Citizen Participation and Government Accountability: National-Scale Experimental Evidence from Pollution Appeals in China

Mark Buntaine* Michael Greenstone• Guojun He‡

Mengdi Liu○ Shaoda Wang† Bing Zhang▪

[March 2022]

Abstract

Countries around the world have launched public disclosure programs to stimulate citizen participation in environmental governance, yet little is known about when such participation affects regulation and pollution. We conducted a national-scale field experiment that randomly varied how citizen appeals about violations of pollution standards were sent to regulators or the violating firms. We find that, appealing a firm's violations to the regulator publicly through social media increased both regulatory oversight and firm compliance, which reduced subsequent violations by 60% and air and water pollution emissions by 12.4% and 3.8%, respectively. In contrast, appealing to the regulator through private channels only caused a marginal improvement in environmental outcomes. Additionally, we randomly varied the proportion of firms subject to appeals at the prefecture-level and find that pollution appeals filed against the treated firms are unlikely to crowd out local governments' regulation of control firms. Analysis of ambient pollution data and back-of-the-envelope calculations both suggest that encouraging more public participation in environmental governance would lead to significant improvements in China's aggregate environmental quality.

Keywords: citizen participation, environmental governance, pollution appeals

JEL: Q52; P26; P28

*University of California, Santa Barbara. Email: buntaine@bren.ucsb.edu.

• University of Chicago. Email: mgreenst@uchicgao.edu.

‡ University of Hong Kong. Email: gjhe@hku.hk.

○ University of International Business and Economics. Email: liumengdi@uibe.edu.cn.

† University of Chicago. Email: shaoda@uchicago.edu.

▪ Nanjing University. Email: zhangb@nju.edu.cn.

I. Introduction

Across the globe, billions of people live under extreme pollution, which has severe consequences for health (Greenstone et al., 2014; Greenstone and Hanna, 2014; Ebenstein et al., 2017), labor productivity (Graff-Zivin and Neidell, 2012; Chang et al., 2016; Adhvaryu et al., 2016), and welfare (Kremer et al. 2011; Currie et al., 2015; Ito and Zhang, 2020; Wang and Wang, 2020). To fight pollution, countries on several continents have launched programs to collect high-frequency, firm-level emissions data, hoping to reduce the information asymmetry between regulators and polluters.[1]

However, even though regulators are equipped with increasingly powerful tools to detect violations of pollution standards, ample evidence suggests that environmental compliance is still far from perfect: many pollution violations, despite being clearly reflected in the regulator's own data, remain unregulated. And as a result, there exists a widespread failure of governments to achieve compliance with their own environmental standards (Greenstone and Jack, 2015; United Nations Environment Program, 2019).[2] Why is non-compliance still prevalent, even when regulators already possess the key information that they need to identify violations of pollution standards? Many believe that the lack of bottom-up participation in environmental governance is a key constraint that limits effective regulation: since environmental regulations typically impose substantial economic costs (Greenstone, 2002; Greenstone et al., 2012; Walker, 2013; He et al. 2020), regulators might lack incentives to strictly enforce environmental regulations in the absence of enough public pressure.

In this paper, we focus on China – the world's largest polluter and manufacturer – where the Ministry of Ecology and Environment (MEE) maintains a Continuous Emissions Monitoring System (CEMS) that automatically collects hourly emissions data for 25,000

[1] Prominent examples of such programs include the Toxic Release Inventory (TRI) in the US, the Greenhouse Gas Reporting Program (GHGRP) in the US and Canada, the Maharashtra Star Rating Program (MSRP) in India, the Program for Pollution Control, Evaluation, and Rating (PROPER) in Indonesia, and the Continuous Emissions Monitoring System (CEMS) in China.

[2] In a meta-analysis covering a total of 251 effect sizes, Doan and Sassen (2020) find that there is a weak and negative association between environmental disclosure and firms' environmental performance.

major polluting plants nationwide, covering more than 75% of the country's total industrial emissions. While the CEMS data provides substantial new information to the MEE to identify violations, environmental compliance remains imperfect: in 2019, more than 33% of the CEMS firms committed pollution violations. This could reflect the local regulators' lack of incentives to take costly actions to audit and punish the powerful local polluters, as well as the MEE's lack of leverage to pressure the local regulators and polluters into full compliance, especially when the local regulators may have competing goals such as promoting economic growth.

To investigate when and why bottom-up, citizen participation can help hold the local regulators accountable for enforcing pollution standards, we conducted an eight-month national-scale field experiment in China. Leveraging the CEMS data, we determined the identity of all firms in violation of relevant emissions standards daily and in real time. We randomly assigned each CEMS firm to either a control arm or one of several treatment arms that involved recruiting citizen volunteers to file appeals against violations. The treatments mirrored the officially sanctioned ways that many citizens and non-governmental organizations already participate in monitoring pollution. Specifically, when a treated firm committed a violation, citizen volunteers who cooperated with our experiment filed an appeal through one of two broadly-defined channels: (1) private appeals, in which the citizen volunteers privately appealed to the regulator or the firm about the violation; (2) public appeals, in which the citizen volunteers publicly appealed about the violation on Weibo, a popular Chinese social media platform that is comparable to Twitter. We randomized treatment at the firm level, so during our eight-month experimental period, a treated firm faced the same type of intervention whenever it violated an emission standard.

We find that publicly appealing violations of pollution standards on social media significantly reduced firms' subsequent violations and emissions: firms assigned to the public appeals treatment arm committed 60% fewer violations, and their measured sulfur dioxide (SO_2) emission concentrations declined by 12.4% and chemical oxygen demand (COD) emission concentrations fell by 3.8% during the 8-month study period, relative to control firms. In contrast, privately appealing to either regulators or the firms themselves, even when using essentially the same content and wording as the public appeals, only led to a marginal improvement in the firms' environmental performance, regardless of the specific channel through which the private appeal was delivered. The different impacts of appeals filed through private and public channels highlight the central role of publicity in determining the impact of bottom-up citizen participation.

We investigate the potential channels through which public appeals reduced violations of pollution standards. We find suggestive evidence that making appeals public increased effort by regulators: when we randomly increased the visibility of a social media appeal about a violation by adding "likes" and "shares" to the Weibo post, local regulators became significantly more responsive and were 30% more likely to conduct an onsite investigation of the violation. We also find evidence against several other potential mechanisms, including that the treatments generated more appeals by other citizens outside of the experiment or that they caused firms to manipulate CEMS data.

Moreover, we find that the pollution appeals filed against the treatment firms did not crowd out local governments' regulation of control firms. Specifically, following Crepon et al. (2013), we cross-randomized treatment intensity at the prefecture level. In 60% of the prefectural cities, we assigned up to 95% of the CEMS firms to be treated, while in the other 40% of the prefectural cities, we assigned 70% of the CEMS firms to be treated. This double randomization design allows us to causally identify the spillover effects of citizen participation by comparing violations and emission concentrations of the control firms between the high-treatment-intensity and low-treatment-intensity prefectures. The estimates, while imprecise, are most consistent with either no spillover effect or a positive spillover effect on the compliance of untreated firms. This suggests that more citizen participation does not just prompt a reallocation of regulatory effort, but rather increases overall compliance.

Based on our experimental estimates, we infer the likely impacts of scaling up citizen participation in environmental governance. Our conservative calculations show that putting all CEMS firms under public scrutiny would reduce pollution violations by more than 35%. The economically significant returns to public participation in environmental governance are also reflected in aggregate pollution levels: according to data collected by national air monitoring stations, which are independent from the CEMS, high-treatment-intensity prefectures experienced an additional 3.7% drop in ambient SO_2 levels during our experimental period, relative to prefectures treated at lower intensity.

This paper makes four contributions. First, this national-scale experiment allows us to offer unique insights about when and how citizen participation affects governance. Citizen participation has long been promoted as the key to improving government accountability and public service delivery, especially in policy areas that are directly related to citizen welfare (Stiglitz, 2002; Mansuri and Rao, 2004; World Bank, 2004). However, the existing empirical literature has found mixed evidence on the effectiveness of public participation on governance outcomes (Kremer and Vermeersch, 2002; Olken, 2007; Banerjee and Duflo, 2006; Bjorkman and Svensson, 2009; Banerjee et al., 2010; Duflo et al., 2011; Grossman et al. 2018; Buntaine et al. 2021), and there exists little direct evidence on the underlying mechanisms through which public participation may or may not improve government accountability.

While participation by citizens and non-governmental organizations in environmental governance is now commonplace in China and elsewhere, the empirical literature mostly tracks governmental responsiveness to participation (Anderson et al. 2019; Colmer et al. 2022). We provide evidence connecting citizen participation, governmental responsiveness, and environmental outcomes, showing how participation can meaningfully decrease pollution. Additionally, the unprecedented scale of our experiment permits us to vary the publicity, channel, and target of citizen appeals and thereby provide new insights into when and why citizen participation affects regulatory and pollution outcomes.

Second, we add to the discussion on the roles of big data and monitoring technology in modern governance. While a growing literature has documented cases where increased information can improve the effectiveness of governance and thus benefit the public (Orphanides, 2001; Muralidharan et al., 2016; Greenstone et al., 2021), it has also been shown that information might fail to cause such improvements when there are misaligned incentives between the government and the public (Duflo et al. 2013 and 2018). Specifically, in the context of environmental regulation, the existing literature has found that collecting and disclosing detailed firm-level emissions data, while theoretically empowering the regulators with information needed to identify violations, have only mixed impacts (Konar and Cohen 1997; Foulon et al., 2002; Hahn et al., 2003; Bui and Mayer, 2003). Our paper contributes to this line of work by showing that public participation, which holds the government accountable to the public when the two have conflicting interests, can help ensure that information and monitoring technology benefit the public.

Third, we add to the literature on the political economy of environment. Existing work in this area has mostly focused on the strategic behavior of politicians in determining and implementing environmental policies (List and Sturm, 2006; Kahn et al., 2015; Jia, 2017, Greenstone et al., 2020), or the strategic interactions among local governments over environmental externalities (Burgess et al., 2012; Lipscomb and Mobarak, 2016; He et al., 2020; Wang and Wang, 2020). In this paper, we provide experimental evidence on how pollution appeals by citizens hold local governments in China accountable in enforcing existing environmental standards. More generally, this paper also relates to the literature on the cost and benefit of different environmental policies (Henderson 1996; Becker and Henderson 2000; Walker 2013; Ryan 2012; Kahn and Mansur 2013): our results demonstrate that mobilizing the public to engage in monitoring the performance of governments and firms might be a cost-effective way to improve compliance with existing environmental laws (although whether the existing environmental laws are optimal or sufficient is beyond the scope of this paper).[3]

Fourth, this paper bridges two strands of literature on the political economy of China's local governance model. The existing literature has pointed out that local governments in China have incentives to facilitate growth and provide support to the firms through both formal and informal institutions (Qian and Weingast, 1997; Xu, 2011; Bai et al., 2020); and when dealing with the citizens, Chinese local governments have strong incentives to maintain local stability (Chen, 2012; Lorentzen, 2013; Campante et al., 2019). Our paper

[3] Relatedly, this paper clarifies the pathways by which transparency and information disclosure affect government and firm behavior. Increasing the amount of information disclosed to the public has become a common policy to improve regulatory and government performance (Gavazza and Lizzeri 2007; Mattozzi and Merlo 2007; Reinikka and Svensson 2011). Previous research focusing on disclosures about firms has focused on how transparency affects market capitalization (Konar and Cohen 2001; Bui and Mayer 2003). We provide evidence of a key alternate pathway that allows information disclosure to affect regulatory outcomes: by allowing the public to hold governments accountable for implementing policies effectively.

connects these two lines of literature by documenting the interactions between the state-citizen relationship and the state-business relationship: when the public gets more involved in China's process of environmental governance, the regulatory relationship between government and polluting firms is reshaped, which results in increased governmental effort and better compliance by firms. Investigating the interactions between firms, citizens, and the state in a synthesized framework deepens our understanding of China's system for local governance.

The remainder of this paper proceeds as follows. Section II introduces the institutional background. Section III discusses our experiment and data. Section IV presents the main empirical findings, while Section V investigates the underlying mechanisms. Section VI discusses the economic significance of our findings. Section VII concludes.

II. Institutional Background

In this section, we introduce the institutional background for our field experiment. In Section II.A, we explain the development of citizen participation in environmental governance in China. In Section II.B, we discuss China's continuous emissions monitoring system.

A. Public Participation in China's Environmental Governance

In the late 1990s and early 2000s, after two decades of rapid economic growth and industrialization, China faced severe air and water pollution problems, which caused increasing social unrest and protests across the country (Jing, 2000; Steinhardt and Wu, 2016). When President Hu Jintao took office in 2002, the central government launched a series of environmental policies and reforms, which mostly aimed at incentivizing local governments to tackle pollution, such as by setting explicit environmental performance targets for local officials (He et al., 2020), constructing automatic local pollution monitoring stations (Greenstone et al., 2020), and allowing local governments to charge pollution levies on large emitters (Gowrisankaran et al., 2020).

In addition to these "top-down" command-and-control type approaches to environmental protection, the central government also explicitly encouraged "bottom-up" initiatives in the form of citizen participation. Specifically, in 2006, the Ministry of Environmental Protection (MEP) issued the "Interim Measures for Public Participation in

Environmental Impact Assessment," which emphasized the legal rights of citizens to get involved in making and implementing environmental policies.

Also in 2006, the MEP established the "12369 Environmental Appeals Center," which hosted an official national hotline (under the phone number 12369) that allowed citizens across the country to make environmental appeals against potential violations of pollution standards. Later, the MEP expanded the 12369 platform to include an official website. It also instructed each prefectural city's environmental protection agency (EPA) to open an office to address appeals.[4] Nowadays, when a citizen makes an appeal via the 12369 platform, either by calling the hotline or leaving a message on the website, her appeal will be directed to the corresponding local EPA, which has legal responsibilities to investigate and issue fines to the polluter if a violation is confirmed. Between 2017 and 2019, the 12369 platform received a total of 1,860,149 appeals, 56% of which arrived by the hotline, and the rest by the online platform.

In 2014, as part of China's grand "war on pollution," the central government released several additional policy documents that explicitly encouraged citizen participation in environmental protection, including the "Guiding Opinions on Promoting Public Participation in Environmental Protection" and the "Measures for Public Participation in Environmental Protection." In addition to reiterating the importance of the existing official channels for citizen participation in environmental protection, these policy documents laid out new channels that the public could use to participate in the enforcement of environmental policies. Specifically, the MEP required the prefectural EPAs to set up official accounts on popular Chinese social media platforms, namely Weibo and WeChat, to make it easier for the public and local EPAs to communicate. As of December 2017, all local EPAs in China's 338 prefectural cities operated official Weibo and WeChat accounts. In the past few years, an increasing number of citizens and NGOs have used the Weibo and WeChat platforms to express their dissatisfaction with violations of pollution standards (Wu et al., 2021). Specifically, between 2014 and 2016, we identified 5,336 Weibo posts appealing against alleged violations by CEMS firms, 1563 of which posted by NGOs, and the rest by individual citizens. In 2018, a Jiangsu-based NGO named Public Environmental Concerned Center (PECC) filed 1579 public appeals on Weibo based on pollution violations identified from the CEMS data.

[4] The online appeal platform can be accessed via: http://1.202.247.200/netreport/netreport/index

Each prefectural EPA typically has a specific clerical staff member assigned to handle citizen appeals, including those filed via the 12369 platform, and the Weibo and WeChat accounts. Upon receiving an appeal, the staff member routes it to relevant offices in the EPA. Then, local enforcement teams decide what to do about the appeal. Sometimes, they may just call the polluting firm and collect relevant information. If they consider the case to be more severe, however, a team of inspectors will investigate the matter in the field. Once a conclusion is reached, the EPA will file a case report and decide whether the report can be shared with the person making the appeal. The EPA has significant discretion in levying penalties against violations.

B. China's Continuous Emissions Monitoring System

In 2004, to improve the quality of environmental management, the MEP launched a nationwide, automatic system of environmental monitoring that targeted key polluting firms. The system consisted of the installation of automatic monitoring equipment and the creation of a monitoring center to process the data. Automatic monitoring equipment includes apparatuses and flow (current) meters installed on the site of pollution sources to monitor pollutant discharges, CCTVs covering all pollution prevention and control facilities, data collection and transmission apparatuses, and other related facilities. Each local EPA houses a monitoring center that automatically collects data for each key pollutant from each installed meter in real time.

