Clearing the water? The impact of the Central Environmental Protection Inspection on water quality

Minhui Liu (minhui@pku.edu.cn)
University of Science and Technology of China
Qianqian Yuan
Beijing Institute of Technology https://orcid.org/0000-0001-5829-2315
Feng Yang
University of Science and Technology of China

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Abstract

This study examined whether China's Central Environmental Protection Inspection (CEPI), an innovative environmental regulation, has successfully reduced water pollution. We compiled a new water pollution data file and found that the third round of inspection significantly reduced the concentrations of ammoniacal nitrogen (NH_3-H) and chemical oxygen demand using potassium permanganate as an oxidizing agent (COD_{Mn}) (indicators often mentioned in government reports). However, no improvements were found in DO concentrations (not mentioned in reports). This suggests that a more comprehensive water quality indicator system or standard should be provided in advance to better guide water quality improvement. Additionally, based on the characteristics of the CEPI, this research explored water pollution externalities. We found that the inspection mitigates water pollution externalities across jurisdictional boundaries when it is judged by NH_3-N concentrations.

1 Introduction

China has enjoyed decades of spectacular economic growth but also suffered from severe environmental pollution (Guan et al., 2008; Lee and Oh, 2015). Despite a number of environmental regulations, environmental pollution continues largely unabated (Xiang and van Gevelt, 2020). In 2015, the water quality at 35.5% of surface water monitoring sites across China was above Grade III, and 78.4% of cities at or above the prefecture level across the country failed to meet the national ambient air quality standards (Ministry of Environmental Protection of China, 2016).[1],[2] The literature attributes the ineffective implementation of environmental regulations to the decentralized environmental governance structure (Lo, 2015; Ran, 2013, 2017). In the context of the current phase of recentralization (Kostka and Nahm, 2017; Van Rooij et al., 2017), the Central Environmental Protection Inspection (CEPI) was initiated by the central government in January 2016, aiming to stem the increasingly severe environmental pollution.[3]

The CEPI is different from previous representative environmental regulations, which have been extensively studied. First, unlike the central government's eleventh Five-Year Plan (2006-2010), which required local governments to reduce their chemical oxygen demand (COD) emissions to meet quantitative targets by 2010 (Chen et al., 2018; Kahn et al., 2015; Wu et al., 2017), the inspections are directly led by the central government and implemented intensively in a short time. From January 2016 to May 2017, 23 provinces were inspected, and the central government required local governments to take immediate action against violations of environmental regulations documented during these inspections. Second, unlike measures such as restrictions on private vehicle use and plant closures adopted by certain cities to reduce air pollution during important meetings and events, such as the 2014 Asia-Pacific Economic Cooperation and the 2008 Beijing Olympic Games (Chen et al., 2013a; Lin et al., 2017; Shen and Ahlers, 2019; Viard and Fu, 2015; Wang et al., 2009), the inspections target all provinces. Further, they focus on many aspects of environmental pollution, including air and water pollution. The specific question of whether the forefront of China's environmental efforts can improve the environment is crucial in terms of improving well-being. Research suggests that environmental pollution has had a serious impact on public health (Chen et al., 2013b; Currie and Neidell, 2005; Ebenstein, 2012; Heyes and Zhu, 2019). Further, Lai (2017) and Zeng et al. (2010) found strong evidence that environmental pollution seriously damages elderly people's health. The Chinese population is projected to age quickly in the next decades (Zeng and Hesketh, 2016), with the percentage of over-65s expected to reach 17% in 2030 (United Nations, 2019). Thus, health care costs for the elderly caused by environmental pollution will present an enormous challenge.

The literature suggests that the inspections have positive effects on improving air quality (Jia and Chen, 2019; Tan and Mao, 2021). However, we are not aware of any studies comprehensively assessing the effect of the CEPI on water quality or even collecting water pollution data that could allow such an assessment. There is no doubt that water resources in China are not abundant. In 2017, the total renewable water resources per capita were 1,955.23 m^3—only one-tenth of the world average (FAO, 2017). Therefore, the impact of environmental regulations on water quality requires further study.

This study conducted a systematic evaluation of the effect of the CEPI on water quality with a new water pollution data file. The data comprise 146 monitoring sites and cover 115 weeks (from May 2015 to July 2017). We assessed the effect of the

CEPI using a difference-in-differences (DD) study design. Additionally, we controlled for a range of socioeconomic and demographic characteristics, as well as a rich set of site-specific weather condition. Importantly, we controlled for potential preexisting differential trends in pollution across monitoring sites to draw inferences about the causal impact. If effective, the CEPI should affect several measures of water quality.

Previous studies have documented water pollution externalities across jurisdictional boundaries due to the decentralization of environmental policies, and scholars have thus emphasized the importance of cooperation to keep excessive water pollution externalities in check (Cai et al., 2016; Chen et al., 2018; Lipscomb and Mobarak, 2017; Sigman, 2002, 2005). In this study, we further explored whether the central government's intensive intervention targeting all provinces in a fairly short period can mitigate water pollution externalities.

The remainder of this paper is organized as follows: Section 2 provides a description of the background of the CEPI. Section 3 describes the collected data. Section 4 outlines the empirical strategy. Section 5 reports and discusses the results. Section 6 concludes the paper.

[1] According to the Environmental Quality Standard for Surface Water (GB 3838-2002), surface water quality is graded on a six-point scale, where □ is the best water and □ indicates the worst (for details please see http://www.mee.gov.cn/ywgz/fgbz/bz/bzwb/shjbh/shjzlbz/200206/W020061027509896672057.pdf).
[2] After the institutional restructuring of the State Council of China in 2018, the Ministry of Environmental Protection was renamed the Ministry of Ecology and Environment.
[3] The inspection was referred to as the Central Environmental Protection Inspection in news reports on the website of the Ministry of Ecology and Environment: http://english.mee.gov.cn/News_service/news_release/201607/t20160721_361108.shtml.

2 Background

The Central Environmental Protection Inspection is a new institutional arrangement that aims to stem the increasingly severe environmental pollution in China. A new department was established to organize the inspections and coordinate the inspection teams. Different teams are sent to different provinces at a time, and each team is led by a high-ranking government official (the same level as that of a province governor).

During the one-month inspection, the central government united the public to fight against malfeasance of local governments (Li et al., 2020; Xiang and van Gevelt, 2020). Mail boxes and telephone lines were set up for receiving complaints about environmental pollution from local residents directly. The inspection teams scrutinize local governments' actions against environmental pollution over the years, especially environmental pollution that is of major concern for the public. They audit local governments' and regional departments' implementation of the central government's decisions on ecological and environmental protection to identify compliance failures. The central government has declared zero tolerance toward violations of environmental regulations and requires local governments to take immediate action against violations found during the inspections.

After the inspections, meetings for feedback are held to ascertain the progress of rectification. Local governments are required to submit to the central government their plans to continuously improve the ecological environment within 30 working days after the meeting. Fig.1 shows the inspection process. According to Chinese news reports on these meetings, inspection findings and concerns are swiftly addressed. After the first round of inspections, meetings were held in November 2016. By that time, each province had already addressed the inspection findings and concerns presented to it. After the second round, all the findings and concerns had been addressed by the end of February 2017. After the third round, nearly all findings and concerns had been addressed within one month.[4] These relatively short periods help distinguish the effects of the CEPI from those of confounding factors. This offers the opportunity to understand the effectiveness of environmental regulations implemented intensively in a short time by regimes in which the central government has great administrative power, like that of China.

