Local officials' promotion chances are enhanced by their success in achieving economic growth (Jia 2013, and Wu et al. 2014).

Aware of the cross-boundary pollution problem, the central government introduced a major policy shift in 2006. In the outline of the eleventh Five-Year Plan (FYP) in 2006, the government announced a binding target requiring the decline of COD and sulfur dioxide discharges. 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 the subnational level who failed to meet the pollution targets. The eleventh FYP set environmental targets as a mandatory requirement for local governments and provided no "wiggle room" for poor performance on these environmental criteria.[5]

To ensure the effectiveness of these policies, the central government announced in 2007 that the COD and sulfur dioxide reduction targets had to be attained by the end of 2010 and be incorporated into the responsibility contracts signed with local governments at various levels. The central government announced that it would place special weight on COD and sulfur dioxide reductions in evaluating the performance of local governors.[6] Local governors therefore have been incentivized to meet these emissions targets.

China's new environmental policy is a target-based system. The central government sets binding national environmental targets during the five-year planning period and assigns specific targets for each province. Provincial governments are required to meet their overall targets and the central government only appraises the total value of the reduction. To avoid the possibility of shirking by provincial governments, the central government requires them to annually set and fulfill their emissions targets. At the beginning of each year, each provincial governor will sign an individual responsibility contract, documenting specific COD discharges-reduction requirements for their locality.

In practice, the new emissions reduction regulatory system allows for some flexibility at the local level. Provincial governments are allowed to allocate targets within their administrative boundaries and to control the timing of when regulations come into effect in order to achieve the five-year planning target. Local leaders also have some flexibility over the spatial geography of where activity takes place within their jurisdiction. They can strategically move polluters far from areas where central regulators are monitoring.

The net effect of the new environmental policy regime is that a local leader's career trajectory is now tied to local environmental performance. Free riding is discouraged since each region is required to achieve the COD emission reduction target.

To avoid possible cross-boundary disputes, China's new environmental policy requires upstream regions to take responsibility for the pollution experienced in downstream regions.[7] The source region will be held liable if discharges "contribute

[5] In the eleventh Five-Year Plan (FYP), the central government required that local governments reduce their COD emissions by 10 percent below their 2005 levels by the year 2010.

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

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

significantly" to noncompliance with water quality standards in any other region.[8] Once this threshold is reached, it must prohibit any source from emitting any pollutant that interferes with compliance in any other region.[9] Under the new promotion rules, upstream leaders will have an incentive to devote more effort to reducing border pollution in order to avoid disputes with downstream leaders.

Overall, China's new environmental policy features two major elements.[10] First, the "within-province policy" uses career incentives to encourage environmental protection. Second, the "between-province policy" authorizes downstream regions to supervise upstream regions. This increases the effort by upstream regions to limit boundary pollution.

III. Data

The water pollution data used in our analysis are obtained from the *China Environmental Yearbooks* published in various years. Our sample covers six water quality indicators at 499 stations between 2004 and 2010, which results in an unbalanced panel of 3,377 individual observations.[11] The pollution variables are COD, BOD, Ammonia Nitrogen (NH), Petroleum, Mercury, and Phenol. All of these water pollutants capture general forms of anthropogenic pollution and can travel reasonably far downstream, causing significant spillovers at many monitoring stations on domestic rivers.

We partition the monitoring stations into two categories: provincial boundary stations and interior monitoring stations. The *China Environmental Yearbooks* report whether a station is located at a provincial boundary. We double-checked this definition using the coordinates of each station based on its address. We also calculate each monitoring station's distance to the province boundary and create a continuous measure of each station's proximity to the nearest boundary.[12]

Table 1 reports water pollution summary statistics by year; we report these statistics separately for border and nonborder stations.[13] In 2004 and 2005, the average COD level is much higher at the border stations, but over time this differential narrows. Between 2004 and 2010, average border COD levels declined by 54 percent, while average nonborder COD levels declined by 39 percent.

Data quality is a major concern in environmental studies focused on China.[14] The statistical data are often manipulated by local authorities since the data are related

[8] In general, water quality testing is jointly conducted at the boundary river section under the coordination of the National Environmental Monitoring Centre (NEMC). The collected sample is split into two subsamples to be analyzed by the neighboring provinces individually, and the average of the results is used for water quality assessment. If the neighboring provinces have any dispute about the monitoring data, then the NEMC makes the final decision.

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

[10] We thank a reviewer for this suggestion.

[11] The *China Environmental Yearbook* has stopped publishing the water pollution at the station level in 2011. Summary statistics are reported instead. Our data are the most up-to-date data publicly available.

[12] The distance of each monitoring station to the closest provincial boundary is calculated using its coordinates and the provincial boundary shape file. We thank a reviewer for this suggestion.

[13] We thank a reviewer for this suggestion.