The CEMS monitors the emission concentrations of both water pollutants (COD and NH_3-N) and air pollutants (SO_2, PM, NO_X), and covers all the key polluters in China. Whether a firm is considered as a key polluter depends on its pollutant emissions in the previous two years. For example, to determine which water-polluting firms should be included in the CEMS list in 2019, the MEP examines all the water-polluting plants documented in the Chinese Environmental Statistics (CES) in 2017 and 2018, and ranks them by their COD and NH_3-N emissions in these two years. Those plants who rank above a certain cutoff are included in the 2019 CEMS list. Overtime, the MEP has lowered the cutoffs and expanded the CEMS coverage. As of January 2020, the CEMS program monitored more than 24,620 plants that collectively accounted for more than 75% of China's industrial air and water pollutant emissions.[5]

[5] While China currently operates the world's largest CEMS system, other countries use similar systems for various regulatory purposes. For example, the United States EPA and many state governments require firms

While the CEMS started collecting data in 2004, prior to 2013, the data was only shared internally with the government and the monitored firms. In 2013, to increase transparency and to facilitate citizen participation in environmental governance, the MEP released the "Measures for the Self-Monitoring and Information Disclosure of National Key Monitoring Enterprises (Trial)," which required each provincial and prefectural EPA to establish a Continuous Emissions Monitoring System (CEMS) and publicize in real time the hourly emissions data of every monitored plant to the public. The publicized CEMS data also includes standards for emission concentrations, which allows the public to check whether each plant violates its permitted standards each hour.

The MEP exerts substantial effort to ensure the quality and authenticity of the CEMS data. First, the list of CEMS firms is publicized on the MEP website, so that local governments cannot omit any CEMS firm from the publicized emission data. Second, the MEP has strict protocols for the installation and operation of the CEMS equipment. Installation must be conducted by a third-party team designated by the MEP and 24-hour CCTVs are installed near the monitoring equipment to ensure that the plant cannot interfere with the equipment. Third, the MEP uses various algorithms and technologies to detect abnormalities and inconsistencies in the CEMS data and hosts monthly supervisory sessions to discuss any anomalies that are detected with the local EPAs. Fourth, the MEP requires on-site inspections at least once a month to ensure the proper functioning of the automatic monitoring equipment and the proper compliance of the firms. Because of these efforts, the polluting plants and local EPAs have very limited scope to interfere with the CEMS, which ensures that the publicized emission data is high quality.

Despite the central government's efforts to collect and publicize high-quality data, under the current environmental law, it needs to rely on local regulators to enforce pollution standards. Specifically, if the CEMS data indicates that a firm violates an emissions standard, the environmental law requires that the local EPA conduct an onsite investigation to confirm the violation before punishing the firm. In addition, to take tougher measures against the firm's violation, such as issuing a large fine or a temporary

to install CEMS equipment to demonstrate compliance with permitted emission levels (United States EPA 2021). In India, specific provinces have started to require firms to install continuous monitoring equipment to support emissions trading (Greenstone et al. 2020). Likewise, the European Union has made continuous emissions monitoring support operation of its Emissions Trading Scheme (EU 2021). Yet, none of these schemes have approached the scale of the CEMS in China, where it is used as a systematic regulatory tool for all key industrial polluters.

shutdown, the local EPA needs to issue a warning in its first onsite visit to the firm, and then catch the firm violating again in a second onsite visit in the subsequent month. Given the non-trivial effort required by local regulators in this process, the information asymmetry in enforcement details between the central government and the local regulators, as well as large polluters' potential ability to defy or even capture the local regulators, it is not surprising that disclosing the CEMS data alone does not lead to perfect compliance. Additionally, both the central and local governments have competing goals of maximizing production and controlling pollution, and thus likely seek to maintain some flexibility in applying emissions standards, especially when violations do not cause significant public discontent.

In Figure 1, we plot the percentage of CEMS firms violating emission standards daily between 2018 and 2021. In January 2018, around 4% of CEMS firms violated air emission standards on any given day, and 1% violated water emission standards. In the following three years, the rate of daily violations for both water and air pollutants declined steadily. This pattern is consistent with China's overall improvement in ambient air quality and water quality since 2014. However, in 2019, the year before our experiment, around 2% of CEMS firms violated air or water pollution standards on any given day, amounting to more than 180,000 total daily violations. Bringing these firms into compliance with standards would significantly improve China's environmental quality: if violating firms reduced pollutant concentrations to just below the standards in 2019 (assuming no change in emission flows), SO_2 emissions would drop by 279,000 tons, a 7% reduction in aggregate industrial SO_2 emissions in China; and COD emission would drop by 31,000 tons, a 4% reduction in aggregate industrial COD effluents.

III. Experiment and Data

In this section, we describe our field experiment and data. In Section III.A, we discuss the experimental design. In Section III.B, we provide the details of the implementation of the experiment. In Section III.C, we introduce the data and present balance tests across the experimental arms.

A. Experimental Design

Using the publicized CEMS data, we developed an algorithm that identified in real-time all firms violating their emission standards, based on their average emission concentrations of pollutants in the previous 24 hours, which was consistent with the official definition of pollution violations set by the Ministry of Ecology and Environment (MEE).[6] We then employed a group of environmental science graduate students to manually double-check each identified violation. After a violation was confirmed, citizen volunteers recruited for the experiment filed an appeal through different channels according to each firm's assigned treatment. We discuss the ethical considerations with the design and implementation of the experiment in Appendix C.

Our experimental design is illustrated in Figure 2. We randomly assigned the CEMS firms to three broad groups of experimental arms: the control group (C), the "private appeals" group (T1), and the "public appeals" group (T2). Within the groups of experimental treatments, we assigned firms to sub-treatment arms to help investigate the underlying mechanisms of the effects. The treatments mirror existing and approved ways that citizens participate in environmental governance and allow us to study the effects of different types of engagement that cannot be easily observed or identified observationally. We use the following experimental arms:

- **Control Group (C):** When the CEMS data indicated that the firm violated its emission standards, we *did not* intervene in any way. About 1/7 of the CEMS firms were assigned to this group.
- **Private Appeals Group (T1):** When the CEMS data indicated that the firm violated its emission standards, a citizen volunteer filed a private appeal against that violation that was not observable by the general public. About 5/7 of the CEMS firms were assigned to this group. Specifically, these private appeals were delivered in several different ways following the MEE's recommended channels for citizen participation in environmental monitoring:[7]
    - **T1A: sending direct message to regulator on social media.** A citizen volunteer sent a *private* message to the corresponding local EPA's official Weibo account, notifying them about the pollution violation and requesting that they check the issue.

[6] The MEE was established in 2018 in replacement of the MEP.

[7] Admittedly, our interventions cannot exhaust all the possible channels through which private pollution appeals can be filed. Nevertheless, we believe that the subset of appeal channels that we choose are the most common types of private pollution appeals in China. They were also explicitly endorsed by the MEE itself in its guidelines for citizen participation in environmental governance.

- **T1B: appealing to regulator on government website.** A citizen volunteer filed a *private* appeal via the 12369 website to the corresponding local EPA, notifying the local EPA about the violation and requesting that they check the issue.
- **T1C: appealing to regulator by calling government hotline.** A citizen volunteer called the 12369 hotline to *privately* appeal to the corresponding local EPA. In the phone call, she notified the local EPA about the violation and requesting that they check the issue.
- **T1D: appealing to firm by phone call.** A citizen volunteer called the violating firm to *privately* appeal the violation. In the phone call, she notified the firm about its violation and requesting that they check the issue.

Furthermore, we cross-randomized T1C and T1D, such that half of the firms receiving T1C also simultaneously received T1D, and *vice versa*.

- **Public Appeals on Group (T2):** When the CEMS data indicated that the firm violated its emission standards, a citizen volunteer wrote a post on Weibo (a popular Chinese social media platform comparable to Twitter), and "@" the official Weibo account of the corresponding local EPA. The post appealed to the EPA about the violation and demanded that the EPA check on the issue. The content and wording of the appeal was consistent with T1. We assigned 1/7 of the CEMS firms to this group.
    - **Appeal-level randomization of publicity:** within T2, we also randomly promoted the publicity of Weibo appeals, by hiring an outside social media firm to increase the number of "likes" and "retweets" for a randomized half of the Weibo posts.

For each arm, we prepared a detailed script for the citizen volunteers to follow. The core content of these scripts remained consistent across T1 and T2, while we randomly varied the exact wording in each appeal to avoid appearing repetitive to the regulator or firm. Samples of these appeal scripts are translated and listed in Appendix B. Our main outcomes of interest include each firm's daily violation status and daily average emissions concentrations during our sample period.

Under this experimental design, the differences between the treatments in T1 and C identify the causal effects of *privately* appealing against violations through various channels, and similarly, the difference between T2 and C identifies the causal effect of *publicly* appealing about violations on social media. The comparison between the treatments in T1 and T2 thus identifies the relative effectiveness of private appeals vs. public appeals.

Additional design features of our experiment allow us to examine the potential channels through which publicity might reduce violations. First, we test whether more publicity incentivized the government to exert more effort at enforcement by cross-randomizing the publicity of the Weibo appeals (T2): by randomly adding "likes" and "retweets" to half of the Weibo posts, which made them substantially more visible to other Weibo users, we can investigate whether the local EPA's responsiveness and regulatory efforts vary according to the level of publicity.

Second, since public appeals (T2) could simultaneously reach the regulator and the violating firm, their impact could result from making both parties respond to the citizen dissatisfaction with violations, which effectively combines the impacts of separately appealing to each of these two parties. To investigate this possibility, we cross-randomized T1C (calling regulator to appeal) and T1D (calling firm to appeal), such that half of the firms in T1C also simultaneously received T1D, and *vice versa*. We can thus test whether firms that received both T1C and T1D exhibited larger treatment effects relative to firms that only received either T1C or T1D alone.

We also experimentally investigate the spillover effect of pollution appeals, the sign of which is ambiguous *ex ante*. On the one hand, it is possible that when a subset of the CEMS firms receive constant attention from the public, they will be less likely to violate emission standards, but they may also crowd out the regulatory resources that would have otherwise been allocated to non-treated polluting firms in the same region. If that is the case, then public appeals would have a negative spillover effect and lead to more violations from the non-treated firms. On the other hand, public participation might also create a positive spillover effect by: (1) making local governments positively adjust their beliefs about the level of the public's dissatisfaction with the enforcement of environmental regulations in their jurisdictions and enforce regulations more stringently on all firms; and (2) changing the expectations of non-treated firms about the likelihood of enforcement after observing peers being regulated more stringently and therefore making them more willing to comply with standards.

To examine the direction and the magnitude of the spillover effects of the citizen participation, we cross-randomize treatment intensity across different regions: in 60% of the prefectural cities, 95% of the CEMS firms were assigned to the treatment groups, while in the other 40% of the prefectural cities, 70% of the CEMS firms were assigned to the treatment groups. This "double randomization" design allows us to causally identify the spillover effects of citizen participation by comparing the control firms across the high- and low-treatment-intensity regions.

B. Experimental Implementation

As of 2020, the CEMS covered a total of 24,620 polluting firms, which we randomly assigned to experimental treatments. In January 2020, we collected the phone number of every CEMS firm, and the official Weibo account of every local EPA. Between January and March 2020, we trained research assistants to identify and verify violations of emissions standards, and trained citizen volunteers to file appeals via different channels following the experimental assignments. We conducted a small-scale pilot in April to ensure all the research assistants could complete the daily tasks on time. The treatment period started on May 6, 2020, and ended on December 31, 2020. During the treatment period, we identified more than 12,000 pollution violations by more than 2,000 CEMS firms. During the treatment period, the daily procedure involved three main steps: (1) identifying and verifying CEMS firms that violated the emission standards based on the pollutant concentrations in the past 24 hours; (2) filing different types of appeals as defined by the treatment assignments; and (3) documenting any government responses to the appeals.

For the first step, every morning, our algorithm automatically identified firms that violated the national emission standards based on their daily average concentration of pollutant emissions. The CEMS equipment often continues to run immediately after production is suspended, and since there is little air flow during this period, emission concentrations can be abnormally high for a short period of time. To rule out data errors caused by suspended production and other mechanical spikes, every morning we had eight trained research assistants blinded to treatment assignment, who are graduate students majoring in environmental science, carefully check the automatically identified violations, and then eliminate those abnormal concentration levels reported in the data, based on complementary indicators such as oxygen demand and water/gas flows. Once the research assistants confirmed the list of firms that violated the emission standards in the past 24 hours, they took screenshots from the CEMS webpages as proof (see Appendix B for details). This process was time-consuming and each of our research assistants needed to spend 4 to 5 hours a day to screen and verify the violations from different provincial CEMS websites.

For the second step, after we compiled the list of pollution violations and gathered relevant evidence, we generated appeals based on each firm's assigned treatment. We assigned the appeals to a field team consisting of citizen volunteers, whom we recruited through a partnering environmental NGO. The volunteers filed the appeals, using the contents and instructions that we provided them. Specifically, every day, once we generated the content of the appeals, we randomly assigned the task of appealing to the volunteers. To ensure nearly perfect compliance with the implementation protocol (reporting by phone is limited to the working hours of the receiver), we gave each volunteer no more than 10 appeals per day. In Appendix B, we lay out the implementation protocol in greater detail and provide screenshots to visualize the appeals made by the citizen volunteers in each arm. For a randomized subset of the Weibo appeals, we hired an external social media promotion company to boost their publicity. Specifically, the company operates many active Weibo accounts, which they used to add roughly 10 "likes" and "retweets" to randomly selected Weibo appeals that were part of the experiment. On average, a promoted Weibo appeal attracts 10.15 likes and retweets, while a non-promoted Weibo appeal has 0.34 likes and retweets.

For the third step, following the appeals, the citizen volunteers tracked the responses from the local governments, which come back as Weibo direct messages, Weibo public replies, 12369 phone calls, 12369 website replies, among other possible channels. We recorded the timing and content of each government response and matched them to the corresponding pollution appeal.

C. Data and Balance Tests

We use several data sources in our analysis. First, from the MEE, we obtained access to the universe of CEMS data in 2020, which covers 24,620 heavy polluters in China, with information on firm name, firm social credit code, industry, main pollutant type, hourly emission concentrations of various pollutants, hourly gas and water flows, pollution violation status, among other measures. In 2020, due to the COVID-19 lockdown, most CEMS firms suspended production until the economy reopened in mid-March. Therefore, throughout this paper, we drop the first 10 weeks of the 2020 CEMS data from our sample.[8] We match the official CEMS data to our experimental data, including intervention type, appeal content, visibility, and response by government.[9]

Second, we have access to data on the universe of pollution fines in 2020, which is maintained by the MEE. From these data, we can observe every pollution fine issued by a local EPA to a polluter, which we matched to the CEMS data based on firm name.

Third, also from the MEE, we obtained the records of all citizen appeals through 12369 website and phone made against the CEMS firms in 2020. By excluding our own appeals, we can count the number of appeals made by other citizens regarding each violation, which allows us to examine whether our appeals crowded out or crowded in appeals by the public.

Fourth, from the Ministry of Commerce, we obtain administrative data on firm registrations, which contain information on unified social credit code, date of establishment, industry, business address, business type, registration status, among other measures. We match the firm registration data to all the CEMS firms based on social credit code, and classify the CEMS firms into different industries.

In Table 1, we conduct balance tests across the experimental arms. In Column (1), we present the mean and standard deviation of the control group, along with important pre-treatment variables, including levels of violations, emission concentrations, hours of operations, and industry type. We then compare each treatment arm to the control arm, implemented by running a regression of each outcome variable on a group of treatment dummies. In Columns (2) to (7), we present the regression coefficients and standard errors for each variable-arm combination. As we can see, the treatment arms are well balanced with the control arm along almost all dimensions, confirming that our randomization was well executed. In Appendix Table A1, we also report the detailed breakdown of industries by experimental arm.

---

[8] Note that from mid-January to mid-March 2020, China was struck by COVID-19 and many CEMS firms suspended their production due to compulsory lockdowns. By late March 2020, however, almost all Chinese cities re-opened because COVID-19 was already under control. During our experimental period, production fully resumed and firms operated as usual.

[9] For analysis, we use the official CEMS data provided annually by MEE, rather than the data published daily on the provincial government websites used to identify violations. The official data from MEE are more complete and have been cleaned of basic errors that can sometimes appear in the real-time data.

