

# **Truth Telling by Third-Party Audits and the Response of Polluting Firms: Experimental Evidence from India**

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**Grantee Final Report**

**Accepted by 3ie: March 2013**



## **Note to readers**

This impact evaluation has been submitted in fulfilment of the requirements of grant OW2.094 issued under Open Window 2. 3ie has accepted it as final. The authors retain sole responsibility for the content of their report and for any errors. This report will be edited, formatted and produced to the 3ie publication standards in the next few months. The title and some content may change, but no substantives changes to the data or findings are expected. The following is the correct citation for the grantee final report:

Duflo, E., Greenstone, M., Pande, R., and Ryan, N. 2013, Truth Telling by Third-Party Audits and the Response of Polluting Firms: Experimental Evidence from India, 3ie Grantee Final Report

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*Esther Duflo, Michael Greenstone, Rohini Pande and Nicholas Ryan*

## **Acknowledgements**

We thank Sanjiv Tyagi, R. G. Shah and Hardik Shah for their advice and support over the course of this project. We thank Pankaj Verma, Eric Dodge, Vipin Awatramani, Logan Clark, Yuanjian Li, Sam Norris and Nick Hagerty for their excellent research assistance and numerous seminar participants for their comments.

The research discussed in this publication has been funded by the International Initiative for Impact Evaluation, Inc. (3ie) through the Global Development Network (GDN), the Sustainability Science Program (SSP), the Harvard Environmental Economics Program, the Center for Energy and Environmental Policy Research (CEEPR), the International Growth Centre (IGC) and the National Science Foundation (NSF Award #1066006). Ryan is grateful for an AMID Early Stage Researcher Fellowship for financial support. All views and errors are solely ours.

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## Abstract

### A. Summary: Strengthening environmental audits improves reporting and reduces pollution

In many regulated markets, firms choose and pay private, third-party auditors, potentially creating a conflict of interest. This paper reports on a two-year field experiment in the Indian state of Gujarat that sought to curb such a conflict by reforming the system of environmental audits for industrial plants.

In the control group, plants remained in the status quo system, wherein they directly chose and paid their third-party auditors. In the treatment group, the researchers assigned auditors to plants randomly and paid them a fixed fee from a central pool. Independent agencies subjected their reports to random backchecks. In the second year, the auditors working in the treatment group additionally received a bonus for accurate reporting.

There are three main results. First, the status quo system was largely corrupt, with auditors systematically reporting plant emissions just below the standard, although the true emissions were typically higher. Second, the treatment caused auditors to report more truthfully and reduced the fraction of plants that they falsely reported as being compliant with pollution standards. Third, the treatment plants, in turn, reduced their pollution emissions. The results suggest that reformed incentives for third-party auditors can improve the quality of their reports and make regulation more effective.

### B. Main results

The main results of the experiment are:

- **Auditors working in the standard scheme (control group of plants) report too low.** As feared by many, some auditors under the standard scheme systematically under-report pollution readings. Further, their reports tend to cluster just below the Gujarat Pollution Control Board (GPCB) norm.
- **Auditors working in the modified scheme (treatment group of plants) report much more accurately.** The audit reports in the modified scheme are much more accurate, as comparisons of auditor reports and independent backchecks show.
- **Plants subject to improved audits (treatment group of plants) reduce their pollution emissions.** After two years, the plants in the treatment group showed lower concentrations of pollution than the plants in the regular scheme.

Data analysis of the second treatment arm, an increase in government inspection frequency, is ongoing. We report details of a preliminary analysis of this intervention in this report. The main findings with respect to the inspection treatment thus far are:

- **The inspection treatment was properly implemented.** The assignment of recently retired GPCB staff to conduct more inspections roughly doubled the annual number of inspections from two to four per plant.

- **Auditors cited inspection treatment plants for more violations.** They were more likely to cite firms in the inspection treatment than those in the control group for violations of pollution standards, especially for water pollution, and more likely to threaten them with closure.
- **The inspection treatment plants did not significantly reduce their pollution relative to the control plants.** The point estimate for the effect of more inspections on pollution is about -0.1 standard deviations, but not significantly different from zero.

We interpret these findings as evidence that more inspections bring more plants under scrutiny but, because the threat of sanctions is still several steps removed from the inspection, they have a weak effect on pollution.

### C. Policy recommendations

We propose three policy recommendations based on the components of the treatment:

- **Auditor assignment.** The GPCB should conduct the assignment of industries to auditors each year centrally on a random basis.
- **Backchecks of auditing work.** The GPCB should hire outside experts to backcheck the work of the regular auditors in the field after some audit visits.
- **Audit payments.** The GPCB should fix the structure of payments to auditors.

These recommendations are also relevant to other regulations in India that third parties help to monitor, in particular the national system of Environmental Impact Assessments.

### D. Objective of the study

Environmental degradation is a serious issue in many developing countries and corruption may limit the effectiveness of regulations in easing this problem. The objective of this study is broadly to test whether sensible regulatory reforms could improve the effectiveness of regulation and reduce pollution.

### E. Project design

This project involves a randomised controlled trial (RCT) with two treatment arms. To our knowledge, it is the first RCT of environmental regulation anywhere in the world.

The treatment consists of three changes to the audit regulation intended to improve auditors' independence from plants:

- **Auditor assignment.** The researchers randomly assigned auditors to plants in the modified scheme, rather than the audited plants choosing them.
- **Backchecks of auditing work.** Technical staff of outside experts in the field backchecked a random set of 20 per cent of the auditor visits to plants in the modified scheme.
- **Audit payments.** The auditors in the modified scheme received payment from a central pool of funds raised for the study, rather than from plants.

This project treated 233 plants of a sample of 473 audit-eligible plants in Ahmedabad and Surat for two years, 2009 and 2010. There was a second treatment with government-run inspections:

- **Inspection frequency.** GPCB inspection teams inspected plants in a randomly selected half of the sample more frequently.

This intervention applied to a larger sample of plants including both audit-eligible and audit-ineligible plants.

## **F. Data**

We collate data from several sources. The data include audit reports and contemporaneous backchecks of the true level of pollution at audited plants. The availability of backcheck and auditor results from the same period offers a unique opportunity to compare the true plant-level emissions with the auditors' reports of those emissions in both the treatment and the control plants. Roughly six months after the last audit visit in the experiment, we ran an independent endline survey of pollution outcomes in all the treatment and control plants to measure the impact on emissions. Finally, we collect administrative data from the GPCB. These data include its own inspections of the plants, as well as the subsequent responses and penalties and ensuing correspondence with the plants.



# Main Report

## A. Introduction

A growing literature documents high levels of pollution in emerging economies, often despite stringent pollution standards, and correspondingly high welfare costs including lower labour productivity (Hanna and Oliver, 2011), higher infant mortality (Hanna and Greenstone, 2011) and lower life expectancy (Chen et al., 2010, 2011). It is unclear whether better-designed regulation can reduce pollution in a developing-country context, since corruption may undermine information flows and reduce welfare (Olken and Pande, 2012). Still, even in settings with typically weak enforcement institutions, reforms that strengthen financial incentives and increase monitoring can improve compliance with regulations (Duflo et al., 2012; Olken, 2007).

Conflicts of interest may limit third-party auditing itself. The use of third-party auditing to monitor the compliance of firms with regulations is ubiquitous. Third-party audits are the norm in financial regulation, which requires public companies to file independently audited financial statements, and in many countries credit ratings from third-party agencies play an important regulatory role. Consumer and commodity markets use third-party auditors to monitor standards, including those for food safety and health care, flowers, timber and many durable goods. With respect to environmental regulation, several countries use third-party auditors to verify firms' compliance with national laws and regulations. Countries also use third-party auditing to enforce international environmental standards, including ISO 14001 certification and verification of carbon abatement in the carbon offset market.

In all of these settings, the auditor receives payment from and reports to the audited firm, which creates a conflict of interest between reporting the truth and reporting what is beneficial for the client. To maintain business, third-party auditors have incentives to shade or falsify their reports, which may corrupt information provision and, in turn, undermine regulation. However, despite periodic calls for reform to increase the independence of third-party auditors, we are unaware of a single instance of an enacted reform that addressed the core problem that firms, when they hire their auditor directly, can buy a favourable report.

Our study then tests whether feasible regulatory reforms can improve the efficacy of regulation and reduce pollution emissions. Do better incentives for auditors lead to more accurate reporting? Do more accurate audit reports hold plants accountable for pollution? Do plants respond to such reports by reducing their pollution emissions? The wider context for these research questions is whether environmental regulation can be effective *at all* in a developing country, or whether the weak institutions or even the social preferences for relaxed regulatory standards limit it too sharply.