[14] 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, and Wang et al. 2008) or collected via field work (e.g.,

Table 1—Descriptive Statistics

	COD(mg/L)		BOD(mg/L)		NH(mg/L)	
Year	Nonborder	Border	Nonborder	Border	Nonborder	Border
2004	7.42	12.59	7.17	9.01	2.29	3.42
	(12.58)	(21.36)	(23.43)	(13.97)	(5.63)	(7.17)
2005	7.05	10.59	6.14	8.30	2.09	3.44
	(12.04)	(15.28)	(17.86)	(12.96)	(5.02)	(7.62)
2006	7.05	9.48	6.78	7.38	2.14	2.90
	(14.43)	(12.40)	(19.84)	(10.24)	(5.39)	(5.58)
2007	6.27	9.37	5.59	7.57	2.00	3.19
	(9.81)	(13.12)	(16.09)	(11.03)	(5.27)	(6.68)
2008	5.17	8.06	3.75	6.81	1.73	2.68
	(5.84)	(10.79)	(6.47)	(10.40)	(4.65)	(5.55)
2009	4.65	6.43	3.37	5.09	1.54	2.51
	(4.57)	(7.26)	(5.44)	(6.20)	(4.34)	(5.18)
2010	4.50	5.77	3.36	4.78	1.36	2.20
	(4.54)	(5.72)	(6.65)	(5.80)	(3.76)	(5.06)
Total	6.01	8.92	5.16	7.00	1.88	2.91
	(9.91)	(13.37)	(15.32)	(10.58)	(4.91)	(6.20)
	Petroleum(ug/L)		Mercury(ug/L)		Phenol(ug/L)	
	Nonborder	Border	Nonborder	Border	Nonborder	Border
2004	15.85	19.97	4.26	3.43	0.77	0.63
	(51.78)	(35.51)	(15.92)	(2.59)	(2.74)	(1.76)
2005	12.37	19.37	3.40	3.83	0.65	0.85
	(31.25)	(40.89)	(6.88)	(5.22)	(2.79)	(3.45)
2006	10.71	14.52	3.65	3.57	0.67	0.95
	(26.17)	(29.56)	(16.46)	(5.40)	(3.32)	(5.99)
2007	10.55	16.26	2.98	2.42	0.42	0.82
	(36.15)	(37.49)	(11.60)	(2.20)	(1.39)	(5.02)
2008	6.11	12.87	2.86	3.16	0.37	1.48
	(8.89)	(23.34)	(3.06)	(2.84)	(1.34)	(10.13)
2009	5.71	11.23	2.95	2.90	0.28	0.34
	(9.83)	(20.37)	(5.18)	(1.56)	(0.89)	(1.07)
2010	5.01	7.53	2.96	2.99	0.21	0.26
	(9.68)	(11.27)	(3.58)	(1.79)	(0.50)	(0.51)
Total	9.46	14.57	3.29	3.19	0.48	0.76
	(29.28)	(30.24)	(10.35)	(3.44)	(2.11)	(5.06)

Notes: This table shows the descriptive statistics of six water quality measurements in our data. They are chemical oxygen demand (COD), biochemical oxygen demand (BOD), and the densities of ammonia nitrogen (NH), petroleum, mercury, and phenol, respectively. The value is calculated for the border and nonborder stations, respectively. Standard deviations are in parentheses.

to the performance evaluations of local governments (Chen et al. 2012). Our study avoids these issues. First, the monitoring stations in our sample are all run by the central government. Local governments have limited influence on these stations. Second, our paper focuses on the dynamics of water pollution levels at boundary

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.

versus interior monitoring stations. The central government is unlikely to have an incentive to systematically report false data for these subsets of stations.

We have collected additional economic and climate data to include as control variables. The city-level gross domestic product (GDP) and population data used in this paper are collected from the *China Statistical Yearbook for Regional Economy* published in various years.[15] Luminosity data comes from the Defense Meteorological Satellite Program (DMSP) that reports images of the earth at night captured from 20:30 to 22:00 local time. Temperature data is obtained from the records of each monitoring station's nearest meteorological station provided by China Meteorological Data Sharing Service System.

To account for the heterogeneity of career concerns among different political leaders, we also collect detailed biographical information on chief governors and chief provincial party secretaries from several publicly accessible sources including the internet services *China Vitae* and individual biographies.[16] The data allow us to establish the month and year in which they were born, as well as when they took and left office.

IV. Empirical Results

A. *Water Pollution Dynamics at Borders*

We test for whether there is differential COD water pollution progress at river boundaries relative to pollution progress at interior monitoring stations. We conduct a difference-in-differences estimation to capture the effect of general environmental regulation on water pollutant discharges, the pollution level at a boundary station, and the environmental regulation effects at a boundary station relative to similar stations elsewhere. We estimate equation (1):

$$COD_{i,t} = \beta_1 Post2005_t + \beta_2 BD_i + \beta_3 BD_i \times Post2005_t + \gamma \mathbf{X}_{i,t} + \mathbf{r}_i + \varepsilon_{i,t}, \tag{1}$$

where $COD_{i,t}$ is the water COD outcome in station i at year t; BD_i is the boundary dummy that is equal to 1 if station i is located on the boundary of two neighboring provinces and 0 otherwise; $\mathbf{r}_i$ is a vector of river dummies; and $\varepsilon_{i,t}$ is the error term. $Post2005_t$ indicates the post-treatment period, i.e., $Post2005_t = 1 \forall t > 2005$ and $= 0$ otherwise.