IV. Empirical Results

In this section, we present the empirical findings. For the baseline analysis, we estimate the following econometric model:

$$Y_{ijt} = \sum_j \alpha_j T_{ij} \cdot Post_t + \gamma_i + \eta_t + \epsilon_{ijt} \quad (1)$$

where Y_{ijt} is the outcome of interest for firm i, assigned to arm j, on day t. T_{ij} represents the randomly assigned arm of firm i; $Post_t$ is a dummy variable that equals one if the experiment has already started by day t,[10] and zero otherwise; γ_i stands for firm fixed effects, and η_t stands for day fixed effects. Since we cross-randomize treatment intensity at the prefecture level, to control for regional dynamics of regulation enforcement, we also estimate more saturated specifications controlling for province-by-day fixed effects. The standard error is two-way clustered at the prefecture and week levels.

In Section IV.A, we present the baseline findings. In Sections IV.B, we present the findings on emission concentrations. In Section IV.C, we discuss the robustness of our baseline findings.

A. Pollution Appeals and Environmental Performance

We first investigate the impacts of the interventions on firms' environmental performance. The main outcome variable is $violation_{ijt}$, which is a dummy variable indicating whether firm i committed any pollution violation on day t. Using Equation (1), we estimate the effects of different types of appeals on emission violations.

Table 2 summarizes the results. In Panel A, we present the impacts of all treatment arms relative to the control arm. Different types of private pollution appeals show minimal to modest effectiveness in reducing pollution violations. In contrast, public pollution appeals on social media lead to large and significant reductions in firms' pollution violation rates. These results are robust to controlling for different sets of fixed effects. According to the conservative specification controlling for province-by-day FE, firms under the public appeals treatment on average commit 0.0058 fewer pollution violations per day, representing a roughly 60% reduction from the baseline daily violation rate. For any given private appeals arm, we can reject the null hypothesis that the public appeal is not more effective at the 1% level.

[10] The week of May 7th is the 18th week of the year. Since the first 10 weeks are excluded from our sample due to COVID lockdown, the pre-treatment period corresponds to the first 7 weeks in our sample.

The difference between private and public appeals becomes clearer when we combine all the differentiated private appeal arms into a bundled experimental group for private appeals (T1), and compare its average effectiveness relative to the control group (C) and the public appeals group (T2) in Panel B. As we can see, across both specifications, public pollution appeals are significantly more effective than the pooled group of private appeals treatments in reducing violations.

To understand the dynamic effects of citizen participation, we also estimate an event-study model that investigates how the trends of pollution violations evolve before and after the start of our experiment. As shown in Figure 3, for both the private and public appeals groups, the treatment firms followed similar trajectories as the control firms prior to the start of our experiment, confirming that our randomization was well executed. After the start of our experiment, firms in the various "private appeals" treatments had only modest breaks in trends relative to the control firms on average. But firms assigned to the "public appeals" arm experienced a sharp decline in violations after the start of the experiment, which became statistically significantly lower than that of the control group after five weeks, and remained so until the end of our eight-month experimental period. This initial gradual decline in violation rate is consistent with the fact that a firm needed to first commit at least one violation to trigger its assigned appeal intervention, and only then would the firm realize that its pollutant emissions are under the scrutiny of citizens. We also disaggregate T1 and present the trends of each sub-treatment arm, which show similar patterns.

B. Pollution Appeals and Emission Concentrations

Our baseline findings suggest that on the extensive margin, private appeals marginally reduce violations, while public appeals make firms significantly less likely to violate the emission standards. To quantify the environmental consequences of the reduction in pollution violations, in this section, we examine the intensive margin and investigate how private and public appeals affect the average emission intensity of the CEMS firms.

Our econometric model for this exercise is still Equation (1), where the outcome variable is now the firms' daily emission concentrations for a given type of pollutant. We focus on two main pollutants: SO_2 for air pollution, and COD for water pollution, as these two have the most comprehensive coverage for CEMS firms and are the most high-stakes "criterion pollutants" initially assigned by the MEE to evaluate the environmental performance of local government officials (He et al., 2020).

As shown in Table 3, the emission patterns are consistent with the violation results: firms do not significantly reduce their emission concentrations if they are assigned to one of the private appeals treatments but do so when assigned to the public appeals arm. According to our preferred specification controlling for prefecture-by-day FEs, public appeals reduced the average firm's daily average SO_2 emission concentration by 16.53 ug/m^3, and its daily average COD emission concentration decreased by 2.23 ug/L, representing 12.4% and 3.8% drops from the baseline SO_2 and COD emission concentration levels, respectively. These estimates suggest that public appeals lead to economically significant improvements in environmental outcomes.

While the CEMS does not directly report hourly data on total emissions, we infer the changes in total emissions by investigating the hourly gas/water flows reported by the CEMS, which can be linked to the emission concentrations to back out the total amount of emissions per hour for each pollutant type. As shown in Appendix Table A2, the flow of pollutants barely had any differences across various experimental arms, which indicates that changes in emission concentrations also reflect changes in total emissions.

Again, we estimate event-study models to understand the dynamics of the effects on emissions. As illustrated in Appendix Figure A1, for the treatments in the private appeals group, there are no visible breaks in trends relative to the control group following the start of the treatment period. Firms in the public appeal arm had similar trends to the control firms prior to treatment but showed significantly lower emission concentrations afterwards. These patterns are consistent with the reduction in pollution violations described in Section IV.A.

We further investigate the impacts of public pollution appeals on the distribution of emission concentrations. Specifically, we first standardize the emission concentrations by dividing the emissions data by firm-pollutant-specific emission limits set by the MEE, and then categorize the standardized emissions data into different bins. By regressing a dummy variable for each bin on our interventions following the same baseline econometric specification, we can thus infer how pollution appeals affect the distribution of emissions for the CEMS firms. As shown in Figure 4 Panel (a), public appeals make firms less likely to commit substantial violations where their emission concentrations surpass the national limits by more than 100%. Instead, public appeals make these firms more likely to have emission concentrations more than 50% below the national limits. In Panel (b), we adjust the dummy for each bin by dividing it by the frequency of firms falling in that bin, which takes into account the fact that the "violation bins" have fewer observations than the "compliance bins." After this adjustment, the coefficients in Panel (b) represent the percentage change in firms' likelihoods of falling into each bin. As we can see, the adjusted results confirm that, public pollution appeals had the largest impact on the most severe pollution violations.

C. Robustness Checks of the Baseline Findings

Our main findings are robust to various alternative specifications. First, it is worth noting that, Equation (1) is estimating an intention to treat effect: α_j reflects a firm's reduction in daily pollution violation rate when it is assigned to arm j. Due to the nature of our interventions, a firm would only be "treated" after it commits at least one pollution violation. And since around 70% of the CEMS firms did not commit any pollution violation during our 8-months experimental window, the intervention was never triggered for these firms. In Appendix Table A3, we re-run the main analysis using only the subsample of firms that ever committed any violation. As we can see, the treatment on the treated results are consistent with the intention to treat results, and by construction, the magnitude of the estimated coefficients are substantially larger. In Appendix Table A4, we also stratify by whether each firm committed any violation during the pre-treatment period, and the findings remain the same.

Second, in the baseline analysis, we use the panel dataset with pre-treatment period observations and exploit within-firm changes in violation rates over time to maximize precision. Instead of estimating this panel model, we can also estimate an alternative cross-sectional model, in which we compare, across different arms, the total number of pollution violations committed by firms during our 8-month experimental period. As shown in Appendix Table A5, the main findings are maintained in this alternative specification, albeit with less precise estimates.

Third, in the baseline analysis, we defined pollution violations based on whether the monitored emission concentration exceeded the standard value set by the MEE. However, it is possible that some of these monitored values are driven by mechanical errors or production suspensions, instead of actual pollution violations. To examine the robustness of our findings with respect to the definition of pollution violations, in Appendix Table A6, we refine the definition of pollution violations to exclude cases with minimal levels of measured air flows. Using the refined subsample to re-run the baseline regressions leads to quantitatively similar results.

Fourth, we separately estimate the baseline results for state-owned enterprises (SOEs) and private enterprises. As shown in Appendix Table A7, the baseline empirical patterns are present in both subsamples, with the effectiveness of public appeals almost doubling in size for the SOEs.

V. Mechanisms

As discussed in Section IV, our baseline results show that public pollution appeals significantly improve the CEMS firms' environmental performance. The combination of our experimental design and other datasets allow us to investigate channels through which the *publicity* of pollution appeals reduced violations. In this section, we examine these channels respectively.

A. Public Appeals and Government Incentives

The first channel we investigate is that the public visibility of appeals incentivizes local governments to exert more effort in enforcing standards. To test this possibility, we randomly increase the amount of "likes" and "retweets" for half of the public appeals posted on Weibo, which creates exogenous variation the how visible appeals are to other Weibo users.

We examine whether local regulators respond differently based on the amount of publicity an appeal is assigned on Weibo. As shown in Table 4 Columns 1 and 2, when a Weibo appeal is randomly promoted, the local government's response rate to the post increases by 9%, representing a more than 60% increase from the baseline level. In addition, as shown in Columns 3 to 6, when a Weibo appeal is randomly promoted, the government is significantly more likely to conduct an on-site investigation of the violation before responding and writes significantly more words in its response to the submission. These results suggest that more publicity significantly increases local governments' responsiveness and effort to regulate pollution.

B. Public Appeals and Firm Compliance

Another possibility is that, by posting pollution appeals on social media, both the regulator and the firm become aware of public dissatisfaction about the firm's violation. To the extent that the effects of appealing to the regulator and appealing to the firm are additive, being able to reach both parties could be a reason why public appeals are more effective than privately appealing to either the regulator or the firm alone.

To test this hypothesis, we exploit the cross-randomization of T1C (calling regulator to appeal) and T1D (calling firm to appeal): if the two effects are not additive, then the firms simultaneously assigned to both treatments should not be more compliant than those receiving just T1C or T1D alone. Therefore, by testing whether $|T1C + T1D + T1C * T1D| \leq \max\{|T1C|, |T1D|\}$, we can examine whether simultaneously appealing to both the regulator and the firm is more effective than appealing to either the regulator or the firm alone.

Based on the results in Table 2 Panel A, at the 1% level, we can reject the null hypothesis that receiving both T1C and T1D is no more effective than just receiving one of them, indicating that the impacts of appealing to the regulator and appealing to the firm are additive. This result suggests that publicity of an appeal simultaneously affects both the regulator and the firm.[11]

C. Other Potential Mechanisms

In this section, we discuss several other potential mechanisms for our baseline results.

One possibility is that the public appeals posted on social media as part of our experiment were observed by other citizens, who might have been inspired to file their own appeals against the pollution violations, thereby increasing the overall impact of public appeals. To investigate this potential channel, we obtain the universe of citizen appeals data through 12369 website and phone from the MEE and match this information to each CEMS firm in our sample. As shown in Appendix Table A8, our interventions did not significantly change the number of appeals filed by other citizens, and the null results are precisely estimated, suggesting that the effect of publicly appealing violations is not driven by crowding in other appeals.

Another possibility is that, when facing public appeals, the polluting firm might respond by manipulating the CEMS monitoring data, rather than abating pollution. This could potentially confound our baseline results even if there is no actual improvement in environmental outcomes. As explained in Section IIB, the CEMS utilizes a series of technologies and follows strict protocols to ensure the accuracy of the data, which leaves

[11] An additional possibility is that, maybe simultaneously appealing to the regulator and the firm creates a common knowledge between the two parties, which changes their behaviors in regulatory enforcement. This hypothesis implies that in addition to being addible to each other, T1C and T1D might also have an interactive effect when implemented together. However, this hypothesis is not supported by our data, as the interaction term between these two treatments is small and statistically insignificant.

little room for the firms to influence the automatic emission readings. Nevertheless, we directly investigate this possibility by comparing the frequency of suspicious readings across the experimental arms. As shown in Appendix Table A9, our experimental interventions had no impact on firms' likelihood of showing unusually high missing hours or unusually low emission concentrations in the CEMS system, indicating that data manipulation is unlikely to drive our main findings.[12] Moreover, as will be discussed in detail in Section VIC, our findings on firm-level emission reductions can also be corroborated by changes in ambient pollution levels at the prefectural city level, further suggesting that the main findings reflect real changes in firms' emissions.

Another potential interpretation is that CEMS firms might respond more to public pollution appeals because they worry that bad publicity will damage their brand among their consumers. We think this interpretation is unlikely to drive our main findings, since most of the CEMS firms are industrial manufacturers that supply intermediate inputs to other downstream industrial plants, rather than directly selling to consumers. We verify this hypothesis by estimating the impacts of public pollution appeals separately for the subsamples of CEMS firms that produce intermediate goods and those that produce final consumer goods. As displayed in Appendix Table A10, if anything, CEMS firms producing intermediate goods respond more strongly to the public pollution appeals, suggesting that incentives for corporate social responsibility do not drive the main results.

It is also possible that public appeals on social media make the local regulators fear that the central government might notice the violation and get involved, which incentivizes the local regulators to take action (Anderson et al. 2019; Buntaine et al. 2021). This mechanism is unlikely in our context, since in the 12369 platform, any citizen appeal is automatically documented in the MEE's central system, and there should be little information asymmetry between the MEE and the local EPAs for any appeal. Nevertheless, we still attempt to test this hypothesis directly. In half of the appeals, we randomly threatened the local regulator that "if the issue does not get resolved, we will bring it to the upper-level government." As displayed in Appendix Table A11, the threat to appeal to the upper-level government only led to a marginal increase in the local regulator's response rate, suggesting

[12] We define a firm's missing hours as "unusually high" if it records more than 4 hours of missing CEMS data in a given day; we define a firm's emission concentration reading as "unusually low" if it records an average emission concentration level below 10% of its yearly average on a fully operating day.

that escalating an appeal and heightening the salience that the central government might get involved is unlikely to drive the baseline findings.

VI. Spillover Effects and Economic Significance

In this section, we investigate the spillover effects of our experimental interventions, discuss the economic significance of our findings in the presence of spillover effects, and corroborate our firm-level results with prefecture-level ambient pollution monitoring data.

A. Spillover Effects

A potential concern is that appeals by citizens might crowd out local governments' regulatory efforts on non-treated firms: if the local regulators only focus on the CEMS firms that we filed appeals against, then firms not subject to appeals might be allowed to pollute even more, which could create a negative spillover effect and thus undermine the effectiveness of participation in the general equilibrium.

We exploit the "double randomization" feature of the experiment to causally identify the spillover effects of pollution appeals, by comparing the non-treated firms in the high- vs. low-treatment-intensity regions. Specifically, we use the sample of all control firms and estimate the following equation:

$$Y_{ist} = High_{is} \cdot Post_t + \gamma_i + \eta_t + \epsilon_{ist} \quad (2)$$

where Y_{ist} is the outcome of interest for firm i on day t; $High_{is}$ is a dummy variable indicating whether prefecture s, which hosts firm i, is assigned as a high-treatment-intensity region where 95% of the CEMS firms receive treatment; $Post_t$ is a dummy variable indicating whether day t is after the treatments had begun. γ_i and η_t are firm and day FEs, respectively. The standard errors are two-way clustered at the prefecture and week levels.

As reported in Table 5, we find no evidence that the interventions crowd out regulatory efforts on non-treated firms. If anything, the control firms in high-treatment-intensity regions appear to commit fewer violations during our experimental period, although these violation reductions are not precisely estimated, and do not translate into significant reductions in emissions concentrations. Nonetheless, the estimates do allow us to rule out large negative spillover effects that might be expected if appeals only caused a reallocation of regulatory effort with no net effect on compliance.

B. Ambient Pollution Levels

Given that pollution appeals can significantly improve firms' environmental performance and do not crowd out regulatory efforts for firms not subject to appeals, it is possible that the treatments caused detectable differences in ambient pollution levels between high-treatment-intensity and low-treatment-intensity regions. Specifically, in our context, industrial production is responsible for more than 80% of China's total SO_2 emissions, while less than 50% of China's total COD emissions. Therefore, we expect to have more statistical power in detecting differences in ambient SO_2 levels between high- and low-treatment-intensity regions, while less so for ambient COD levels.

