Crackdowns in Hierarchies: Evidence from China's Environmental Inspections *

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Abstract

We evaluate the effect of the central government's rotating crackdowns (2016-2017) on the environmental performance of cities and firms in response to China's air pollution crisis. During one-month crackdowns, concentrations of sulfur dioxide (SO_2) at coal power plants in targeted cities fall on average by 25-27%, but increase once scrutiny ends. Pollution reverts earlier at state-owned plants accountable to the central government, compared to plants accountable to the local (city) government. Our findings suggest that crackdowns visibly demonstrated central government effort but did not result in lasting environmental improvement.

Keywords: hierarchy, enforcement, industrial firms

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1 Introduction

Air pollution is a byproduct of industrial activity that harms human health and causes premature death (Cohen et al., 2017; Ebenstein et al., 2017). Several weeks of hazardous air quality in Beijing in 2013 known as the "Airpocalypse" raised awareness of China's pollution domestically and overseas (Beech, 2013), leading President Xi Jinping to declare "war" on air pollution. As part of its response, China's central government announced rotating crackdowns (*huanbao ducha* in Chinese) during 2016-2017 to strengthen enforcement by city environmental protection bureaus against polluting firms. These crackdowns involved sequentially dispatching teams of inspectors to cities for approximately one month to scrutinize pollution prevention and control activities. While scholars have begun to study the effectiveness of environmental policies in developing countries (Greenstone and Hanna, 2014; Blackman et al., 2018), we know very little about centrally-led crackdowns as a strategy for improving the environmental performance of governing bureaucracies.

Here we examine the role of crackdowns using the case of China's rotating environmental inspections. We quantify effects in high-frequency, plant-level data on the concentrations of a major short-lived industrial air pollutant, sulfur dioxide (SO_2). We find that during the one-month period while crackdowns are in progress, pollution falls by 25-27%.[1] We find that pollution reverts to prior levels within two to three months after inspectors leave. Reversion occurs fastest among firms accountable to the central government, which originated the crackdowns, while cleanup persists longer among firms accountable to the local government. The selection and timing of each crackdown wave is used to identify effects on SO_2 pollution, given that it is orthogonal to a city's environmental performance. To improve comparability of treatment and control groups across inspection rounds, we employ entropy balancing (Hainmueller, 2012).

Our study provides empirical evidence of how crackdowns work in authoritarian state-business hierarchies, adding to the literature on the economics of crackdowns (Di Tella and Schargrodsky, 2003; Dell, 2015; Johannesen and Zucman, 2012; Eeckhout et al., 2010). Centrally-led crackdowns are a common approach to closing local enforcement gaps in China (Perry, 2019; Van Rooij, 2006), We find that while in progress, China's environmental crackdowns result in large pollution

[1] Changes in SO_2 pollution are expressed in log points.

reductions, comparable in magnitude to the SO_2 reductions required by a recently-implemented SO_2 emissions standards (Karplus et al., 2018). The observation that pollution reverts after inspectors leave suggests that the crackdown temporarily altered local firms' incentives, rather than information or knowhow. Our findings raise the question of why, given that the central government presumably had the ability to observe the return to polluting behavior (air quality monitoring was automated and accessible to central administrators during this period), did firm pollution nevertheless revert?

We further use firm response patterns to diagnose the organizational origins of poor environmental performance in China, contributing to a broader literature on incentives in public bureaucracies (Banerjee, 1997; Rose-Ackerman, 1986; Lipsky, 1980). Variation in power plant accountability to different levels of the hierarchy allows us to empirically test a phenomenon described in the literature on environmental enforcement in China known as the "central state-owned enterprise (SOE) problem" (Eaton and Kostka, 2017), in which local governments struggle to enforce regulations against state-owned enterprises accountable to national authorities. We find that when central scrutiny is high during crackdowns, reductions are similar across plants. However, once the center withdraws, plants not directly accountable to the city government more quickly return to prior polluting levels. This response heterogeneity suggests that a local government's difficulty in enforcing regulations at a firm that "outranks" them may be contributing to China's ongoing environmental problems.

Our analysis is structured as follows. In Section 2, we describe our setting, data construction, and empirical approach. We present our main results on the magnitude and duration of crackdowns' effects in Section 3. Section 4 examines how firm linkages to different government levels affect responses. Section 5 concludes.

2 Background

2.1 Crackdowns: Definition and Prior Studies

We define a crackdown as a pre-announced increase in the stringency of regulatory scrutiny or enforcement (Eeckhout et al., 2010). Building on prior literature (Di Tella and Schargrodsky, 2003; Eeckhout et al., 2010; Dell, 2015; Johannesen and Zucman, 2012), several elements are common: there is a targeted behavior (speeding on roadways, corruption, cheating on exams, policy brutality, polluting the environment, laundering money) that has exceeded an acceptable frequency, drawing attention and resources to reduce it. Crackdowns increase the probability that targeted activities are detected or punished by a higher authority. In many cases, there is a regulation (e.g., a speed limit, procurement procedures, or environmental standards) that defines acceptable performance.

Prior work suggests that some crackdowns are effective at reducing targeted activities. Eeckhout et al. (2010) theorizes that random crackdowns deter violations at the margin by increasing likelihood of detection, and thus can be part of an economically optimal approach to monitoring. In other settings, crackdowns involve a one-time step up in scrutiny, as in the case of crackdowns on drug trafficking (Dell, 2015), money laundering (Johannesen and Zucman, 2012), or corruption in hospital procurement (Di Tella and Schargrodsky, 2003). Spatial (Dell, 2015; Johannesen and Zucman, 2012) and temporal (Di Tella and Schargrodsky, 2003) leakage of illicit activities has been shown to limit a crackdown's effectiveness. In all of these studies, crackdowns involve state action against an agent (individual or firm) directly, rather than via layers of a governing bureaucracy. Our setting allows us to examine a hierarchical setting, in which pressure originating with a principal (central government) are transmitted via a supervisor (local government) to an agent (polluting firm), similar to the three-layer hierarchy introduced in (Tirole, 1986).

We study a crackdown that is short-lived, originates at the apex of a governing hierarchy, and ultimately affects all cities and polluting firms. While selection is assured, timing is unpredictable. We differentiate between a firm's accountability to the originator of the crackdown (the central government) and its main target (the city government). By studying the extent and timing of plant responses to crackdowns, we can infer the extent of pressure exerted by their overseers, an approach similar in spirit to inferring the value of firms' political connections using abnormal stock market returns (Fisman, 2001) or of firms' government relationship-building activities by observing perk expenditures (Fang et al., 2018). Observed response patterns reveal the dynamic balancing of objectives at different levels of the government hierarchy.

Ensuring that local actions align with central objectives has been a centuries-old governance challenge in China, captured by the ancient Chinese proverb, "the mountains are high and the emperor is far away." The crackdown approach dates back to the founding of the People's Republic of China, with earlier analogs in the country's imperial history. During the Qing and earlier Ming dynasties, the Imperial Commissioner (*qinchai dachen* in Chinese) was charged with ensuring common practices were employed throughout China's localities, typically in response to large-scale national disasters or challenges. The approach of mobilizing "work teams" (*gongzuo zu* in Chinese) was later introduced from the Soviet Union and combined with local practices after the People's Republic of China was founded in 1949 (Perry, 2019). Work teams involved dispatching central cadres to localities, often reaching over the intermediate layers of the bureaucracy, to advance population control, heath and sanitation, anticorruption, or environmental quality goals (Perry, 2019; Van Rooij, 2006). China's recent environmental inspections are a modern example of this approach. Chinese media have likened the current environmental inspections to the Imperial Commissioner (Ma, 2017; Zhi, 2016). Although they have long been an important in the central governance of China's periphery, the effectiveness of crackdowns has never been studied empirically.

2.2 China's rotating environmental inspections

As part of the response to the country's air pollution crisis, China's Central Commission on Comprehensively Deepening Reforms proposed the creation of a "Central Environmental Inspection Team" in July 2015 (State Council, 2015). Inspection teams are overseen by the Ministry for Environmental Protection (MEP)[2] and are patterned on teams that carried out a recent nationwide anticorruption crackdown (Xu, 2017). Teams are deployed to cities, where they conduct month-

[2]The Ministry of Environmental Protection was reorganized as the Ministry of Ecology and Environment (MEE) in mid-2018.

long reviews of local governments' environmental protection efforts. The goal of the inspections is to ensure all provincial-level regions follow the central government's direction when implementing pollution control measures.[3] For the coal power plants in our study sample, this involved monitoring plant compliance with emissions concentration standards and investigating citizen complaints. The crackdown consisted of five rounds of inspections, starting in December 2015 and ending in late 2017. During these two years, the inspection team covered all 31 provincial-level administrative regions in mainland China [4]. The timing and composition of inspection rounds are summarized in Table 1.