[Insert Fig1.eps here]

A pilot round took place in Hebei Province in January 2016. After that, four consecutive rounds were conducted from July 2016 to September 2017, targeting the other 30 provinces. Seven to eight provinces were inspected in each round. Fig.2 shows the spatial distribution of provinces inspected in different rounds. Fig.7 in the Appendix shows the chronological sequence of the main events of the first three rounds of inspections. A detailed listing of the times of provinces' inspections and subsequent meetings is provided in Table A1 in the Appendix.[5]

[Insert Fig2.eps here]

[4] The Chinese news reports about the meetings for feedback are available on the website of MEE: http://www.mee.gov.cn/ywgz/zysthjbhdc/dcjl/.
[5] The detailed list was compiled based on the Chinese news reports found on the website of MEE: http://www.mee.gov.cn/ywgz/zysthjbhdc/dcjl/.

3 Data

To perform the analysis, we compiled the most comprehensive panel data file ever assembled on water pollutant concentrations, weather data, city- and province-level socioeconomic data. City- and province-level data were matched to monitoring sites in the corresponding cities and provinces. This section describes each data source and the data processing process and provides corresponding summary statistics.

3.1 Water Pollution Data

We obtained weekly water pollution data from the China National Environmental Monitoring Center (CNEMC) and from the Data Center and the Department of Ecological and Environmental Monitoring of the Ministry of Ecology and Environment (MEE) of the People's Republic of China. The CNEMC started issuing weekly water pollution data in November 2007. In 2019, it developed a system that publishes daily instead of weekly data. We obtained most weekly data from the CNEMC. However, these data are not consecutive in time, and some weeks' data are missing. We therefore turned to the Data Center of the MEE to obtain the missing weekly data. However, some weeks' data could not be obtained from this source, either. Thus, we applied for a government information release and received the missing data (except for the 26th week of 2016) from the Department of Ecological and Environmental Monitoring of the MEE. We then collected a few monitoring sites' weekly data for the 26th week of 2016 from local governments' websites. We finally collected 115 weeks' water pollution data covering the period from the 21st week of 2015 to the 31st week of 2017. This period corresponds to the pilot round and the first three rounds of inspections. Since the pilot round was only conducted in Hebei Province, we deleted the data of two monitoring sites in that province to eliminate potential bias. Our dataset thus contained 143 monitoring sites' weekly data before the second week of 2016. Three more sites' weekly data were subsequently added. Except for the three new monitoring sites added in the second week of 2016, there were no changes in the composition of sites. Sometimes, when the machine at a monitoring site failed or the river stopped flowing, no data were collected during that period. For most monitoring sites, not all weekly data are available, which resulted in an unbalanced panel data.

These 146 monitoring sites are spread across China's main river systems. They are treated as the key sites of the national surface water environment monitoring network. These sites are under the direct control of the central government, and the local governments have limited authority over them. This makes it possible to evaluate the performance of local governments and the effectiveness of the CEPI objectively. Of the 146 monitoring sites, 65 are located in provinces inspected in the first round, 14 are located in provinces inspected in the second round, and 34 are located in provinces inspected in the third round. Each province has at least one monitoring site. Fig.2 maps the monitoring sites' locations.

Our sample covers five measures of water quality. We focused on three indicators: ammoniacal nitrogen (NH_3-N), COD using potassium permanganate as an oxidizing agent (COD_{Mn}), and dissolved oxygen (DO) concentrations. NH_3-N is a measure of the amount of ammonia and can be used to assess the health of water in rivers or lakes. COD_{Mn} is an indicator of the amount of oxygen that can be consumed by reaction (using potassium permanganate as an oxidizing agent) in a measured solution and can be used to quantify the amount of oxidizable pollutants in surface water.[6] High values of NH_3-N and COD_{Mn} indicate heavy pollution. In the case of DO, low values suggest greater pollution, as waterborne waste hinders the mixing of water with the surrounding air and hampers oxygen production from aquatic plant photosynthesis (Greenstone and Hanna, 2014).

Tables 1A and 1B show corresponding summary statistics providing the average concentrations of studied indicators, grouped by inspection round, for the entire sample period and sub-periods. It can be seen from Table 1B that, compared to the corresponding sub-period before the inspections, the concentrations of NH_3-N decreased after the inspections, and water quality was improved in terms of COD_{Mn} and DO concentrations after the first and third rounds of inspections. However, without further analysis, the effects of the CEPI on water quality cannot be clearly discerned from those of confounding factors.

[Insert Tables 1A and 1B here]

The CNEMC reports whether a monitoring site is located at a provincial boundary. In our sample, 45 of the 146 monitoring sites were located at provincial boundaries, and 33 were located at national boundaries or estuaries. Fig.3 plots the average concentrations of studied indicators, grouped by location, from the 21st week of 2015 to the 31st week of 2017. Panels a and b of Fig.3 show that the water quality at borders is worse than that in non-border locations.

[Insert Fig3.eps here]

3.2 Weather Data

In this analysis, we controlled for temperature, as Sigman (2005) mentioned that water temperature affects biological activities and chemical conditions in the river and thus the natural attenuation rates of pollutants. We also included precipitation as a control after a discussion with a person working in the local Ecology and Environment Bureau, who noted that precipitation affects surface water quality. We obtained weather data (from May 1, 2015 to July 31, 2017) from the China Meteorological Data Service Center (CMDC). The CMDC provides daily minimum and maximum temperatures and precipitation measured at 699 weather stations across China. These weather stations are not typically adjacent to water quality monitoring sites. To obtain weekly weather conditions at each monitoring site, we proceeded as follows. We first cleaned the daily weather data and converted them to weekly data. The weekly minimum and maximum temperatures were defined as the minimum and maximum daily temperatures of the week, respectively. The weekly precipitation was defined as the sum of the daily precipitation of the week. We then calculated each monitoring site's geodetic distance from all weather stations and obtained the five closest stations. The coordinates of each monitoring site were obtained from the National Platform for Common Geospatial Information Services based on its address. The coordinates of weather stations had already been provided by the CMDC. We matched the three climate variables of the nearest weather station to the time series of water quality indicators. If the weather data of the closest weather station were missing for some weeks, the corresponding monitoring site's weekly readings were matched to the second closest station's data if available, and so on. Following these steps, all water quality indicators were matched to a full set of climate variables. The mean distance to the matched weather stations was 43.3 kilometers. The distance of over 90% of the 146 monitoring sites to matched stations was less than 80 kilometers. We believe that this provided a good proxy for weather observations at each monitoring site.

3.3 Socioeconomic Data

We also collected socioeconomic data to use as control variables. City-level per capita gross domestic/regional product, share of industrial production in GDP, and GDP growth data were obtained from the Statistical Yearbook of each province for 2016–2018. The per capita gross domestic/regional product is measured in yuan with the base year 2015. City-level data on population density and literacy rates are difficult to obtain. We instead collected province-level data from the China Statistical Yearbooks 2016, 2017, and 2018. The population density is measured in persons per square kilometer for the urban areas. The literacy rates are the percentages of illiterate population to total aged 15 and over. These city- and province-level data were matched to the monitoring sites in the corresponding cities and provinces.

[6] For details please see Wikipedia: https://en.wikipedia.org/wiki/Ammoniacal_nitrogen; https://en.wikipedia.org/wiki/Chemical_oxygen_demand.

4 Empirical Strategy

We conducted a DD estimation to capture the effect of the CEPI on water quality. The DD approach identified the effect by comparing the changes in concentrations of studied indicators at monitoring sites following the start of the CEPI in treated provinces with the changes in provinces that had not yet been inspected, which were used as controls. Our basic DD model is given as follows:

$$y_{it} = \alpha + \beta Treat_{it} + \mu_i + \eta_t + \varepsilon_{it}. \quad (1)$$

where is the value of one of the three water quality indicators recorded at monitoring site on date , and is the monitoring site fixed effects, which captures all unobserved time-constant factors that affect . The date fixed effects controls for unobserved time shocks that are common to all monitoring sites located in both the treated and control provinces, and is the error term.