We report on a two-year field experiment, conducted in collaboration with the environmental regulatory body in Gujarat, India. The current audit system is the typical practice the world over: plants hire and pay auditors directly, with very little oversight. The regulator theoretically uses the information from the audits to penalise firms, but in conversations held before beginning this study, the regulators, auditors and polluting plants all agreed that the status quo audit system produces unreliable information. Indeed, the reported market price for an audit is frequently lower than the cost of collecting pollution readings, suggesting that measurements are often not even taken.

Our experiment aims to lessen this conflict of interest by creating an alternative market structure to incentivise accurate reporting. We randomly assign our sample, which consists of all the firms regulated under the audit scheme in two heavily polluted regions of Gujarat, into treatment and control groups. We change the regulatory structure for the treatment group in the following way:

- **Auditor assignment.** We assign the auditors in the modified scheme randomly to industries, rather than the audited industry choosing them directly.
- **Backchecks of audit work.** Technical staff of outside experts in the field backcheck a random group of 20 per cent of auditor visits to industries in the modified scheme.
- **Audit payments.** A central pool of funds raised for the study pays the auditors in the modified scheme, rather than the industries.

We carry out the modified audit scheme for two years, 2009 and 2010, and collect data on the reporting of auditors and the pollution from industries under both the modified scheme and the standard scheme.

In addition to the modified audit scheme, the experiment involves another component that increases the frequency of inspection for half of the sample plants. In this component, the project hires recently retired GPCB engineers and scientists to form inspection teams, of two persons each, in three different regions of the state. The research team assigns these inspection teams to visit randomly selected plants at an increased frequency, with a target of increasing the inspection frequency by two inspections per year on average.

The remainder of the report summarises the procedure and findings of the study. Section 2 contains information on the study background and the state of the literature. Section 3 describes the intervention in detail. Section 4 contains an overview of the programme implementation. Section 5 presents the results and Section 6 provides policy recommendations.

## **B. Context**

### **1. Background**

Our study is conducted in Gujarat, which is one of India's fastest-growing industrial states. Since 1991–92, the net state domestic product in Gujarat has grown at an average of 8 per cent per year: today, it accounts for about 5 per cent of the Indian population, but 9 per cent of India's registered manufacturing employment and 19 per cent of its output. However, severe degradation of the air and water quality has accompanied the rapid industrial growth. Gujarat contains the two most polluted industrial clusters in India and three of India's five most polluted rivers. Essentially all the large cities in the state, as well as some industrial areas, violate the National Ambient Air Quality Standards for Respirable Suspended Particulate Matter (RSPM), which is the most dangerous air pollutant for human health.

Such high levels of industrial pollution persist despite national and state laws and court orders setting a stringent regulatory framework for pollution control. The national laws set minimum levels of stringency for pollution standards, but basically all the

enforcement of environmental regulations occurs at the state level. State Pollution Control Boards, such as the Gujarat Pollution Control Board (GPCB), are responsible for enforcing the provisions of the Water Act and the subsequent Air (1981) and Environmental Protection (1986) Acts and their attendant command-and-control pollution regulations. The GPCB is responsible for monitoring and regulating approximately 20,000 plants.

The main instruments that the GPCB uses to limit industrial pollution are plant-level inspections and environmental audits. This paper focuses on the environmental audit system. In 1996, in order to remedy the perceived failure of inspections to enforce the pollution standards, the High Court of Gujarat introduced the first third-party environmental audit system in India. Under the scheme, plants with high pollution potential must submit a yearly environmental audit, hiring and paying an audit firm to conduct it. The scheme classifies audit-eligible plants as Schedule I (most polluting) or Schedule II (less polluting) on the basis of three dimensions: what the plant produces, where it sends its effluent, that is, wastewater, and the volume of that effluent. For example, plants that produce certain types of dyes and dye intermediates are classified in Schedule II, roughly, if their effluent is between 25 and 100 thousand litres per day, with variations around this classification based on whether the effluent discharged by the plant progresses to further treatment in a common effluent treatment plant (CETP). A plant with effluent below 25,000 litres would be exempt from the audit requirement. Schedule I auditors, usually an engineering college or a similar institution, must audit Schedule I plants. Private audit firms, called Schedule II auditors, must audit Schedule II plants. This study concerns the reporting of Schedule II auditors and henceforth we refer to plants in Schedule II as 'audit eligible'.

Auditors visit each plant thrice per year for about one day, observe the environmental management practices and measure the pollution outputs. We track the most important pollutants measured by all the auditors: biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammoniacal nitrogen ( $\text{NH}_3\text{-N}$ ), sulphur dioxide ( $\text{SO}_2$ ), nitrogen oxides ( $\text{NO}_x$ ) and suspended particulate matter (SPM). The auditors compile their findings in a standardised format and submit the audit report to the plant and the GPCB by 15 February of the following year. The final audit report describes the production process and the physical state of the plant, including the measures the plant has taken for pollution control and the results of pollution sampling during each of the visits. Finally, the auditors provide the plant with recommendations for pollution control.

The environmental audit system includes several safeguards, mostly from the original 1996 court order, to limit the conflict of interest in the third-party audit markets. Each four-member audit team must meet technical standards and achieve recertification from the regulator every two years. The standards are relatively strict: they require team members to have degrees in environmental engineering, chemical engineering, chemistry and biology, and a minimum of two members must have at least one year's experience in environmental management. Audit teams can audit at most 15 plants per year, and an audit firm, which may employ several teams, can audit a plant at most three years in a row.

On paper, the audit system also includes severe statutory penalties for plants and auditors breaking the rules. Failure to submit an audit is punishable by closure and disconnection of water and electricity. In practice, some plants do not submit reports,

usually claiming non-eligibility. A report showing noncompliance with the terms of a plant's environmental consent can also result in punishment by penalties up to the closure of the plant. Moreover, if the Board finds auditors' reports to be inaccurate it is liable to decertify them and declare their reports on behalf of other plants void, providing an incentive to build a reputation for quality.

All sides consider the audit system, as originally implemented, to function poorly. The industry recently litigated against the scheme, somewhat ironically and without success, to force the High Court of Gujarat to throw out the audit requirement on account of the GPCB not following up on audit reports. The regulator, for its part, believes that inaccurate reporting renders audits useless for enforcement, so the GPCB's review of submitted audits is mostly a matter of form.

Consistent with auditor shopping, we observe strong price competition in the environmental audit market. In the interviews conducted prior to the experiment, both auditors and plants claimed that plants could purchase an audit report for as little as INR 10,000–15,000 (roughly \$200–\$300). Further, our data on the actual prices that control plants pay indicate that, conditional on reporting any payment, plants report a mean payment of roughly INR 24,000.

These audit prices appear lower than the true cost of conducting an audit. Using the GPCB's pollution sampling and analysis charges, we estimate that the cost of performing a thorough audit is roughly between INR 20,000 and INR 40,000, varying according to a plant's industry and other characteristics. Textile plants are at the high end of this range with an average cost for an audit of roughly INR 40,000. Since 80 per cent of our audited sample consists of textile plants, the prices reported above suggest that a significant portion of the audit reports are purchased at prices below the cost of a duly performed audit.

Given such prices, it seems likely that the full set of required pollution samples, which can require expensive laboratory analysis, may not be collected for many audits. As a further indication of the market's low quality, many of the auditors whom the GPCB identified as having the best reputations reported to us that they had scaled back or closed their auditing businesses to focus on environmental consulting because it is impossible to produce accurate reports profitably.

## **2. Related literature**

The paper contributes to several streams of literature. Our results on status quo reporting support a key insight from the literature on the market behaviour of information intermediaries, that competition can lead to inaccurate information provision and reduce efficiency (Bolton et al., 2011; Dranove and Jin, 2010).

The paper also relates to the literature on corruption in developing countries. Authors have indicated poor information flows, and the resultant agency problems, as a reason for corruption in developing countries, with adverse growth and welfare implications (Olken and Pande, 2012). Alongside this, an emerging body of evidence shows that, even in settings with typically weak enforcement institutions, reforms that strengthen financial incentives and increase monitoring can improve compliance with regulations (Duflo et al., 2012; Olken, 2007).

With respect to environmental regulation, growing literature documents high levels of pollution in emerging economies, often despite stringent pollution standards, and correspondingly high welfare costs, including lower labour productivity (Hanna and Oliva, 2011), higher infant mortality (Hanna and Greenstone, 2011) and lower life expectancy (Chen et al., 2010, 2011).

## **C. Intervention and theory of change**

### **1. Intervention**

In collaboration with the GPCB, we design a modification of the existing audit system in order to increase the independence of auditors and the accuracy of auditors' reporting.

We conduct the modification as a randomised evaluation within a group of audit-eligible industries in the regions of Ahmedabad and Surat. We randomly assign industries that are eligible for audits in the study regions to either a treatment or a control group. In the control group, industries remain in the existing environmental audit scheme. In the treatment group, we require industries to participate in a modified environmental audit scheme. The modified audit scheme differs along three dimensions.

First, we randomly assign the auditors in the modified scheme to the industries, rather than the audited industry choosing them directly.