During their stay (4-5 weeks) in a targeted province, the inspection teams reported lapses in compliance with central environmental requirements, oversaw rectification efforts, reviewed public complaints, and diagnosed weaknesses in local environmental oversight. Inspectors released results of the inspections to the public on the provincial environmental protection bureau's website and to local newspapers shortly after they became available. As a result of the two-year rotating crackdowns, inspectors investigated over 135,000 complaint cases, punished over 29,000 companies and imposed fines totaling 1.4 billion yuan (224 million US dollars) (People's Daily, 2017). A total of 1,527 people were detained and almost 18,000 officials were held accountable. Table 1 summarizes key statistics for the five inspection rounds, while the geographic distribution is shown in Appendix Figure A.1. When the inspections were launched, it was not clear whether or not they would be repeated. Only after the completion of the first inspection round in December 2017 did the central government announce plans to repeat inspections every few years.

2.3 Inspection time line and procedures

Inspections proceed in stages. First, members of the inspection team are selected anew in each round, primarily from two agencies: the national Ministry of Environmental Protection and its sub-branches and the General Office of the Communist Party of China (the Central Office) and its personnel arm. Some inspection teams also included journalists and regional environmental protection agency workers. By the end of this stage, the exact details of the on-site inspection

[3] We use the term "provinces" to refer to all provincial-level regions, including provinces, autonomous regions and municipalities.
[4] Environmental inspection teams were not dispatched to Taiwan and two special administrative regions (Hong Kong and Macau).

plan were announced to the provincial-level government for the first time, no more than six weeks prior to arrival.

Next, the central inspection team locates in the targeted province(s) for approximately five weeks. While locally based, the team conducts their own unannounced inspections of firms and set up telephone hotlines, mailboxes, and social media channels to receive tip-offs on pollution sources from local citizens. Complaints are passed on to the city environmental protection bureau for verification and follow up, while the central inspection team oversees the process. Once the accuracy of complaints is verified, firms could be required to shut down or to rectify pollution, in addition to paying fines and/or facing legal action. Government officials could also be held accountable for firms' regulatory violations.

After the inspection ends, teams evaluate the performance of the cities included in each round and submit their findings in a report to each provincial government. Reports evaluate local regulatory enforcement capabilities and described areas needing improvement. Some of the common problems found were: insufficient implementation of environmental regulations, a lack of an approach to evaluate and respond to pollution monitor readings in excess of standards, and weak environmental leadership. After the findings were handed to the provinces, cities entered the "Rectification and enforcement" stage. Within 30 days, each city government was required to develop and submit a "rectification plan" to the State Council for approval. The plan was to include a detailed response to every finding in the inspection team's report, for example, by elaborating on how the city would address problematic polluters and improve local environmental governance practices. After approval by the State Council, provincial leaders must publish the "rectification plan" and provide updates on its implementation status to the public.

2.4 Coal power plant incentives

Coal power plants in China produce electricity for industrial and residential users, emitting SO_2 and other air pollutants as a byproduct. Plants are subject to regulations on the concentration of SO_2 emissions in their stack gases, which are defined by emission standards. Standards for SO_2 have become increasingly stringent since July 2014, when the standard GB13223-2011 went into effect (Karplus et al., 2018).[5]

In addition to altering plant output, a manager has several options to control SO_2: (1) increasing the use of low-sulfur coal, (2) adjusting boiler efficiency, or (3) installing and operating a pollution removal device. The third option has been the primary plant response to increased standard stringency since 2014 (Tang et al., 2019). Plants remove SO_2 pollution from waste gas streams using a technology installed on the plant's exhaust stack known as flue gas desulfurization, or a "scrubber." Historically, low rates of scrubber installation and operation have contributed to high air pollutant emissions from China's coal power plants (Xu, 2009). Operating a scrubber is costly: one estimate suggests operating costs are equivalent to a fourth of a generator's profit margin (Xu, 2011).

Historically, power plants in China were compensated based on annual generation quotas at prices set by the government. Since 2015, an increasing share of above-quota production can now be sold "out-of-plan" via bilateral contracts or markets, typically at lower prices than electricity sold under annual quotas. Plants with scrubbers are entitled to sell their electricity at a premium, although it is unclear whether scrubber operation is verified.

2.5 Data Construction

2.5.1 Timing of Environmental Inspections

To determine the start and end date of inspections, we rely on public announcements scraped from the MEP (now MEE) website,[6] and corroborate them with the dates reported by various media outlets.[7] In principle, plants could have learned of an inspection as soon as the next round of locations was selected. We define treatment as the beginning of the pre-inspection "Announce" period six weeks prior to the inspectors' on-site arrival. This allows us to detect any early divergence in treated plants' polluting behavior.

[5]Tougher "ultra-low emissions" standards were proposed in September of 2014, requiring an additional 65% reduction in SO_2 concentrations relative to GB13223-2011 by 2020.

[6]Detailed information on the timing of inspections is available from the MEE (2019).

[7]We compiled reports from multiple news outlets including *China Daily*, Sina news, and Wangyi 163 news.

2.5.2 SO_2 emissions

We focus on emissions of SO_2 for several reasons. SO_2 is a major pollutant and contributes to the formation of ambient particulate matter (PM). Both SO_2 and PM cause cardiovascular and respiratory disease in humans. Monitoring of SO_2 in China is well established, and during our sample period coverage of SO_2 is comprehensive across space and time. SO_2 is a short-lived pollutant, and thus ambient measurements near power plants are a good proxy for plant emissions. Moreover, SO_2, unlike NO_x, is largely not emitted from transportation sources. We assemble hourly air quality data for SO_2, measured as ambient concentration ($\mu g/m^3$) at the level of individual monitors nearest to coal power plants. Monitor-level data are directly related to human health impacts and are available for all coal power plants before, during, and after crackdowns.

The China National Environmental Monitoring Center provides a publicly-available data platform that publishes hourly pollutant concentrations at all monitoring stations.[8] Cities typically install multiple monitors, with an average of five monitors per city. Our data set spans the period from May 2014 to May 2018, which allows us to evaluate pollution at the plant level before, during, and after the inspections. To reduce noise, all hourly air quality measures are averaged at the weekly level. Missing observations, which correspond to periods when a monitor was not operational (e.g., due to maintenance), are dropped when computing weekly averages for individual monitors. We examine the inspections' effects in city-level data for all provinces, and plant-level data for six provinces in which data were available and complete: Hebei, Henan, Hubei, Guangdong, Shanxi and Shandong. Our power plant sample is comprised of 973 plants in 89 cities, and covers all five inspection rounds.

2.5.3 Empirical approach

We use the timing of inspections to identify average effects on SO_2 pollution around targeted firms. In order to attribute changes to the central inspection team's arrival, the selection and timing of inspections must be uncorrelated with firms' environmental performance. This is plausible for two

[8] The platform can be accessed at `http://106.37.208.233:20035/`.

reasons. First, all provinces were inspected, regardless of environmental record, and timing was chosen for reasons unrelated to pollution patterns, such as maintaining regional diversity within each round and limiting predictability. Second, central officials internally decided the upcoming round of provinces several weeks in advance and withheld this information from localities until a few days before inspectors arrived (our empirical specification allows for the possibility that some plants may have been notified up to six weeks in advance). Thus even plants in regions included in the final round, which might have otherwise foreseen inspections, would not have been able to anticipate the timing. Plants in untreated cities within each round serve as controls, and we isolate the effect of being in a treated city relative to a control city after inspections begin within each round.