We take the first three rounds of inspections as a whole. The dummy variable indicates whether the province where monitoring site is located was inspected on date . We define the weeks to which the starting and ending dates of inspection belong as the starting and ending weeks, respectively. In Eq. (1), equals 1 as of the starting week of inspection, and is the coefficient of interest that indicates the effects of the CEPI.

As in the empirical strategy of Auffhammer and Kellogg (2011), we use the following equation to further evaluate the effectiveness of each round of inspection:

$$y_{it} = \alpha + \beta \times Treat_{it} + \mu_i + \eta_t + \varepsilon_{it}. \quad (2)$$

The only difference between Eq. (1) and Eq. (2) is that in the latter is a vector composed of three variables indicating whether the province where monitoring site is located was inspected in one of the first three rounds of inspections on date . The indicator variables equal 1 as of the start of the respective round, and β is a vector of the three parameters of interest.

Whether the treatment-control comparison set up by the DD design is ideal for providing a causal inference warrants careful consideration. The key identification assumption of Eq. (1) is that indicator concentrations of monitoring sites in the treated and control provinces should follow parallel trends in the absence of inspections. If a systematic difference in trends exists before the inspections, the estimation of β will be biased even after adjustment for monitoring site and date fixed effects. To improve the precision of the estimation, we augment Eq. (1) and Eq. (2) by including more controls as follows:

$$y_{it} = \alpha + \beta Treat_{it} + \delta \times X_{it} + \sigma \times W_{it} + \theta \times Trend_{it} + \mu_i + \eta_t + \varepsilon_{it}. \quad (3)$$

$$y_{it} = \alpha + \beta \times Treat_{it} + \delta \times X_{it} + \sigma \times W_{it} + \theta \times Trend_{it} + \mu_i + \eta_t + \varepsilon_{it}. \quad (4)$$

The variable represents socioeconomic and demographic factors, including GDP growth rate, per capita GDP, share of industrial production in GDP, population density, and literacy rate, and denotes site-specific weather conditions, including a flexible polynomial in temperature and precipitation and interactions between these variables (Auffhammer and Kellogg, 2011).[7] The variable absorbs site-specific long-term linear time trends in indicator concentrations that may vary across monitoring sites. This allows treatment and control provinces to follow different trends in a limited but potentially revealing way (Angrist and Pischke, 2008). This specification explicitly controls for any effects through differential trends (Tanaka, 2015). Thus, we can distinguish the impacts of regulations from long-term trends driven by unobservables (Auffhammer and Kellogg, 2011).

Like Chen et al. (2013a), we divide the entire period covered by the data into several sub-periods to assess the time-varying effects of the inspections. The vector in Eq. (2) and Eq. (4) is now composed of separate dummy variables for different periods before and after the inspections. Specifically, the dummy variables represent three, two, and one months before the inspection, the time of the inspection, and one, two, and three months or more after the inspection.[8] To further assess the time-varying effects of a particular round of inspections, following Jia and Chen (2019), we estimate the effects separately by restricting our sample to monitoring sites of the provinces inspected in the particular round and in the fourth round.

To examine whether the CEPI, which is directly organized and initiated by the central government to improve the environment of all provinces, mitigates water pollution externalities, we use the following equation:

$y_{it} = \alpha + \beta_1 Treat_{it} + \beta_2 Treat_{it} \times boundary_i + \delta \times X_{it} + \sigma \times W_{it} + \mu_i + \eta_t + \varepsilon_{it}$. (5)

where is a dummy variable indicating whether monitoring site is located on the boundary between two neighboring provinces. We also conduct estimation with monitoring sites located at national boundaries or estuaries using Eq. (5).

A monitoring site was included in the sample if it had at least 75% of the observations from the 21st week of 2015 to the 31st week of 2017. For inferences, we report standard errors using a robust variance estimator. To allow for both series and spatial correlations, we cluster the standard errors along two dimensions: monitoring site and river system (Bertrand et al., 2004; Kahn et al., 2015).

[7] Specifically, includes cubic polynomials in minimum and maximum temperatures (TempMax and TempMin), the interaction of TempMax and TempMin, quadratics in precipitation, the interaction of precipitation and TempMax, one-week lags of TempMax and TempMin, the interaction of TempMax and its one-week lag, the interaction of TempMax and one-week lag of TempMin, and the interactions of all these variables with a week-of-year variable to allow weather effects to vary over the year.

[8] For convenience, we define each month as four weeks.

5 Results And Discussion

5.1 Impacts of the CEPI on Water Quality

The DD estimates of the effect of inspections on water quality are shown in Table 2.[9] In each panel, each column reports the coefficient of interest and standard errors in parentheses from separate regressions.

In panel A, we take the first three rounds of inspections as a whole. Columns 1, 4, and 7 of panel A display the results of estimating Eq. (1), which includes monitoring site fixed effects and date fixed effects without additional controls. Both point estimates for NH_3-N and COD_{Mn} have a negative sign, which means that the inspections reduced water pollutant concentrations at monitoring sites in treated provinces compared to those in control provinces. However, the results are statistically insignificant. The DO result, on the other hand, indicates that the inspections are associated with a worsening in DO concentrations. However, the result is also statistically insignificant. The remaining columns of panel A progressively add control variables to the specification, moving from Eq. (1) to Eq. (3). Columns 2, 5, and 8 include the control variables for weather ( ) and socioeconomic factors ( ). The signs of the point estimates do not change after the inclusion of these variables. Although the point estimates vary substantially, they are still statistically insignificant. Columns 3, 6, and 9 add linear site-specific time trends to the specification. Although both point estimates in columns 3 and 6 are statistically insignificant, we estimate that the inspection is associated with a DO decrease of 0.353, which is statistically significant at the 10% level.

[Insert Table 2 here]

In panel B, we estimate the treatment effects of each round of inspections. The dummy variables *treat1*, *treat2*, and *treat3* represent the first, second, and third rounds, respectively. The specification used in columns 1, 4, and 7 is given by Eq. (2). Neither the first nor the second round is estimated to have a significant impact on water pollutant concentrations. Conversely, we estimate that the third round had a major impact: it is associated with an NH_3-N decrease of 0.21, which is statistically significant at the 5% level, and a COD_{Mn} decrease of 0.788, which is statistically significant at the 1% level. The results indicate that the third round improved NH_3-N and COD_{Mn} concentrations. However, the DO results in column 7 suggest that the third round worsened DO concentrations, with a decline of 0.512, which is statistically significant at the 5% level. Columns 2, 5, and 8 of panel B use the specification given by Eq. (4) but do not include the time trends. The additional controls result in minor changes to the estimated impact of the third round of inspections on NH_3-N and COD_{Mn}. The estimated effect on DO, however, drops to −0.358 and is not statistically significant. Again, the results suggest an insignificant impact of the first and second rounds on water pollutant concentrations. Columns 3, 6, and 9 of panel B use the exact specification given by Eq. (4). Adding time trends causes modest increases in the estimated effect of the third round on NH_3-N and COD_{Mn} compared to the effect without time trends. The effects on NH_3-N and COD_{Mn} are −0.37 and −0.825, respectively, and are both statistically significant at the 1% level. However, with a linear time trend, the effect on DO increases substantially to −0.665 and is statistically significant at the 10% level. Unlike the third round of inspections, the results provide little evidence that the first and second rounds improved water quality, with the exception of an insignificant effect (−0.006) of the second round on NH_3-N. We estimate that the first round increased NH_3-N by a statistically significant 0.207 and that the second round is associated with a statistically significant COD_{Mn} increase of 0.308 (both at the 10% level).