We include additional explanatory variables $\mathbf{X}_{i,t}$ as controls in the estimation. GDP per capita of cities in the river basin city are included to control the possible pollution-income relationship. The GDP growth rate of cities in the river basin is added as another control since previous studies have noted that environmental degradation is driven by the rate of economic growth (Brock and Taylor 2005). Building on recent research (e.g., Henderson, Storeygard, and Weil 2012; and Michalopoulos

[15] At the borders, we average the two neighboring cities' economic variables.
[16] See http://www.chinavitae.com/.

and Papaioannou 2013), we use the nighttime luminosity to identify urban settlements around each monitoring station.[17] Finally, we include the monitoring station's annual average temperature as a control since water temperature can "affect biological activity and chemical conditions in the river and thus the natural attenuation rates of pollutants" (Sigman 2005).

To deal with potential heteroskedasticity and spatial correlation, we report robust standard errors and cluster the standard errors along two dimensions (Bertrand, Duflo, and Mullainathan 2004). We cluster by monitoring station to consider the series correlation; and to allow for spatial correlations, we cluster by river/year.

In Table 2, we document evidence that free riding was taking place along China's rivers. The coefficient on the boundary dummy is statistically significant and equals 2.814. This positive coefficient is consistent with the free riding hypothesis. Over time, this free riding attenuated. The coefficient on *Post*2005 is statistically significant and negative. Given our interest in COD dynamics at boundaries, we focus on our estimate of β_3 in equation (1). As shown in column 1 of Table 2, this coefficient is statistically significant and has a coefficient of -1.888. This result is consistent with the hypothesis that the new regulation is having a differential impact on improving COD at boundaries.

Column 2 in Table 2 uses a continuous measure, *Proximity to Boundary*, instead of the boundary dummy to capture the impact of the new policy regime.[18] We posit that there will be a larger decline in COD for stations that are closer to the boundary.[19] The stations at the border have the maximum value of this variable, and the proximity values for other stations decay in correlation with the distance to the border. The coefficient on the interaction term between *Proximity to Boundary* and *Post*2005 is statistically significant and negative. The COD readings at stations closer to provincial borders decline more rapidly after 2005.

To further test for whether the policy regime shift is associated with declining COD pollution levels at borders, we estimate models including monitoring station fixed effects. This regression is presented in equation (2),

$$(2) \qquad COD_{i,t} = \beta BD_i \times Post2005_t + \rho \mathbf{Year}_t + \gamma \mathbf{X}_{i,t} + \boldsymbol{\mu}_i + \varepsilon_{i,t},$$

where $\mathbf{Year}_t$ is a vector of year dummies; $\boldsymbol{\mu}_i$ is a vector of station dummies. We posit that β will be negative. Since the error terms are potentially correlated temporally and spatially, the standard errors are clustered both by monitoring station and by river/year.[20]

[17] To extract the light data, every pixel with a digital number greater than zero was classified as night-time light on the Defense Meteorological Satellite Program image covering the years 2004 to 2010. With each monitoring station as the center, we buffered a concentric circle with a radius of 5 km. The circles were used for nighttime light extraction and defined as the analytical units for our analysis.

[18] We thank a reviewer for this suggestion.

[19] *Proximity to Boundary* is defined as 50 minus each station's distance to the closest province boundary. Distance is measured in 10 kilometer units. The maximum distance to boundary in our sample is 441 km.

[20] As we discuss below, we have also estimated standard errors using Conley's (1999, 2008) method when we estimated our equation (2). This approach allows for the possibility of spatial correlation across the monitoring stations (see Thiemo 2014). The results are consistent with the findings reported in Table 3. We report estimates using the Conley standard errors in the online Appendix Table A1.

TABLE 2—COD DISCHARGES AND ITS DETERMINANTS WITH RIVER FIXED EFFECTS

Independent variables	(1)	(2)
Post2005	−1.528***	3.139*
	(0.137)	(1.869)
Boundary	2.814**	
	(1.398)	
Boundary × *Post2005*	−1.888**	
	(0.751)	
Proximity to boundary		0.169**
		(0.074)
Proximity to boundary × *Post2005*		−0.112**
		(0.045)
River system dummy	Yes	Yes
Controls	Yes	Yes
R^2	0.177	0.175
Observations	3,377	3,377

Notes: Standard errors are clustered by monitoring station and by river/year. *Boundary* is a dummy variable to indicate whether the station is at the provincial border; *Proximity to boundary* is defined as 50 minus each station's distance to the closest province boundary. Distance is measured in 10 kilometers units.
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

TABLE 3—COD DISCHARGES AND ITS DETERMINANTS WITH STATION FIXED EFFECTS

Independent variables	(1)	(2)	(3)	(4)	(5)
Boundary × *Post2005*	−2.138*	−2.012*			
	(1.271)	(1.192)			
Boundary × *Time_Trend*			−0.543		
			(0.342)		
Proximity to boundary × *Post2005*				−0.129**	
				(0.057)	
Proximity to boundary × *Time_Trend*					−0.052**
					(0.023)
Station dummy	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes
Temperature	Yes	Yes	Yes	Yes	Yes
Economic controls		Yes	Yes	Yes	Yes
R^2	0.730	0.731	0.732	0.731	0.732
Observations	3,372	3,372	3,372	3,372	3,372