Even if the timing of inspections is plausibly exogenous, differences in the economic composition of cities may complicate comparisons between treatment and control plants. We examine predictors of a city's targeting in different rounds using linear probability and logit models (Appendix Table A.1), using all cities in the 31-province sample. We find that population density predicts inclusion in the Trial Round and Round 4. Other covariates do not predict inclusion in the treatment group. We then perform a t-test to detect differences in a wide range of observable city and plant characteristics (per-capita GDP, population density, distance to city center, plant share of city business revenue, company age, state ownership, and baseline SO_2 concentrations) between treatment and control groups within rounds. As show in Appendix Table A.2, treatment and control groups are not balanced on observables within rounds. We therefore implement a data preprocessing strategy, entropy balancing (Hainmueller, 2012), to generate a comparable control group for treated plants by round. We calibrate each observation's weight to ensure re-weighted plants in treated cities and those in control cities are balanced on covariates.[9] We balance on the first-order covariates, but the results are robust to balancing on second and higher-order moments of the covariate distributions. We include the following list of covariates in the entropy balancing routine: (i) city characteristics of per-capita income and population level; (ii) firm characteristics of geographical location, revenue share, company age, ownership and oversight level; and (iii) SO_2

[9] We use the STATA package "ebalance" developed by (Hainmueller and Xu, 2013). The package can be accessed at `https://web.stanford.edu/~jhain/Paper/JSS2013.pdf`.

concentrations in the baseline period (7 to 12 weeks prior to the arrival of the central inspection team). After entropy balancing, balance tests in Appendix Table A.3 show observed company characteristics and baseline pollution levels are not statistically different between treatment and control firms for all five inspection rounds.

3 Main Results

3.1 Visual Evidence

To examine how crackdowns affect SO_2 pollution, we begin by visually inspecting changes in raw measurements of ambient SO_2 in cities while the inspectors are present. For this comparison, we make use of average SO_2 pollution levels for all cities in China. Figure 1 compares logged SO_2 pollution levels before, during, and after an inspection in targeted (treated) and non-target (control) cities. Plots are centered on the start of the inspection period (vertical line at week 0) in a city. Weekly observations represent the unweighted average of hourly SO_2 measures, which are subsequently averaged at the city level by treatment status. The lighter shaded area corresponds to the six-week period between when inspections are announced and inspectors arrive on site. On average, treated cities (solid line) show visual evidence of SO_2 reductions during the "Announce" period (lighter shaded area), while SO_2 in control cities (dotted line) appears to slightly increase. During the on-site inspection period (subsequent darker shaded area), the reduction in pollution in treated versus control cities is readily apparent. This gap persists from the beginning of the announcement period until approximately eight weeks following the completion of on-site inspections, when they converge again, as shown in the longer post-period in (b).

The remainder of our analysis focuses on observations of ambient SO_2 pollution at monitors nearest to power plants in our six-province sample. The nationwide pattern in Figure 1 is replicated in Appendix Figure A.2 for power plants in our six-province sample. To evaluate how well monitor measures capture plant emissions concentrations from a proximate facility, we compare ambient SO_2 concentration at monitors nearest a plant with plant-specific measures from continuous emission monitoring systems (CEMS) installed on plant smokestacks for Henan province.

CEMS measurements are available for very few plants at the start of inspections, so we use ambient monitor measures to ensure coverage of pre-period observations. Appendix Figure A.3 shows a strong correspondence between the monitor and plant stack SO_2 measurements for plants, suggesting our monitor measure is an acceptable proxy for direct emissions from power plants.

3.2 Regressions and Event Study

To obtain the impact of an inspection on plant-level SO_2 emissions, we estimate the following difference-in-differences (DID) regression:

$$\ln(\mathrm{SO}_{2it}) = \alpha + \delta(\mathrm{Announce}_{it}) + \lambda(\mathrm{Onsite}_{it}) + \xi(\mathrm{Post}_{it}) + \sigma(\mathrm{Elsewhere}_{it}) + \gamma_i + \lambda_t + \epsilon_{it} \quad (1)$$

Here, the dependent variable is the ambient pollution level reported by the monitor located nearest to each coal power plant in our six-province sample. SO_{2it} is plant i's average SO_2 concentration ($\mu g/m^3$) in week t. $\mathrm{Announce}_{it}$ equals 1 one to six weeks before central inspection team arrives in inspected cities, and is otherwise zero. Onsite_{it} equals 1 during the inspection period (when the central inspection team is physically on site) in inspected cities, and is otherwise zero. Post_{it} equals 1 in the post period (after the central inspection team leaves the province) in inspected cities, and is otherwise zero, for 12 weeks in the short-run estimates and 36 weeks in the long-run estimates. $\mathrm{Elsewhere}_{it}$ equals 1 in inspected cities if the inspection team is physically on site in a non-focal city (a subset of the control group) during the post-period, which occurs at least three months after the inspection ends in the focal province (and is zero otherwise). Changes in SO_2 before, during, and after to crackdowns are estimated in log points relative to the average baseline SO_2 pollution level (7-12 weeks prior to inspection). Power plant fixed effects γ_i control for time-invariant differences in SO_2 pollution around plants, due for instance to local geography, climatic conditions, or electricity demand. We include week fixed effects λ_t for SO_2 concentration changes due to seasonality of weather or electricity demand, and year fixed effects to capture changes in plant technology or SO_2 policy (such as the ongoing implementation of national SO_2 standards) over time that are common to all power plants. Standard errors are clustered at the city level.

Table 2 summarizes the estimated effects of inspections, with specifications that include a short-run (12-week), medium-run (24-week), and long-run (36-week) post-inspection horizon for both the original and entropy balanced samples. When inspection teams are on-site, SO_2 levels at plants drop by 25-27% in log points (entropy-balanced sample). This is a substantial reduction in average ambient SO_2, relative to baseline levels. While the effect magnitude is slightly lower, coefficient magnitudes between the entropy-balanced and original samples are similar.[10] After the crackdown ends, reductions gradually attenuate, returning to baseline levels by 24-36 weeks after the inspection team has left (see estimates in columns 7 and 8). Summing the coefficient on Post and Post (24-36 wks) in column 8 gives a reduction in the latter third of the post period that is no different from zero, relative to baseline levels. The positive and moderately-significant (at the 5% level) coefficient on "Elsewhere" reflects the fact that a subset of the control cities have lowered their emissions in response to the start of on-site inspections.

Our data further allow us to observe the mechanism(s) by which firms reduced pollution during crackdowns. Over the short (multi-week) time frames we use to resolve effects of crackdowns, firms had limited options to reduce SO_2 emissions. One option was to operate an already-installed SO_2 emissions control device (or "SO_2 scrubber"). Approximately 80% of the firms in our sample had SO_2 scrubbers installed prior to the arrival of inspectors. When working properly, scrubber operation results in near-complete removal of SO_2 pollution from a plant's waste gas stream. Running a scrubber requires variable inputs of labor and energy and is thus costly to firms.

A second option for plants to curb SO_2 emissions is to reduce output. As a proxy for electric power production, we focus on another pollutant, NO_X, which is formed when nitrogen reacts with ambient air during combustion and thus scales with plant output (unlike SO_2, it is not related to the chemical composition of the fuel). Appendix Table A.5 shows how NO_x levels change before, during, and after the inspections. We use the entropy-balanced sample but exclude plants that

[10]Results are further robust to removing the six plants that are permanently shut down after the on-site period (see Appendix Table A.4), which would be expected to bias post-period reductions downward.

have NO_x scrubbers installed (204 plants) in order to ensure that observed changes are due only to adjustments in plant output, and not end-of-pipe NO_x removal. We find that on average plants reduce NO_x (electricity output) by 3-7% during the on-site phase of the inspection. However, the lowering of output can only partially explain the large reductions in SO_2 observed during the inspection period, and therefore plants must be operating SO_2 scrubbers to achieve deeper pollution reductions during inspections.[11] Thereafter output increases above baseline levels for nearly six months, by 3-6%, suggesting that plants may have deferred productive activity. Power plants in China are compensated according to annual production schedules. Shifting output to periods with lower environmental scrutiny is consistent with behavior observed in other settings in which managers face quotas or deadlines that affect performance evaluation (Oyer, 1998, 2002). Vehicles also emit NO_x, and if crackdowns altered vehicle activity near power plants, our estimates of plant output responses may be biased upward.

4 Government oversight and plant responses to crackdowns

We ask whether plants responses differ as a function of their accountability to the central versus the local state. State-owned enterprises (SOEs) in China are differentiated by their accountability to their respective levels of China's governing hierarchy. In China's power sector, 61% of installed coal capacity is majority state-owned (Hervé-Mignucci et al., 2015). We introduce heterogeneity by differentiating accountability to "upper" levels (provincial and national governments, here an "Upper SOE"), which outrank the city government, and "lower" levels (city and below, here a "Lower SOE"), which are subordinate to the city government. City environmental protection bureaus have been found in prior work to face greater difficulty in enforcing regulations at plants that are not directly accountable to the city through oversight ties, a phenomenon known as the "central SOE problem" (Eaton and Kostka, 2017). We are able to examine the role of rank empirically, by examining separately the responses around state-owned plants accountable to various levels of the government hierarchy, as well as the responses of private plants, which are not structurally

[11] In theory, plants could also switch to low sulfur coal use, however, by 2015 plants in China were already using low sulfur coal, and this shift offers more limited SO_2 reduction potential compared to running scrubbers.

accountable to the government through oversight ties.