Summarizing the above results, we can make the following observations:

(i) Among the first three rounds of inspections, only the third round is associated with significant improvements in water pollutant concentrations. Zhang et al. (2021) suggested the importance of public participation in environment governance. We speculate that a better interaction between the central government and the public contributed to these significant improvements. Fig. 4 shows facts related to each round of inspections obtained from Chinese news reports on the meetings for feedback. Figure 4a shows that the average public tip-offs resolved in the third round exceeded the sum of the previous two rounds.[10] This led to more enterprises required for rectification and more enterprises and individuals punished. Obviously, with its better interaction with the public, there is a positive impact on water pollutant concentrations.

[Insert Fig. 4.eps here]

(ii) The results show that the specific impacts on different water quality indicators vary. It is conceivable that subnational officials focus on criteria that are explicitly linked to political evaluations (He et al., 2020) and tend to shirk other environmental measures (Kahn et al., 2015). Thus, we expected that the greatest impacts would be on NH_3-N and COD_{Mn} levels because of their frequent presence in the official CEPI reports, and no improvements would be identified in DO concentrations which were not mentioned in the reports. The results reported in panel B of Table 2 suggest that the third round of inspections substantially reduced NH_3-N and COD_{Mn} concentrations. The estimates remain robust after the inclusion of weather and socioeconomic controls and site-specific time trends. However, no improvements were found in DO.

We also examined whether the main findings are robust to eliminating outliers. Specifically, we eliminated observations below the 1st and above the 99th percentile. The results are reported in Table A3 in the Appendix. Eliminating outliers caused modest declines in the estimated effects of the third round of inspections. Our main findings remain largely unchanged.

5.2 Policy Impact Dynamics

To further examine how the effect of the CEPI changed over time, we break down the entire study period into several sub-periods. Table 3 presents the estimated time-varying effects of the CEPI in detail when we study the first three rounds of inspections as a whole. The specification used in columns 1, 3, and 5 is given by Eq. (2), while the remaining columns add more controls by estimating Eq. (4) but do not include the time trends. The results suggest that, with the exception of DO, the water quality indicators in the inspected provinces did not change significantly in the sub-periods before the inspections. In summary, there is little evidence of an impact of the CEPI on water quality in the sub-periods during and after the inspections when taking the first three rounds of inspections as a whole. Fig. 5 plots the coefficients and their associated 95% confidence intervals. Figures 5a, 5b, and 5c correspond to columns 2, 4, and 6 of Table 3.

[Insert Table 3 here]

[Insert Fig. 5.eps here]

Table 4 presents the estimated time-varying effects of the third round of inspections obtained using the same specifications as those presented in Table 3 but with a dataset consisting only of monitoring sites in the provinces inspected in the third and fourth rounds. Controlling for monitoring site fixed effects and date fixed effects, column 1 shows that there were no significant changes in NH_3-N before and during the inspections. The only significant improvement in NH_3-N is observed in the first month after the inspection (−0.162; statistically significant at the 10% level). After controlling for weather and socioeconomic factors, column 2 suggests that the third round significantly reduced NH_3-N in the two sub-periods after the inspection. A significant and ever-increasing improvement in COD_{Mn} can be observed since the first month before the inspection, and it is robust with all specifications. This provides evidence that local governments had taken precautions against water pollution before the third round of inspections. Columns 5 and 6 show that DO increased significantly before the inspection but decreased significantly afterward. Fig. 6 plots the coefficients and their associated 95% confidence intervals. Figures 6a, 6b, and 6c correspond to columns 2, 4, and 6 of Table 4.

[Insert Table 4 here]

[Insert Fig. 6.eps here]

Tables A4 and A5 in the Appendix report the results of the estimated time-varying effects of the first and second rounds of inspections, respectively. There is little evidence of an improvement in water quality, except for a statistically significant decrease in COD_{Mn} in the second month after the first round and a statistically significant increase in DO in the second month after the second round.

5.3 Water Pollution Externalities

Table 5 presents the results of Eq. (5). In panel A, we use a dataset with monitoring sites at provincial boundaries or interiors. Columns 1, 3, and 5 only include monitoring site fixed effects and date fixed effects. The specification used in columns 2, 4, and 6 is exactly that given by Eq. (5). Given our interest in whether the CEPI mitigates water pollution externalities across jurisdictional boundaries, we focus on our estimate of in Eq. (5). As shown in column 1, for NH_3-N, the coefficient of the interaction term is −0.152 and is statistically significant at the 1% level. The point estimate decreases in magnitude after more controls are included in the specification but remains negative and statistically significant (also at the 1% level). The point estimates for COD_{Mn} in columns 3 and 4 are −0.111 and −0.173, respectively, and those for DO in columns 5 and 6 are −0.135 and −0.154, respectively. However, they are not statistically significant. In panel B, the monitoring sites not considered in panel A are also included in the dataset. Thus, the dummy variable in panel B equals 1 when the monitoring site is at a provincial border, the national boundary, or an estuary. Panel B shows similar results but with point estimates modestly less in magnitude than those reported in panel A. Based on the results displayed in Table 5, judging by NH_3-N concentrations, we conclude that the CEPI mitigates water pollution externalities and even promotes good neighbor behavior. However, we found no evidence of differential improvements of DO at boundaries.

[Insert Table 5 here]
[9] Results from the entire sample data are provided in Table A2 in the Appendix, which demonstrate that the findings from Table 2 are largely unchanged.
[10] Although the exact number of public tip-offs related to water pollution was not given, the overall dramatic increases in the number of public tip-offs were likely to be accompanied by increases in the public tip-offs related to water pollution.

6 Conclusion

Using data obtained from the CNEMC and the MEE, this study examined the effect of the CEPI on three available measures of water quality: NH_3-N, COD_{Mn}, and DO. We show that, among the first three rounds of inspections, the third round is associated with significant improvements in NH_3-N and COD_{Mn} concentrations, which are frequently mentioned in the official CEPI reports. However, no improvements were found in DO concentrations, which is not mentioned in the reports. It is worth noting that, judging by NH_3-N concentrations, the CEPI mitigates water pollution externalities across jurisdictional boundaries.

Our results suggest that the central government's intensive interventions in a fairly short period, combined with strong public support, can improve water quality. Our study also points to improvements needed in the CEPI. Local governments may focus only on the water quality indicators frequently mentioned in the official reports or even curtail water quality monitoring. The central government should therefore clarify the specific targets for reducing environmental pollutant concentrations (including air, water, and other forms of pollution) before inspections and require that local governments meet the targets within specified time frames after the inspections. Kahn et al. (2015) found that the target system can incentivize government officials to devote efforts to reducing pollution.

The CEPI is not a campaign-style project. After the fourth round of inspection in August 2017, the central government sent inspection teams to provinces again in 2018 to check the progress of the implementation of the rectification plans. New rounds of inspections took place in 2019 and 2020. Like Greenstone and Hanna (2014), future studies could collect air and water pollution data over a longer period to analyze and compare possible different impacts of the central government's intervention on air and water quality and even explore the impact on elderly people's health.

Declarations

-Ethical Approval

Not applicable.

-Consent to Participate

Not applicable.

-Consent to Publish

All of the authors have read and approved the paper and we would like to submit the manuscript entitled "Clearing the water? The impact of the Central Environmental Protection Inspection on water quality" to be considered for publication in Water Resources Management.

-Authors Contributions

M. Liu: Conceptualization, Methodology, Resources, Software, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Visualization.

Q. Yuan: Conceptualization, Writing - Review & Editing, Validation, Supervision, Funding acquisition.

F. Yang: Project administration, Writing - Review & Editing, Supervision, Validation, Funding acquisition.

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-Competing Interests

The authors declare that they have no known competing interests or personal relationships that could have appeared to influence the work reported in this paper.

-Availability of data and materials

Data and materials are available on request.