Second, technical staff of Schedule I auditors backcheck in the field a random set of 20 per cent of auditor visits to industries in the modified scheme soon after the initial audit visits. Auditors are aware of the possibility of being backchecked, and know that backcheck results will be used for quality control, although in the first year we specify no sanctions for poor performance in advance and pay auditors the same amount regardless of their accuracy. In the second year, payment varies with accuracy.

Third, a central pool of funds raised for the study pays the auditors in the modified scheme, rather than the industries. We fix the payment at INR 45,000 in the first year (roughly \$900). We estimate this rate by applying the GPCB's sampling charges to the average plant characteristics in the sample and adding a small margin; it should thus represent the average cost of completing an audit, although it is in the high range of the market prices. In the second year, 2010, we rank the auditors by accuracy into three terciles. The payments for each tercile are INR 35,000, 40,000 and 52,500. This payment scheme maintains a mean payment of INR 45,000, but pays the most accurate firms substantially more.

In addition to the audit treatment there is a secondary treatment increasing the inspection frequency for a randomly selected half of the sample plants. This treatment assigns GPCB-managed inspection teams to raise the rate of inspections by an average of two per year.

### **2. Theory of change**

The theory of change underlying this experiment is presented in Figure 1. This theory of change is a simple version of the theory laid out by Duflo et al. (2012), which describes the strategic interactions between polluting plants, auditors and the environmental regulator (GPCB). In the audit market, plants offer auditors payments that may depend on the reports the auditors send to the regulator. Auditors consider the payments for

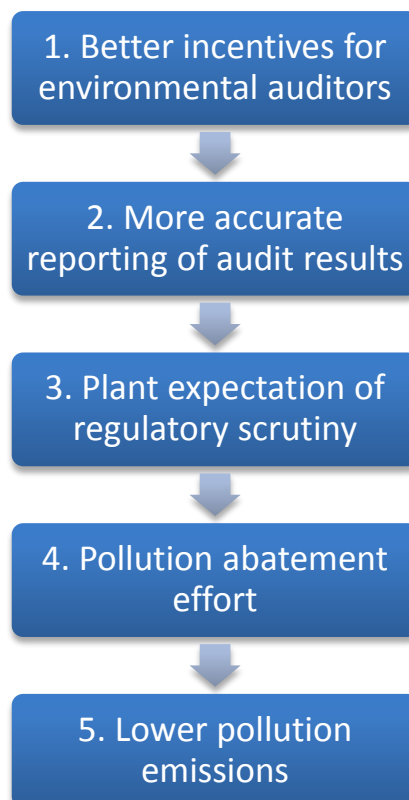
each possible report and choose to submit the report that maximises the sum of their payments and their own reputational concerns. The regulator observes the audit reports and penalises firms that are reported to cause high levels of pollution.

In the baseline case, as observed in the control group of the experiment, we observe that auditors nearly always report low levels of pollution, though many plants are in fact well above the pollution standard. The theory of change of the experiment is that changing the incentives for auditors could change the *plant* behaviour by putting the plants at greater risk of regulatory penalties. This theory makes a series of assumptions across each causal step.

First, the experimental interventions must change the auditor incentives. We introduce auditor assignments, backchecks and incentive pay in order to give the auditors independence from the client firms. If these measures are not effective, for example because they are not credible, they are not strong enough or auditor loyalty to firms is too strong, then we would not change the auditor incentives.

Second, given that the auditors had incentives for accuracy, we theorise that these will lead to more accurate auditor reporting. This step from incentives to accuracy relies on auditors having the technical skill to collect and submit pollution readings showing the true state of firm pollution. We expect this link to be robust as auditors appear qualified and often perform well as consultants outside the environmental audit market.

**Figure 1: Theory of Change**



Third, given more accurate reporting, it follows that plants must expect greater regulatory scrutiny and corresponding penalties for high pollution. If plants do not expect the regulator to review the environmental audits or do not expect that such a

review could lead to penalties for high levels of pollution, then they would not respond to the increased accuracy of audit reports. We have some evidence that the regulator does indeed impose costly fines on plants from time to time and gather more concrete evidence on this point during the experiment.

Fourth, given the plants' expectation of penalties, it must be the case that they make a pollution abatement effort. It may be that plants expect to be penalised but have no viable channel to reduce pollution—the cost of pollution abatement may be very high, in other words. In that case, they could choose to accept a fine rather than reduce their pollution, and we would observe an improvement in auditor reporting but no change in pollution.

Fifth and last, it must be that the abatement undertaken is effective and measurable. Many plants in Gujarat have effluent treatment plants for wastewater treatment and air pollution control measures for air pollution abatement, suggesting that abatement is at least possible. Anecdotally, this equipment was installed under pressure from the GPCB, but was not being used because the cost of pollution is so low that it outweighs even the small cost of reducing pollution. We measure pollution at the outlet of effluent from the plant and in the boiler stack to maximise the chances of finding a meaningful effect.

The secondary outcome we use measures the accuracy and unbiasedness of the audits.

- **Audit accuracy improves.** The audit reports are closer to the true pollution levels as measured by backchecks.

Our primary outcome indicators are as follows:

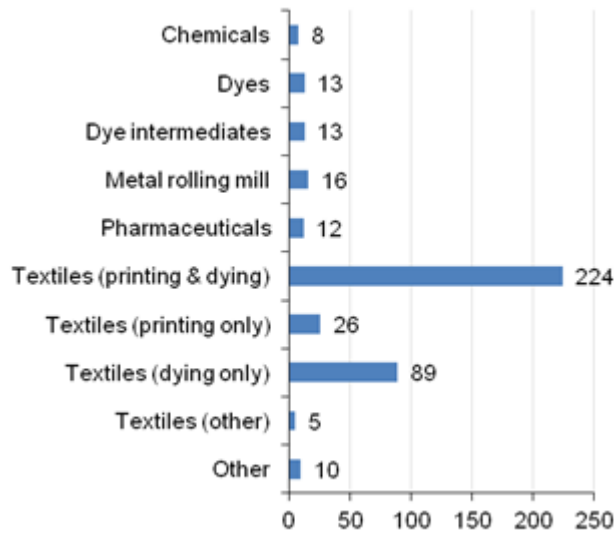
- **Pollution reduction.** The treatment group firms reduce pollution relative to the control group, as the endline survey shows.
- **Compliance improvement.** The pollution reductions are concentrated among noncompliant firms.

## D. Programme implementation

We conducted the randomisation in early 2009. We obtained from the GPCB a list of all 2,771 firms with high pollution potential and reported capital investment less than INR 100 million (about \$2 million), which are designated small or medium scale. Based on the available data, we select 633 plants that are likely to be audit-eligible as a provisional sample. After randomisation, stratified by region, we collect detailed information from the plants to determine their eligibility absolutely. After discarding the ineligible plants, we are left with a sample of 473 plants. These plants are informed of their treatment status by a letter from the GPCB.

Our sample is balanced across the baseline variables we collect (see Figure 3). Due to the large volume of effluent produced by textile firms, many of the plants that the GPCB oversees are at least partially involved in textiles. Our sample reflects that, and consists of 91 per cent textiles firms (see Figure 2).

**Figure 2: Number of Industries in the Sample by Sector**

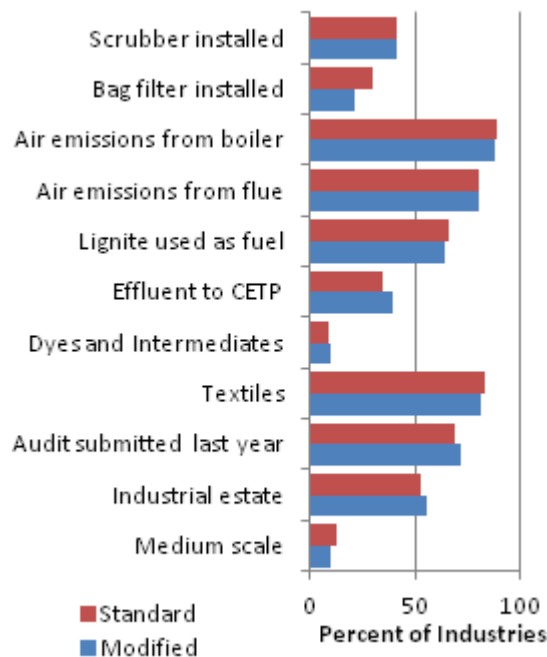


We assign auditors to the treatment plants. For auditor recruiting, at the start of each year we solicit all the GPCB-certified Schedule II auditors for their interest in participating in the treatment. In both years the interest is oversubscribed, relative to the number of treatment plants. Consequently, at the beginning of each year, we randomly allocate auditors to a number of plants in proportion to their capacity, measured by the number of certified audit teams, which is predetermined. The auditors' interest in the programme is likely to reflect the fact that it offers better working terms, including payments that are in the high range of the market.