Notes: Standard errors are clustered by monitoring station and by river/year. *Boundary* is a dummy variable to indicate whether the station is at the provincial border; *Proximity to boundary* is defined as 50 minus each station's distance to the closest province boundary. Distance is measured in 10 kilometers units.
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table 3 presents the results based on equation (2). Column 1 only includes station and year fixed effects, and temperature factors. The coefficient of the interaction term between the border dummy and the post-2005 dummy, $(BD_i \times Post_t)$, is negative and statistically significant. In column 2, we include three sets of controls. The key interaction term drops in magnitude but its coefficient remains negative and statistically significant (at the 10 percent level). Based on the results reported in columns 1 and 2, we conclude that the average COD value at boundary monitoring stations decreased by around 2.0 mg/L after the regulation regime shift, compared with the average decline at the nonboundary monitoring stations. In Table 3, column 3, we drop the post-2005 dummy and instead include a linear time trend that we interact with the boundary dummy. We estimate a negative but statistically insignificant coefficient with a *p-value* of 0.112.

In Table 3, columns 4 and 5, we reestimate equation (2) but use the continuous measure, *Proximity to the Boundary*. In this case, we are comparing COD reading dynamics for monitoring stations closer to and further from the border. The main coefficients in both columns are negative and statistically significant at the 5 percent level. This finding is consistent with the hypothesis of greater COD progress at monitoring stations closer to provincial borders. [21]

B. *COD Dynamics versus Other Indicators of Water Pollution*

Since the central government's promotion criteria only target COD pollution, we posit that this measure of water pollution should improve by a greater amount at borders than do other water pollution indicators. To test this, we report regressions where we focus on other measures of water pollution, some of which are more important to public health than COD; however, the government does not use these as performance criteria.

In equation (3), we present our regression equation, which allows for the border effect to vary by calendar year.

$$PL_{i,t} = \beta BD_i \times \mathbf{Year}_t + \rho \mathbf{Year}_t + \gamma \mathbf{X}_{i,t} + \boldsymbol{\mu}_i + \varepsilon_{i,t}. \tag{3}$$

In equation (3), $PL_{i,t}$ is the water pollutant outcome at station i at year t; $BD_i \times \mathbf{Year}_t$ are the interactions between the boundary station dummy and the calendar year dummies. The year 2004 is the omitted category.

Table 4 reports the results. The regressions differ because we report results using six different measures of water pollution. Panel A reports the boundary dummies interacted with year dummies. The results for COD are presented in Table 4, column 1. The coefficients of the interaction terms are all negative and statistically significant except for the 2009 interaction. The magnitude of coefficients on these interaction terms generally increases over time in absolute value. We observe a large decline of COD at border stations between 2008 and 2010. The final year of the eleventh Fifth Year Plan was 2010, and we posit that local government officials allocated more resources to meet the central government's targets. For the non-COD regressions

[21] One reviewer suggested that some of the reductions in pollution at border stations are possibly caused by a diversion of upstream pollution downstream using investments in hidden pipelines. Such pipes would bypass the border monitoring station. While we acknowledge this possibility, we believe that our results presented in Table 3, columns 4 and 5 (where we include the continuous proximity to the border measure) address this concern because this interaction term captures that monitoring stations differ with respect to their proximity to the border so that there are stations near, but not at, the border. If upstream discharges a pollutant through a hidden pipeline, the reading at a monitoring station close to the border will be abnormally high. The negative and statistically significant results suggest that the pipeline hypothesis cannot be the main reason for the facts we document.

Table 4—Water Pollutants and Their Determinants

Independent variables	COD	BOD	NH	Petroleum	Mercury	Phenol
Panel A						
Boundary × *Year_Dummy2005*	−1.609*	0.463	0.268	2.874	1.285	0.315
	(0.829)	(0.950)	(0.366)	(3.616)	(1.089)	(0.273)
Boundary × *Year_Dummy2006*	−2.737*	−1.114***	−0.355	0.040	0.777	0.409
	(1.570)	(0.331)	(0.264)	(2.996)	(1.510)	(0.361)
Boundary × *Year_Dummy2007*	−1.958**	0.451	0.149	2.028	0.225	0.513
	(0.789)	(0.685)	(0.310)	(6.032)	(1.190)	(0.318)
Boundary × *Year_Dummy2008*	−2.358*	0.835	−0.310	2.974	1.050	1.212
	(1.407)	(1.171)	(0.267)	(4.353)	(0.961)	(0.878)
Boundary × *Year_Dummy2009*	−3.218	0.024	−0.130	1.389	0.731	0.173
	(2.090)	(0.955)	(0.265)	(3.854)	(1.119)	(0.249)
Boundary × *Year_Dummy2010*	−3.942*	−0.903	−0.444	−2.137	0.834	0.101
	(2.090)	(0.938)	(0.278)	(2.885)	(1.090)	(0.283)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Station dummies	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
F-statistics	61.45***	21.32***	59.05***	13.97**	6.42	8.53
R^2	0.730	0.730	0.730	0.730	0.730	0.730
Observations	3,372	3,372	3,372	3,372	3,372	3,372
Panel B						
Proximity to Boundary × *Year_Dummy2005*	−0.011	−0.064**	−0.016**	0.099	0.041	−0.003
	(0.054)	(0.033)	(0.008)	(0.197)	(0.097)	(0.009)
Proximity to Boundary × *Year_Dummy2006*	−0.004	−0.054	−0.037	−0.009	−0.085	0.015
	(0.086)	(0.036)	(0.028)	(0.158)	(0.177)	(0.016)
Proximity to Boundary × *Year_Dummy2007*	−0.072*	−0.089	−0.010	0.001	−0.060	0.022
	(0.040)	(0.061)	(0.013)	(0.208)	(0.137)	(0.021)
Proximity to Boundary × *Year_Dummy2008*	−0.160**	−0.188**	−0.032	0.213	−0.005	0.054
	(0.070)	(0.085)	(0.025)	(0.318)	(0.086)	(0.045)
Proximity to Boundary × *Year_Dummy2009*	−0.214*	−0.265***	−0.037	0.096	−0.011	0.009
	(0.112)	(0.100)	(0.034)	(0.366)	(0.110)	(0.020)
Proximity to Boundary × *Year_Dummy2010*	−0.241*	−0.292**	−0.051	−0.071	0.016	0.008
	(0.126)	(0.122)	(0.033)	(0.318)	(0.099)	(0.021)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Station dummies	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
F-statistics	11.35**	12.50***	7.39	22.32***	7.84	6.35
R^2	0.732	0.716	0.882	0.587	0.400	0.467
Observations	3,372	3,372	3,372	3,372	3,372	3,372