We obtained ambient SO_2 data from more than 1,600 air quality monitoring stations in China, which are independent from the CEMS network and cannot be influenced by the CEMS firms. In Table 6, we compare the prefecture-level ambient SO_2 concentration levels between the high-treatment-intensity regions and low-treatment-intensity regions, and find that following the start of the treatment period, SO_2 concentrations decreased by an additional 3.7% in the high-treatment-intensity prefectures.[13] In addition to testifying to the far-reaching impacts of our national-scale interventions,[14] the findings on ambient pollution also confirms that the baseline improvements in CEMS firms' environmental performance are not confounded by manipulation of the CEMS data.

C. Overall Impacts of Public Pollution Appeals

In the setting of our experiment, many pollution appeals are already filed through private channels by citizens and non-governmental organizations (e.g., more than 600,000 per year via the 12369 platforms). Encouraging citizens to switch to public appeals, while requiring little additional effort, could potentially lead to substantial improvements in compliance with pollution standards. Leveraging our experimental estimates, we conduct simple back-

[13] Note that ambient air quality measures, while being independent from the CEMS system, also have limitations. First, ambient air quality measures are affected by other emission sources (like household coal consumption and non-CEMS polluting firms) and cannot accurately capture the changes in CEMS firms' emission activities. Second, changes in meteorological conditions can significantly affect ambient air quality. Third, air pollutants can travel across different cities.

[14] Industrial production accounts for 80% of China's total SO_2 emission, the CEMS firms account for more than 75% of China's total industrial emissions, our interventions reduce SO_2 emissions by 4% to 14%, and the ratio of treated CEMS firms vary between high- and low-treatment-intensity regions by 25%; so we expect that the average ambient SO_2 levels differ between high- and low-treatment-intensity regions by 0.6% (80%*75%*4%*25%) to 2.1% (80%*75%*14%*25%). Since national air monitoring stations are typically located in areas with higher densities of industrial activities, we think the estimated 3.7% difference in ambient SO_2 levels is consistent with our firm-level results.

of-the-envelope calculations to shed light on the aggregate impacts if all CEMS firms were covered by public Weibo appeals.

According to the most conservative estimate controlling for prefecture-by-day FEs, if a CEMS firm's emission activity is under the scrutiny of the public such that its violations would be appealed on Weibo, its daily violation rate would be reduced by 0.57 percentage point, which represents a roughly 60% drop from the baseline. Assuming public pollution appeals do not generate spillover effects, which is consistent with our findings in Table 5, then a simple calculation indicates that if all 24,620 CEMS firms are put under public appeals for their violations, there would be nearly 51,000 fewer pollution violations every year.[15] If there is a positive spillover effect from pollution appeals (which is suggested by our results), then the reduction in violations would be even larger.

While the CEMS does not directly report hourly data on total emissions, we can link estimates on emission concentrations to the hourly gas/water flows reported by the CEMS, to back out the total amount of emissions per hour for each pollutant type. As shown in Appendix Table A10, the flow of pollutants barely changed across different experimental arms, which indicates that emission concentrations could also reflect the total change in emissions. Based on this finding, a conservative calculation ignoring spillover effects indicates that putting all CEMS firms under public appeals would reduce China's total industrial SO_2 emissions by 355,860 tons, and total COD emissions by 28,950 tons, representing 9.3% and 2.9% reductions from the baseline, respectively.[16]

VII. Conclusion

In this paper, we report a national-scale field experiment in China, in which we used the CEMS data to identify pollution violations in real time, and then randomly appealed against violations through officially sanctioned channels. We find that when polluting firms' pollution violations were subject to citizen appeals to either the regulator or the firm

[15] Calculation for violations is obtained by multiplying reduced daily violation rate with the number of days per year and the number of CEMS firms: $0.00567 * 365 * 24620 = 50952.$

[16] China emits 3,954,000 tons of industrial SO_2 every year, roughly 75% of which from the CEMS firms. So by reducing the CEMS firms' industrial SO_2 emissions by 12.4%, China's total industrial SO_2 emissions will fall by $3954000 * 75\% * 12.4\% = 367{,}722$ tons. Similarly, China's yearly industrial COD emission is about 772,000 tons, and roughly 75% of which from the CEMS firms. So by reducing the CEMS firms' industrial COD emissions by 3.8%, China's total industrial COD emissions will fall by: $772000 * 75\% * 3.8\% = 22{,}002$ tons.

privately, there was only a marginal improvement in firms' environmental performance; but when firms' pollution violations were subject to public appeals by citizens on social media, the firms significantly improved their environmental performance, cutting the rate of pollution violations by 60% and air and water emission concentrations by 12.4% and 3.8%, respectively.

Our experimental design allows us to investigate underlying mechanisms for the baseline findings. We find that publicity improved the quality of environmental governance through two important channels: (1) incentivizing the regulator to exert more effort in enforcing environmental regulations; and (2) simultaneously reaching the regulator and the firm. These findings shed light on the discussion of how citizen participation could shape development and government accountability. They also deepen our understanding of how governments, firms, and citizens interact in China's local governance system.

Exploiting the cross-randomization of appeal intensity at the prefectural city level, we show that the experimental interventions did not generate a negative spillover large enough to diminish the net effects on citizen participation on compliance and emissions, and instead could have generated a positive spillover effect. We find evidence that the experimental interventions translated into significant differences in ambient pollution levels between the high- and low-intensity regions during the study.

Leveraging our experimental estimates, we conduct simple back-of-the-envelope calculations to understand the macro-level implications of encouraging public participation in environmental governance. Our calculations suggest that if all polluting firms in China had their emissions scrutinized by the public using public appeals, total pollution violations in China could be reduced by more than 50%. Given the low marginal cost of citizen participation with the existence of the CEMS infrastructure, our findings point to public participation as an extremely cost-effective approach to improving compliance with pollution standards in China.

References

Adhvaryu, Achyuta, Namrata Kala, and Anant Nyshadham. "Management and shocks to worker productivity: evidence from air pollution exposure in an Indian garment factory." *Unpublished working paper, University of Michigan* (2014).

Anderson, Sarah E., Mark T. Buntaine, Mengdi Liu, and Bing Zhang. "Non‐Governmental Monitoring of Local Governments Increases Compliance with Central Mandates: A National‐Scale Field Experiment in China." *American Journal of Political Science* 63, no. 3 (2019): 626-643.

Bai, Chong-En, Chang-Tai Hsieh, and Zheng Song. "Special deals with Chinese characteristics." *NBER Macroeconomics Annual* 34, no. 1 (2020): 341-379.

Banerjee, Abhijit V., Rukmini Banerji, Esther Duflo, Rachel Glennerster, and Stuti Khemani. "Pitfalls of participatory programs: Evidence from a randomized evaluation in education in India." *American Economic Journal: Economic Policy* 2, no. 1 (2010): 1-30.

Banerjee, Abhijit, and Esther Duflo. "Addressing absence." *Journal of Economic perspectives* 20, no. 1 (2006): 117-132.

Björkman, Martina, and Jakob Svensson. "Power to the people: evidence from a randomized field experiment on community-based monitoring in Uganda." *The Quarterly Journal of Economics* 124, no. 2 (2009): 735-769.

Bui, Linda TM, and Christopher J. Mayer. "Regulation and capitalization of environmental amenities: evidence from the toxic release inventory in Massachusetts." *Review of Economics and statistics* 85, no. 3 (2003): 693-708.

Buntaine, Mark T., Patrick Hunnicutt, and Polycarp Komakech. "The challenges of using citizen reporting to improve public services: A field experiment on solid waste services in Uganda." *Journal of Public Administration Research and Theory* 31, no. 1 (2021): 108-127.

Buntaine, Mark T., Bing Zhang, and Patrick Hunnicutt. "Citizen Monitoring of Waterways Decreases Pollution in China by Supporting Government Action and Oversight." *Proceeding of the National Academy of Sciences*, forthcoming.

Burgess, Robin, Matthew Hansen, Benjamin A. Olken, Peter Potapov, and Stefanie Sieber. "The political economy of deforestation in the tropics." *The Quarterly journal of economics* 127, no. 4 (2012): 1707-1754.

Campante, Filipe R., Davin Chor, and Bingjing Li. *The Political Economy Consequences of China's Export Slowdown*. No. w25925. National Bureau of Economic Research, 2019.

Chang, Tom, Joshua Graff Zivin, Tal Gross, and Matthew Neidell. "Particulate pollution and the productivity of pear packers." *American Economic Journal: Economic Policy* 8, no. 3 (2016): 141-69.

Chen, Xi. *Social protest and contentious authoritarianism in China*. Cambridge University Press, 2012.

Crépon, Bruno, Esther Duflo, Marc Gurgand, Roland Rathelot, and Philippe Zamora. "Do labor market policies have displacement effects? Evidence from a clustered randomized experiment." *The quarterly journal of economics* 128, no. 2 (2013): 531-580.

Currie, Janet, Lucas Davis, Michael Greenstone, and Reed Walker. "Environmental health risks and housing values: evidence from 1,600 toxic plant openings and closings." *American Economic Review* 105, no. 2 (2015): 678-709.

Doan, My Hanh, and Remmer Sassen. "The relationship between environmental performance and environmental disclosure: A meta-analysis." *Journal of Industrial Ecology* 24, no. 5 (2020): 1140-1157.

Duflo, Esther, Pascaline Dupas, and Michael Kremer. "Peer effects, teacher incentives, and the impact of tracking: Evidence from a randomized evaluation in Kenya." *American Economic Review* 101, no. 5 (2011): 1739-74.

Ebenstein, Avraham, Maoyong Fan, Michael Greenstone, Guojun He, and Maigeng Zhou. "New evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River Policy." *Proceedings of the National Academy of Sciences* 114, no. 39 (2017): 10384-10389.

Foulon, Jérôme, Paul Lanoie, and Benoıt Laplante. "Incentives for pollution control: regulation or information?." *Journal of Environmental Economics and Management* 44, no. 1 (2002): 169-187.

Gavazza, Alessandro, and Alessandro Lizzeri. "The perils of transparency in bureaucracies." *American Economic Review* 97, no. 2 (2007): 300-305.

Gowrisankaran, Gautam, Michael Greenstone, Ali Hortaçsu, Mengdi Liu, Caixia Shen, and Bing Zhang. *Pollution Mitigation and Productivity: Evidence from Chinese Manufacturing Firms*. Working Paper, 2020.

Graff Zivin, Joshua, and Matthew Neidell. "The impact of pollution on worker productivity." *American Economic Review* 102, no. 7 (2012): 3652-73.

Greenstone, Michael. "The impacts of environmental regulations on industrial activity: Evidence from the 1970 and 1977 clean air act amendments and the census of manufactures." *Journal of political economy* 110, no. 6 (2002): 1175-1219.

Greenstone, Michael, and Rema Hanna. "Environmental regulations, air and water pollution, and infant mortality in India." *American Economic Review* 104, no. 10 (2014): 3038-72.

Greenstone, Michael, Guojun He, Ruixue Jia, and Tong Liu. *Can Technology Solve the Principal-Agent Problem? Evidence from China's War on Air Pollution*. No. w27502. National Bureau of Economic Research, 2020.

Greenstone, Michael, John A. List, and Chad Syverson. *The effects of environmental regulation on the competitiveness of US manufacturing*. No. w18392. National Bureau of Economic Research, 2012.

Greenstone, Michael, Janhavi Nilekani, Rohini Pande, Nicholas Ryan, Anant Sudarshan, and Anish Sugathan. "Lower pollution, longer lives: life expectancy gains if India reduced particulate matter pollution." *Economic and Political Weekly* (2015): 40-46.

Grossman, Guy, Melina R. Platas, and Jonathan Rodden. "Crowdsourcing accountability: ICT for service delivery." *World Development* 112 (2018): 74-87.

Hahn, Robert W., Sheila M. Olmstead, and Robert N. Stavins. "Environmental regulation in the 1990s: A retrospective analysis." *Harv. Envtl. L. Rev.* 27 (2003): 377.

He, Guojun, Shaoda Wang, and Bing Zhang. "Watering down environmental regulation in China." *The Quarterly Journal of Economics* 135, no. 4 (2020): 2135-2185.

Henderson, J. Vernon. "Effects of air quality regulation." *The American Economic Review* (1996): 789-813.

Ito, Koichiro, and Shuang Zhang. "Willingness to pay for clean air: Evidence from air purifier markets in China." *Journal of Political Economy* 128, no. 5 (2020): 1627-1672.

Jia, Ruixue. "Pollution for promotion." *21st Century China Center Research Paper* 2017-05 (2017).

Jing, Jun. "Environmental protests in rural China." *Chinese society: change, conflict and resistance* (2000): 143-60.

Kahn, Matthew E., Pei Li, and Daxuan Zhao. "Water pollution progress at borders: the role of changes in China's political promotion incentives." *American Economic Journal: Economic Policy* 7, no. 4 (2015): 223-42.

Kahn, Matthew E., and Erin T. Mansur. "Do local energy prices and regulation affect the geographic concentration of employment?." *Journal of Public Economics* 101 (2013): 105-114.

Konar, Shameek, and Mark A. Cohen. "Information as regulation: The effect of community right to know laws on toxic emissions." *Journal of environmental Economics and Management* 32, no. 1 (1997): 109-124.

Kremer, Michael, Jessica Leino, Edward Miguel, and Alix Peterson Zwane. "Spring cleaning: Rural water impacts, valuation, and property rights institutions." *The Quarterly Journal of Economics* 126, no. 1 (2011): 145-205.

Kremer, Michael, and Christel Vermeesh. "School committee empowerment: Preliminary notes." *Cambridge, MA: Harvard University* (2005).

Lipscomb, Molly, and Ahmed Mushfiq Mobarak. "Decentralization and pollution spillovers: evidence from the re-drawing of county borders in Brazil." *The Review of Economic Studies* 84, no. 1 (2016): 464-502.

List, John A., and Daniel M. Sturm. "How elections matter: Theory and evidence from environmental policy." *The Quarterly Journal of Economics* 121, no. 4 (2006): 1249-1281.

Lorentzen, Peter L. "Regularizing rioting: Permitting public protest in an authoritarian regime." *Quarterly Journal of Political Science* 8, no. 2 (2013): 127-158.

Mansuri, Ghazala, and Vijayendra Rao. "Community-based and-driven development: A critical review." *The World Bank Research Observer* 19, no. 1 (2004): 1-39.

Mattozzi, Andrea, and Antonio Merlo. "The transparency of politics and the quality of politicians." *American Economic Review* 97, no. 2 (2007): 311-315.

Muralidharan, Karthik, Paul Niehaus, and Sandip Sukhtankar. "Building state capacity: Evidence from biometric smartcards in India." *American Economic Review* 106, no. 10 (2016): 2895-2929.

Olken, Benjamin A. "Monitoring corruption: evidence from a field experiment in Indonesia." *Journal of political Economy* 115, no. 2 (2007): 200-249.

Orphanides, Athanasios. "Monetary policy rules based on real-time data." *American Economic Review* 91, no. 4 (2001): 964-985.

Qian, Yingyi, and Barry R. Weingast. "Federalism as a commitment to reserving market incentives." *Journal of Economic perspectives* 11, no. 4 (1997): 83-92.

Reinikka, Ritva, and Jakob Svensson. "The power of information in public services: Evidence from education in Uganda." *Journal of Public Economics* 95, no. 7-8 (2011): 956-966.

Ryan, Stephen P. "The costs of environmental regulation in a concentrated industry." *Econometrica* 80, no. 3 (2012): 1019-1061.

Steinhardt, H. Christoph, and Fengshi Wu. “In the name of the public: Environmental protest and the changing landscape of popular contention in China.” *The China Journal* 75, no. 1 (2016): 61-82.

Stiglitz, Joseph E. “Participation and development: Perspectives from the comprehensive development paradigm.” *Review of development economics* 6, no. 2 (2002): 163-182.

United Nations Environment Program. “Environmental rule of law: First global report.” (2019).

Walker, W. Reed. “The transitional costs of sectoral reallocation: Evidence from the clean air act and the workforce.” *The Quarterly journal of economics* 128, no. 4 (2013): 1787-1835.