In both the treatment and the control group, there is less than 100 per cent submission, much of it unpunished: 70 and 74 per cent for treatment and control, respectively, in 2009; 70 and 64 per cent in 2010. For each year, a t-test rejects the hypothesis that plants in one group are more likely to submit than plants in the other.



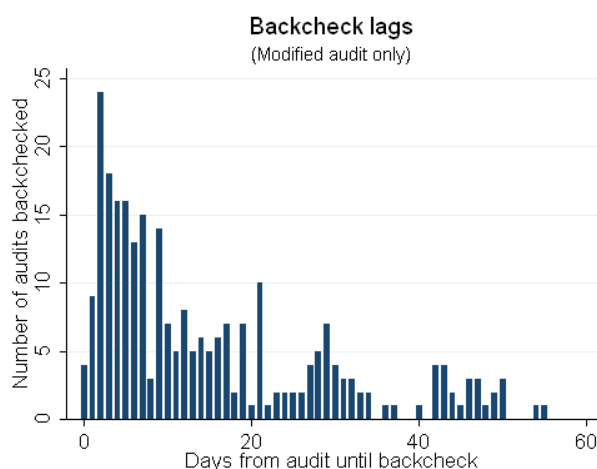
**Figure 3: Plant Types under the Modified and the Standard Scheme are Similar at the Outset of the Study**



Expert teams from Schedule I audit firms perform backchecks. The median backcheck occurs six days after an audit visit (see Figure 4). Endline data are collected in April and July of 2011, roughly six months after the last audit visits in the treatment group. For the most part, we use the same Schedule I auditors who provide the backchecks.

There is some attrition between the start of the intervention and the endline data collection. A somewhat greater share of plants are surveyed in the treatment group, 88.8 per cent, versus 83.8 per cent of control plants; the difference of 5.09 percentage points (standard error 3.16 percentage points) in these rates is not statistically significant. Our main concern with attrition beforehand was that the treatment plants would close at a greater rate due to greater regulatory scrutiny and costly penalties; this is not the case. Nearly all the attrition is due to plant closure during the intervening period. As plants that are closed are not polluting at all, including closed plants as zeroes would somewhat reduce the pollution in the control group relative to the treatment group.

**Figure 4: Days from Audit to Backcheck**



## E. Impact results

We report three main results, A1–A3, of the audit intervention: auditors misreport in the control group; the treatment improves auditor accuracy; and plants respond by reducing pollution. While these results are evident across all the pollutants measured, as shown in the Annexures and the full paper by Duflo et al. (2012), we report these results here only for selected pollutants, for brevity. We also report three preliminary results, I1–I3, of the inspection intervention.

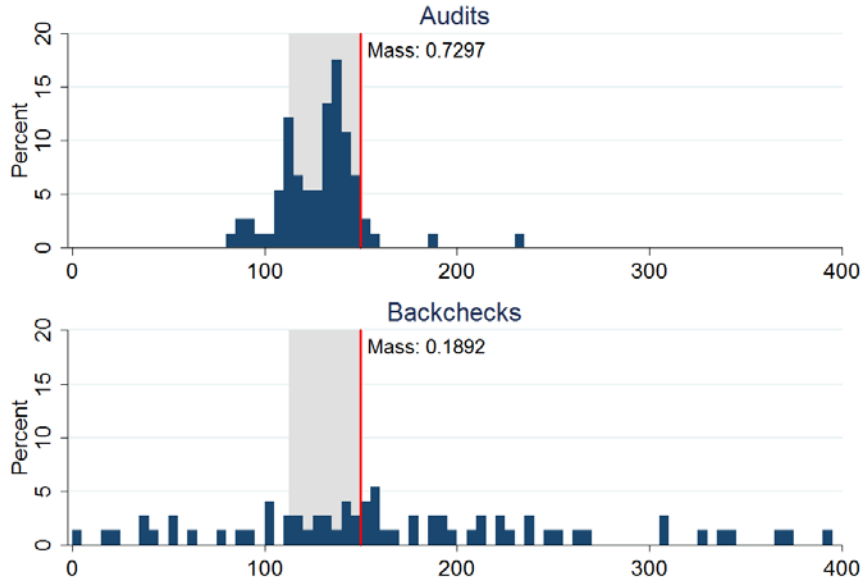
### A1. Audit readings are too low under the standard scheme, in the control group

The auditors working in the control plants report much lower pollution than that observed in the independent backchecks. Figure 5 shows histograms of audit measurements for suspended particulate matter in the standard and modified audit schemes, as well as the true distribution as measured by backchecks, which is similar for plants under both treatment conditions. The red line represents the regulatory limit. As shown by Panel A, auditors working in the control report that many readings cluster just beneath the regulatory standard. This could be the case if, for example, many plants reduce their pollution in order to comply narrowly. However, we see that the backcheck readings of the same pollutant are generally much higher and do not cluster beneath the standard. This pattern of systematic misreporting in the control group holds for all the pollutants considered.

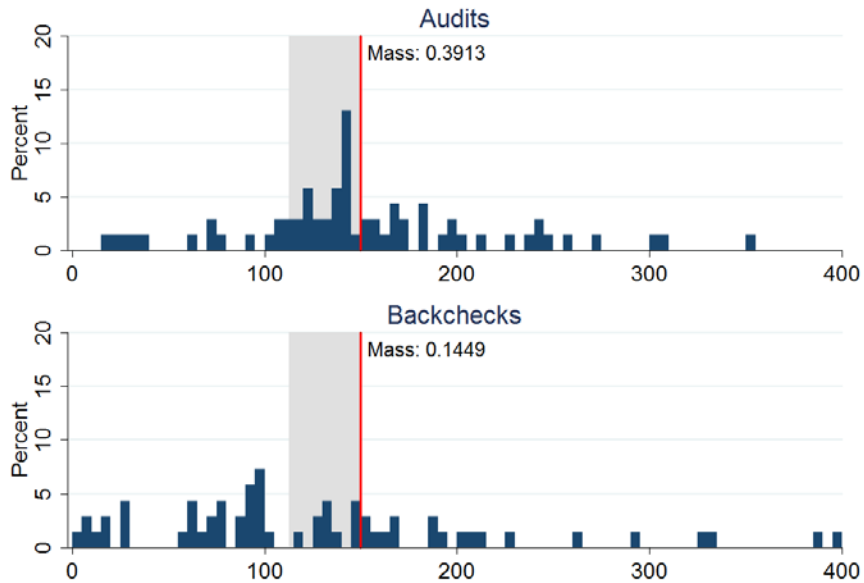
**Figure 5: Distribution of Concentration Readings from Standard Audits, Modified Audits and Backchecks (for SPM)**

**Suspended particulate matter, mg/Nm<sup>3</sup>**

**A. Control, midline**



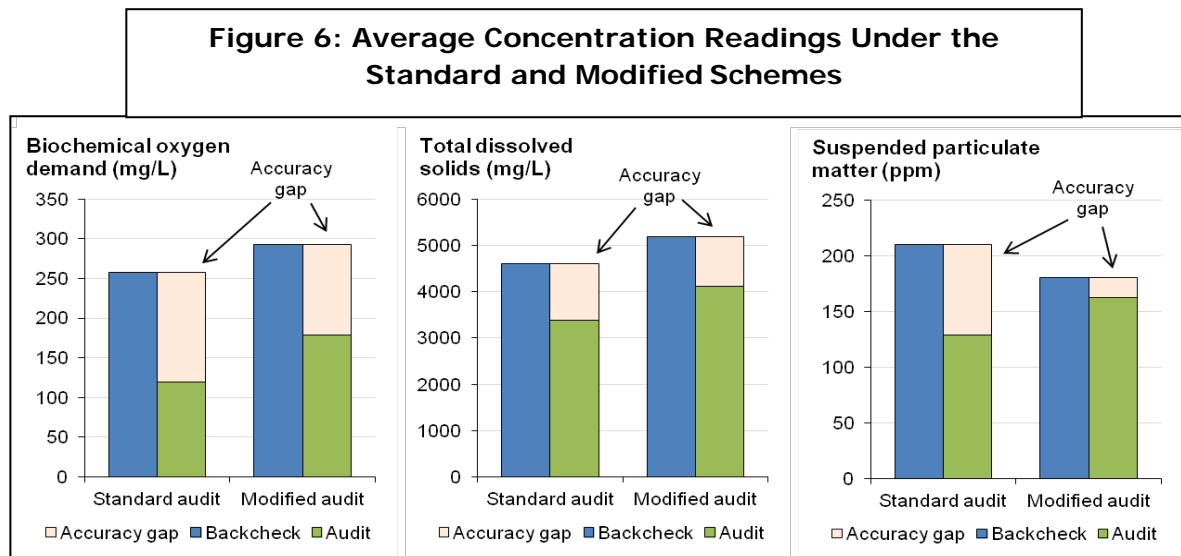
**B. Treatment, midline**



**A2. Auditors working under the audit treatment report much more accurately**

Again consider Figure 5. The shaded area to the left of the line represents the space between 75 per cent of the limit and the limit itself. The distribution of readings reported under the audit treatment is much closer to the true distribution; auditors report only an extra 25 per cent of plants just below the limit, as opposed to 60 per cent in the control group. This dramatic improvement in reporting is also seen across all the pollutants considered.