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Tables

Table 1
A Summary Statistics: Entire Sample Period

	Round				**Total**
Water quality	**1st**	**2nd**	**3rd**	**4th**	
NH_3-N(mg/L)					
Mean	0.29	0.38	0.60	0.55	0.43
Standard deviation	(0.32)	(0.50)	(1.29)	(1.41)	(0.97)
Observations	7126	1588	3798	3693	16205
COD_{Mn}(mg/L)					
Mean	4.31	2.83	4.07	3.94	4.02
Standard deviation	(2.92)	(1.51)	(3.12)	(2.58)	(2.82)
Observations	7102	1586	3673	3655	16016
DO(mg/L)					
Mean	8.25	7.82	8.01	8.25	8.15
Standard deviation	(2.16)	(2.32)	(2.73)	(2.56)	(2.42)
Observations	7081	1581	3776	3662	16100

Table 1B Summary Statistics: Sub-Periods

	1st round		2nd round		3rd round	
Water quality	Before	After	Before	After	Before	After
NH_3-N(mg/L)						
Mean	0.30	0.27	0.43	0.40	0.50	0.35
Standard deviation	(0.37)	(0.25)	(0.56)	(0.54)	(0.97)	(0.57)
Observations	3603	3523	487	501	439	469
COD_{Mn}(mg/L)						
Mean	4.38	4.23	2.71	2.75	4.28	3.50
Standard deviation	(3.01)	(2.83)	(1.51)	(1.45)	(3.05)	(2.35)
Observations	3589	3513	485	501	432	426
DO(mg/L)						
Mean	8.24	8.26	8.27	8.16	6.67	6.74
Standard deviation	(2.08)	(2.24)	(2.30)	(2.51)	(1.87)	(2.19)
Observations	3588	3493	487	497	433	473

Notes: Standard deviations are in parentheses. In Table 1B, (i) 1st round, Before: period from the 21st week of 2015 to the 28th week of 2016; After: period from the 29th week of 2016 to the 31st week of 2017. (ii) 2nd round, Before: period from the 48th week of 2015 to the 31st week of 2016; After: period from the 48th week of 2016 to the 31st week of 2017. (iii) 3rd round, Before: period from the 18th week of 2016 to the 31st week of 2016; After: period from the 18th week of 2017 to the 31st week of 2017.

Table 2
Difference-In-Differences Estimation Results

	Dependent var: NH_3-N			COD_{Mn}			DO		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A.									
treat	-0.012	-0.002	-0.049	-0.210	-0.235	-0.152	-0.172	-0.212	-0.353*
	(0.061)	(0.051)	(0.059)	(0.150)	(0.144)	(0.188)	(0.137)	(0.142)	(0.214)
Observations	15,800	15,800	15,800	15,489	15,489	15,489	15,616	15,616	15,616
R^2	0.051	0.072	0.116	0.029	0.051	0.121	0.311	0.376	0.420
Panel B.									
treat1	0.031	0.043	0.207*	-0.133	-0.171	0.213	-0.099	-0.175	-0.118
	(0.064)	(0.050)	(0.120)	(0.165)	(0.168)	(0.209)	(0.140)	(0.145)	(0.264)
treat2	-0.003	0.026	-0.006	0.006	-0.034	0.308*	-0.147	-0.221	-0.271
	(0.078)	(0.073)	(0.077)	(0.249)	(0.258)	(0.167)	(0.246)	(0.217)	(0.296)
treat3	-0.210**	-0.221**	-0.370***	-0.788***	-0.731**	-0.825***	-0.512**	-0.358	-0.665*
	(0.090)	(0.090)	(0.128)	(0.295)	(0.302)	(0.311)	(0.212)	(0.218)	(0.361)
Observations	15,800	15,800	15,800	15,489	15,489	15,489	15,616	15,616	15,616
R^2	0.054	0.075	0.122	0.032	0.053	0.124	0.312	0.376	0.420
Monitoring site FEs	YES	YES	YES	YES	YES	YES	YES	YES	YES
Week FEs	YES	YES	YES	YES	YES	YES	YES	YES	YES
Weather controls	NO	YES	YES	NO	YES	YES	NO	YES	YES
Socioeconomic controls	NO	YES	YES	NO	YES	YES	NO	YES	YES
Monitoring site-specific trends	NO	NO	YES	NO	NO	YES	NO	NO	YES

Notes: Dummy variable *treat* indicates whether the province where monitoring site is located was inspected during the first three rounds, and *treat1*, *treat2*, and *treat3* indicate the first, second, and third rounds, respectively. Standard errors in parentheses are clustered by monitoring site and river system.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 3
Difference-In-Differences Estimation Results: Policy Impact Dynamics of The First Three Rounds of Inspections

	Dependent var: NH_3-N		**COD_{Mn}**		**DO**	
	(1)	(2)	(3)	(4)	(5)	(6)
treatb3	0.110	0.090*	-0.132	-0.207	0.605***	0.399***
	(0.069)	(0.053)	(0.201)	(0.195)	(0.158)	(0.125)
treatb2	0.109	0.095	0.116	-0.010	0.448**	0.354*
	(0.073)	(0.061)	(0.225)	(0.199)	(0.186)	(0.205)
treatb1	0.057	0.066	-0.107	-0.201	0.170	0.156
	(0.060)	(0.063)	(0.160)	(0.141)	(0.232)	(0.236)
treatd	0.050	0.054	-0.222	-0.315	0.099	-0.004
	(0.079)	(0.079)	(0.270)	(0.258)	(0.261)	(0.262)
treata1	0.001	-0.003	-0.057	-0.138	-0.088	-0.204
	(0.067)	(0.061)	(0.238)	(0.201)	(0.195)	(0.208)
treata2	0.019	0.015	-0.229	-0.265	-0.033	-0.119
	(0.083)	(0.074)	(0.187)	(0.177)	(0.261)	(0.234)
treata3	0.013	0.030	-0.269	-0.320	-0.064	-0.110
	(0.062)	(0.051)	(0.204)	(0.206)	(0.174)	(0.178)
Observations	15,800	15,800	15,489	15,489	15,616	15,616
R^2	0.052	0.073	0.030	0.051	0.313	0.377
Monitoring site FEs	YES	YES	YES	YES	YES	YES
Week FEs	YES	YES	YES	YES	YES	YES
Weather controls	NO	YES	NO	YES	NO	YES
Socioeconomic controls	NO	YES	NO	YES	NO	YES

Notes: Dummy variables *treatb3*, *treatb2*, *treatb1*, *treatd*, *treata1*, *treata2* and *treata3* represent three, two, and one months before the inspection, the time of the inspection, and one, two, and three months or more after the inspection. Standard errors in parentheses are clustered by monitoring site and river system.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 4
Difference-In-Differences Estimation Results: Policy Impact Dynamics of The Third Round of Inspection

	Dependent var: NH_3-N		**COD_{Mn}**		**DO**	
	(1)	(2)	(3)	(4)	(5)	(6)
treat3b3	0.235	0.161	-0.281	-0.500	1.960***	1.548***
	(0.208)	(0.111)	(0.270)	(0.329)	(0.448)	(0.394)
treat3b2	0.083	0.108	-0.211	-0.410	1.385***	1.199***
	(0.168)	(0.127)	(0.475)	(0.442)	(0.339)	(0.415)
treat3b1	-0.059	-0.033	-0.743***	-0.880***	0.736**	0.709**
	(0.088)	(0.088)	(0.280)	(0.267)	(0.338)	(0.300)
treat3d	-0.075	-0.050	-0.828**	-0.916**	0.378	0.368
	(0.123)	(0.100)	(0.353)	(0.367)	(0.348)	(0.356)
treat3a1	-0.162*	-0.198***	-0.982***	-1.007***	-0.870***	-0.734**
	(0.093)	(0.066)	(0.315)	(0.306)	(0.308)	(0.331)
treat3a2	-0.120	-0.198**	-0.974**	-1.022**	-0.645**	-0.503*
	(0.124)	(0.083)	(0.458)	(0.459)	(0.284)	(0.296)
Observations	7,432	7,432	7,148	7,148	7,299	7,299
R^2	0.078	0.110	0.031	0.047	0.349	0.381
Monitoring site FEs	YES	YES	YES	YES	YES	YES
Week FEs	YES	YES	YES	YES	YES	YES
Weather controls	NO	YES	NO	YES	NO	YES
Socioeconomic controls	NO	YES	NO	YES	NO	YES

