Impact Evaluation Report 10

Truth-telling by third-party audits and the response of polluting firms

Experimental evidence from India

Esther Duflo, Michael Greenstone, Rohini Pande and Nicholas Ryan

October 2013

International Initiative for Impact Evaluation

Cover: Collecting an air sample from a small stack. Depending on the pollutant being sampled, air sampling typically takes 30–45 minutes. All air samples are manually collected.
Photo: J-PAL

About 3ie

The International Initiative for Impact Evaluation (3ie) was set up in 2007 to meet growing demand for more and better evidence of what development interventions in low- and middle-income countries work and why. By funding rigorous impact evaluations and systematic reviews and by making evidence accessible and useful to policymakers and practitioners, 3ie is helping to improve the lives of people living in poverty.

3ie Impact Evaluations

3ie-supported impact evaluations assess the difference a development intervention has made to social and economic outcomes. 3ie is committed to funding rigorous evaluations that include a theory-based design and that use the most appropriate mix of methods to capture outcomes and impact usefully in complex development contexts.

About this report

3ie accepted the final version of this report, *Truth telling by third-party audits and the response of polluting firms: Experimental evidence from India*, as partial fulfilment of requirements under grant OW2.094 issued under Open Window 2. The content has been copyedited and formatted for publication by 3ie. Due to unavoidable constraints at the time of publication, a few of the figures may be less than optimal. All of the content is the sole responsibility of the authors and does not represent the opinions of 3ie, its donors or its Board of Commissioners. Any errors and omissions are also the sole responsibility of the authors. All affiliations of the authors listed in the title page are those that were in effect at the time the report was accepted.

Funding for this impact evaluation was provided by 3ie's donors, which include UKaid, the Bill and Melinda Gates Foundation, Hewlett Foundation and 12 other 3ie members that provide institutional support. A complete listing is provided on the 3ie website at http://www.3ieimpact.org/en/about/3ie-affiliates/3ie-members/

Suggested citation: 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 Impact Evaluation Report 10*. New Delhi: International Initiative for Impact Evaluation (3ie)

3ie Impact Evaluation Report Series executive editors:
Jyotsna Puri and Beryl Leach

Managing editors: Radhika Menon and Thomas de Hoop

Assistant managing editor: Kanika Jha

Production manager: Lorna Fray

Copy editor: Lucy Southwood

Proofreader: Becky Owens and Proof Reading Service

Designer: John F McGill

Cover design: Via Interactive

Truth-telling by third-party audits and the response of polluting firms
Experimental evidence from India

October 2013
3ie Impact Evaluation Report 10

Esther Duflo
Massachusetts Institute of Technology

Michael Greenstone
Massachusetts Institute of Technology

Rohini Pande
Harvard University

Nicholas Ryan
Harvard University

International Initiative for Impact Evaluation

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 (3ie) through the Global Development Network, the Sustainability Science Program, the Harvard Environmental Economics Program, the Center for Energy and Environmental Policy Research, the International Growth Centre and the National Science Foundation. Nicholas Ryan is grateful for an Actors Markets and Institutions in Developing Countries Early Stage Researcher Fellowship for financial support. All views and errors are solely those of the authors.

3ie would like to acknowledge Thomas de Hoop, Jyotsna Puri and Howard White for their technical support and feedback to the research team and Minna Madhok for her management of the grant.

Abstract

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.[1] 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.

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.

With regards to the second treatment arm – an increase in government inspection frequency – data analysis is ongoing. The details we report for this intervention are therefore from a preliminary analysis. 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; they were also 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.

1 In this report, the term 'backcheck' means rechecking the work of the auditors.

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.

Policy recommendations

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

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

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.

Project design

This project involves a randomised controlled trial with two treatment arms. To our knowledge, it is the first randomised controlled trial 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; and
- **Audit payments:** The auditors in the modified scheme received payment from a central pool of funds raised for the study, rather than from the 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.

Data

We collated data from several sources, including 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. We also collected administrative data from GPCB, including their own inspection reports, subsequent responses, penalties and correspondence with the plants.