The overall accuracy gap is summarised in Figure 6. The blue bars represent the average reading for the backcheck and the green bars the average reading in the audit reports. The difference, indicated by the beige bar, represents the accuracy gap. For each pollutant, the accuracy gap shrinks in the modified audit treatment.

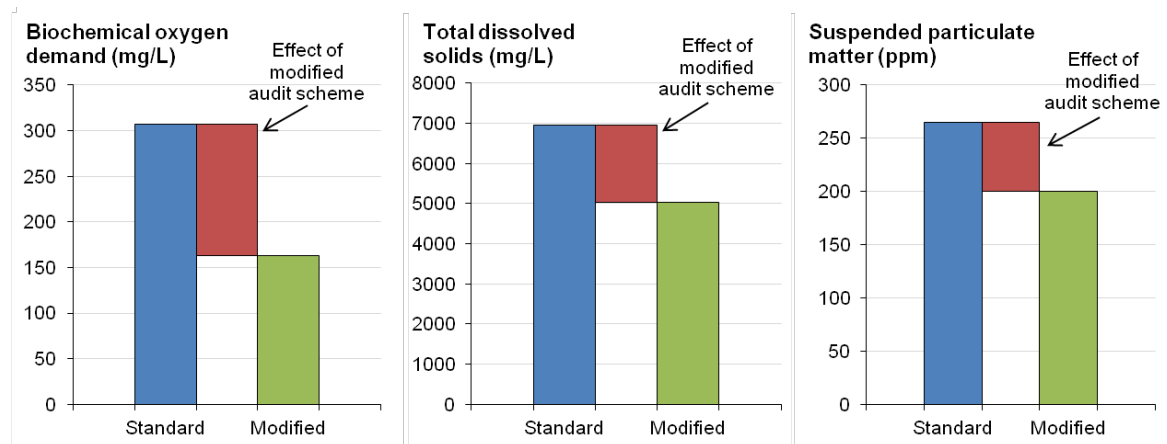


### A3. The audit treatment causes plants to reduce pollution

Audits are a means to an end: the purpose of the audit regulation is not to produce reports, but to incentivise firms to reduce their pollution. We find that the audit treatment, beyond improving the accuracy of the reports, causes plants to reduce the concentration of their pollution emissions.

Figure 7 shows the concentration of pollutants at the endline survey for industrial units under the standard audit scheme and the modified audit scheme. The blue bar shows the average pollution concentration under the standard scheme, the red bar the

**Figure 7: Concentration of Pollutants at Endline**



reduction in pollution due to the modified scheme and the green bar the new, lower average levels of pollution under the modified audit scheme. The modified audit scheme leads to a significant reduction in pollutant concentrations. For example, for BOD, industries in the standard scheme on average show effluent concentrations at the final

point of discharge of about 300 milligrams/litre. By contrast, industries in the modified scheme show effluent concentrations cut fully in half, at around 150 milligrams/litre. The reductions for other pollutants are similar but perhaps somewhat smaller. The average level of SPM in boiler stacks declined from over 250 parts per million to under 200 parts per million in the modified scheme. As the norm for SPM is 150 parts per million, the modified audit scheme cuts the distance between the average plant's emissions and the GPCB norm by half.

### **I1. The inspection treatment raises the frequency of inspections as designed.**

The proximate objective of the inspection treatment is to raise the frequency with which auditors inspect plants. Table 1 shows that the experiment achieves just that; on average, over the course of the experiment, the treatment firms receive 3.14 inspections and the control firms 1.39, a difference of 1.75 (standard error 0.15), which is highly significant both statistically and economically. The average rate of inspection across all the GPCB plants is about 0.5 before our experiment; the sample plants are inspected at a higher rate because they are more polluting. Nonetheless, the treatment more than doubles the frequency of inspection, almost precisely in line with the experimental design.

**Table 1: Inspections by Year and Treatment Status**

|  | Treatment | Control | Difference |
|--|-----------|---------|------------|
| Number of inspections in 2009, annual rate | 3.74      | 1.19    | 2.56***    |
|  | [4.20]    | [1.93]  | (0.21)     |
| Number of inspections in 2010              | 2.97      | 1.45    | 1.53***    |
|  | [3.99]    | [1.91]  | (0.20)     |
| Number of inspections in 2011, annual rate | 2.69      | 1.53    | 1.16***    |
|  | [3.47]    | [2.25]  | (0.19)     |
| Total inspections, annual over three years | 3.14      | 1.39    | 1.75***    |
|  | [3.52]    | [1.60]  | (0.18)     |
| Observations                               | 481       | 480     |            |

\* p < 0.10, \*\* p < .05, \*\*\* p < .01

### **I2. The GPCB cites more inspection treatment plants for violations**

Inspections are the first step of a multi-stage process through which the regulator learns about the plant's compliance status and then may threaten or sanction it to compel the plant to reduce its pollution. The regulator has a range of actions available to move plants towards compliance. Most basically, it can cite plants for non-compliance by sending them a legal notice informing them that the pollution was measured to be above the legal limits. If the violations are mild, such a notice might conclude the matter. For more severe violations, though, the regulator will apply more costly penalties, including requiring the plant to post a bond (or 'bank guarantee') against future performance, threatening the plant with closure, actually closing the plant, ordering the disconnection of its electricity or water or mandating the plant to install a costly piece of abatement equipment.

All of these actions occur with some regularity in our sample plants. Table 2 below shows the rate at which they occur in the treatment and control plants during the experiment

and the difference in that rate. The actions are in rough order of increasing severity from the top of the table to the bottom.

**Table 2: Regulatory Interactions During the Experiment**

|                              | Treatment       | Control         | Difference          |
|------------------------------|-----------------|-----------------|---------------------|
| Total citations              | 0.35<br>[0.69]  | 0.15<br>[0.42]  | 0.20***<br>(0.037)  |
| Total water citations        | 0.12<br>[0.37]  | 0.046<br>[0.22] | 0.071***<br>(0.020) |
| Total air citations          | 0.042<br>[0.20] | 0.021<br>[0.14] | 0.021*<br>(0.011)   |
| Total closure warnings       | 0.17<br>[0.48]  | 0.094<br>[0.34] | 0.077***<br>(0.027) |
| Total closure directions     | 0.20<br>[0.54]  | 0.16<br>[0.48]  | 0.041<br>(0.033)    |
| Total bank guarantees        | 0.064<br>[0.25] | 0.060<br>[0.27] | 0.0040<br>(0.017)   |
| Total equipment mandates     | 0.040<br>[0.23] | 0.027<br>[0.19] | 0.012<br>(0.014)    |
| Total utility disconnections | 0.042<br>[0.20] | 0.040<br>[0.22] | 0.0020<br>(0.013)   |
| Observations                 | 481             | 480             |                     |

\*  $p < 0.10$ , \*\*  $p < .05$ , \*\*\*  $p < .01$

The table shows that the inspection treatment greatly increases what might be called ‘threatening’ regulatory actions but does not significantly increase really costly sanctions against plants. In the first row, the GPCB cites plants 0.35 times in the treatment, versus 0.15 in the control, over the two-year experiment, a large and significant difference. Plants receive significantly more citations for water pollution, air pollution and other categories (not shown), such as hazardous waste. The GPCB also threatens to close down plants 0.08 times more, about a doubling of the base rate. These citations and warnings do not generate more costly actions against plants. As the bottom four rows of the table show, while the plants in the treatment group have slightly more costly actions taken against them, this difference is not significant.

There are a couple possible reasons for this difference. First, the most costly sanctions are reserved for very highly polluting plants, where highly polluting is defined relative to their peers. Therefore, only a few of these plants will be caught up by a random increase in inspection frequency. Second, the regulator may have known about most of the highly polluting plants already, so that the treatment gives the GPCB relatively little information about heavy polluters.

### **I3. Inspection treatment plants do not significantly reduce their pollution**

Finally, we examine the impact of the inspection treatment on pollution. We estimate that the inspection treatment does not significantly reduce pollution. The point estimates are negative for all water and air pollution, and largest for water pollution, for which we

see the greatest increase in citations. The magnitude of the point estimates is about one-tenth of one standard deviation, half the size of the pollution response due to environmental audits. This size effect still represents a meaningful reduction in pollution and would be enough to shift some firms from noncompliance to compliance.