Notes: Dummy variables *treat3b3*, *treat3b2*, *treat3b1*, *treat3d*, *treat3a1* and *treat3a2* represent three, two, and one months before the third round of inspection, the time of the inspection, and one, and two months after the inspection. Standard errors in parentheses are clustered by monitoring site and river system.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 5
Different Measures of Water Quality at Borders

	Dependent var: NH_3-N		**COD_{Mn}**		**DO**	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A.						
treat	0.078	0.080	-0.179	-0.190	-0.183	-0.233
	(0.062)	(0.053)	(0.264)	(0.253)	(0.186)	(0.177)
treat × provincial_border	-0.152***	-0.133***	-0.111	-0.173	-0.135	-0.154
	(0.035)	(0.040)	(0.204)	(0.198)	(0.139)	(0.151)
Observations	12,297	12,297	11,993	11,993	12,239	12,239
R^2	0.056	0.074	0.028	0.048	0.350	0.393
Panel B.						
treat	0.044	0.048	-0.185	-0.176	-0.146	-0.171
	(0.051)	(0.041)	(0.251)	(0.231)	(0.172)	(0.167)
treat × boundary	-0.123***	-0.113***	-0.055	-0.134	-0.058	-0.094
	(0.034)	(0.044)	(0.244)	(0.213)	(0.112)	(0.102)
Observations	15,800	15,800	15,489	15,489	15,616	15,616
R^2	0.053	0.073	0.029	0.051	0.311	0.376
Monitoring site FEs	YES	YES	YES	YES	YES	YES
Week FEs	YES	YES	YES	YES	YES	YES
Weather controls	NO	YES	NO	YES	NO	YES
Socioeconomic controls	NO	YES	NO	YES	NO	YES

Notes: Dummy variable *treat* indicates whether the province where monitoring site is located was inspected during the first three rounds. Dummy variable *provincial_border* indicates whether the monitoring site is at a provincial border. Dummy variable *boundary* indicates whether the monitoring site is at a provincial border, the national boundary, or an estuary. Standard errors in parentheses are clustered by monitoring site and river system.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Figures