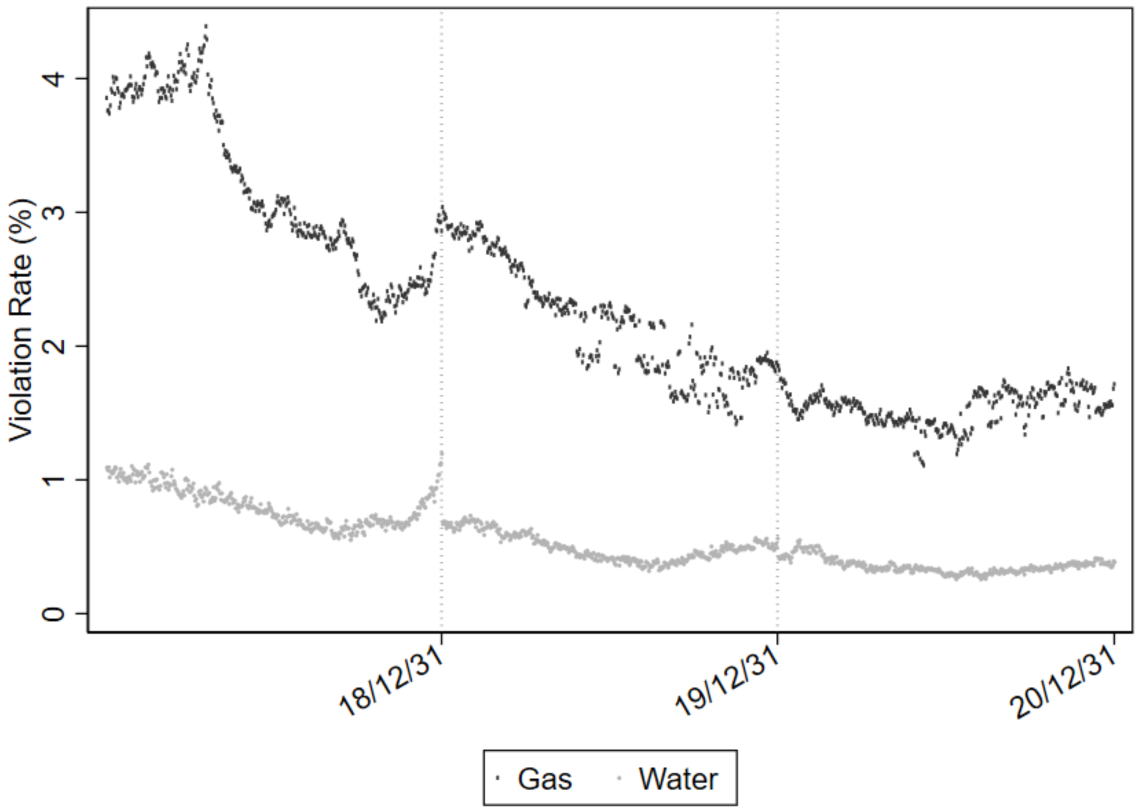
Wang, Shaoda, and Zenan Wang. “The Environmental and Economic Consequences of Internalizing Border Spillovers.” (2020).

World Bank. *World development report 2004: making services work for poor people*. The World Bank, 2004.

Wu, Wenqi, Wenwen Wang, Lu Zhang, Qiaoyu Wang, Lujing Wang, and Ming Zhang. "Does the public haze pollution concern expressed on online platforms promoted pollution control?–Evidence from Chinese online platforms." *Journal of Cleaner Production* 318 (2021): 128477.

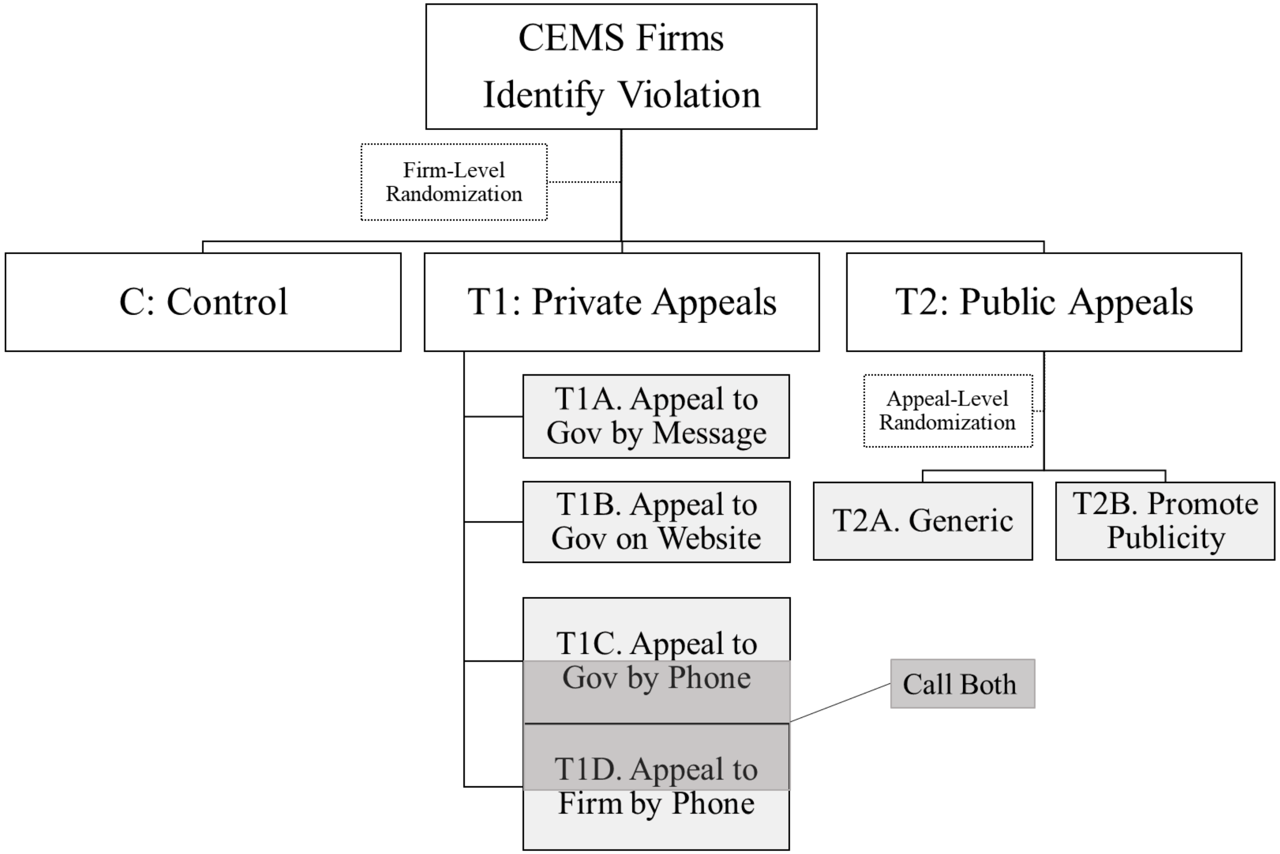
Xu, Chenggang. “The fundamental institutions of China’s reforms and development.” *Journal of economic literature* 49, no. 4 (2011): 1076-1151.

Figure 1. Violation Rates over Time



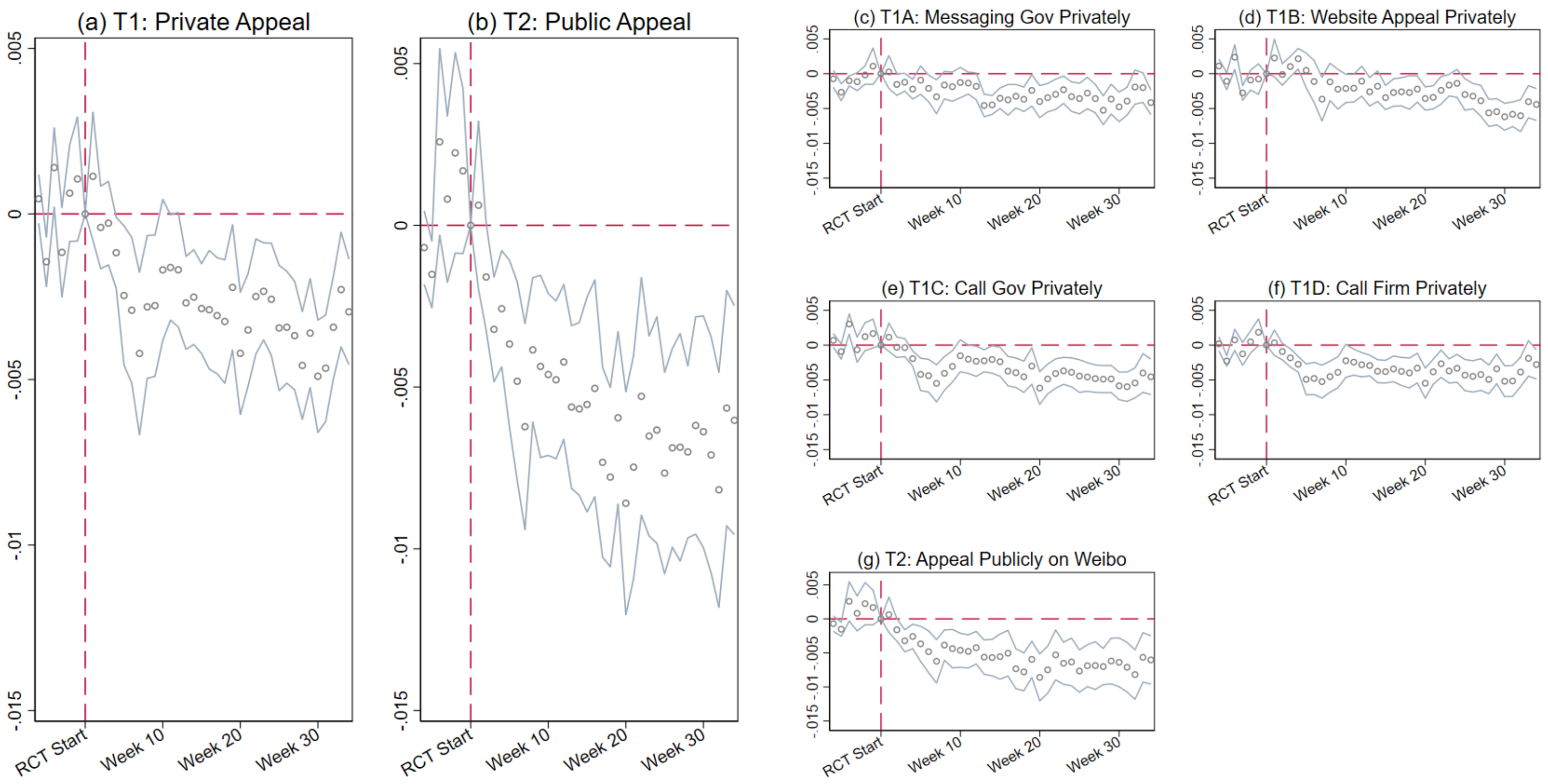
Note: This figure plots the daily trends of waste gas and water emission violations in the CEMS data, between 2018 and 2020. The Y-axis represents the percentage of CEMS firms violating the emission standard on any given day.

Figure 2. Experimental Design



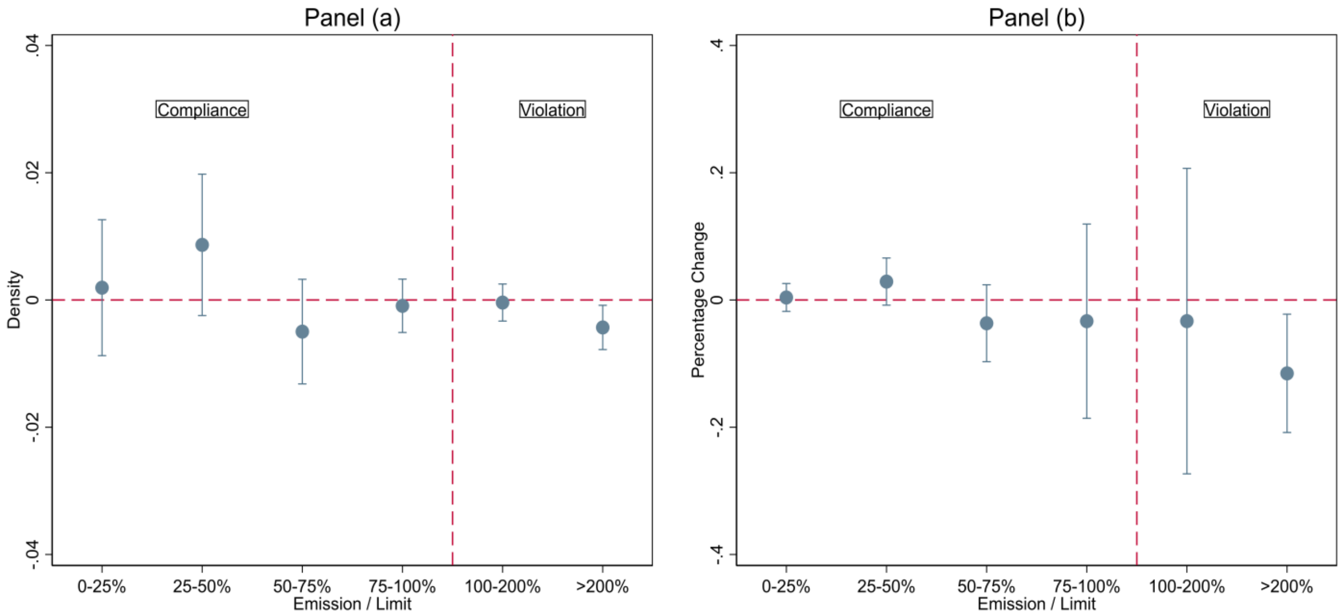
Note: This figure illustrates our experimental design, in which each CEMS firm is randomly assigned to one of seven different arms.

Figure 3. Event Studies



Note: This figure presents coefficients and 90% confidence intervals on Treatment*Week interactions from regressions of violation on Treatment *Week, firm FE, and week FE. Standard errors are clustered two-way by prefecture and week.

Figure 4. Effects on Excessive Violations



Note: In this figure, we visualize how public pollution appeals shift the distribution of emission concentrations. We divide each firm's emission concentration of a certain type of pollutant on a given day by the emission limit set by the MEE, and generate six bins using this standardized emission as the stratifying variable. In Panel (a), we regress the dummy variable for each bin on our treatment variables, using the same baseline specification in equation (1), and plot the coefficients and 90% CIs from these regressions. In Panel (b), we divide the dummy for each bin by the frequency of firm-day observations showing up in this bin in the pre-RCT period, to adjust for the fact that different bins contain different number of observations; therefore, the regression coefficients plotted in Panel (b) represent the percentage changes in the likelihoods of firm-day observations falling in different bins. Standard errors are clustered two-way by prefecture and week.

Table 1. Balance Test

	(1)	(2)	(3)	(4)	(5)	(6)
	Control	Private Appeals				Public Appeals
		Messaging	Website	Call Gov	Call Firm	Weibo
	C	T1A-C	T1B-C	T1C-C	T1D-C	T2-C
Panel A: Outcomes						
SO2	0.217	0.0112	0.0300	0.0221	0.0516	0.0820
Violations	(2.202)	(0.0516)	(0.0718)	(0.0525)	(0.0585)	(0.0776)
COD	0.095	0.0142	0.00573	0.000552	0.0170	0.0361
Violations	(0.862)	(0.0225)	(0.0232)	(0.0199)	(0.0236)	(0.0251)
Total	0.739	0.0842	0.0344	0.0000565	0.120	0.181
Violations	(4.927)	(0.125)	(0.128)	(0.128)	(0.136)	(0.156)
SO2	135.159	-21.71	-14.55	-19.10	-36.99	-8.370
Concentrations	(981.966)	(21.59)	(15.77)	(22.94)	(33.49)	(18.15)
COD	57.646	1.256	3.842	1.788	2.004	0.629
Concentrations	(69.125)	(2.225)	(3.132)	(3.475)	(2.405)	(3.625)
Gas Penalty	0.008	0.000856	-0.00343	-0.000197	0.00215	-0.00278
	(0.146)	(0.00367)	(0.00268)	(0.00243)	(0.00365)	(0.00305)
Water Penalty	0.001	0.00107	0.00167	0.00310	0.00191	0.00183
	(0.055)	(0.00148)	(0.00178)	(0.00213)	(0.00153)	(0.00155)
Total Penalty	0.009	0.00188	-0.00180	0.00285	0.00401	-0.000943
	(0.156)	(0.00434)	(0.00317)	(0.00281)	(0.00419)	(0.00343)
Panel B: Industries						
Mining	0.024	0.00141	-0.00429	0.00115	-0.00181	0.00285
Industry	(0.154)	(0.00426)	(0.00561)	(0.00499)	(0.00346)	(0.00627)
Manufacturing & Power Plants	0.73 (0.444)	0.0150 (0.0116)	0.0183 (0.0145)	0.0215 (0.0141)	0.0115 (0.0113)	0.0192 (0.0146)
Sewage	0.166	-0.0171*	-0.0146	-0.00749	-0.00673	-0.0123
Treatment	0.372	(0.0101)	(0.0125)	(0.0133)	(0.00977)	(0.0133)
Others	0.0803	0.000633	0.000612	-0.0151	-0.00298	-0.00979
	(0.272)	(0.00676)	(0.01000)	(0.0104)	(0.00659)	(0.00949)

Note: This table reports balance tests across different experimental arms using data from the pre-treatment period. For outcomes on pollution concentrations and violations, the sample includes eight weeks before the start of the experiment. For pollution penalties, the sample is from 2019. Column 1 reports the means and standard deviations of the control arm. Columns 2-7 report the difference between each appeal arm and the control arm; the corresponding standard errors are reported in the parentheses.