The effluent treatment plant at a chemical plant, with the earlier stages of treatment in the background and later stages in the foreground. Larger industrial plants must treat their effluent in-house before discharging to a common facility for further treatment or a waterway.
Photo: J-PAL

Contents

List of tables and figures

Abbreviations and acronyms

3ie	International Initiative for Impact Evaluation
BOD	biochemical oxygen demand
CETP	common effluent treatment plant
COD	chemical oxygen demand
EIA	environmental impact assessment
GPCB	Gujarat Pollution Control Board
INR	Indian rupee
J-PAL	Abdul Latif Jameel Poverty Action Lab
NH_3-N	ammoniacal nitrogen
NO_X	nitrogen oxides
SO_2	sulphur dioxide
SPM	suspended particulate matter
SS	suspended solids
TDS	total dissolved solids
TSS	total suspended solids

Introduction

1

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 Oliva 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).

Opposite page: Looking upwards at the boiler stack of a textile plant. Larger textile plants can use several tonnes of solid fuel an hour or more.
Photo: J-PAL

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 healthcare, 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.

The main industrial shed at a chemical plant. Though this plant is fairly large, it is still technically classified as a small- and medium-enterprise (SME).
Photo: J-PAL

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

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

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

In addition to the modified audit scheme, the experiment involved another component that increased the frequency of inspection for half of the sample plants. In this component, the project hired recently retired GPCB engineers and scientists to form inspection teams, of two persons each, in three different regions of the state. The research team assigned 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.

Context

2

2.1 Background

Our study is conducted in Gujarat, which is one of India's fastest-growing industrial states. Since 1991–1992, the net state domestic product in Gujarat has grown at an average of eight per cent per year: today, it accounts for about five per cent of the Indian population, but nine 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, 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 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. GPCB is responsible for monitoring and regulating approximately 20,000 plants.

The main instruments that 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 or 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 25,000 and 100,000 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. 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 three times a year for about one day, to observe environmental management practices and measure pollution outputs. We tracked the most important pollutants measured by all the auditors: biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), ammoniacal nitrogen (NH_3-N), sulphur dioxide (SO_2), nitrogen oxides (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 GPCB by 15 February 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. 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 non-compliance with the terms of a plant's environmental consent can also result in punishment by penalties, the highest of which is plant closure. Likewise, if the board finds auditors' reports to be inaccurate, it is liable to decertify them and void their reports on other plants, thus 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 GPCB not following up on audit reports. The regulator, for its part, believes that inaccurate reporting renders audits useless for enforcement, so 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 INR10,000–15,000.[2] 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 INR24,000.

These audit prices appear lower than the true cost of conducting an audit. Using GPCB's pollution sampling and analysis charges, we estimate that the cost of performing a thorough audit is roughly INR20,000–40,000, 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 INR40,000. 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.

2
All monetary data for this report was collected in Indian rupees (INR). Data collection for this report was carried out between 2009 and 2011 and the average exchange rate for USD1 was approximately INR47 during this period.

A large tank for biological treatment of waste effluent at a common effluent treatment plant that collects waste effluent from hundreds of small plants.
Photo: J-PAL

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 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.

2.2 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 (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, 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 Oliva 2011); higher infant mortality (Hanna and Greenstone 2011); and lower life expectancy (Chen *et al.* 2010, 2011).

Intervention and theory of change 3

3.1 Intervention

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

We conducted the modification as a randomised evaluation within a group of audit-eligible industries in the regions of Ahmedabad and Surat. We randomly assigned industries that are eligible for audits in the study regions to either a treatment or a control group. Those in the control group remained in the existing environmental audit scheme, while those in the treatment group participated in a modified environmental audit scheme. The modified audit scheme differs along three dimensions.

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

Second, technical staff from Schedule I auditors backchecked 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 were aware of the possibility of being backchecked, and knew that backcheck results would be used for quality control. However, in the first year we specified no sanctions for poor performance in advance and pay auditors a flat rate, regardless of accuracy. In the second year, payment varied with accuracy.

Third, a central pool of funds raised for the study paid the auditors, rather than the industries. We fixed the payment at INR45,000 in the first year. We estimated this rate by applying GPCB's sampling charges to the average plant characteristics in the sample and adding a small margin, thus representing the average cost of completing an audit, albeit at the high end of market prices. In the second year (2010), we ranked the auditors by accuracy into three terciles, with payments of INR35,000, INR40,000 and INR52,500. This payment scheme maintained a mean payment of INR45,000, but paid the most accurate firms substantially more.