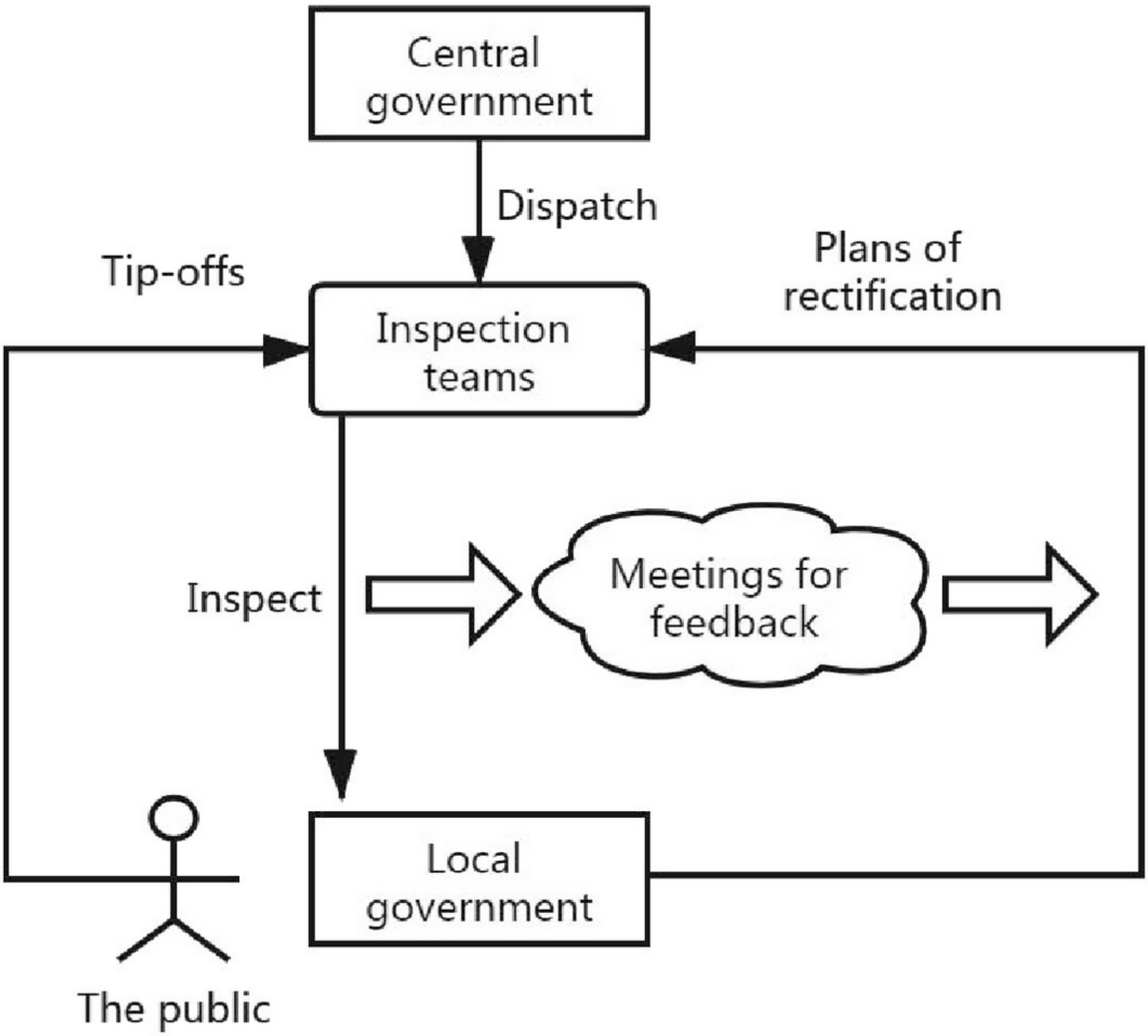

Figure 1

Inspection Process

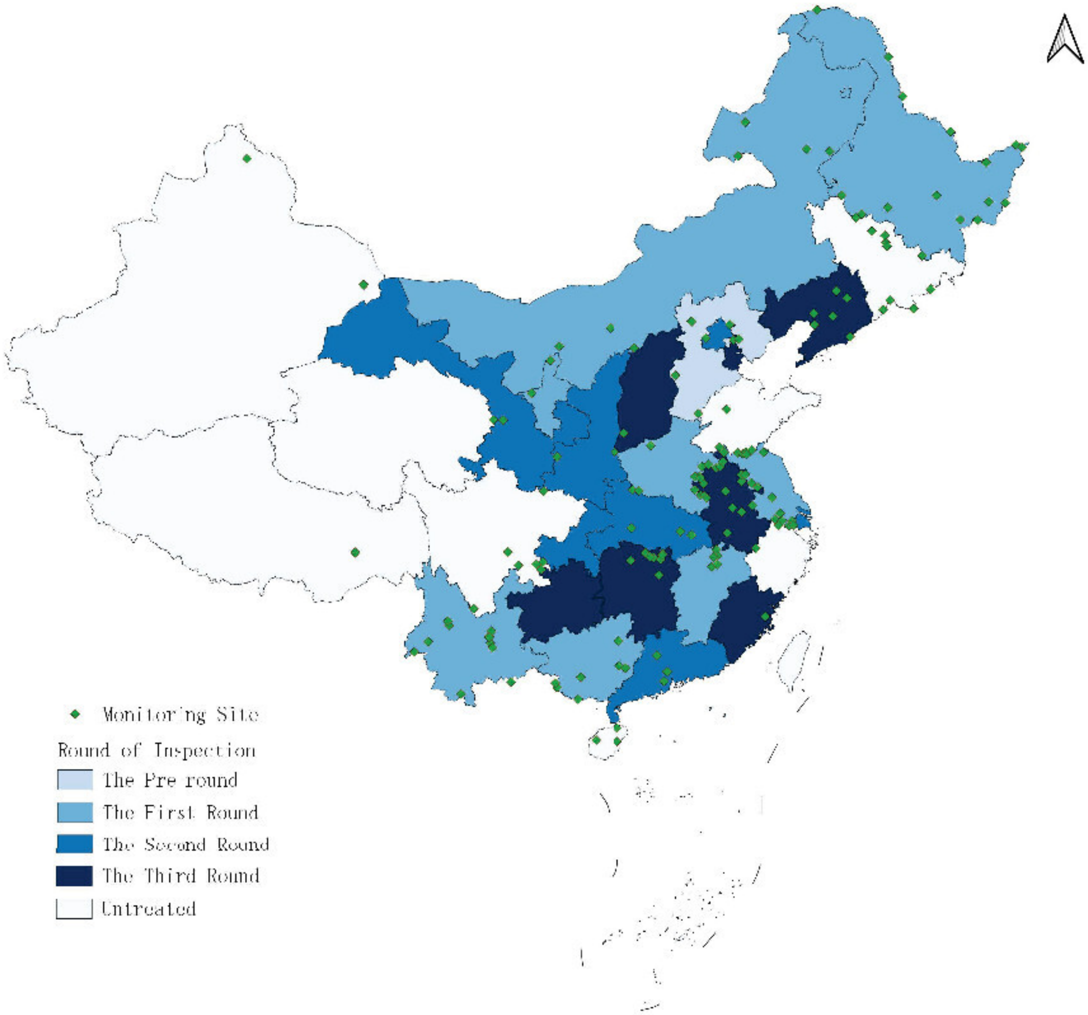

Figure 2

The Spatial Distribution of Provinces Inspected in Different Rounds and Water Quality Monitoring Sites

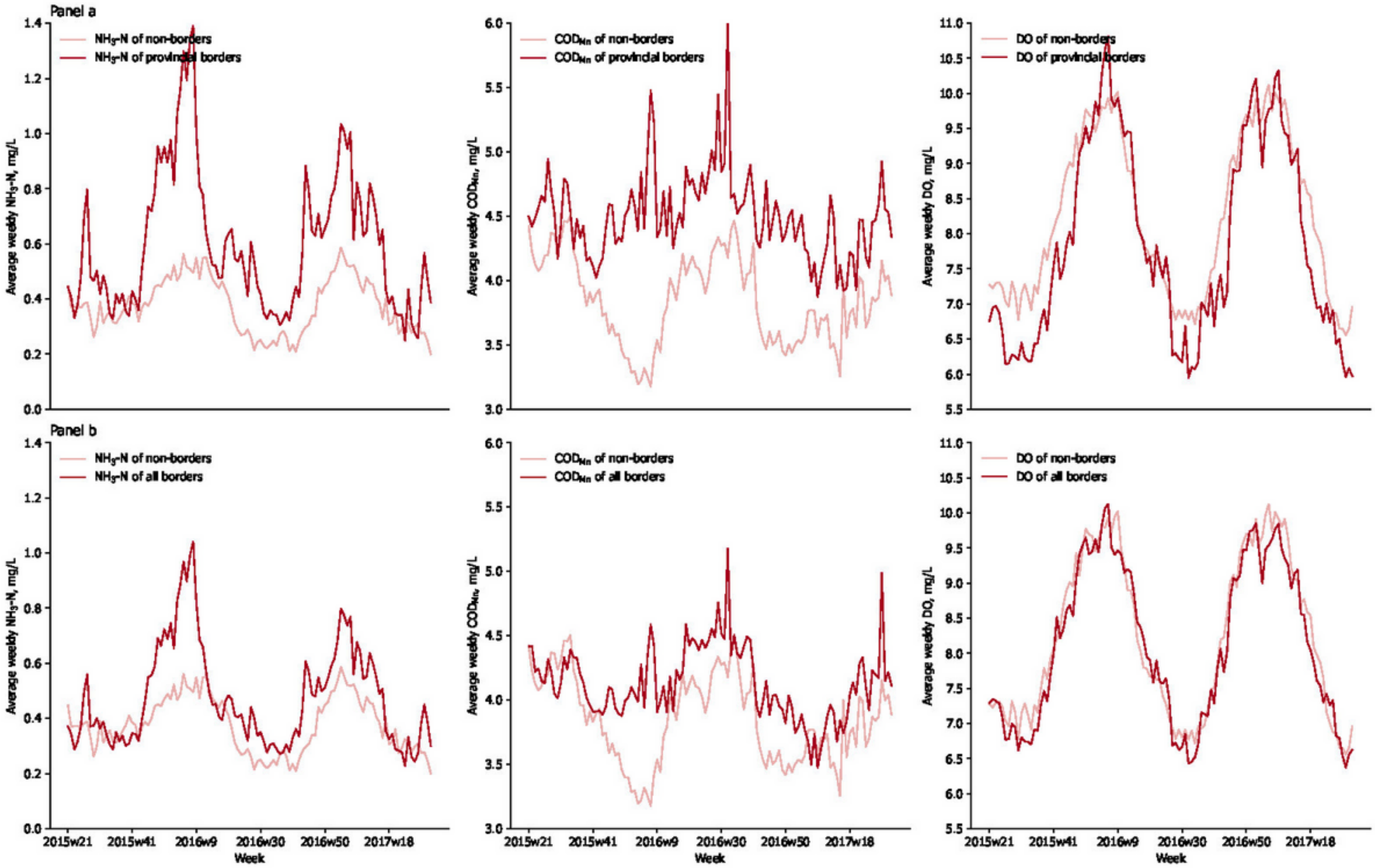

Figure 3

Average Water Quality Measured by Studied Indicators

Notes: In Panel B, “all borders” includes provincial boundaries, national boundaries and estuaries.

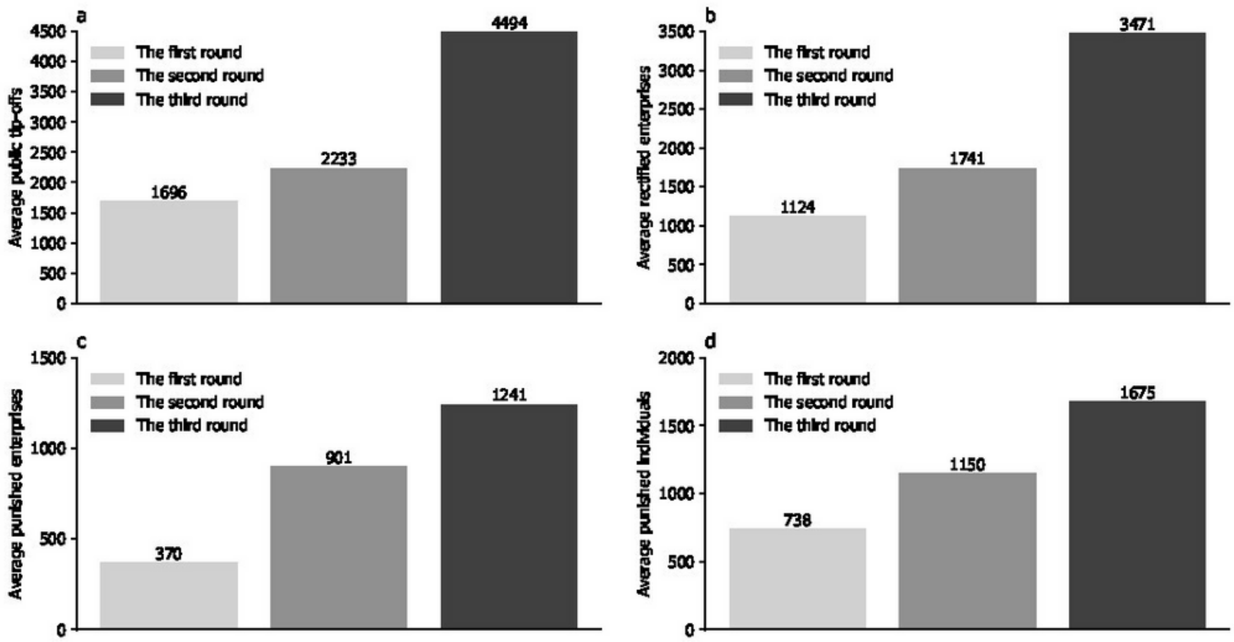

Figure 4

Average Public Tip-Offs, Rectified Enterprises, Punished Enterprises, and Punished Individuals