Table 2. Pollution Appeals and Firm Violations

	(1) Violation	(2) Violation
Panel A. Impacts of the Sub-Treatments		
Messaging Gov Privately (T1A*Post)	-0.00191*	-0.00189*
	(0.00104)	(0.00102)
Appeal Gov Website Privately (T1B*Post)	-0.00205*	-0.00132
	(0.00114)	(0.00118)
Call Gov Privately (T1C*Post)	-0.00300**	-0.00240*
	(0.00114)	(0.00120)
Call Firm Privately (T1D*Post)	-0.00127	-0.00143
	(0.000987)	(0.000976)
Call Gov*Call Firm (T1C*TID*Post)	-0.00122	-0.000648
	(0.00157)	(0.00142)
Appeal Publicly on Weibo (T2*Post)	-0.00618***	-0.00580***
	(0.00174)	(0.00144)
H0: T1A>T2	P=0.00679	P=0.00334
H0: T1B>T2	P=0.00264	P=0.000718
H0: T1C>T2	P=0.0167	P=0.00513
H0: T1D>T2	P=0.00417	P=0.000935
Panel B. Impacts of Private and Public Appeals		
Private Appeals (T1*Post)	-0.00273***	-0.00227**
	(0.000934)	(0.000939)
Public Appeals (T2*Post)	-0.00618***	-0.00576***
	(0.00174)	(0.00143)
H0: T1>T2	P=0.00617	P=0.00135
Control Mean	0.00936	0.00936
Control SD	0.0963	0.0963
Firm FE	Yes	Yes
Day FE	Yes	
Province by Day FE		Yes
Observations	7100881	7100881

Notes: This table reports the regression results from estimating Equation (1). Violation is a dummy variable that equals 1 if the firm violates an emission standard on that day, and zero otherwise. In Column 1, we control for firm FE and day FE; in Column 2, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3. Pollution Appeals and Emission Concentrations

	(1)	(2)	(3)	(4)
	SO2	SO2	COD	COD
Panel A. Impacts of the Sub-Treatments				
Messaging Gov Privately (T1A*Post)	-2.997	-3.362	-0.0891	-0.0656
	(8.065)	(8.023)	(1.095)	(1.084)
Appeal Gov Website Privately (T1B*Post)	-4.815	-4.696	-0.296	-0.445
	(5.561)	(5.581)	(1.119)	(1.038)
Call Gov Privately (T1C*Post)	-3.987	-4.626	-0.656	-0.634
	(5.764)	(5.552)	(0.835)	(0.765)
Call Firm Privately (T1D*Post)	-4.739	-5.131	-0.549	-0.623
	(4.292)	(4.424)	(1.213)	(1.204)
Call Gov*Call Firm (T1C*TID*Post)	-1.922	-1.503	1.356	1.260
	(7.808)	(7.690)	(1.414)	(1.401)
Appeal Publicly on Weibo (T2*Post)	-15.75***	-16.31***	-2.079*	-2.228*
	(4.389)	(4.471)	(1.197)	(1.150)
H0: T1A>T2	P=0.0668	P=0.0661	P=0.0437	P=0.0308
H0: T1B>T2	P=0.0366	P=0.0305	P=0.0573	P=0.0611
H0: T1C>T2	P=0.0132	P=0.0155	P=0.0799	P=0.0612
H0: T1D>T2	P=0.0292	P=0.0354	P=0.124	P=0.114
Panel B. Impacts of Pooled Private and Public Appeals				
Private Appeals (T1*Post)	-5.599	-5.864	-0.287	-0.352
	(3.569)	(3.642)	(0.884)	(0.843)
Public Appeals (T2*Post)	-15.75***	-16.17***	-2.079*	-2.229*
	(4.388)	(4.448)	(1.197)	(1.152)
H0: T1>T2	P=0.0125	P=0.0152	P=0.0346	P=0.0328
Control Mean	132.5	132.5	59.10	59.10
Control SD	539.5	539.5	78.75	78.75
Firm FE	Yes	Yes	Yes	Yes
Day FE	Yes		Yes	
Province by Day FE		Yes		Yes
Observations	2216476	2216208	2459671	2459622

Notes: This table reports the regression results from estimating Equation (1). In Columns 1 to 3, the outcome variable is the daily average emission concentration of SO2 (mg/m3); In Columns 4 to 6, the outcome variable is the daily average emission concentration of COD (mg/L). In Columns 1 and 3, we control for firm FE and day FE; in Columns 2 and 4, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4. Social Media Publicity and Government Responsiveness

	(1) Whether Respond	(2) Whether Respond	(3) Response Length	(4) Response Length	(5) Onsite Audit	(6) Onsite Audit
Promoted Appeal	0.0566*	0.0606**	34.59**	33.83**	0.0408*	0.0462**
	(0.0306)	(0.0301)	(13.43)	(13.44)	(0.0233)	(0.0229)
Control Mean	0.155	0.155	33.15	33.15	0.0722	0.0722
Control SD	0.363	0.363	117.9	117.9	0.259	0.259
Day FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE		Yes		Yes		Yes
Observations	662	658	662	658	662	658

Notes: This table reports the regression results for public Weibo appeals on local government responsiveness. We use the sample of firms in the public Weibo appeal to government arm. The unit of analysis is each Weibo appeal. Whether respond is a dummy variable that equals 1 if the government replies to our Weibo appeal, and 0 otherwise; response length is the word count of the government's Weibo reply to our appeal, which is counted as zero if there is no response; onsite audit is a dummy variable that equals 1 if the government replies to our Weibo appeal with proof of an onsite investigation, and 0 otherwise. In Columns 1, 3 and 5, we control for month FE; in Columns 2, 4, and 6, we control for month FE and province FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5. Spillover Effects of Pollution Appeals

	(1)	(2)	(3)	(4)	(5)	(6)
	Violation	Violation	SO_2	SO_2	COD	COD
High Intensity Region*Post	-0.00326	-0.00254	-5.301	-9.048	1.528	1.945
	(0.00316)	(0.00287)	(5.550)	(7.615)	(2.147)	(1.928)
Control Mean	0.00936	0.00936	132.1	132.1	58.87	58.87
Control SD	0.0963	0.0963	536.4	536.4	76.95	76.95
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Day FE	Yes		Yes		Yes	
Province by Day FE		Yes		Yes		Yes
Observations	1026414	1026414	296695	296604	356285	356265

Notes: This table reports the regression results from estimating Equation (2). We use the sample of firms in the control arm. In Columns 1, 3, and 5, we control for firm FE and day FE; in Columns 2, 4, and 6, we control for firm FE and province-by-day FE. Since some CEMS firms are being monitored for pollutants other than SO_2 and COD, the violation sample is larger than the sum of the two emissions samples. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6. Pollution Appeals and Ambient Air Pollution Levels

	(1)	(2)
	SO_2	SO_2
High Intensity Region*Post	-0.358*	-0.370*
	(0.214)	(0.211)
Control Mean	10.06	10.06
Control SD	6.593	6.593
City FE	Yes	Yes
Day FE	Yes	
Province by Day FE		Yes
Observations	90603	89443

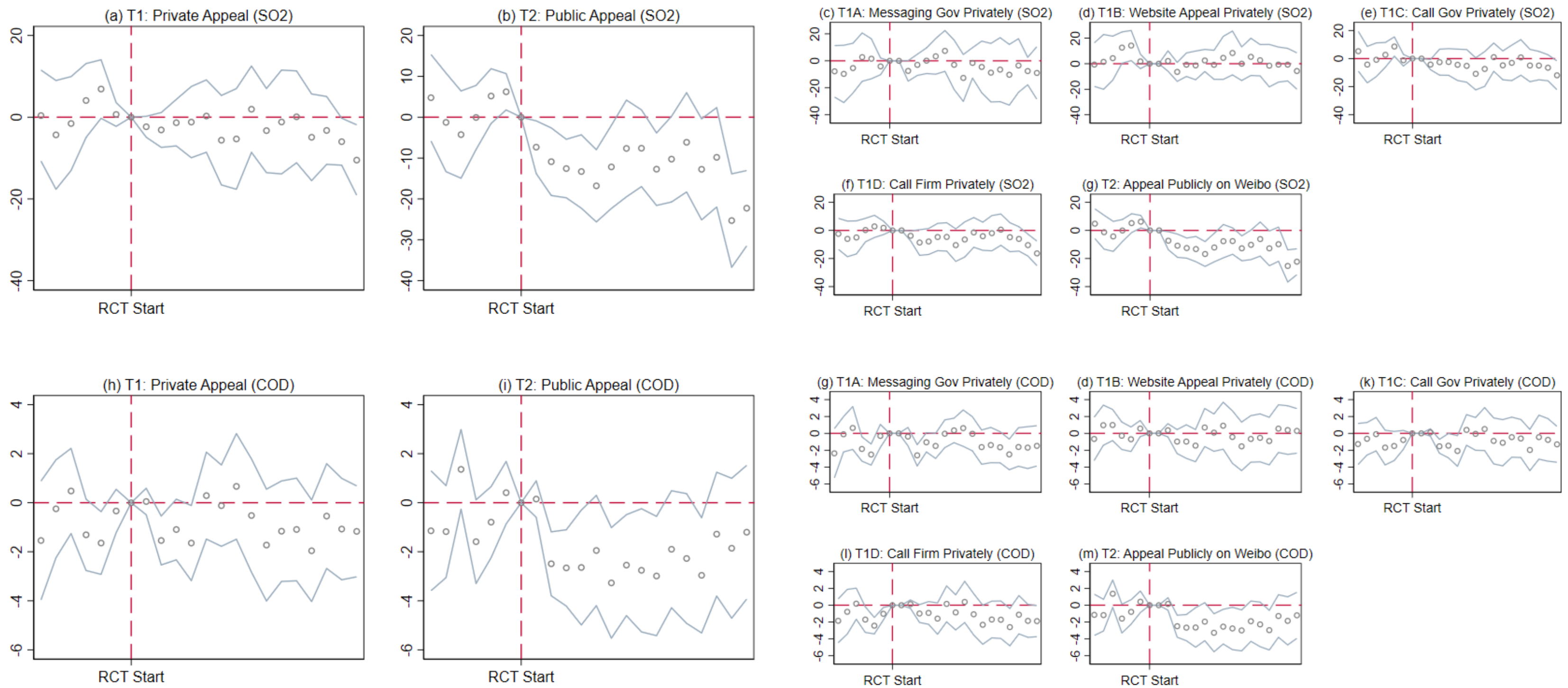
Notes: This table reports the regression results using ambient SO_2 air quality data from more than 1,600 air quality monitoring stations in China. The unit of analysis is prefecture-day. In Column 1, we control for city FE and day FE; in Column 2, we control for city FE and province-by-day FE. Standard errors are clustered at the prefecture level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Online Appendix to

"Public Participation and Government Accountability? National-Scale Experimental Evidence from Pollution Appeals in China"

APPENDIX A: FIGURES AND TABLES

Figure A1. Event Studies for Public Appeals on Emission Concentrations



Note: Figure presents coefficients and 90% confidence intervals on Treatment*Week interactions from regressions of concentration on Treatment *Week, firm FE, and week FE. Standard errors are clustered two-way by prefecture and week.

Figure A2. Distribution of Pollution Emission Standards

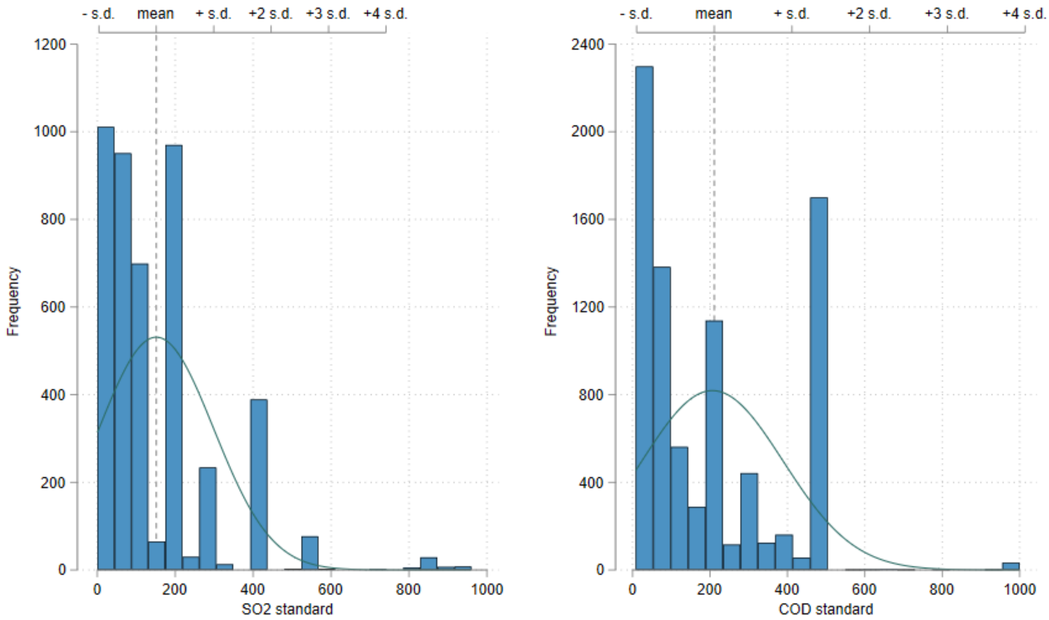


Table A1. Industry Distribution

	(1)	(2)	(3)	(4)	(5)	(6)
	Control	Private Appeals				Public Appeals
		Messaging	Website	Call Gov	Call Firm	Weibo
	C	T1A	T1B	T1C	T1D	T2
Water production and sewage treatment plant (46)	16.55%	15.00%	17.07%	16.80%	17.03%	17.40%
Electricity and heat production and supply (44)	12.00%	11.93%	11.88%	12.18%	11.26%	12.26%
Chemical raw materials and products (26)	6.20%	6.89%	9.16%	9.87%	8.64%	9.99%
Textile printing and dyeing (17)	9.68%	9.34%	9.16%	8.50%	8.44%	8.55%
Non-metallic mineral products (30)	6.63%	7.18%	7.64%	8.32%	7.79%	7.98%
Agri-food processing (13)	3.49%	3.57%	5.03%	4.16%	3.65%	4.27%
Paper products (22)	4.79%	5.67%	4.55%	4.62%	4.84%	4.22%
Ferrous metal smelting and rolling processing (31)	4.99%	4.79%	3.30%	3.76%	4.07%	3.40%
Pharmaceutical manufacturing (27)	2.86%	2.44%	2.88%	3.02%	3.27%	3.09%
Petroleum, coal and other fuel processing (25)	2.47%	2.39%	2.72%	3.20%	2.67%	2.99%
Metal products (33)	3.73%	2.54%	3.51%	2.94%	3.32%	2.73%
Liquor, beverage and refined tea manufacturing (15)	1.31%	2.20%	2.41%	2.49%	2.60%	2.47%
Food manufacturing (14)	1.36%	1.76%	2.04%	1.85%	1.67%	1.65%
Coal mining and washing (6)	1.40%	1.52%	1.26%	1.60%	1.42%	1.60%
Electronic equipment manufacturing (39)	1.65%	1.03%	1.20%	1.12%	1.10%	1.60%
Leather, fur, feathers and their products (19)	2.23%	2.49%	1.20%	1.57%	1.82%	1.34%
Total	81.32%	80.74%	85.03%	85.99%	83.60%	85.53%