**Table 3: Pollution Levels in the Treatment Group**

|                                       | all<br>(1)          | water<br>(2)      | air<br>(3)          |
|---------------------------------------|---------------------|-------------------|---------------------|
| Inspection treatment assigned<br>(=1) | -0.0997<br>(0.0810) | -0.120<br>(0.122) | -0.0499<br>(0.0391) |
| Observations                          | 4168                | 2665              | 1503                |

Standard errors in parentheses

Includes year and region fixed effects and controls for being in the audit sample, in the audit treatment group and in the audit × inspection treatment.

\*  $p < 0.10$ , \*\*  $p < .05$ , \*\*\*  $p < .01$

### Cost-effectiveness

A comprehensive estimate of cost-effectiveness is difficult to make because there are several items on both the cost and the benefit side that are very hard to measure. We believe that the data limitations make such a calculation speculative. Nevertheless, we propose a rough cost–benefit calculation below.

On the administrative cost side, the extra costs associated with the treatment audits are:

- 1) Actually performing the audits (increased auditor effort): auditors not carrying out the work in the status quo scheme properly may have reduced costs. To conduct a proper audit, the additional cost of travel and sample collection and analysis is about \$400 per plant-year, if we assume, quite conservatively, that all auditors are shirking in the control group and no auditors shirk in the treatment group. This calculation turns out about the same as the difference between the market price paid to the auditors in the control group and the price paid in the treatment group, which is meant to reflect the technical cost plus a modest profit margin.
- 2) Backcheck: the scheme backchecks 20 per cent of auditors in year 1, and we can assume we would keep this proportion in a scaled-up system. This adds a cost of \$180 per plant-year.

On the plant side, there are additional costs of pollution abatement and any changes in production in response to the increased scrutiny from audits. We collect data on abatement costs in the endline survey. We see no significant differences in abatement investments or operating expenditures, though our estimates are extremely noisy as abatement investments are lumpy and operating expenditures are very difficult to measure. Plants producing a high level of pollution may be able to abate with modest operational changes at marginal costs too low for our measures to detect. We therefore ignore production and abatement cost changes for the rest of this analysis.

The final benefit of this extra cost is a reduction in pollution. On the side of social benefits, there are few comprehensive estimates of the marginal damages of *any* pollutant. One approach to measuring marginal damages is to look at estimates from households choosing, through their behaviour, a desired level of exposure to pollution and balancing this choice against their wages or housing costs. We could not find credible studies of this type for the eight air and water pollutants we are concerned with in India. Past work, such as that by Dasgupta (2004) and Brandon and Homman (1995) (as cited in Maria, 2003), measures household valuations for fecal coliform, which is a domestic and not an industrial pollutant. The estimates of the values of particulate matter are quite variable.

As a best guess for marginal damage, we take a different approach and look for cases in which developing-country governments had applied taxes per unit of pollution for the pollutants measured in our sample, as a measure of the social willingness to pay to avert pollution. We find such marginal charges for all of our pollutants in China, which has a pollution levy system, and Colombia. Summing them up, we estimate that the reductions in pollution due to the experiment could be valued at \$7,275 per plant on average, with \$4,537 of these benefits due to reductions in suspended particulate matter in air and much of the balance, \$1,663, due to reductions in total dissolved solids in water.

The reductions in pollution at the plant level are suggestive that the system may have large net social benefits. However, the estimates of both costs and benefits are at best tentative. In particular, we are uncertain about the appropriate values of marginal damage in urban Gujarat and our estimates of abatement costs, on the plant side, are imprecise enough to swamp the estimated benefits from pollution reductions. These limitations constrain us to say that we cannot reject that the treatment did not change social welfare.

### **External validity**

The project is conducted jointly with the environmental regulator in an important Indian state and therefore has remarkably broad *internal* validity across a population of some 50 million people in Gujarat. With respect to external validity, India has a federal system of environmental regulation and so all other states enforce similar standards with similar procedures to those observed and used in Gujarat. We therefore believe that the findings have broad external validity within environmental regulation across India and are engaged in active discussions with another State Pollution Control Board to introduce an environmental audit system of its own, along the lines of the treatment scheme discussed here.

Our study employs Schedule II auditors to audit Schedule II audit-eligible plants. Schedule I facilities are larger and required to have audits from large institutions rather than small, private firms. We have no data on these facilities or on the accuracy of their audits. We speculate that such large plants are cleaner to begin with than the plants in our sample: though Schedule I plants are the 'most polluting', this determination is often on the basis of effluent volume, with the concentration of effluent lower than in Schedule II plants. The GPCB also visits Schedule I plants more frequently. The Schedule I auditors, being large and mostly non-profit institutions, may have stronger concerns for their reputation and lower incentives to distort the results to gain business. Thus, we think that the modified audit system is less applicable to Schedule I plants, mainly because the problems of misreporting may be less severe.



Aside from state-level regulation, India has an Environmental Impact Assessment (EIA) programme in which the proponents of large projects in industry, power, mining and so forth must provide a report stating the anticipated environmental effects of their projects. This EIA regulation is structured similarly to the control group in our study: proponents hire their own consultant to prepare an impact report, which is invariably clean. The Ministry of Environment and Forests might assign auditors in the EIA programme in a similar manner to the GPCB in this study.

Beyond environmental regulation, our findings are related to the more general literature on monitoring and incentive regulation when the regulator has imperfect information. The problem we are trying to solve is a third-party agent monitoring a plant. We are looking for a contract that will provide the right incentives for the monitor, when monitoring is costly, privately observable, unilateral (in that the plant does not also monitor its auditor) and not verifiable by the principal.

Rahman (2012) addresses exactly the problem of our audit market in 'But Who Will Monitor the Monitor?'. He builds on the earlier group incentive literature for moral hazard in teams when monitoring is verifiable (Holmstrom, 1982). Rahman offers a contract that includes the principal randomly altering the client outcome (for example adding \$20 dollars to the cash register to check whether the cashier will report a surplus of \$20). In our setting, this would amount to the regulator randomly encouraging plants to pollute more and seeing whether this change is reflected in the audits. Such interference may be impractical, but backchecks verifying true pollution, which itself has some randomness, may be the next best thing.

The theoretical work on the tools of contracting in similar environments is extensive. It runs from the work of Becker (1968), Becker and Stigler (1974) and Mookherjee and Png (1992, 1995) on crime to the literature on financial markets, for example Morgan and Stocken (2003) on the reporting of stock analysts who may or may not have incentives aligned with investors; Bolton et al. (2012) on credit ratings and competition; and Farhi, Lerner and Tirole (2010) on the incentives of information intermediaries to disclose.

The optimal contract varies greatly across the theoretical settings above. We draw two main connections between the theory literature and our design. First, while audit probability and punishment are often substitutable, the selection between these instruments will depend on risk aversion, the costs of false reporting and so forth. Therefore, a previous robust contract, drawn up without knowledge of these parameters, will probably involve moderate probabilities of audit and degrees of punishment. Second, the market structure affects information quality. In particular, Bolton et al. (2012) find that greater competition reduces information quality and efficiency. Therefore, everything else being equal, market structures that restrict auditor shopping may be welfare improving.

The particular solution we recommend is feasible and robust, if not necessarily optimal, in the political economy and institutional context. In particular, it is consistent with the court order and with the law. In contrast, extremal solutions for mechanism design, such as a low probability of detection and a bigger stick for penalties, are infeasible for institutional and political economy reasons. First, the environmental regulator is constrained by law in the tools it can use. Second, extremal solutions are more likely to be evaded in practice. As the probability of a backcheck decreases, the coordination cost

of bribing the backchecker decreases even as the benefit of doing so—because fewer samples are being used to judge audit quality—increases. Therefore, there would be issues with making the incentives from backchecks more high-powered even with risk-neutral agents.

Our proposed and tested policy solution is thus motivated by the literature, and combines all the tools (except the proposal to alter the state randomly), which is likely to reduce costs. For example, because the incentive to cheat for the auditor is reduced under random assignment to the plant, it becomes cheaper to provide incentives not to cheat.

## F. Policy recommendations

### Recommendations

We propose three policy recommendations that aim to increase the effectiveness of the current audit system.

- **Backchecks of audit work.** The GPCB would retain expert Schedule I auditors to backcheck the work of Schedule II auditors in the field after selected audit visits, as the original audit scheme envisioned.
- **Auditor assignment.** The GPCB would centrally conduct the assignment of industries to auditors each year on a random basis.
- **Audit payments.** The GPCB would fix the structure of payments to auditors, collect proof of payment and verify the payment amount against the fixed pay structure.

The costs of these changes to the GPCB would be minimal. Specifically, they would be limited to the small, annual administrative task for the staff responsible for the audit scheme. These recommendations are also well within the GPCB's current capabilities. The GPCB can conduct random assignment of auditors using Excel, and has the capacity to schedule backchecks in a timely manner. Importantly, the GPCB oversees enough plants that it could hire fulltime backcheck teams for short contracts and keep them fully occupied.