Our results show that while all firms reduce SO_2 emissions during crackdowns, Upper SOEs revert more quickly to prior levels after crackdowns end. During the on-site period, we do not see a difference in the reductions achieved by Upper SOEs relative to other firm types (see column (2) of Table 3). However, Table 3 shows that Upper SOEs revert faster once the central inspection team leaves, as indicated by the coefficient on eleven weeks post inspection interacted with Upper SOE (see column (3)). This effect attenuates thereafter, as shown by the lack of significance of the coefficients on Upper SOE interacted with the later two-thirds of the post-period, shown in columns (4) and (5), respectively.

When we narrow the sample to Upper SOEs only and interact the post inspection period with scrubber status in Table 4, we find that Upper SOEs with scrubbers revert faster during the post period (column (2)), while emissions remain low at plants without scrubbers. This effect is not significant for lower SOEs that are directly accountable to the city government, as shown in column (3). Private firms with scrubbers also see pollution rise sharply in the post-inspection period relative to those that lack control equipment. The magnitude is about two-thirds of that for Upper SOEs with scrubbers, as shown in column (4). It is difficult for regulators to observe when a firm ceases scrubber operation and SO_2 is invisible, thus the likelihood of detection during the post period was plausibly low. Our results are consistent with a scenario in which Upper SOEs with scrubbers lowered their expectations about the likelihood of detection and/or punishment following an inspection, while lower SOEs did not, at least initially. Given that Upper SOEs tend on average to be larger firms, we test size as an alternative explanation for the pattern we observe. As shown in Appendix Table A.6, the relationship between scrubbers and reversion is statistically significant for all size categories. While the magnitude of effects increase with size, size alone cannot explain why firms accountable to the city government do not revert as rapidly as centrally-controlled firms.

5 Conclusion

Our analysis examines crackdowns as a response to gaps in the performance of a governing bureaucracy. We find that in China, crackdowns achieve large pollution reductions (25-27%) that do not persist. In treated cities, SO_2 pollution falls sharply during crackdowns before returning to baseline levels, interrupting a long-run reduction trend that predated the crackdowns.[12] This reversion occurs despite the fact that emissions monitoring data are regularly transmitted to, and readily observable by, China's central Ministry of Ecology and Environment.

Our findings can be interpreted alongside prior work on crackdowns to generalize several additional factors that influence effectiveness. How the cost and reversibility of firm responses interact with a crackdowns' time horizon appear to be important determinants of whether the targeted behavior is deterred entirely or merely displaced in time or space. In Eeckhout et al. (2010), rotating crackdowns on speeding induced drivers to slow down, a response that did not incur high private (e.g., investment) costs. Duration and expectations about the frequency of a crackdown's recurrence may interact with firm decisions about whether to implement a (less costly) short-term or (potentially more costly) long-term solution. In the case of China's environmental inspections, we found that firms employed short-term measures—turning scrubbers on, or temporarily restricting electricity output—that were relatively easy and rewarding to reverse. Our findings are consistent with more limited scrutiny of firms with scrubbers, suggesting that scrubbers may have served as a readily-observable proxy for real-time performance.

We further show that the level of government to which a firm is accountable affects its SO_2 reduction patterns once an inspection ends. During inspections, the presence of central authorities may exert uniformly strong pressure on plants to clean up. The differential rates of reversion may reflect an updating of plants' expectations about the likelihood of punishment by the remaining (local) authority once the center has left. Managers of upper SOEs may have been more certain that they could escape detection or punishment, and thus returned to polluting sooner, while lower SOEs may have faced residual uncertainty about the extent of any increased stringency in local

[12] When we examine the coefficients on the year fixed effects in Table 2, we find SO_2 concentrations gradually decreased between 2015 and 2018. These reductions have been attributed to the introduction of China's ultra-low emissions standards, which require substantial reductions in emissions of SO_2 and other pollutants by 2020 (Tang et al., 2019). Our results suggest that environmental inspections did not contribute to this long-run change.

government oversight. Our results are consistent with this uncertainty resolving several months after inspections end, when all plants returned to baseline pollution levels.

Our results may be indicative of a broader administrative challenge Chinese cities face when controlling outranking SOEs. For example, it was reported recently that officials in Hunan Province were afraid of and unwilling to tackle environmental violations by central SOEs (Zhang, 2019). One solution could be for the central government to continuously scrutinize upper SOEs directly on an ongoing basis, and consistently punish violations. Indeed, when the second full round of inspections began in 2019, it included direct inspection of two central SOEs (China Minmetals Corporation and China National Chemical Corporation) in addition to the geographical targeting of the first round. Ongoing scrutiny of firms outside of inspection periods is now possible with the MEE's extensive network of environmental monitors and continuous emissions monitoring systems, which is likely to lower the costs of real-time oversight.

If inspections were not effective in a permanent sense, why did the central government initiate them? We offer three possible explanations.

First, the center may have been serious about cracking down on local regulatory lapses, but crossing multiple layers of the hierarchy to punish firms infringes on local authority. Launching centralized crackdowns may have been an acceptable alternative. Firms may have perceived crackdowns as a short-lived, one-time shock, leaving them with little incentive to develop permanent cleanup strategies. At the conclusion of the first round, the government announced that crackdowns would be repeated, first for a subset of provinces and later for all in a full-fledged second inspection round. Moving from a one-time experiment to a repeated game may change firm responses, an important area for future study.

Second, the center may have viewed crackdowns as a way to gather information on the nature and extent of local environmental problems, as well as discontent, in order to better direct scarce enforcement and public relations efforts. Soliciting citizen complaints on egregious polluters, which was an important component of the crackdowns, may have helped the central government to accomplish this goal.

Third, central authorities may have launched crackdowns to demonstrate effort and deflect blame. By publicly revealing regulatory lapses at the level of local governments and firms, inspection teams may have reinforced the perception that inadequate local government oversight was responsible for air quality lapses, directing scrutiny away from central authorities. This practice is akin to the sacking of local officials over their handling of food safety scandals, environmental accidents, or epidemics such as SARS or the Covid-19 coronavirus. However, if crackdowns are not accompanied by permanent changes in local officials' and firms' incentives, performance improvement cannot be expected to last.

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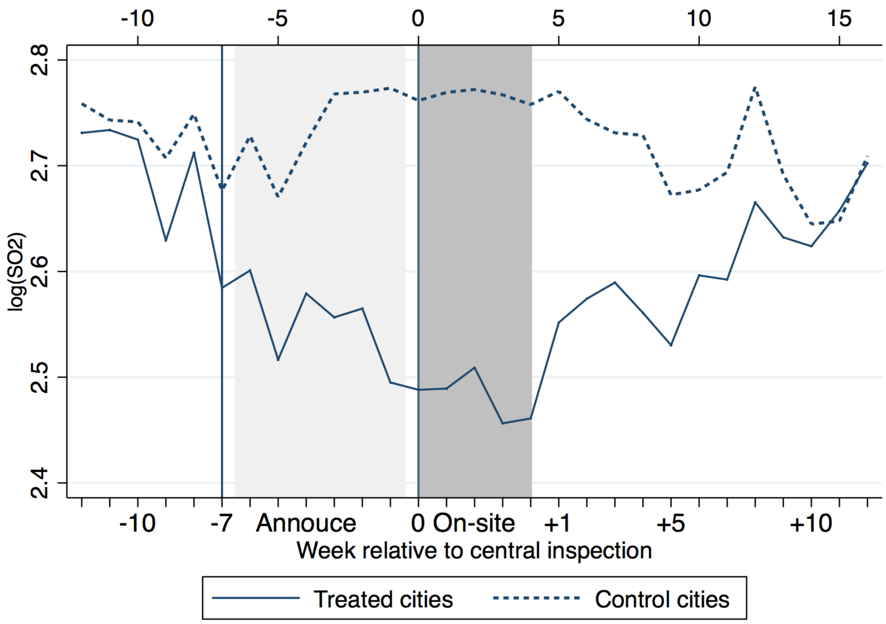
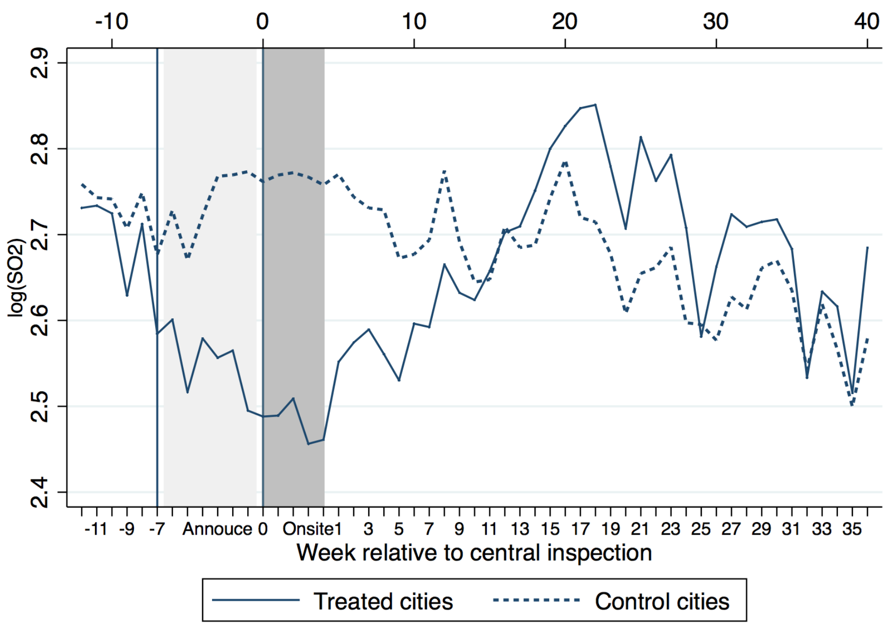