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

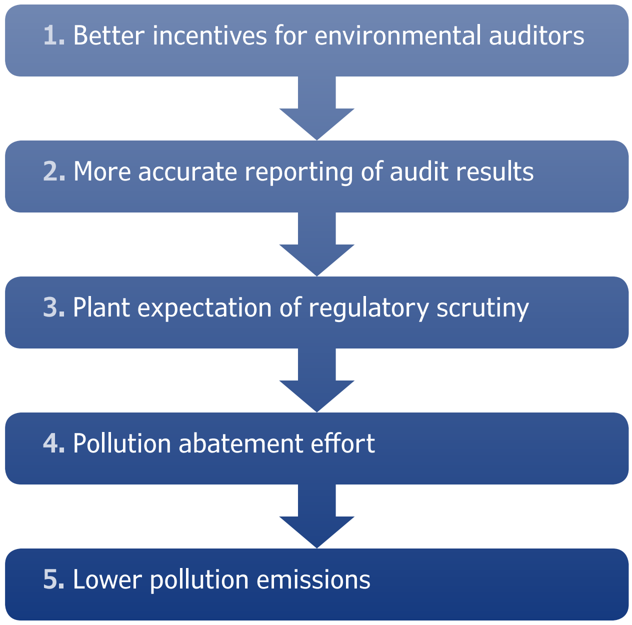
3.2 Theory of change

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, we find that auditors nearly always reported low levels of pollution, though many plants were in fact well above the pollution standard. The experiment's theory of change is that varying the incentives for auditors could change the plant's 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 introduced 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.

Figure 1: Theory of change



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.

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 we 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 — in other words, the cost of pollution abatement may be very high. 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.

Taking a sample from the outlet of a common effluent treatment plant. Many industrial plants minimally treat their waste effluent before sending it on for further treatment at a common facility. Hence the output of this common facility is very concentrated.
Photo: J-PAL

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 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 measured 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 unbiased nature 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; and
- **Compliance improvement:** The pollution reductions are concentrated among non-compliant firms.

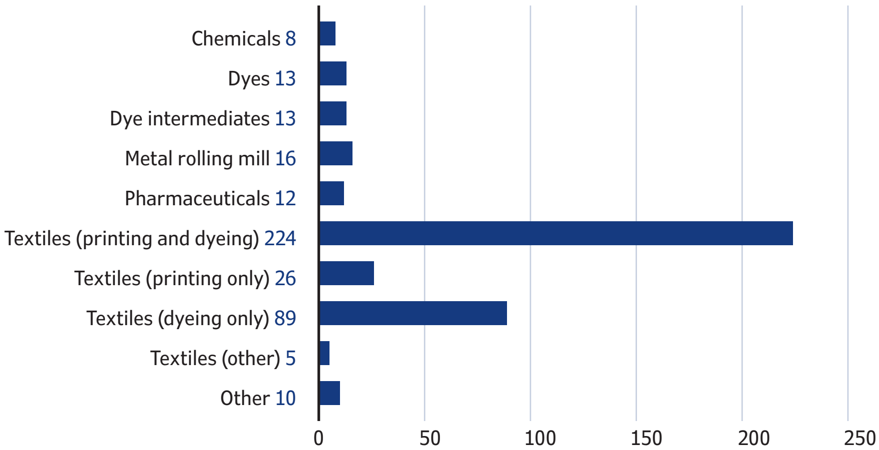
Programme implementation

4

We conducted the randomisation in early 2009. We obtained from GPCB a list of all 2,771 firms with high pollution potential and reported capital investment less than INR100 million, which are designated small- or medium-scale. Based on the available data, we selected 633 plants that were likely to be audit-eligible as a provisional sample. After randomisation, stratified by region, we collected detailed information from the plants, to determine their eligibility absolutely. After discarding the ineligible plants, we were left with a sample of 473 plants. We informed these plants of their treatment status with a letter from GPCB.