Notes: Standard errors are clustered by monitoring station and by river/year and reported in parentheses. The H0 hypothesis of *F*-statistics is that the coefficients on the interacted terms between *Boundary/Proximity to Boundary* and 2006–2010 year dummies are jointly equal to 0. *Boundary* is a dummy variable to indicate whether the station is at the provincial border; *Proximity to Boundary* is defined as 50 minus each station's distance to the closest province boundary. Distance is measured in 10 kilometers units. The baseline is the pollution level of each station in 2004.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

reported in Table 4, panel A, we find little evidence of differential boundary pollution progress. At the bottom of panel A in Table 4, we report an *F*-statistic testing for the joint statistical significance of the 2006 to 2010 boundary interaction terms.

We reject the null hypothesis for COD, BOD, Ammonia Nitrogen and Petroleum. Between 2006 and 2010, COD, BOD and Ammonia Nitrogen declined more at border stations than at interior stations and the petroleum density increases over time.[22]

In Table 4, panel B, we report additional estimates of equation (3) but replace the boundary dummy with the continuous measure of how close each station is to the nearest boundary. In the COD regression, the interaction term coefficients are almost all negative and statistically significant after 2007.[23] The BOD results are similar to the COD. This is not surprising, as both measure the amount of organic compounds in water. [24] Based on the results reported in Table 4, we conclude that China's recent environmental target-based responsibility scheme mainly promotes good neighbor behavior as measured by COD and BOD, but for other indicators of water pollution we do not observe differential water progress at stations along or close to borders.

C. *Leader Career Concerns and Pollution Dynamics*

Meeting the central government's environmental performance standards may be a more important goal for younger local leaders who have a longer planning horizon. We focus on the ages of two provincial leaders. At the provincial level of China, the party secretary is the top position, followed immediately by the provincial governor. In general, party secretaries are responsible for supervising the government, while the governor is in charge of detailed government affairs.[25] They are "just like the middle-level managers in a multidivisional corporation who are responsible for their divisional performance" (Li and Zhou 2005).

Since the *Decision to Build a Retiring Scheme for Senior Cadres* (1982)[26] ruled out the reappointment of civil servants after the age of 65, age has become a critical variable determining official turnover (Li and Zhou 2005). To better manage the bureaucrats and curb factionalism, the *Temporary Regulations on Terms of Cadre of China Communist Party and Government* (2006)[27] further ruled that governors and secretaries should not serve terms longer than five years. These norms serve as powerful tools to guarantee that relatively young leaders reach more advanced leadership positions.

[22] The major source of Ammonia Nitrogen (NH) pollution is agriculture, which during the years 2004 to 2010 was shrinking in China. See http://www2.epa.gov/nutrientpollution/sources-and-solutions.

[23] In the online Appendix Table A2, we report additional estimates of equation (3) using a different econometric approach to account for spatial correlations. In this case, we cluster the standard errors spatially and temporally using Conley's methods (1999, 2008). We assume that the spatial correlation only exists among stations whose distance is closer than 50 km and the serial correlation is limited to one lagged period. The results are generally consistent with our main results. We also try 5 km and 100 km as the distance cutoff and two period lag. The results are consistent with the results we report in the main tables.

[24] BOD refers to the amount of oxygen that bacteria in water will consume in breaking down waste, the largest source of which is the use of nitrogen and phosphate-based fertilizers. COD is similar in function of BOD. However, COD is less specific since it incorporates the effect of other pollutants on the rate of oxidization (Lamb 1985). We thank a reviewer for this point.

[25] See Tan (2006) for qualitative discussions on the roles of party secretaries and governors.