(a) Short-term (up to 12 weeks post inspection)



(b) Long-term (up to 36 weeks post inspection)

Figure 1. Raw comparison of SO_2 concentration in treated and control cities around the inspection event window. The graph is centered on the timing of announcement and inspection in treated cities, while non-target cities serve as a control group in each respective round. Data covers all 31 provincial-level administrative regions in mainland China (excluding Taiwan, Hong Kong and Macau which are not visited by the inspection teams). Treated cities are actively experiencing an inspection, while control cities are not. Every city appears once in the treated group and four times in the control group.

Table 1. Summary statistics for the five inspection rounds.

Summary	Trial Round	Round 1	Round 2	Round 3	Round 4
Number of provinces	1	8	7	7	8
Start date	2015/12/31	2016/07/12	2016/11/24	2017/04/24	2017/08/07
End date	2016/02/14	2016/08/19	2016/12/30	2017/05/28	2017/09/15
Avg. GDP (billion)	3207	2577	3024	2139	2255
Avg. population (million)	63	41	37	36	32
Avg. per-capita GDP	51108	60725	85410	67145	60949
Pre-Inspec SO_2 Conc	42	26	17	29	18
Complaints	2856	1637	2233	4494	5005
Cases filed	125	NA	901	1241	1351
Fines (million)	NA	NA	NA	5238	6755
Persons detained	123	39	38	58	53
Persons interviewed	65	272	667	951	607
Officials accountable	366	428	446	666	809

Notes: Trial Round, the pilot program, was launched in Hebei province. Round 1 includes 8 provincial-level regions: Inner Mongolia, Ningxia Hui, and Guangxi autonomous regions, as well as Heilongjiang, Jiangsu, Jiangxi, Henan, and Yunnan provinces. Round 2 include 7 provincial-level regions: Beijing, Shanghai, and Chongqing municipalities, as well as Hubei, Guangdong, Shaanxi, and Gansu provinces. Round 3 include 7 provincial-level regions: Tianjin municipality, as well as Shanxi, Liaoning, Anhui, Fujian, Hunan, and Guizhou provinces. Round 4 include 8 provincial-level regions: Tibet, and Xinjiang Uygur autonomous regions, as well as Qinghai, Sichuan, Hainan, Shandong, Zhejiang, and Jilin provinces. "NA" means that information is not available. "Conc" is concentration. Data are from portals describing environmental inspections by province, which are available via the Ministry of Ecology and Environment's website (MEE, 2018). Data are available upon request.

Table 2. Average effects of the announcement, on-site, and post-inspection periods in the entropy-balanced and original samples.

	Short-term		Medium-term		Long-term			
	EB	Original	EB	Original	EB	Original	EB	Original
	(1) log(SO_2)	(2) log(SO_2)	(3) log(SO_2)	(4) log(SO_2)	(5) log(SO_2)	(6) log(SO_2)	(7) log(SO_2)	(8) log(SO_2)
Announce	-0.058	-0.044	-0.044	-0.032	-0.064	-0.030	-0.060	-0.028
	(0.043)	(0.038)	(0.041)	(0.037)	(0.039)	(0.036)	(0.039)	(0.036)
On-site	-0.273	-0.272	-0.254	-0.286	-0.251	-0.279	-0.255	-0.280
	(0.046)	(0.044)	(0.039)	(0.038)	(0.038)	(0.035)	(0.038)	(0.035)
Post	-0.178	-0.166	-0.117	-0.103	-0.061	-0.046	-0.078	-0.067
	(0.038)	(0.029)	(0.025)	(0.017)	(0.019)	(0.013)	(0.020)	(0.013)
Elsewhere	0.024	0.025	0.074	0.052	0.058	0.050	0.057	0.049
	(0.017)	(0.013)	(0.020)	(0.015)	(0.018)	(0.013)	(0.019)	(0.014)
Post 12-23 wks							-0.019	-0.011
							(0.017)	(0.018)
Post 24-36 wks							0.091	0.104
							(0.038)	(0.032)
Observations	103,502	129,697	145,548	182,960	186,731	235,682	186,731	235,682
R-squared	0.711	0.744	0.708	0.738	0.700	0.727	0.701	0.727
# of plants	973	973	973	973	973	973	973	973
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: EB refers to estimates using the entropy-balanced sample. Baseline weeks (prior to the announcement period) are the omitted reference group. All specifications include plant, year, and week fixed effects. "Announce" refers to the announcement period, the earliest window during which a city would have learned inspectors were coming. "On-site" refers to the inspection period. "Post" refers to the period after the inspection ends. "Elsewhere" controls for an inspection underway in a non-focal province. All specifications control for plant, year, and week fixed effects, which would absorb the effect of time-invariant unobservable characteristics, plus annual policy or operational changes and seasonal fluctuations in electricity demand. Robust standard errors are given in parentheses. Standard errors are clustered at the city level.

Table 3. Effect of inspections interacted with a firm's Upper SOE (USOE) status in the on-site and post-inspection periods.

	(1) log(SO_2)	(2) log(SO_2)	(3) log(SO_2)	(4) log(SO_2)	(5) log(SO_2)
Announce	-0.056	-0.057	-0.056	-0.056	-0.056
	(0.031)	(0.032)	(0.032)	(0.031)	(0.032)
On-site	-0.252	-0.254	-0.252	-0.252	-0.253
	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
Post 0-11 wks	-0.178	-0.172	-0.202	-0.178	-0.178
	(0.028)	(0.028)	(0.034)	(0.028)	(0.028)
Post 12-23 wks	-0.092	-0.086	-0.092	-0.086	-0.092
	(0.022)	(0.020)	(0.022)	(0.023)	(0.022)
Post 24-36 wks	0.025	0.030	0.025	0.025	0.037
	(0.026)	(0.024)	(0.026)	(0.026)	(0.029)
Elsewhere	0.047	0.047	0.047	0.047	0.047
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
On-site × Upper SOE		-0.020			
		(0.019)			
Post 0-11 wks × Upper SOE			0.065		
			(0.036)		
Post 12-23 wks × Upper SOE				-0.016	
				(0.023)	
Post 24-36 wks × Upper SOE					-0.035
					(0.031)
Observations	186,731	186,731	186,731	186,731	186,731
R-squared	0.703	0.703	0.703	0.703	0.703
Number of plants	973	973	973	973	973
Plant FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes	Yes

Notes: Uses the entropy balanced power plant sample. USOE - Upper SOE. Coefficient estimates are average effects within multi-week periods, relative to the inspection. Baseline weeks (prior to the announcement period) are the omitted reference group. "Announce" refers to the announcement period, the earliest window during which a city would have learned inspectors were coming. "On-site" refers to the inspection period. "Post" refers to the period after the inspection ends. "Elsewhere" controls for an inspection underway in a non-focal province. Regression is the full interaction of Upper SOE status with covariates. The interaction between ownership/oversight status and Post periods of varying length captures variation in the post-inspection response by ownership/oversight level. All specifications include plant, year, and week fixed effects. All specifications control for plant, year, and week fixed effects, which would absorb the effect of time-invariant unobservable characteristics, plus annual policy or operational changes and seasonal fluctuations in electricity demand. Robust standard errors are given in parentheses. Standard errors are clustered at the city level.