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

Figure 2: Number of industries in the sample by sector

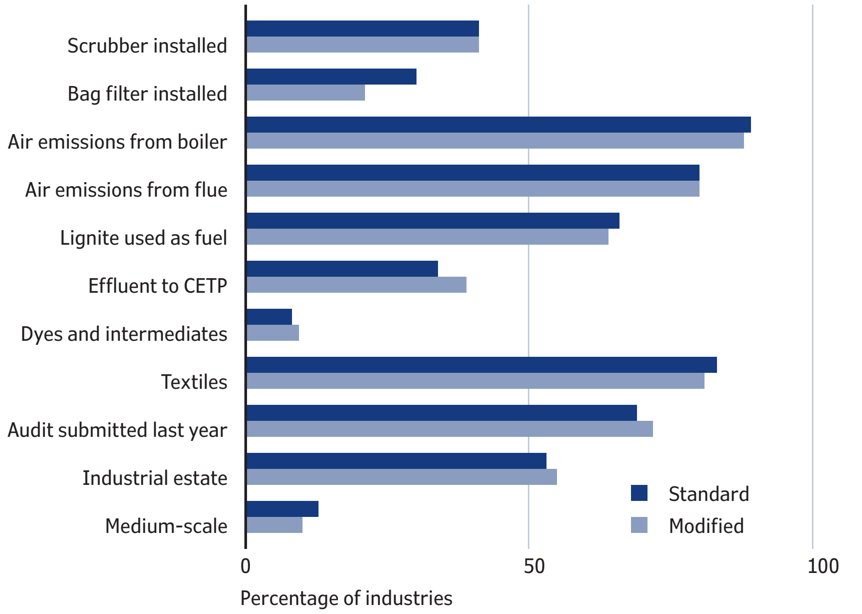


We assigned auditors to the treatment plants. For auditor recruiting, at the start of each year we solicited all GPCB-certified Schedule II auditors for their interest in participating in the treatment. In both years, the interest was oversubscribed, relative to the number of treatment plants. Consequently, at the beginning of each year, we randomly allocated auditors to a number of plants in proportion to their capacity, measured by the number of certified audit teams, which was predetermined. It is likely that the auditors' interest in the programme reflected the fact that it offered better working terms, including payments that were at the high end of the market.

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

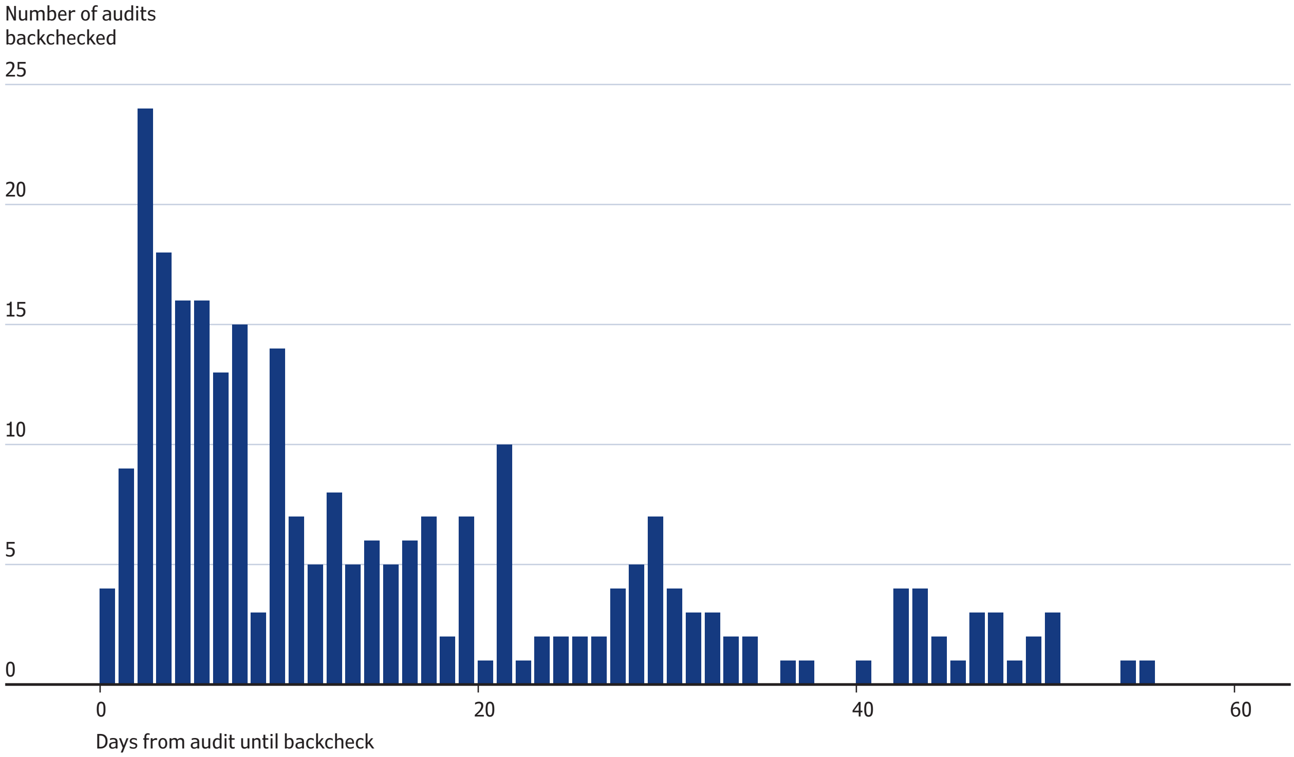
Expert teams from Schedule I audit firms performed the backchecks, with the median time lapse being six days after an audit visit (see Figure 4). Endline data was collected in April and July 2011, roughly six months after the last audit visits in the treatment group. For the most part, we used the same Schedule I auditors who provided the backchecks.