Table A2. Pollution Appeals and Air Flow

	(1) log(Flow)	(2) log(Flow)
Panel A. Impacts of the Sub-Treatments		
Messaging Gov Privately (T1A*Post)	-0.00799	-0.0104
	(0.0618)	(0.0618)
Appeal Gov Website Privately (T1B*Post)	-0.117	-0.0397
	(0.0705)	(0.0758)
Call Gov Privately (T1C*Post)	0.00517	-0.0171
	(0.0964)	(0.0909)
Call Firm Privately (T1D*Post)	0.0877	0.0725
	(0.0787)	(0.0699)
Call Gov*Call Firm (T1C*TID*Post)	-0.203	-0.193
	(0.143)	(0.114)
Appeal Publicly on Weibo (T2*Post)	-0.0220	-0.0275
	(0.0514)	(0.0631)
H0: T1A>T2	P=0.386	P=0.342
H0: T1B>T2	P=0.917	P=0.578
H0: T1C>T2	P=0.397	P=0.452
H0: T1D>T2	P=0.0699	P=0.0717
Panel B. Impacts of Pooled Private and Public Appeals		
Private Appeals (T1*Post)	-0.0267	-0.0242
	(0.0516)	(0.0586)
Public Appeals (T2*Post)	-0.0220	-0.0224
	(0.0474)	(0.0633)
H0: T1>T2	P=0.535	P=0.515
Control Mean	5.747	5.747
Control SD	4.452	4.452
Firm FE	Yes	Yes
Day FE	Yes	
Province by Day FE		Yes
Observations	3979183	3979180

Notes: This table reports the regression results from estimating Equation (1) on the logged volume of flows. In Column 1, we control for firm FE and day FE; in Column 2, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3. Baseline Analysis with Non-Zero Violation Sample

	(1) Violation	(2) Violation
Panel A. Impacts of the Sub-Treatments		
Messaging Gov Privately (T1A*Post)	-0.00642*	-0.00576
	(0.00346)	(0.00343)
Appeal Gov Website Privately (T1B*Post)	-0.00677*	-0.00386
	(0.00372)	(0.00379)
Call Gov Privately (T1C*Post)	-0.00964**	-0.00771*
	(0.00372)	(0.00392)
Call Firm Privately (T1D*Post)	-0.00434	-0.00505
	(0.00328)	(0.00317)
Call Gov*Call Firm (T1C*TID*Post)	-0.00337	-0.00129
	(0.00492)	(0.00449)
Appeal Publicly on Weibo (T2*Post)	-0.0189***	-0.0168***
	(0.00502)	(0.00391)
H0: T1A>T2	P=0.00642	P=0.00379
H0: T1B>T2	P=0.00202	P=0.000593
H0: T1C>T2	P=0.0155	P=0.00582
H0: T1D>T2	P=0.00324	P=0.000629
Panel B. Impacts of Private and Public Appeals		
Private Appeals (T1*Post)	-0.00891***	-0.00726**
	(0.00309)	(0.00308)
Public Appeals (T2*Post)	-0.0189***	-0.0167***
	(0.00502)	(0.00390)
H0: T1>T2	P=0.00498	P=0.00110
Control Mean	0.0318	0.0318
Control SD	0.175	0.175
Firm FE	Yes	Yes
Day FE	Yes	
Province by Day FE		Yes
Observations	2255186	2254899

Notes: This table reports the regression results from estimating Equation (1) using firms that violated emissions standards at least once during the treatment period. The unit of analysis is firm-day. Violation is a dummy variable that equals 1 if the firm violates an emission standard on that day, and zero otherwise. In Column 1, we control for firm FE and day FE; in Column 2, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4. Baseline Analysis with Pre-treatment Non-Zero Violation Sample

	(1) Violation	(2) Violation
Panel A. Impacts of the Sub-Treatments		
Messaging Gov Privately (T1A*Post)	-0.00928	-0.00960
	(0.00848)	(0.00857)
Appeal Gov Website Privately (T1B*Post)	-0.00101	-0.00114
	(0.00869)	(0.00858)
Call Gov Privately (T1C*Post)	-0.0166*	-0.0184**
	(0.00869)	(0.00889)
Call Firm Privately (T1D*Post)	-0.00883	-0.0117
	(0.00836)	(0.00862)
Call Gov*Call Firm (T1C*TID*Post)	-0.00504	0.00177
	(0.0109)	(0.0111)
Appeal Publicly on Weibo (T2*Post)	-0.0355***	-0.0337***
	(0.0102)	(0.00855)
H0: T1A>T2	P=0.00250	P=0.00102
H0: T1B>T2	P=0.000179	P=0.000209
H0: T1C>T2	P=0.0160	P=0.0177
H0: T1D>T2	P=0.00534	P=0.00315
Panel B. Impacts of Private and Public Appeals		
Private Appeals (T1*Post)	-0.0136*	-0.0140*
	(0.00742)	(0.00734)
Public Appeals (T2*Post)	-0.0355***	-0.0336***
	(0.0102)	(0.00853)
H0: T1>T2	P=0.00227	P=0.000848
Control Mean	0.0553	0.0553
Control SD	0.229	0.229
Firm FE	Yes	Yes
Day FE	Yes	
Province by Day FE		Yes
Observations	813348	813056

Notes: This table reports the regression results from estimating Equation (1) using the firms that violated emissions standards at least once in the pre-treatment period. The unit of analysis is firm-day. Violation is a dummy variable that equals 1 if the firm violates an emission standard on that day, and zero otherwise. In Column 1, we control for firm FE and day FE; in Column 2, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5. Baseline Analysis using Cross-sectional Sample

	(1) Violation	(2) Violation
Panel A. Impacts of the Sub-Treatments		
Messaging Gov Privately (T1A)	-0.352*	-1.553**
	(0.187)	(0.625)
Appeal Gov Website Privately (T1B)	-0.222	-1.294**
	(0.191)	(0.626)
Call Gov Privately (T1C)	-0.353*	-1.961***
	(0.190)	(0.621)
Call Firm Privately (T1D)	-0.292	-1.446**
	(0.186)	(0.619)
Call Gov*Call Firm (T1C*TID)	0.158	1.205
	(0.266)	(0.868)
Appeal Publicly on Weibo (T2)	-0.417**	-2.006***
	(0.190)	(0.620)
Baseline Violations	2.117***	1.997***
	(0.0207)	(0.0389)
H0: T1A>T2	P=0.364	P=0.230
H0: T1B>T2	P=0.151	P=0.122
H0: T1C>T2	P=0.367	P=0.470
H0: T1D>T2	P=0.252	P=0.178
Panel B. Impacts of Private and Public Appeals		
Private Appeals (T1)	-0.340**	-1.689***
	(0.146)	(0.487)
Public Appeals (T2)	-0.416**	-1.998***
	(0.190)	(0.620)
Baseline Violations	2.117***	1.995***
	(0.0207)	(0.0389)
H0: T1>T2	P=0.302	P=0.255
Control Mean	2.354	2.354
Control SD	11.58	11.58
City FE	Yes	Yes
Observations	24745	7186

Notes: This table reports the regression results from cross-sectional sample. The unit of analysis is firm. Violation is a dummy variable that equals 1 if the firm violates an emission standard, and zero otherwise. In Column 1, we include all firms; in Column 2, we include non-zero sample only. We control for prefecture FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A6. Pollution Appeals and Verified Environmental Violations

	(1) Violation	(2) Violation
Panel A. Impacts of the Sub-Treatments		
Messaging Gov Privately (T1A*Post)	-0.00172**	-0.00165*
	(0.000827)	(0.000827)
Appeal Gov Website Privately (T1B*Post)	-0.00249***	-0.00173*
	(0.000913)	(0.000880)
Call Gov Privately (T1C*Post)	-0.00158	-0.000961
	(0.00105)	(0.00109)
Call Firm Privately (T1D*Post)	-0.000889	-0.000938
	(0.000824)	(0.000807)
Call Gov*Call Firm (T1C*TID*Post)	-0.000846	-0.000532
	(0.00129)	(0.00122)
Appeal Publicly on Weibo (T2*Post)	-0.00476***	-0.00422***
	(0.00143)	(0.00123)
H0: T1A>T2	P=0.0120	P=0.0138
H0: T1B>T2	P=0.0176	P=0.00682
H0: T1C>T2	P=0.00713	P=0.00281
H0: T1D>T2	P=0.00475	P=0.00302
Panel B. Impacts of Private and Public Appeals		
Private Appeals (T1*Post)	-0.00198**	-0.00153*
	(0.000779)	(0.000786)
Public Appeals (T2*Post)	-0.00476***	-0.00420***
	(0.00143)	(0.00122)
H0: T1>T2	P=0.00728	P=0.00341
Control Mean	0.00685	0.00685
Control SD	0.0825	0.0825
Firm FE	Yes	Yes
Day FE	Yes	
Province by Day FE		Yes
Observations	7244467	7244467

Notes: This table reports the regression results from estimating Equation (1), using pollution violations that are double checked by our team as the outcome variable. The unit of analysis is firm-day. Violation is a dummy variable that equals 1 if the firm violates an emission standard on that day, and zero otherwise. In Column 1, we control for firm FE and day FE; in Column 2, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7. Main Results by Ownership

	(1)	(2)	(3)	(4)
	Violation	Violation	Violation	Violation
	SOEs	SOEs	Private	Private
Panel A. Impacts of the Sub-Treatments				
Messaging Gov Privately	-0.00689*	-0.00623	-0.00151	-0.00156
(T1A*Post)	(0.00404)	(0.00423)	(0.00118)	(0.00117)
Appeal Gov Website Privately	-0.00662	-0.00487	-0.00140	-0.000709
(T1B*Post)	(0.00416)	(0.00342)	(0.00117)	(0.00140)
Call Gov Privately	-0.00780	-0.00593	-0.00315**	-0.00263*
(T1C*Post)	(0.00481)	(0.00478)	(0.00119)	(0.00136)
Call Firm Privately	-0.00184	-0.00103	-0.00103	-0.00127
(T1D*Post)	(0.00380)	(0.00388)	(0.00114)	(0.00113)
Call Gov*Call Firm	-0.00125	-0.00176	-0.00114	-0.000391
(T1C*TID*Post)	(0.00711)	(0.00712)	(0.00161)	(0.00148)
Appeal Publicly on Weibo	-0.0134**	-0.0103**	-0.00564***	-0.00541***
(T2*Post)	(0.00578)	(0.00428)	(0.00172)	(0.00156)
H0: T1A>T2	P=0.126	P=0.174	P=0.0118	P=0.00831
H0: T1B>T2	P=0.0351	P=0.0478	P=0.00611	P=0.00242
H0: T1C>T2	P=0.165	P=0.173	P=0.0465	P=0.0251
H0: T1D>T2	P=0.00822	P=0.00856	P=0.0113	P=0.00553
Panel B. Impacts of Pooled Private and Public Appeals				
Private Appeals (T1*Post)	-0.00683*	-0.00531	-0.00247**	-0.00207*
	(0.00371)	(0.00346)	(0.000973)	(0.00108)
Public Appeals (T2*Post)	-0.0134**	-0.0102**	-0.00564***	-0.00537***
	(0.00578)	(0.00425)	(0.00172)	(0.00155)
H0: T1>T2	P=0.0521	P=0.0599	P=0.0170	P=0.00743
Control Mean	0.00764	0.00764	0.00958	0.00958
Control SD	0.0871	0.0871	0.0974	0.0974
Firm FE	Yes	Yes	Yes	Yes
Day FE	Yes		Yes	
Province by Day FE		Yes		Yes
Observations	409792	409792	5606870	5606870

Notes: This table reports the regression results from estimating Equation (1). The unit of analysis is firm-day. Violation is a dummy variable that equals 1 if the firm violates an emission standard on that day, and zero otherwise. In Columns 1 and 2, we use the sample of SOEs; in Columns 3 and 4, we use the sample of private firms. In Columns 1 and 3, we control for firm FE and day FE; in Columns 2 and 4, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A8. Impacts on Other Citizen Appeals

	(1) Other Citizen Appeals	(2) Other Citizen Appeals
Panel A. Impacts of the Sub-Treatments		
Messaging Gov Privately (T1A*Post)	0.0000426	0.0000284
	(0.000110)	(0.000113)
Appeal Gov Website Privately (T1B*Post)	0.0000377	-0.0000122
	(0.0000852)	(0.000104)
Call Gov Privately (T1C*Post)	-0.0000605	-0.000118
	(0.000169)	(0.000167)
Call Firm Privately (T1D*Post)	-0.0000988	-0.000104
	(0.000139)	(0.000138)
Call Gov*Call Firm (T1C*TID*Post)	0.000223	0.000230
	(0.000201)	(0.000202)
Appeal Publicly on Weibo (T2*Post)	-0.00000522	-0.0000675
	(0.000146)	(0.000140)
H0: T1A>T2	P=0.377	P=0.255
H0: T1B>T2	P=0.376	P=0.342
H0: T1C>T2	P=0.627	P=0.617
H0: T1D>T2	P=0.693	P=0.576
Panel B. Impacts of Private and Public Appeals		
Private Appeals (T1*Post)	-0.00000381	-0.0000397
	(0.0000992)	(0.0000996)
Public Appeals (T2*Post)	-0.00000522	-0.0000676
	(0.000146)	(0.000139)
H0: T1>T2	P=0.496	P=0.415
Control Mean	0.00936	0.00936
Control SD	0.0963	0.0963
Firm FE	Yes	Yes
Day FE	Yes	
Province by Day FE		Yes
Observations	7100952	7100952

Notes: This table reports the regression results of replacing the dependent variables of Equation (1) with the number of appeals made by other citizens. The unit of analysis is firm-day. Violation is a dummy variable that equals 1 if the firm violates an emission standard on that day, and zero otherwise. In Column 1, we control for firm FE and day FE; in Column 2, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A9. Pollution Appeals and Abnormal Concentrations

	(1)	(2)	(3)	(4)
	Abnormal Hour	Abnormal Hour	Abnormal Concentration	Abnormal Concentration
Panel A. Impacts of the Sub-Treatments				
Messaging Gov Privately	0.00203	0.00285	0.00287	0.00300
(T1A*Post)	(0.00555)	(0.00492)	(0.00532)	(0.00513)
Appeal Gov Website Privately	-0.00477	-0.00894	-0.00476	-0.00628
(T1B*Post)	(0.00661)	(0.00595)	(0.00693)	(0.00622)
Call Gov Privately	-0.00354	-0.00693	0.00147	0.0000929
(T1C*Post)	(0.00590)	(0.00498)	(0.00678)	(0.00596)
Call Firm Privately	-0.00636	-0.00579	-0.000916	-0.000396
(T1D*Post)	(0.00570)	(0.00541)	(0.00581)	(0.00575)
Call Gov*Call Firm	0.00953	0.00746	0.00263	0.00114
(T1C*TID*Post)	(0.00717)	(0.00708)	(0.00852)	(0.00851)
Appeal Publicly on Weibo	-0.00515	-0.0112*	0.00225	-0.000950
(T2*Post)	(0.00626)	(0.00572)	(0.00648)	(0.00556)
Panel B. Impacts of Private and Public Appeals				
Private Appeals (T1*Post)	-0.00260	-0.00472	0.000369	-0.000491
	(0.00465)	(0.00434)	(0.00529)	(0.00473)
Public Appeals (T2*Post)	-0.00515	-0.0110*	0.00225	-0.000844
	(0.00626)	(0.00571)	(0.00648)	(0.00553)
Control Mean	0.0921	0.0921	0.0932	0.0932
Control SD	0.289	0.289	0.291	0.291
Firm FE	Yes	Yes	Yes	Yes
Day FE	Yes		Yes	
Province by Day FE		Yes		Yes
Observations	3367354	3367117	3367354	3367117

Notes: This table reports the regression results from estimating Equation (1). The unit of analysis is firm-day. Abnormal Hour is a dummy variable that equals 1 if the firm's hourly records are fewer than 20 on that day, and zero otherwise. Abnormal Concentration is a dummy variable that equals 1 if the firm's daily average emission concentration of SO_2 (mg/m3) or COD (mg/L) is smaller than 1/10 annual average level, and zero otherwise. In Columns 1 and 3, we control for firm FE and day FE; in Columns 2 and 4, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A10. Main Results by Firms that Produce Final versus Intermediate Products