Table 4. Direct effect of campaign with interactions on scrubber technology in different post periods by plant oversight.

	All (1) log(SO_2)	Upper SOE (2) log(SO_2)	Lower SOE (3) log(SO_2)	Private (4) log(SO_2)
Announce	-0.055	-0.056	-0.042	-0.062
	(0.039)	(0.040)	(0.072)	(0.040)
On-site	-0.253	-0.245	-0.224	-0.263
	(0.037)	(0.052)	(0.054)	(0.031)
Post 0-11 wks	-0.338	-0.399	-0.226	-0.325
	(0.051)	(0.076)	(0.065)	(0.054)
Post 12-23 wks	-0.093	-0.101	-0.070	-0.083
	(0.025)	(0.034)	(0.030)	(0.025)
Post 24-36 wks	0.026	0.012	0.025	0.036
	(0.033)	(0.035)	(0.034)	(0.045)
Elsewhere	0.046	0.058	0.057	0.038
	(0.016)	(0.024)	(0.020)	(0.020)
Post 0-11 wks × SO_2 Scrubber	0.196	0.268	0.067	0.175
	(0.046)	(0.080)	(0.074)	(0.049)
Observations	186,731	65,600	33,527	84,251
R-squared	0.704	0.706	0.694	0.694
Number of plants	973	334	157	465
Plant FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes

Notes: Uses the entropy balanced power plant sample. Column (2) includes only upper SOE firms (state-owned enterprises with national-level or provincial-level oversight). Column (3) includes only firms that are lower SOE (state-owned enterprises with city-level or county-level oversight). Column (4) uses only firms that are private enterprises. Coefficient estimates are average effects over multi-week periods. Baseline weeks (prior to the announcement period) are the omitted reference group. "Announce" refers to the announcement period, the earliest window during which a city would have learned inspectors were coming. "On-site" refers to the inspection period. "Post" refers to the period after the inspection ends. "Elsewhere" controls for an inspection underway in a non-focal province. All specifications control for plant, year, and week fixed effects, to absorb the effect of time-invariant unobservable characteristics, plus annual policy or operational changes and seasonal fluctuations in electricity demand. Robust standard errors are given in parentheses. Standard errors are clustered at the city level.

Appendix

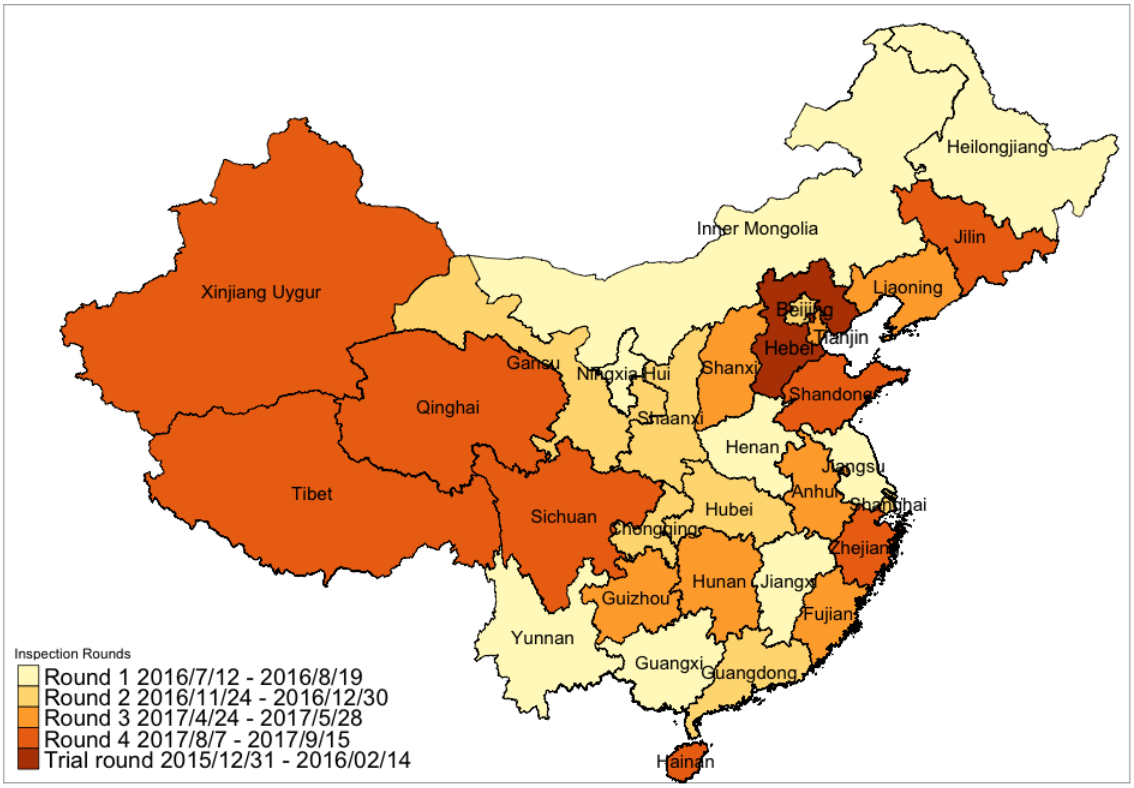
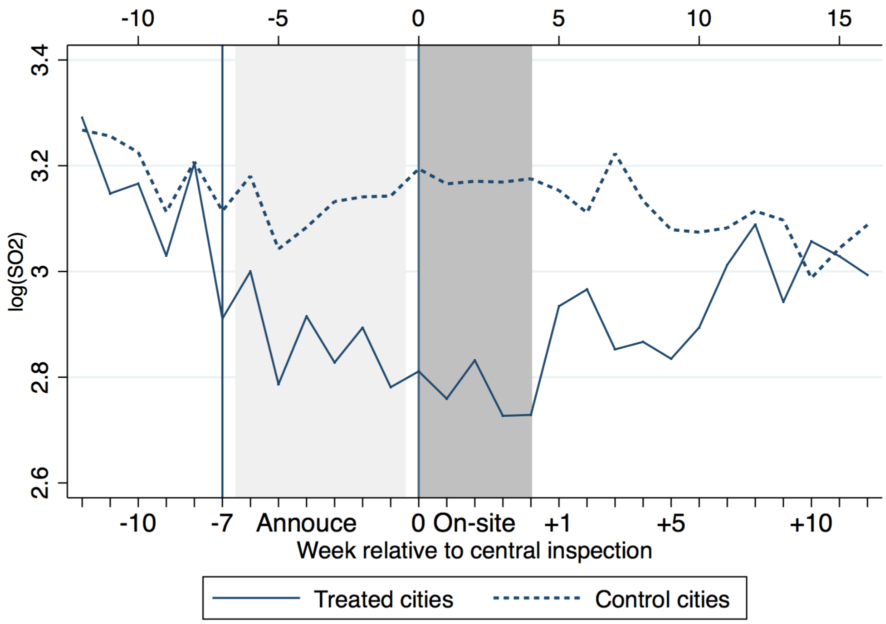
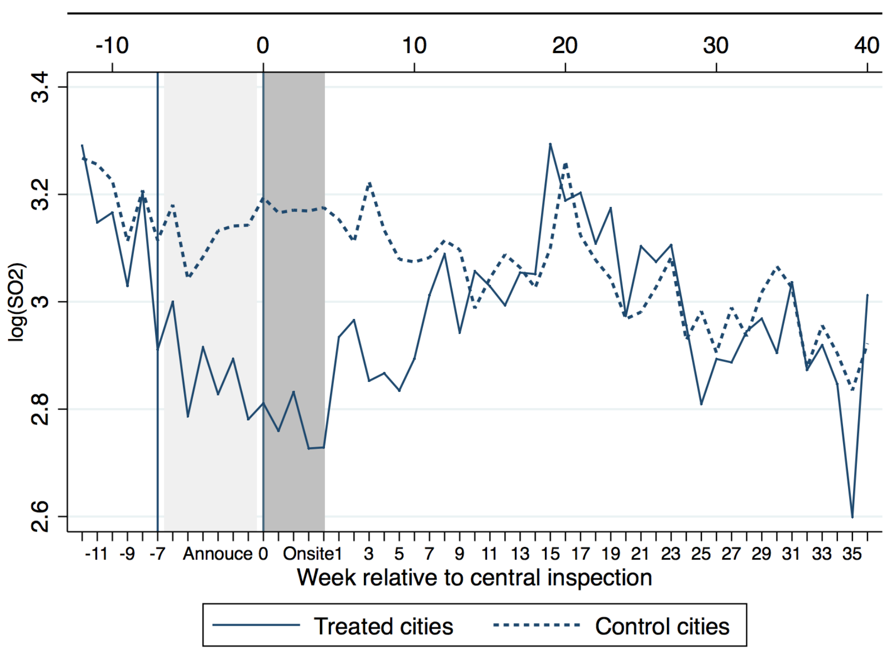


Figure A.1: Geographical composition and timing of the five inspection rounds. Trial round includes only Hebei province. Rounds 1-4 cover either 7 or 8 provinces, and do not cover Hong Kong, Macau, or Taiwan.