Figure 3: Plant types under the modified and the standard scheme are similar at the outset of the study



There is some attrition between the start of the intervention and the endline data collection. A somewhat greater share of plants was 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 increased regulatory scrutiny and costly penalties. This has not turned out to be the case: nearly all the attrition has been 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 between audit and backcheck



Impact results 5

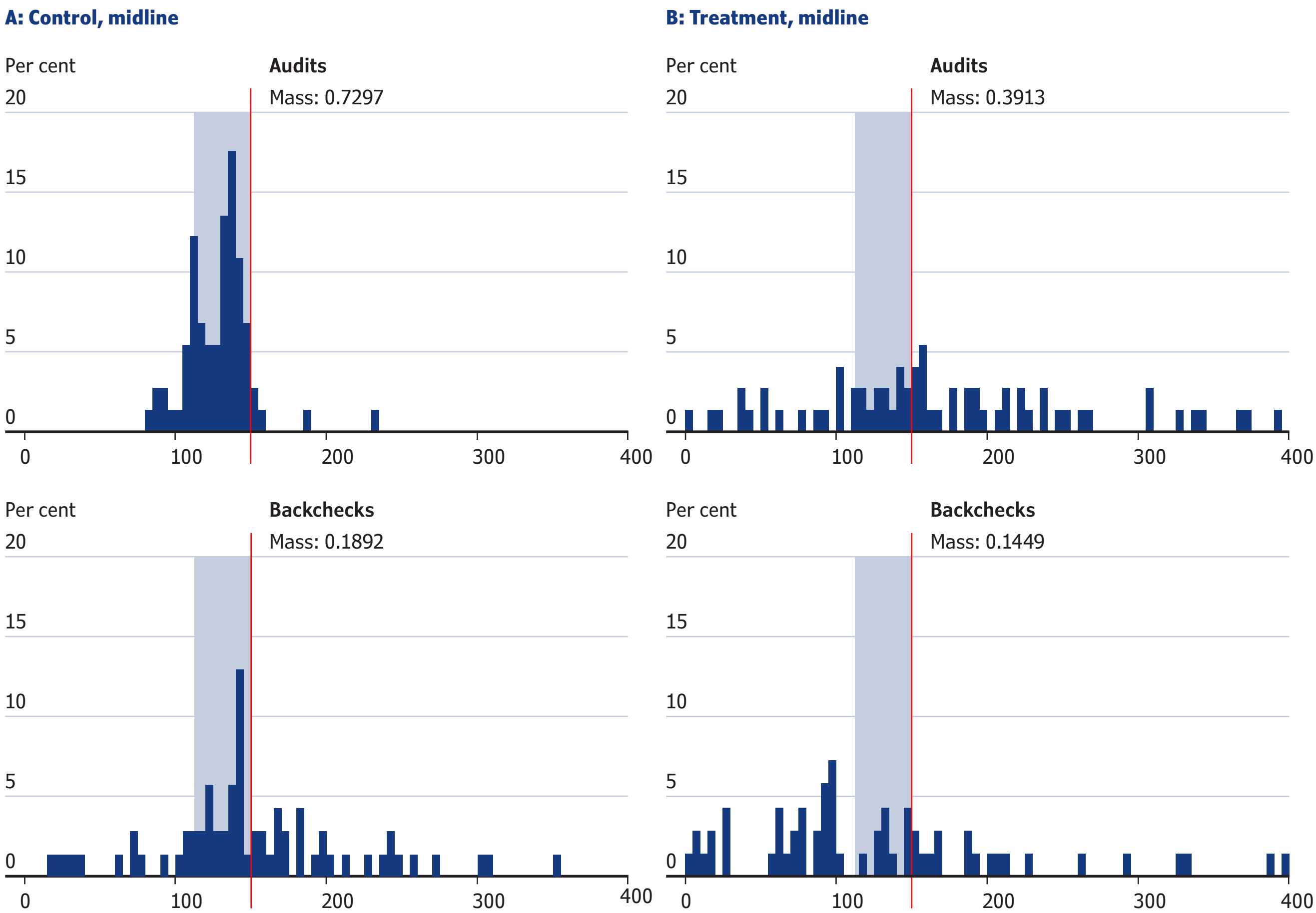
We report three main results of the audit intervention: auditors misreport in the control group; the treatment improves auditor accuracy; and plants respond by reducing pollution. While these results are evident across all the pollutants measured – as shown in the Appendixes and the full paper by Duflo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