[26] The Chinese document can be found on the website of China's governemnt: http://cpc.people.com.cn/GB/64162/71380/71387/71591/4854975.html.

[27] The Chinese document can be found on the website of China's governemnt: http://cpc.people.com.cn/GB/64162/71380/102565/182144/10994167.html.

We hypothesize that younger local leaders are more eager to fulfill the COD discharges cut target since they have a longer career horizon. To test this hypothesis, we estimate equation (4). This regression equation is identical to equation (2) but it includes extra interaction terms related to the upstream leaders' ages.

$$COD_{i,t} = \beta_1 BD_i \times Time\_Trend_t + \beta_2 Age_i \times BD_i \times Time\_Trend_t + \beta_3 Age_i + \rho \mathbf{Year}_t + \gamma \mathbf{X}_{i,t} + \boldsymbol{\mu}_i + \varepsilon_{i,t} \tag{4}$$

Age_i is the age of upstream leaders. In equation (4), the decrease in the COD level over one year at border stations is measured by $\beta_1 + \beta_2 Age_i$. If older leaders put less effort into meeting the new standards, then β_2 should be positive.

Table 5 reports the results. The standard errors are clustered by monitoring station and by river/year.[28] Column 1 only includes the age of the secretary and column 2 includes the age of the governor. We find that, over time, COD pollution declines more at borders when there is a young upstream governor. Column 3 includes the age interaction terms for both the secretary and the governor. Our results are quite similar to the two regressions reported in columns 1 and 2. We consistently find that the governor's age, but not the secretary's age, is a significant correlate of COD progress at borders. This finding is intuitive because in China governors are more likely to be responsible for the local government's performance.[29] The results reported in Table 5, panel B use the continuous measure of a monitoring station's proximity to the border, and the results are consistent with our finding in Table 5, panel A. Our findings are consistent with the hypothesis that younger governors are more likely to take actions to meet the central government's new rules.

To further explore the career concerns hypothesis, we use other measures of water pollution (the same ones reported in Table 4) and reestimate equation (4). The results are reported in Tables 6 and 7. The results in Table 6 use the discrete boundary dummy, while the results in Table 7 use the continuous proximity to the boundary measure. Across both specifications we find no evidence that other indicators of water pollution differentially improved at boundaries where the upstream governor is younger. As shown in Table 7, only the BOD readings follow a similar pattern as the COD results.[30]

V. Exploring One Mechanism: The Location of Pulp and Paper Plants

In China, local governments have a monopoly on land development and the power to zone land for industrial activity. Local governors can influence the location and scale of dirty industry production by using their administrative power. They can shut down and move dirty industry away to improve environmental quality.

[28] The same clustering method used in Table 3 is reported in Tables 5, 6, and 7.

[29] Reviewing the previous environment incidents in China, we find that the Chinese central government only punished the governors. Examples include: the aniline spill in Changzhi Shanxi (December 2012), and the cadmium contamination in Longjiang Guangxi (February 2012).

[30] We also repeat our regressions with Conley Spatial HAC standard errors and the results are reproduced in online Appendix Table A3–A5. The results are consistent with our findings reported in Tables 5 and 7.

Table 5—Career Concerns and Water Pollution

Variables	(1)	(2)	(3)
Panel A			
Boundary × Time_Trend	−1.273	−4.199***	−4.988**
	(1.509)	(1.212)	(2.224)
Secretary Age × Boundary × Time_Trend	0.012		0.012
	(0.023)		(0.022)
Secretary Age	−0.047		−0.052
	(0.058)		(0.062)
Governor Age × Boundary × Time_Trend		0.063***	0.065***
		(0.017)	(0.018)
Governor Age		−0.008	−0.004
		(0.067)	(0.071)
Control variables	Yes	Yes	Yes
Station dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Observations	3,372	3,372	3,372
R^2	0.732	0.732	0.732
Panel B			
Proximity to Boundary × Time_Trend	−0.097***	−0.155***	−0.203***
	(0.036)	(0.047)	(0.067)
Secretary Age × Proximity to Boundary × Time_Trend	0.001**		0.001**
	(0.000)		(0.000)
Secretary Age	−0.117		−0.138
	(0.073)		(0.087)
Governor Age × Proximity to Boundary × Time_Trend		0.002***	0.002***
		(0.000)	(0.001)
Governor Age		−0.162***	−0.140***
		(0.046)	(0.044)
Control variables	Yes	Yes	Yes
Station dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Observations	3,372	3,372	3,372
R^2	0.733	0.734	0.735

Notes: Standard errors are clustered by monitoring station and by river/year. *Boundary* is a dummy variable to indicate whether the station is at the provincial border; *Proximity to Boundary* is defined as 50 minus each station's distance to the closest province boundary. Distance is measured in 10 kilometers units.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

COD, the target pollutant set by the Chinese central government, has three major sources: industry production, home activity and agriculture runoff. According to *China's First National Pollution Census*, industrial activity is responsible for 18.6 percent of the total COD discharges. The remaining part is contributed by domestic activity (37.7 percent) and agricultural runoff (43.7 percent).[31]

Local governments have their greatest control over industry and much less control over household and agricultural activity. The pulp and paper industry is responsible for a very large share of total industrial COD emissions (see Laplante and Rilstone

[31] We thank a reviewer for raising this issue.