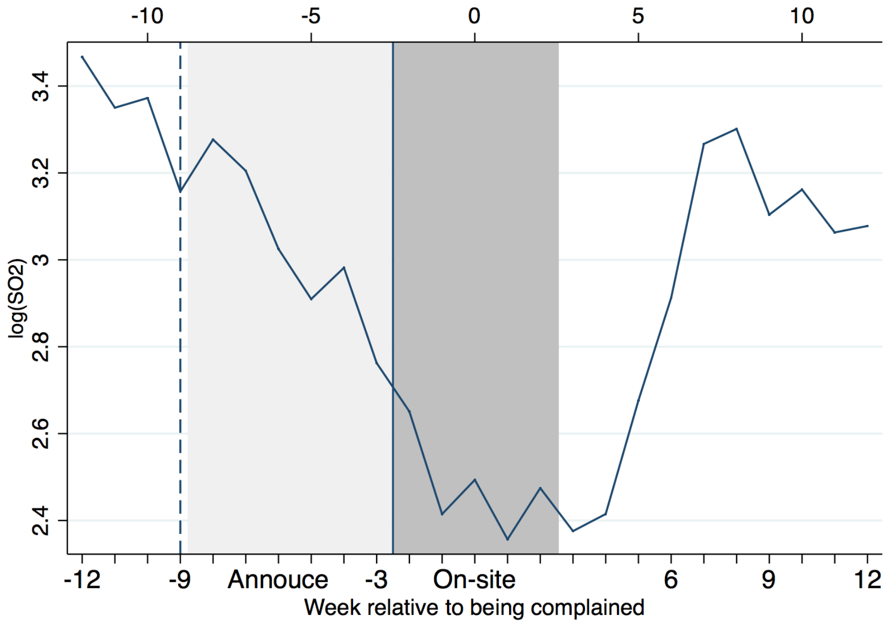


(a) Short-term

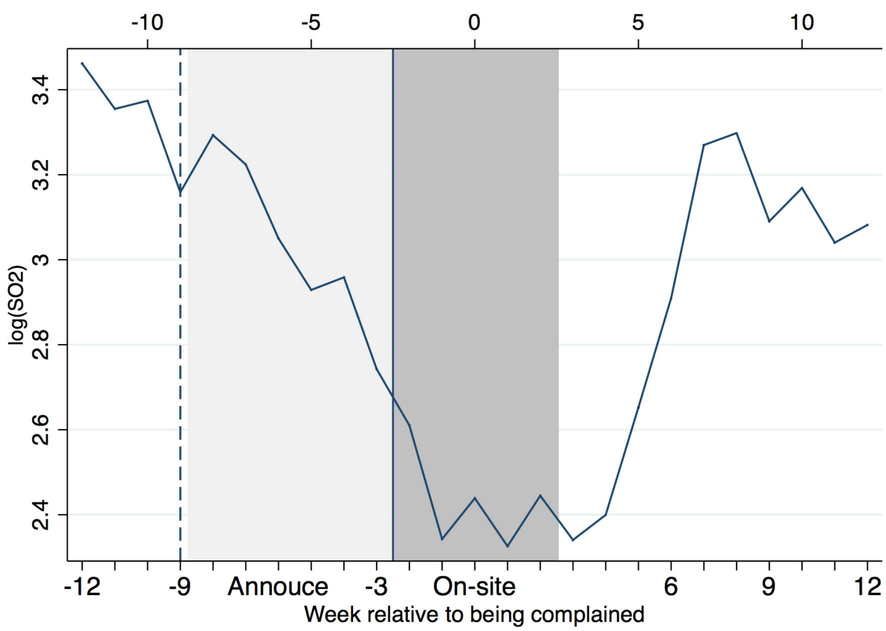


(b) Long-term

Figure A.2: Comparison of $\log(SO_2)$ concentrations at plants in treated and control cities around the inspection event window, using data for the six-province sample. The graph is centered on the timing of inspection in treated cities. Non-target cities serve as a control group in each respective round. Data covers all six provinces in our sample. Treated cities actively experience an inspection during the "on-site" period, while control cities do not. Every city appears once in the treated group and four times in the control group.



(a) Monitor-level data



(b) CEMS data

Figure A.3: Comparison of $\log(SO_2)$ concentrations at power plants during inspections using two different data sources for Henan province. Monitor-level data are ambient pollution measurements by the monitor installed nearest to a power plant, while continuous emissions monitoring system (CEMS) data are measured in the stack gases of an individual power plant. The graph is centered on the timing of receiving a complaint.

Table A.1: Within-rounds linear probability and logit model predicting treatment and control status of cities by round in the 31-province sample.

	(1) Trial Round	(2) Round 1	(3) Round 2	(4) Round 3	(5) Round 4
Linear probability model:					
demeaned baseline SO_2 ($\mu g/m^3$)	0.00171	0.000150	0.00228	0.00274	-0.00689
	(0.53)	(0.02)	(0.33)	(0.36)	(-0.88)
demeaned announce SO_2 ($\mu g/m^3$)	-0.00201	-0.000111	-0.00254	-0.00306	0.00772
	(-0.56)	(-0.01)	(-0.33)	(-0.36)	(0.89)
log(pop density)	0.0331	0.000959	0.0399	0.0483	-0.122
	(2.88)	(0.03)	(1.61)	(1.79)	(-4.37)
log(per capita)	0.000427	-0.00780	-0.0166	-0.0182	0.0422
	(0.03)	(-0.19)	(-0.49)	(-0.50)	(1.11)
Observations	333	333	333	333	333
Logit model:					
demeaned announce SO_2 ($\mu g/m^3$)	0.0616	0.000707	0.0165	0.0167	-0.0358
	(0.61)	(0.02)	(0.35)	(0.38)	(-0.82)
demeaned baseline SO_2 ($\mu g/m^3$)	-0.0682	-0.000522	-0.0184	-0.0187	0.0401
	(-0.60)	(-0.01)	(-0.35)	(-0.38)	(0.84)
log(pop density)	1.560	0.00456	0.300	0.304	-0.607
	(2.90)	(0.03)	(1.61)	(1.79)	(-4.09)
log(per capita)	-0.299	-0.0370	-0.127	-0.118	0.200
	(-0.57)	(-0.19)	(-0.54)	(-0.54)	(0.97)
Observations	333	333	333	333	333

Notes: Compares within-round using the 31-province sample. Announce SO_2 corresponds to the average SO_2 concentration in a city 1 to 6 weeks prior. Baseline SO_2 corresponds to the average SO_2 concentration in a city 7 to 12 weeks prior. t-statistics are shown in parentheses.

Table A.2: Difference-in-means and t-test statistics between plants in treated and control cities in the six-province original sample (before entropy balancing).

	(1) Trial Round	(2) Round 1	(3) Round 2	(4) Round 3	(5) Round 4
log(per capita)	0.194	0.220	-0.101	0.333	-0.255
	(4.23)	(4.83)	(-2.71)	(7.15)	(-8.58)
log(pop density)	-0.352	0.0863	-0.0199	0.580	-0.113
	(-7.35)	(1.77)	(-0.50)	(12.37)	(-3.48)
log(distance to center)	0.0815	0.192	0.233	-0.170	-0.210
	(0.86)	(2.05)	(3.06)	(-1.75)	(-3.36)
revenue share city	0.00187	0.00226	-0.00348	-0.00889	0.00409
	(0.28)	(0.32)	(-0.66)	(-1.20)	(0.90)
log(plant age)	0.00277	-0.000336	-0.00188	-0.000289	0.000380
	(3.19)	(-0.37)	(-2.76)	(-0.30)	(0.65)
Upper SOE	-0.250	-0.170	0.0950	-0.369	0.277
	(-5.49)	(-3.72)	(2.55)	(-7.97)	(9.37)
Lower SOE	0.0238	0.0533	-0.00570	0.152	-0.0941
	(0.67)	(1.50)	(-0.20)	(4.15)	(-3.97)
Baseline SO_2 ($\mu g/m^3$)	-1.073	-0.599	24.96	-24.77	-9.611
	(-0.54)	(-0.31)	(18.88)	(-11.26)	(-7.29)
Observations	973	973	973	973	973

Notes: t-statistics are shown in parentheses. Upper SOE - state-owned enterprise accountable to the central or provincial government. Lower SOE - state-owned enterprise accountable to the city or lower government.