Charging plants that are audit-eligible would maintain the centralised pool of funds to pay for auditors and backchecks. The 'polluter pays' principle is widely accepted in Indian environmental law. The GPCB already charges all plants relatively small amounts, to the order of several thousand rupees, for its own pollution sampling and analysis. It charges larger amounts for the review and approval of industry environmental consent applications, which are a condition of operation and due every five years. Thus, charging industries and paying auditors is in principle no different from the current situation. The main regulatory change would be that the GPCB would have to consider non-submission of audit fees as an offence in itself, similarly to how it presently treats non-submission of fees for environmental consents.

### Dissemination

The dissemination plan is to work through both policy and academic channels. In the policy channel, we are working directly with the Gujarat Pollution Control Board to adopt the modified environmental audit system, as tested in this study, permanently. We are also working with other State Pollution Control Boards and the Ministry of Environment

and Forests to explore their broader applicability to environmental regulation in India. This project has provoked discussions with the Ministry that led to the development of a new project to pilot an emissions trading system for air pollution in three Indian states. The final working paper and policy brief will be disseminated through J-PAL's website and monthly newsletter, which reaches thousands of individuals in the policymaking community in developing and industrialised countries around the world.

The four co-principal investigators have presented the results at a variety of conferences around the world, including the 3ie policy influencing clinic in Colombo, Sri Lanka (16–18 July 2012), International Growth Centre conferences in New Delhi and London and academic seminars at the Bureau for Research and Economic Analysis of Development and many top universities. We are in the final stages of revising an academic paper on the results and will shortly submit it to an economics journal.

## **Annexures**

### **A. Sample design**

The sample is drawn from audit-eligible plants in two regions of Gujarat, Ahmedabad and Surat. In early 2009, we assembled a provisional sample of 633 plants. Based on data available from the GPCB, we judge these firms as likely to be audit-eligible. Sample in hand, we conduct randomisation, stratified by region. Treatment assignment is invariant over the experimental period, 2009 and 2010. After assignment, we conduct a detailed survey of plant characteristics and determine final eligibility. The final sample consists of 473 plants, with 233 in the treatment group and the remainder in the control group.

### **B. Survey instruments**

All the data are collected by third parties: audit firms, skilled Schedule I backcheckers and the GPCB.

#### **1. Audit reports**

Audit reports are prepared by audit firms and submitted to the GPCB in a format that the GPCB specifies. We obtain them directly from the GPCB. The reports contain information on a mandated set of water pollutants (that is, biochemical oxygen demand, chemical oxygen demand, total dissolved solids, total suspended solids, ammoniacal nitrogen) and air pollutants (sulphur dioxide, nitrogen oxides and suspended particulate matter). For water pollutants, we concentrate our analysis on samples collected at the outlet of the effluent treatment plant, although the reports often contain information on samples collected at other points in the production or treatment process. Air samples are restricted to the boiler stack for maximum comparability; most plants have a boiler.

#### **2. Backchecks**

Professional Schedule I auditors undertake backchecks for 20 per cent of the treatment plant audits. They schedule them to occur soon after the audit, to ensure that they measure the same underlying pollution. For comparability, they report the same information as the audit reports.

#### **3. Endline**

We conducted the endline survey approximately six months after the study period ended, in early 2011, collecting samples of all the pollutants measured in the audit and backcheck reports and administering a more expansive questionnaire about other firm characteristics. This information includes the firm history, revenue, employees and expenditures on raw materials, labour, auditor fees levied by the GPCB, environmental consultants, pollution abatement capital and pollution abatement variable inputs (that is, chemicals for water treatment).

The full survey instrument for the endline is attached to this report.

### C. Power calculations

We plan for a sample of slightly fewer than 500 plants, with attrition between 10 and 20 per cent. We expect about seven pollutant measurements from each plant. We anticipate an intra-cluster correlation of about .1, and a somewhat higher one when restricted to only air parameters or only water parameters. Under these conditions, and with a standard alpha of 0.05 and power of 0.8, we can identify coefficients for subsamples of water or air only as small as 0.2 standard deviations. In the GPCB data we examined before the intervention, the standard deviation of final-stage effluent measurements of biochemical oxygen demand amongst small-scale, high-pollution-potential plants in Ahmedabad was 707 milligrams per cubic litre. An effect of size 0.2 is therefore 140 milligrams/cubic litre, or about 23 per cent of the mean BOD level amongst plants that do not output their effluent to a common treatment plant for further treatment.

To gain a sense of whether our treatment is likely to have an effect of this magnitude, we collect historical audit reports to estimate the correlation between the frequency of the GBCP inspections and the measured emissions. Specifically, we enter data on readings of pollution parameters from a random sample of 511 Ahmedabad plants for the past five years. Table A1 reports on the regressions of current pollution parameters on an indicator stating whether the plant was visited by the GPCB in the previous six months. The dependent variables in these regressions are the logs of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS) and suspended solids (SS), all measurements of the quality of wastewater (high readings indicating low quality). As listed here and shown in the regression table, these readings are in decreasing order of importance from the perspective of the GPCB. The table also reports the mean and standard deviation of each of these variables.

**Table A1: Pollution Parameters Regressed on Visit Dummy (Visited in Last Six Months = 1)**

|                          | BOD                 | COD                 | TDS                 | SS                 |
|--------------------------|---------------------|---------------------|---------------------|--------------------|
| Visited in past 6 months | -0.4156<br>(0.1036) | -0.3382<br>(0.1009) | -0.5086<br>(0.0812) | 0.0604<br>(0.0863) |
| Observations             | 1006                | 1006                | 1007                | 1005               |
| Mean                     | 5.4640              | 6.5302              | 8.654               | 4.5600             |
| Standard Dev.            | 1.7047              | 1.6178              | 1.2936              | 1.2564             |

Table A1 shows that three of the four pollution parameters are lower if the GPCB has visited the plant during the past six months. The estimated standardised effects of a GPCB inspection are -0.24 for BOD, -0.21 for COD and -0.39 for TDS. Each of these estimated impacts is greater than what our power calculations indicate we should be able to detect. We also estimate models that control for the reported parameter value in the most recent inspection (that is, the lagged value of the dependent variable), which yield the same basic conclusion.

Our assumptions for intra-cluster correlation are slightly higher than we actually observe, so we are able to identify effects as small as 0.1 standard deviations for all the pooled pollutants.

## D. Descriptive statistics

Table A2 presents the summary statistics for the endline pollutants. All the pollutants have very high variance and a right-skewed distribution—most of the pollution comes from a few highly polluting plants. For the analysis, we normalise each pollutant by the backcheck mean and standard deviation.

**Table A2: Endline Measurements, by Pollutant**

| Parameter |                              | Mean   | SD     | 5th perc. | 95th perc. |
|-----------|------------------------------|--------|--------|-----------|------------|
| AN        | Ammonical Nitrogen           | 18.7   | 58.3   | 0         | 47.6       |
| BOD       | Biochemical Oxygen Demand    | 229.2  | 590.1  | 20        | 556        |
| COD       | Chemical Oxygen Demand       | 807.6  | 1858.7 | 84        | 1971       |
| TDS       | Total Dissolved Solids       | 5821.1 | 8532.5 | 610       | 19770      |
| TSS       | Total Suspended Solids       | 145.4  | 245.8  | 20        | 350        |
| NOX       | Nitrous Oxides               | 14.4   | 11.6   | 0.28      | 35.58      |
| SO2       | Sulphur Dioxide              | 41.4   | 39.4   | 3.05      | 88.5       |
| SPM       | Suspended Particulate Matter | 205.0  | 238.2  | 35.42     | 414        |

Table A3 presents summary statistics for compliance and clumping, for audits and backchecks in the matched control sample. A clump is the share of observations between 75 and 100 per cent of the regulatory limit. The higher value for audit firms indicates, similarly to Figure 5, that the audit firms in the regular scheme are disproportionately reporting firms as immediately below the standard, relative to the true backcheck distribution.