(Grouped by inspection round)

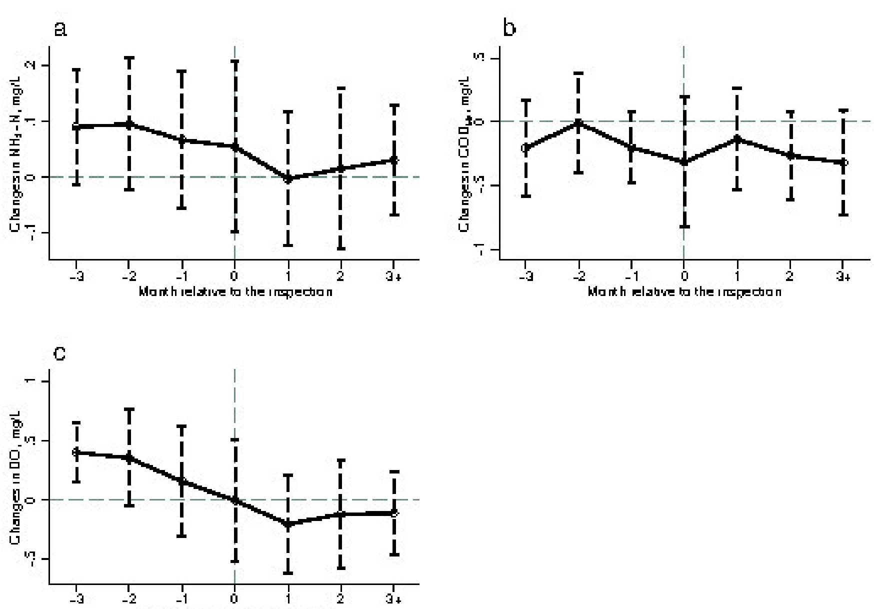

Figure 5

Policy Impact Dynamics—The First Three Rounds of Inspections

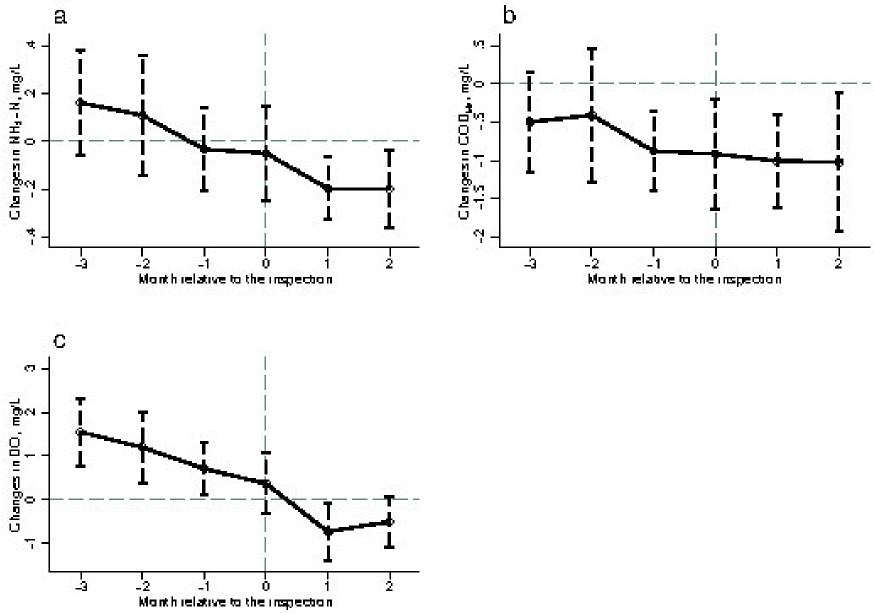

Figure 6

Policy Impact Dynamics—The Third Round of Inspection

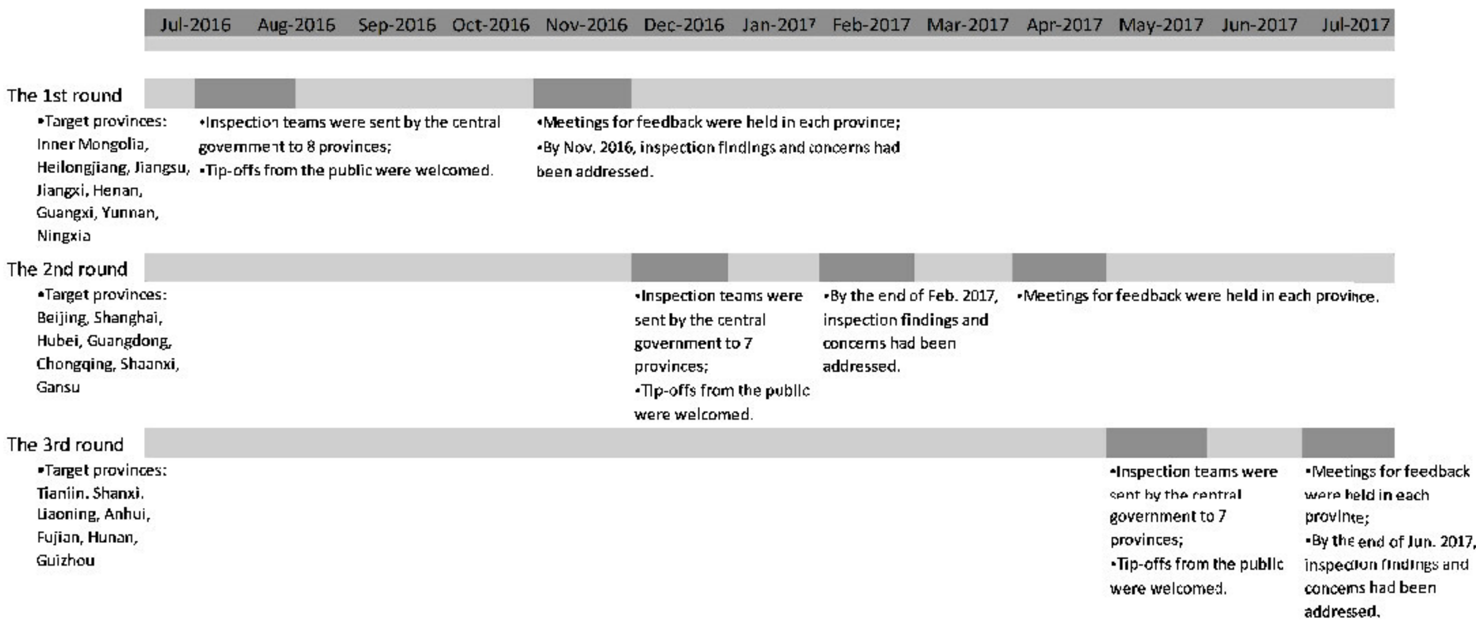

Figure 7

Legend not included with this version.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Appendix.docx