Table A.3: Difference-in-means and t-test statistics between plants in treated and control cities in the six-province entropy-balanced sample.

	(1) Trial Round	(2) Round 1	(3) Round 2	(4) Round 3	(5) Round 4
log(per capita)	-0.0000642	-0.0000133	0.000103	0.0000266	0.00000859
	(-0.00)	(-0.00)	(0.00)	(0.00)	(0.00)
log(pop density)	0.000707	-0.00000350	-0.000170	-0.0000193	0.00000209
	(0.01)	(-0.00)	(-0.00)	(-0.00)	(0.00)
log(distance to center)	-0.00000425	-0.000000462	-0.00000113	0.00000515	0.00000147
	(-0.00)	(-0.00)	(-0.00)	(0.00)	(0.00)
revenue share city	-0.00117	0.00000305	0.000805	-0.00000494	-0.0000171
	(-0.00)	(0.00)	(0.00)	(-0.00)	(-0.00)
log(plant age)	-0.00168	0.0000617	-0.000111	-0.0000800	-0.000134
	(-0.00)	(0.00)	(-0.00)	(-0.00)	(-0.00)
Upper SOE	0.0000363	0.00000333	0.0000588	-0.00000408	-0.00000900
	(0.00)	(0.00)	(0.00)	(-0.00)	(-0.00)
Lower SOE	0.0000707	-0.00000631	0.0000492	-3.83e-08	0.00000300
	(0.00)	(-0.00)	(0.00)	(-0.00)	(0.00)
Baseline SO_2 ($\mu g/m^3$)	-0.00000226	0.000000103	-0.0000566	0.000000320	2.69e-08
	(-0.00)	(0.00)	(-0.01)	(0.00)	(0.00)
Observations	973	973	973	973	973

Notes: Compares predictors of treatment using the entropy-balanced plant sample. Entropy balancing is conducted on characteristics observed prior to the start of an inspection. t-statistics are shown in parentheses. Upper SOE: state-owned enterprise accountable to the central or provincial government. Lower SOE: state-owned enterprise accountable to the city or lower government.

Table A.4: Average effects of the announcement, on-site, and post-inspection periods in the entropy balanced and original samples, excluding plants that are permanently shut down following inspections.

	Short-term		**Medium-term**		**Long-term**			
	EB	Original	EB	Original	EB	Original	EB	Original
	(1) log(SO_2)	(2) log(SO_2)	(3) log(SO_2)	(4) log(SO_2)	(5) log(SO_2)	(6) log(SO_2)	(7) log(SO_2)	(8) log(SO_2)
Announce	-0.056	-0.042	-0.042	-0.029	-0.061	-0.028	-0.057	-0.026
	(0.042)	(0.037)	(0.041)	(0.037)	(0.039)	(0.036)	(0.039)	(0.036)
On-site	-0.271	-0.271	-0.253	-0.284	-0.249	-0.277	-0.253	-0.279
	(0.046)	(0.044)	(0.039)	(0.038)	(0.038)	(0.035)	(0.038)	(0.035)
Post	-0.177	-0.165	-0.117	-0.103	-0.061	-0.046	-0.079	-0.067
	(0.038)	(0.029)	(0.025)	(0.017)	(0.019)	(0.013)	(0.020)	(0.013)
Elsewhere	0.025	0.026	0.075	0.053	0.058	0.051	0.057	0.050
	(0.017)	(0.013)	(0.020)	(0.015)	(0.018)	(0.013)	(0.019)	(0.014)
Post 12-23 wks							-0.020	-0.012
							(0.017)	(0.018)
Post 24-36 wks							0.090	0.103
							(0.038)	(0.032)
Observations	102,914	128,826	144,720	181,731	185,667	234,101	185,667	234,101
R-squared	0.710	0.743	0.708	0.737	0.700	0.726	0.701	0.727
# of plants	967	967	967	967	967	967	967	967
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Six plants that were shut down permanently are omitted from the analysis. EB refers to estimates using the entropy-balanced sample. Baseline weeks (prior to the announcement period) are the omitted reference group. All specifications include plant, year, and week fixed effects. "Announce" refers to the announcement period, the earliest window during which a city would have learned inspectors were coming. "On-site" refers to the inspection period. "Post" refers to the period after the inspection ends. "Elsewhere" controls for an inspection underway in a non-focal province. All specifications control for plant, year, and week fixed effects, which would absorb the effect of time-invariant unobservable characteristics, plus annual policy or operational changes and seasonal fluctuations in electricity demand. Robust standard errors are given in parentheses. Standard errors are clustered at the city level.

Table A.5: Effects on NO_x at plants during the announcement, on-site, and post-inspection periods.

	Short-term	Medium-term	Long-term	
	(1) log(NO_x)	(2) log(NO_x)	(3) log(NO_x)	(4) log(NO_x)
Announce	-0.045	-0.037	-0.036	-0.039
	(0.023)	(0.023)	(0.025)	(0.025)
On-site	-0.071	-0.033	-0.048	-0.043
	(0.028)	(0.029)	(0.028)	(0.028)
Post	0.053	0.060	0.034	0.041
	(0.017)	(0.018)	(0.013)	(0.013)
Elsewhere	-0.001	0.040	0.025	0.027
	(0.018)	(0.017)	(0.015)	(0.015)
Post 12-23 wks				0.031
				(0.015)
Post 24-36 wks				-0.060
				(0.018)
Observations	80,372	113,009	144,958	144,958
R-squared	0.723	0.709	0.708	0.709
Number of plants	769	769	769	769
Plant FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes

Notes: Uses the entropy-balanced power plant sample. NO_x is a proxy for plant power output. All plants included in our subsample do not have NO_x scrubbers installed, to ensure that any changes in NO_x levels are due to fluctuations in plant output. Standard errors are clustered at the city level.

Table A.6: Effect of inspections with interactions on scrubber technology in different post period by plant capacity (MW).

	All	Cap $\leq$ 100 MW	100 MW $<$ Cap $\leq$1000 MW	Cap $>$1000 MW
	(1) log(SO_2)	(2) log(SO_2)	(3) log(SO_2)	(4) log(SO_2)
Announce	-0.055	-0.036	-0.089	-0.026
	(0.039)	(0.049)	(0.037)	(0.041)
On-site	-0.253	-0.234	-0.301	-0.207
	(0.037)	(0.044)	(0.049)	(0.048)
Post 0-11 wks	-0.338	-0.310	-0.446	-0.516
	(0.051)	(0.060)	(0.080)	(0.188)
Post 12-23 wks	-0.093	-0.100	-0.093	-0.066
	(0.025)	(0.024)	(0.029)	(0.041)
Post 24-36 wks	0.026	-0.004	0.075	0.061
	(0.033)	(0.038)	(0.043)	(0.031)
Elsewhere	0.046	0.034	0.065	0.056
	(0.016)	(0.017)	(0.022)	(0.031)
Post 0-11 wks $\times$ SO_2 Scrubber	0.196	0.197	0.263	0.377
	(0.046)	(0.050)	(0.083)	(0.190)
Observations	186,731	107,115	54,718	23,835
R-squared	0.704	0.712	0.697	0.707
Number of plants	973	571	282	116
Plant FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Week FE	Yes	Yes	Yes	Yes

Notes: Uses the entropy balanced power plant sample. Column (2) includes only firms with electricity production capacity $\leq$ 100 MW. Column (3) includes only firms with electricity production capacity $>$ 100 MW and $\leq$ 1000 MW. Column (4) includes only firms with electricity production capacity $>$ 1000 MW. Coefficient estimates are average effects over multi-week periods. Baseline weeks (prior to the announcement period) are the omitted reference group. "Announce" refers to the announcement period, the earliest window during which a city would have learned inspectors were coming. "On-site" refers to the inspection period. "Post" refers to the period after the inspection ends. "Elsewhere" controls for an inspection underway in a non-focal province. All specifications control for plant, year, and week fixed effects, to absorb the effect of time-invariant unobservable characteristics, plus annual policy or operational changes and seasonal fluctuations in electricity demand. Robust standard errors are given in parentheses. Standard errors are clustered at the city level.