Table 6—Career Concerns and Different Measures of Water Pollution

Independent variable	COD	BOD	NH	Petroleum	Mercury	Phenol
Boundary × *Time_Trend*	−4.988**	2.652	−1.991	17.278	1.337*	−0.730
	(2.224)	(2.829)	(1.479)	(11.889)	(0.712)	(1.255)
Secretary Age × *Boundary* × *Time_Trend*	0.012	−0.001	0.013	−0.156**	−0.005**	−0.007
	(0.022)	(0.029)	(0.015)	(0.062)	(0.002)	(0.013)
Secretary Age	−0.052	0.054	0.001	0.337	0.012*	0.092**
	(0.062)	(0.063)	(0.007)	(0.206)	(0.007)	(0.045)
Governor Age × *Boundary* × *Time_Trend*	0.065***	−0.048	0.019**	−0.143	−0.018	0.021
	(0.018)	(0.057)	(0.010)	(0.150)	(0.012)	(0.013)
Governor Age	−0.004	0.202	0.010	−0.183	−0.024	−0.094**
	(0.071)	(0.206)	(0.026)	(0.404)	(0.019)	(0.042)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Station dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
F-statistics	14.81***	1.50	8.48**	9.33**	9.67**	7.66*
Observations	3,377	3,377	3,377	3,377	3,377	3,377
R^2	0.732	0.716	0.883	0.590	0.468	0.401

Notes: Standard errors are clustered by monitoring station and by river/year. The H0 hypothesis of *F*-statistics is that the coefficients on *Boundary* × *Time_Trend*, *Secretary Age* × *Boundary* × *Time_Trend* and *Governor Age* × *Boundary* × *Time_Trend* are jointly equal to 0. *Boundary* is a dummy variable to indicate whether the station is at the provincial border.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table 7—Career Concerns and Water Pollution Outcomes Using a Continuous Measure of Proximity to the Boundary

Variables	COD	BOD	NH	Petroleum	Mercury	Phenol
Proximity to Boundary × *Time_Trend*	−0.203***	−0.187**	−0.022	−0.175	0.035	−0.004
	(0.067)	(0.077)	(0.019)	(0.114)	(0.048)	(0.009)
Secretary Age × *Proximity to Boundary* × *Time_Trend*	0.001**	−0.000	0.000	−0.001	−0.001	−0.000
	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)	(0.000)
Secretary Age	−0.138	0.064	0.005	0.323	0.180*	0.018*
	(0.087)	(0.042)	(0.008)	(0.266)	(0.107)	(0.009)
Governor Age × *Proximity to Boundary* × *Time_Trend*	0.002***	0.002**	0.000	0.004**	0.000	0.000*
	(0.001)	(0.001)	(0.000)	(0.002)	(0.000)	(0.000)
Governor Age	−0.140***	−0.067**	−0.003	−0.758*	−0.158**	−0.068*
	(0.044)	(0.031)	(0.013)	(0.388)	(0.068)	(0.035)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Station dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
F-statistics	16.67***	8.83**	1.56	6.29*	7.10*	4.69
Observations	3,372	3,372	3,372	3,372	3,372	3,372
R^2	0.735	0.719	0.882	0.590	0.468	0.402

Notes: Standard errors are clustered by monitoring station and by river/year. The H0 hypothesis of *F*-statistics is that the coefficients on *Proximity to Boundary* × *Time_Trend*, *Secretary Age* × *Proximity to Boundary* × *Time_Trend* and *Governor Age* × *Proximity to Boundary* × *Time_Trend* are jointly equal to 0. *Proximity to Boundary* is defined as 50 minus each station's distance to the closest province boundary. Distance is measured in 10 kilometer units.

***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

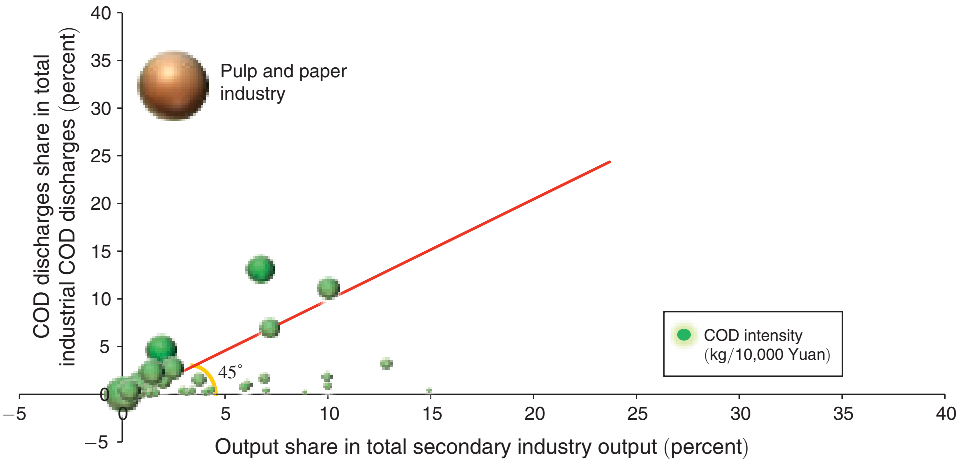

Figure 3. Industrial Output, COD Discharges and Pollution Intensity

Source: China Statistical Yearbook 2005–2009 and *China Environmental Statistical Yearbook* 2005–2009