**Table A3: Control Report Outcome, by Report**

| Report    | Comply | Clump |
|-----------|--------|-------|
| Audit     | 0.68   | 0.28  |
| Backcheck | 0.49   | 0.08  |

## E. Balance test

**Table A4: Audit Treatment Covariance Balance**

|   | Treatment        | Control           | Difference         |
|---|------------------|-------------------|--------------------|
| Capital investment Rs. 50m to Rs. 100m (=1) | 0.092<br>[0.29]  | 0.14<br>[0.35]    | -0.051<br>(0.033)  |
| Located in industrial estate (=1)           | 0.57<br>[0.50]   | 0.53<br>[0.50]    | 0.042<br>(0.051)   |
| Textiles (=1)                               | 0.88<br>[0.33]   | 0.93<br>[0.26]    | -0.030<br>(0.025)  |
| Dyes and intermediates (=1)                 | 0.038<br>[0.19]  | 0.016<br>[0.12]   | 0.018<br>(0.016)   |
| Effluent to common treatment (=1)           | 0.41<br>[0.49]   | 0.35<br>[0.48]    | 0.078<br>(0.049)   |
| Water consumed (kl/day)                     | 510.6<br>[378.8] | 506.4<br>[633.6]  | 15.1<br>(53.1)     |
| Wastewater generated (kl/day)               | 420.5<br>[315.9] | 394.6<br>[323.4]  | 35.4<br>(31.6)     |
| Lignite used as fuel (=1)                   | 0.71<br>[0.45]   | 0.77<br>[0.42]    | -0.024<br>(0.029)  |
| Diesel used as fuel (=1)                    | 0.29<br>[0.45]   | 0.25<br>[0.43]    | 0.038<br>(0.046)   |
| Air emissions from flue gas (=1)            | 0.85<br>[0.35]   | 0.87<br>[0.33]    | -0.0095<br>(0.033) |
| Air emissions from boiler (=1)              | 0.93<br>[0.26]   | 0.92<br>[0.27]    | 0.016<br>(0.026)   |
| Bag filter installed (=1)                   | 0.24<br>[0.43]   | 0.34<br>[0.47]    | -0.10**<br>(0.046) |
| Cyclone installed (=1)                      | 0.087<br>[0.28]  | 0.079<br>[0.27]   | -0.0010<br>(0.027) |
| Scrubber installed (=1)                     | 0.41<br>[0.49]   | 0.41<br>[0.49]    | -0.018<br>(0.050)  |
| Whether audit submitted (=1)                | 0.82<br>[0.38]   | 0.81<br>[0.39]    | 0.022<br>(0.038)   |
| Any inspection conducted (=1)               | 0.79<br>[0.41]   | 0.78<br>[0.42]    | 0.016<br>(0.042)   |
| Any equipment mandated (=1)                 | 0.42<br>[0.50]   | 0.49<br>[0.50]    | -0.047<br>(0.047)  |
| Any citation issued (=1)                    | 0.28<br>[0.45]   | 0.24<br>[0.43]    | 0.035<br>(0.045)   |
| Any water citation issued (=1)              | 0.12<br>[0.33]   | 0.12<br>[0.33]    | -0.0031<br>(0.034) |
| Any air citation issued (=1)                | 0.027<br>[0.16]  | 0.0052<br>[0.072] | 0.021<br>(0.013)   |
| Any utility disconnection (=1)              | 0.098<br>[0.30]  | 0.094<br>[0.29]   | 0.0029<br>(0.031)  |
| Any bank guarantee posted (=1)              | 0.033<br>[0.18]  | 0.026<br>[0.16]   | 0.0045<br>(0.017)  |
| Observations                                | 184              | 191               |                    |

Significance: \* p lt 0.10, \*\* p lt 0.05, \*\*\* p lt 0.01

Table A4 presents summary statistics for the treatment and control plants. The treatment and control columns are the mean and standard deviations of the given

variable, for treatment and control. The difference column is the coefficient of the treatment dummy from a regression of the given variable on a treatment dummy and region fixed effects, at the plant level. The interpretation is identical to a t-test, but allows for controls for plant region. The region control is included to correspond precisely to the randomisation scheme, which is stratified by region.

To examine the effect of the treatment on auditor truth telling, we pool all the pollutant readings from the audits and backchecks. Our two variables of interest are compliance with the regulatory standard and clumping. Clumping is the tendency for the pollutants in audit reports to be just below the regulatory standard. Although this could be the result of firms ensuring that they are just on the correct side of the standard, it could also be the result of auditor misreporting. We regress the two variables of interest on a dummy for audit report interacted with a treatment dummy.

Table A5 provides the results. The treatment increases truth telling about compliance with the regulatory standard across the full set of pollutants. In Panel A, column (1), the audit reports are 8.5 per cent less likely to report a reading in the narrow range of 75–100 per cent of the standard in the treatment group than in the control group. This is a reduction of 37 per cent compared with the control mean. Similarly, in Panel B, column (1) reveals that treatment auditors are 81 per cent less likely to report compliance with the standard. These effects are evident for both water pollutants, in column (2), and air pollutants, in column (3).

**Table A5: Pollution Reports on Report Type and Treatment**

|   | all                 | water                | air                  |
|---|---------------------|----------------------|----------------------|
| <i>Panel A: Report between 75% and 100% of Standard</i> |                     |                      |                      |
| Audit report × audit treatment                          | -.085***<br>(0.034) | -0.212***<br>(0.044) | -0.143***<br>(0.046) |
| Audit report (=1)                                       | 0.270***<br>(0.025) | 0.297***<br>(0.034)  | 0.230***<br>(0.033)  |
| Audit treatment (=1)                                    | -0.034<br>(0.017)   | -0.013<br>(0.025)    | 0.011<br>(0.024)     |
| Control mean  | 0.232               | 0.259                | 0.191                |
| <i>Panel B: Report below Standard</i>                   |                     |                      |                      |
| Audit report × audit treatment                          | -.234***<br>(0.039) | -0.166***<br>(0.05)  | -0.345***<br>(0.056) |
| Audit report (=1)                                       | 0.288***<br>(0.023) | 0.273***<br>(0.033)  | 0.311***<br>(0.032)  |
| Audit treatment assigned (=1)                           | 0.058*<br>(0.034)   | 0.0075<br>(0.048)    | 0.145***<br>(0.041)  |
| Control mean  | 0.701               | 0.674                | 0.741                |
| Observations  | 2236                | 1378                 | 858                  |

Standard errors clustered at the plant level in parentheses.

Regressions include region fixed effects.

To measure the effect of the treatment on the actual pollution, we report the results from a single cross-section of endline survey data on the pollution outcome. The outcome variables are both the continuous pollution outcome and a compliance dummy.

Table A6 reports the results. In Panel A, the outcome variable is a standardised measure of pollution emissions that we calculate by normalising the reported pollution by the



mean and backcheck of the true backcheck distribution. On average, the treatment plants reduce pollution by a statistically significant 0.211 standard deviations. This effect is driven by a large decrease of 0.300 standard deviations in the water pollutant concentrations, as column (2) shows. It is noteworthy that the volume of effluent emitted does not change in response to the experimental treatments, so these reductions in concentrations represent reductions in the total emitted effluent load, rather than a dilution of constant pollutant loads. A quantile regression indicates that most of the effect is from the dirtiest plants.

**Table A6: Pooled Pollution Concentrations on Treatment Status: Inspection Control Only**

|  | all                | water              | air               |
|--|--------------------|--------------------|-------------------|
| <i>Panel A: Pollution Concentrations</i> |                    |                    |                   |
| Audit treatment assigned (=1)            | -0.211**<br>(0.01) | -0.300*<br>(0.159) | -0.053<br>(0.057) |
| Control mean                             | 0.076              | 0.114              | 0.022             |
| <i>Panel B: Regulatory Compliance</i>    |                    |                    |                   |
| Audit treatment assigned (=1)            | 0.027<br>(0.027)   | 0.039<br>(0.039)   | 0.0018<br>(0.028) |
| Control mean                             | 0.573              | 0.16               | 0.656             |
| Observations                             | 1439               | 860                | 579               |

Standard errors clustered at the plant level in parentheses.  
Regressions include region fixed effects.

## F. Study methodology

The research design is a randomised controlled trial, which lends itself to straightforward empirical analysis using ordinary least squares. We also use quantile regressions to examine heterogeneity in the firm response to the treatment.

## Works Cited

- Bolton, P., X. Freixas and J. Shapiro. *The Credit Ratings Game*. No. w14712. National Bureau of Economic Research, 2009.
- Brandon, C., and K. Homman. *The Cost of Inaction: Valuing the Economy-Wide Cost of Environmental Degradation in India*. Asia Environment Division, World Bank, 17 October 1995, mimeo.
- Dasgupta, P. 'Valuing health damages from water pollution in urban Delhi, India: A health production function approach'. *Environment and Development Economics*, 2004, 9 (1).
- Duflo, E., M. Greenstone, R. Pande and N. Ryan. *Truth-Telling by Third-Party Auditors and the Response of Polluting Firms: Experimental Evidence from India*. MIT, 2012, mimeo.
- Dranove, D., and Ginger Zhe Jin. *Quality Disclosure and Certification: Theory and Practice*. No. w15644. National Bureau of Economic Research, 2010.
- Hanna, R., and M. Greenstone. *Environmental Regulations, Air and Water Pollution and Infant Mortality in India*. National Bureau of Economic Research, 2011 (17210).
- Hanna, R., and P. Oliva. *The Effect of Pollution on Labor Supply: Evidence from a Natural Experiment in Mexico City*. No. w17302. National Bureau of Economic Research, 2011.
- Olken, B. A. *Monitoring Corruption: Evidence From a Field Experiment in Indonesia*. No. w11753. National Bureau of Economic Research, 2005.
- Olken, B. A., and R. Pande. *Corruption in Developing Countries*. No. w17398. National Bureau of Economic Research, 2011.