	(1) Violation Final	(2) Violation Final	(3) Violation Intermediate	(4) Violation Intermediate
Panel A. Impacts of the Sub-Treatments				
Messaging Gov Privately	-0.00399*	-0.00413*	-0.00134	-0.00129
(T1A*Post)	(0.00209)	(0.00210)	(0.00132)	(0.00130)
Appeal Gov Website Privately	-0.00224	-0.00267	-0.00168	-0.000492
(T1B*Post)	(0.00204)	(0.00201)	(0.00132)	(0.00162)
Call Gov Privately (T1C*Post)	-0.00401**	-0.00396**	-0.00335**	-0.00253
	(0.00185)	(0.00188)	(0.00138)	(0.00155)
Call Firm Privately (T1D*Post)	-0.00203	-0.00241	-0.000889	-0.00103
	(0.00166)	(0.00166)	(0.00138)	(0.00138)
Call Gov*Call Firm	0.000102	0.000205	-0.00143	-0.000585
(T1C*TID*Post)	(0.00316)	(0.00314)	(0.00203)	(0.00181)
Appeal Publicly on Weibo	-0.00363*	-0.00413**	-0.00682***	-0.00613***
(T2*Post)	(0.00209)	(0.00204)	(0.00220)	(0.00189)
H0: T1A>T2	P=0.556	P=0.500	P=0.00529	P=0.00410
H0: T1B>T2	P=0.244	P=0.238	P=0.00815	P=0.00421
H0: T1C>T2	P=0.575	P=0.467	P=0.0374	P=0.0222
H0: T1D>T2	P=0.202	P=0.174	P=0.00708	P=0.00315
Panel B. Impacts of Private and Public Appeals				
Private Appeals (T1*Post)	-0.00362**	-0.00382**	-0.00257**	-0.00187
	(0.00142)	(0.00145)	(0.00112)	(0.00121)
Public Appeals (T2*Post)	-0.00363*	-0.00409*	-0.00682***	-0.00608***
	(0.00209)	(0.00203)	(0.00220)	(0.00188)
H0: T1>T2	P=0.498	P=0.437	P=0.00963	P=0.00434
Control Mean	0.00629	0.00629	0.0102	0.0102
Control SD	0.0790	0.0790	0.101	0.101
Firm FE	Yes	Yes	Yes	Yes
Day FE	Yes		Yes	
Province by Day FE		Yes		Yes
Observations	1274733	1274733	4741929	4741929

Notes: This table reports the regression results from estimating Equation (1). The unit of analysis is firm-day. Violation is a dummy variable that equals 1 if the firm violates an emission standard on that day, and zero otherwise. In Columns 1 and 2, we use the sample of firms that produce final goods; in Columns 3 and 4, we use the sample of firms that produce intermediate goods. In Columns 1 and 3, we control for firm FE and day FE; in Columns 2 and 4, we control for firm FE and province-by-day FE. Standard errors are clustered two-way by prefecture and week. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A11. Threats and Government Responsiveness

	(1)	(2)	(3)	(4)	(5)	(6)
	Whether Respond	Whether Respond	Response Length	Response Length	Onsite Audit	Onsite Audit
Threat to Tell Upper-Level Government	0.0162	0.0181	12.42	13.66	-0.0245	-0.0163
	(0.0355)	(0.0349)	(15.64)	(15.60)	(0.0271)	(0.0266)
Threat to Tell Media	0.0349	0.0259	10.39	7.203	-0.00395	-0.00322
	(0.0396)	(0.0390)	(17.44)	(17.42)	(0.0302)	(0.0297)
Control Mean	0.172	0.172	45.69	45.69	0.107	0.107
Control SD	0.378	0.378	149.6	149.6	0.310	0.310
Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE		Yes		Yes		Yes
Observations	662	658	662	658	662	658

Notes: This table reports the regression results for Weibo appeals on local government responsiveness. We use the sample of firms in the public Weibo appeal to government arm. The unit of analysis is each Weibo appeal. Whether respond is a dummy variable that equals 1 if the government formally replies to our Weibo appeal, and 0 otherwise; response length is the word count of the government's Weibo reply to our appeal, which is counted as zero if there is no response; onsite audit is a dummy variable that equals 1 if the government replies to our Weibo appeal with proof of an onsite investigation, and 0 otherwise. In Columns 1, 3 and 5, we control for month FE; in Columns 2, 4, and 6, we control for month FE and province FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix B. Sample Templates for Each Arm[17]

T1A: sending direct message to regulator on social media

Hello, I found that the daily average concentration of chemical oxygen demand of Xinxing Paper Co., Ltd. from Youxi County exceeded the standard value on December 25. Please refer to the attached screenshot and check the issue, thank you.

您好，我观察到尤溪县鑫兴纸业有限公司 12 月 25 日化学需氧量日均浓度超越标准值。详情见截图，请您关注并核查，谢谢。

T1B: appealing to regulator on government website

The Fujian online monitoring platform shows that on September 15, the daily average concentration of ammonia nitrogen in the total sewage discharge outlet and the wastewater discharge outlet of Quanzhou Kaiying Power Supply Appliance Co., Ltd. exceeded the emission standard. Please refer to the attached screenshot. Please check and reply.

福建省在线监测平台显示 9 月 15 日泉州市凯鹰电源电器有限公司的污水总排放口、生产废水排放口氨氮日均浓度超标。详情见附件。请核查并说明原因。

***T1C:* appealing to regulator by calling government hotline**

Hello, the Jiangsu Enterprise Automatic Monitoring Information Platform showed that the daily average concentration of total phosphorus in the sewage discharge outlet of Jiangyin Biyue Wastewater Treatment Co., Ltd. exceeded the standard on June 22. Please investigate and give feedback.

您好，江苏省企业自动监测信息平台显示 6 月 22 日江阴碧悦污水处理有限公司污水排放口总磷日均浓度超标。请调查并给予反馈。

T1D: appealing to firm by phone call

Hello, I am an environmental protection enthusiast. I noticed that on May 29th, the daily average value of smoke and dust from your company's No. 1 exhaust gas discharge outlet exceeded the standard. Please pay attention to it and investigate, thank you.

您好，我是环保热心群众。我留意到 5 月 29 日贵公司的 1#废气排放口烟尘日均值超标，请您关注并进行调查，谢谢。

T2: public appeal to government on Weibo

No threat

[17] We randomly varied the exact wording used in each appeal to avoid appearing repetitive to the regulators/firms. But the core content of the appeal remained the same across all treatment arms.

The industrial waste gas discharge outlet of Hengrun Coal Chemical Co., Ltd. located in Shenmu County exceeded the emission standard on May 29th. Please refer to the attached screenshot. Please check and feedback the reason for exceeding the standard in time @ Yulin Ecological Environment Bureau

位于神木县的恒润煤化工有限公司的工业废气排放口 5 月 29 日烟尘日均在线数据超标，见附图，请及时核查并反馈超标原因@榆林市生态环境局

Media threat

Zhejiang Qunzhan Precision Fasteners Co., Ltd. in Jiashan County exceeded the standard value of daily average chemical oxygen demand emission at its wastewater discharge outlet on October 9. Please refer to the attached screenshot. Please check and give feedback @ Jiaxing Ecological Environment Bureau @ Jiashan Ecological Environment Bureau, if there is no response in time, I will contact the media about this matter.

嘉善县的浙江群展精密紧固件股份有限公司 10 月 9 日废水排放口化学需氧量日均值超越标准值，见附图，请核查并作出反馈@嘉兴生态环境 @嘉善环保，若未及时回复将进行媒体公开。

Upper-level government threat

The waste incinerator at discharge outlet No. 1 of Zhejiang Chunhui Environmental Energy Co., Ltd, located in the Shangyu Economic and Technological Development Zone, exceeded the daily standard value of sulfur dioxide emissions on August 16. Please refer to the attached screenshot. Please check and reply @Shaoxing Ecological Environment Bureau. If there's no reply in time, I will report this issue to the upper-level environmental protection department.

上虞经济技术开发区的浙江春晖环保能源有限公司 1#排放口 1#垃圾焚烧炉于 8 月 16 日出现二氧化硫日均值超标情况。详见附图。请核查并作出说明@绍兴生态环境， 如未回复将向上级环保部门反映。

Screenshots of Experiment Implementation Details

Sample CEMS Violation Screenshot:

江苏省重点监控企业自行监测信息发布平台 企业用户登录 环保用户登录

当前位置：首页 > 江苏华电通州热电有限公司

企业基本信息 | 自行监测方案 | 自动监测 | 手动监测 | 未监测原因 | 年度报告

☑ 废水集中排放 ☑ 废气有组织排放 查询

序号	监测点位	监测项目	监测方式	监测频次	标准值下限	标准值上限
1	废水监测点	PH值	自动监测	连续/日/次	6	9
2		化学需氧量	自动监测	连续/日/次		500 mg/l
3	废气监测点1	烟尘	自动监测	连续/日/次		5 mg/m3
4		二氧化硫	自动监测	连续/日/次	0 mg/m3	35 mg/m3
5		氮氧化物	自动监测	连续/日/次	0 mg/m3	50 mg/m3
6	废气监测点2	烟尘	自动监测	连续/日/次	0 mg/m3	5 mg/m3
7		二氧化硫	自动监测	连续/日/次	0 mg/m3	35 mg/m3
8		氮氧化物	自动监测	连续/日/次	0 mg/m3	50 mg/m3

监测点位：废气监测点1 监测项目：氮氧化物 监测时间：2019-12-04 至 2019-12-04 查询 列表 图表

序号	监测点位	监测时间	监测项目	监测值	标准值下限	标准值上限	数据状态	超标倍数	备注说明
13	废气监测点1	2019-12-04 11	氮氧化物	8.70 mg/m3 折 8.70 mg/m3	0 mg/m3	50 mg/m3	正常		
14	废气监测点1	2019-12-04 10	氮氧化物	8.69 mg/m3 折 2600.20 m...	0 mg/m3	50 mg/m3	超标	51.00	
15	废气监测点1	2019-12-04 09	氮氧化物	8.74 mg/m3 折 871.79 mg...	0 mg/m3	50 mg/m3	超标	16.44	
16	废气监测点1	2019-12-04 08	氮氧化物	8.80 mg/m3 折 600.02 mg...	0 mg/m3	50 mg/m3	超标	11.00	
17	废气监测点1	2019-12-04 07	氮氧化物	8.82 mg/m3 折 503.09 mg...	0 mg/m3	50 mg/m3	超标	9.06	
18	废气监测点1	2019-12-04 06	氮氧化物	8.80 mg/m3 折 494.29 mg...	0 mg/m3	50 mg/m3	超标	8.89	
19	废气监测点1	2019-12-04 05	氮氧化物	8.82 mg/m3 折 487.29 mg...	0 mg/m3	50 mg/m3	超标	8.75	
20	废气监测点1	2019-12-04 04	氮氧化物	8.78 mg/m3 折 539.64 mg...	0 mg/m3	50 mg/m3	超标	9.79	

20 | 1 /2 每页 20 条,共 24

目前本站系统仅支持IE6以上浏览器（建议使用IE7或IE9），为您带来的不便我们深感抱歉

技术支持：江苏省生态环境监控中心 联系地址：南京市江东北路176号 邮编：210036 电子邮件：xxzx@jshb.gov.cn

Screenshot for T1:

T1A: sending direct message to regulator on social media

- Find the official Weibo account of the city/county's environmental bureau

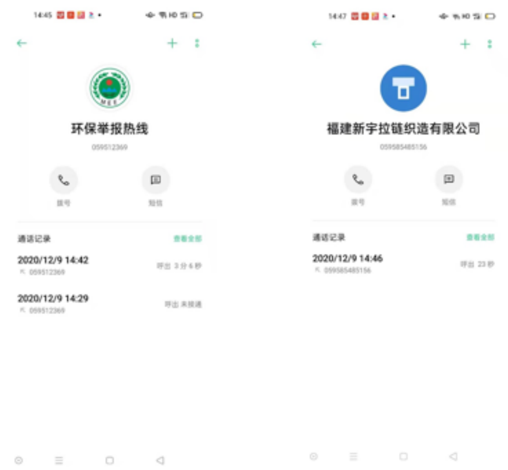
- We send pollution violation information to the government through the private messages
- Testing the information barrier hypothesis

T1B: appealing to regulator on government website

On the 12369 websites, we describe the appeals and upload the screenshot.

After submitting an appeal, we will get a search code, and then we can use it to check the responses.

T1C/T1D: appealing to regulator and/or firm by phone call



Screenshot for T2:

T2: public appeal to government on Weibo

- On Weibo, we publish the company's violation information and relevant screenshots
- Use the @ function of Weibo to remind the official accounts of relevant local environmental protection bureaus to pay attention to this complaint and respond

Appendix C. Ethical Considerations

Overview

This field experiment involved working with a team of graduate students in environmental science to verify the compliance of firms with environmental standards using publicly available data from the Continuous Emissions Monitoring System (CEMS) set up under the "Measures for the Self-Monitoring and Information Disclosure of National Key Monitoring Enterprises (Trial)". We identified violations on a daily basis and, upon observing violations, we generated private or public appeals to be filed with local governments or firms by a group of citizen environmental volunteers that we recruited from China's local environmental protection NGOs. We use responses to the appeals and publicly available data on violations and emissions to measure the impacts of appeals. The central government has encouraged the public to appeal violations and has created specific channels for public participation, which we use to file appeals. Our field experiment is thus layered on top of existing firm-level disclosures mandates and utilizes existing channels sanctioned for public participation in the supervision of environmental regulations. Prior to launching the field experiment, we considered the impacts the treatments may have on several classes of humans and institutions.

Human Subjects

We did not collect data from or about any individual human being as part of this study. All the appeals in the experiment were disseminated to institutional accounts of local governments and firms. All data used for analysis are publicly available (or a direct response to an appeal submitted as part of the experiment) and do not identify any individual government official or firm employee. Prior to launching the experiment, we sought clarification on the status of the research from Institutional Review Boards at the University of Chicago and the University of California, Santa Barbara. Because we did not collect data about or from individual human beings, both boards determined that this project is not considered research with human subjects (UChicago protocols IRB19-1744, and letter of determination dated October 18, 2019 from UCSB FWA#00006361).

Citizen Volunteers

We partnered with several environmental protection NGOs in China to recruit a group of citizen environmental volunteers, who made public and private appeals when violations were identified using the Continuous Emissions Monitoring System (CEMS). We carefully considered the potential impacts of this research on the safety and employability of the citizen volunteers. We reviewed policy documents relevant to public participation in environmental governance in China and determined that the kinds of activities that research staff undertook for the experiment are both permitted and encouraged under current legal standards (for details, please refer to China's new environmental law and the "Interim Measures for Public Participation in Environmental Impact Assessment" and the "Provisional Measures for Encouraging Environmental Violation Appeals"). During the experiment and afterwards, we received no indications that governments or firms attempted to sanction the citizen volunteers in any way for filing appeals, likely because all appeals used channels explicitly permitted and encouraged under central policies.

Impacts on Local Governments

This field experiment increased the number of appeals that local governments had to address related to the non-compliance of key firms with pollution standards, which likely involved time and effort. It is important to note that local governments are expressly mandated to respond to appeals from the public and actively monitor reports of non-compliance through various channels for public participation ("Provisional Measures for Encouraging Environmental Violation Appeals"). Thus, while our experiment may have increased the effort required by local governments to regulate pollution, that effort is consistent with existing mandates and responsibilities under the law.

We considered the possibility that appeals from a research project could make local governments less responsive to public complaints in the future. We believe this is unlikely given the size of our experiment relative to existing public participation in environmental supervision. During the experiment, our citizen environmental volunteers filed more than 3,500 appeals to local governments about pollution violations. Data from channels for public participation such as the 12369 hotline and website indicate that more than 600,000 complaints about pollution are filed by the public each year. Accordingly, we do not believe that the intensity of the treatments will influence government responsiveness to the public in the future. We also consulted with local organizations like the Institute of Public and Environmental Affairs (IPE) and the Public Environment Concerned Center (PECC) to ensure that the appeals filed during the experiment were consistent in channel and content with other public appeals.

Impacts on Firms

The firms that were subject to appeals in this field experiment may have had to increase their effort to comply with environmental standards, which likely imposed costs. We note that appeals were only triggered for firms that exceeded existing pollution standards set by Ministry of Ecology and Environment. Since the current environmental law has made it clear that these violations should be eliminated to promote environmental quality and public health, we considered it acceptable to impose costs of firms through the treatment, since policymakers have judged those costs to be acceptable considering the potential public benefits of reductions in pollution.