1996, and Gray and Shadbegian 1998). In Figure 3 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.[32] The pulp and paper industry stands out as an enormous outlier. While its share of output is roughly 2.5 percent, it produces 32.6 percent of total industry COD. Given this fact, we focus on the economic geography of where these plants cluster over time.[33]

Using data from the China Annual Survey of Industrial Firms 2005–2008, we identify the new pulp and paper plants each year and calculate their distance (in kilometers) to the nearest 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 implemented the new environmental policy), while the other group includes the new pulp and paper plants that opened between 2006 and 2008, when the policy was implemented.

Figure 4 displays the kernel density function of each set of pulp and paper plant's distance to the nearest provincial boundary monitoring station. Most of the new pulp and paper plants from 2006 to 2008 were located further from the boundary station. Figure 5 presents the same kernel density, but this time measures a plant's distance to the nearest nonprovincial boundary monitoring station. The figure shows that the locations of pulp and paper plants relative to a nonboundary station have a similar relationship before and after the implementation of environmental policy. Together, these figures highlight that new pulp and paper plants are being located further from

[32] The data are from the *China Statistical Yearbook* and the *China Environmental Statistical Yearbook* covering the years 2004 to 2008.

[33] Paper production can be divided into five major manufacturing steps: pulp production, pulp processing and chemical recovery, pulp bleaching, stock preparation, and paper manufacturing. All of these steps require a large volume of water. After the pulping stage is complete, residual matter remains which is usually released directly into rivers (Gray and Shadbegian 2004). Production costs are higher if a pulp and 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.

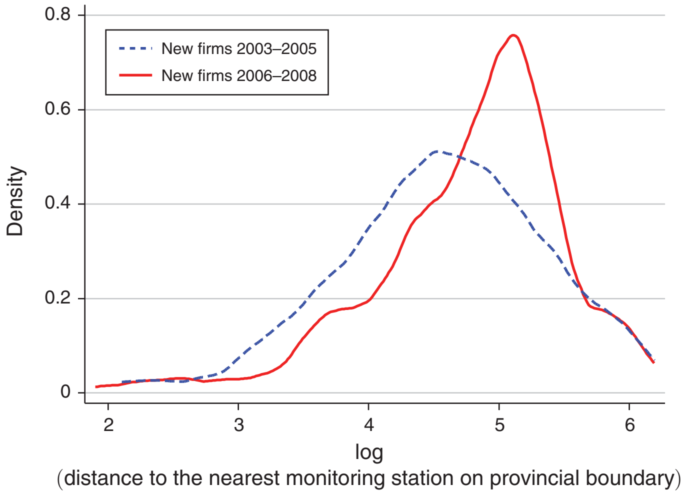

Figure 4. The Kernel Density of the Distance between Pulp and Paper Firms and the Nearest Provincial Boundary Monitoring Station

Source: China Annual Survey of Industrial Firms 2003–2008

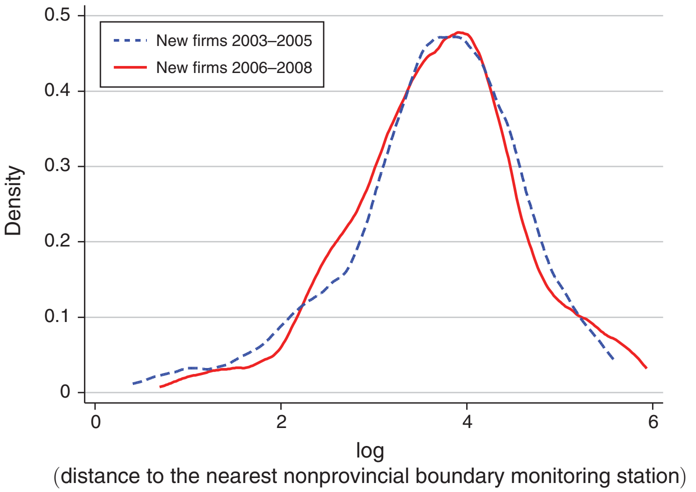

Figure 5. The Kernel Density of the Distance between Pulp and Paper Firms and the Nearest Nonprovincial Boundary Monitoring Station

Source: China Annual Survey of Industrial Firms 2003–2008

the provincial border, while within provinces there are no discernible migration patterns for this polluting industry.[34]

[34] Since pulp and paper plants differ with respect to their scale of operations, local officials concerned about pollution impacts should care more about larger plants. In results available upon request, we find that the employment weighted nonparametric kernel distributions look quite similar to the unweighted distributions presented in Figures 4 and 5. The new pulp and paper plants are located 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's centralized environmental policy as they restrict pulp and paper plants from being built close to the boundary monitoring station.

VI. Conclusion

Free riding at political boundaries causes significant social pollution costs for people who live on the other side of the boundary (Sigman 2002). 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 making greater efforts to reduce water pollution at political boundaries. 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 3 and 4). 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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