5.1 Main results of the audit intervention

5.1.1 Audit readings are too low under the standard scheme, in the control group

The auditors working in the control plants reported much lower pollution than that observed in the independent backchecks. Figure 5 shows the histograms of audit measurements for SPM 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 group reported that many readings cluster just beneath the regulatory standard. This could reflect the fact that, 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)

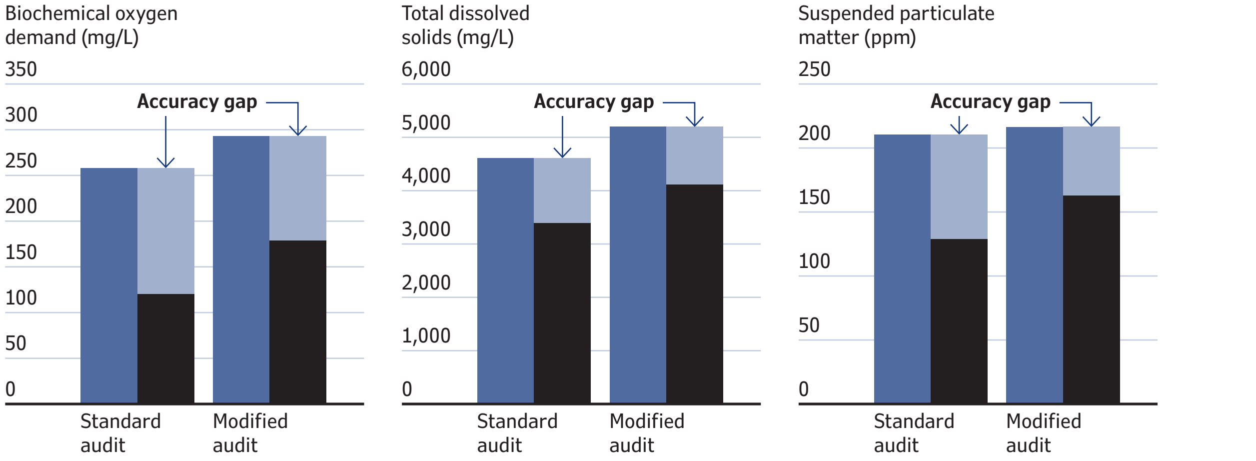


5.1.2 Auditors working under the audit treatment report much more accurately

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; the 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 darker blue bars represent the average reading for the backcheck and the black bars the average reading in the audit reports. The difference, indicated by the light blue bars, represents the accuracy gap. For each pollutant, the accuracy gap shrinks in the modified audit treatment.

Figure 6: Average concentration readings under the standard and modified schemes



Note:
mg/L: milligrams per litre
ppm: parts per million

5.1.3 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: Concentration of pollutants at endline

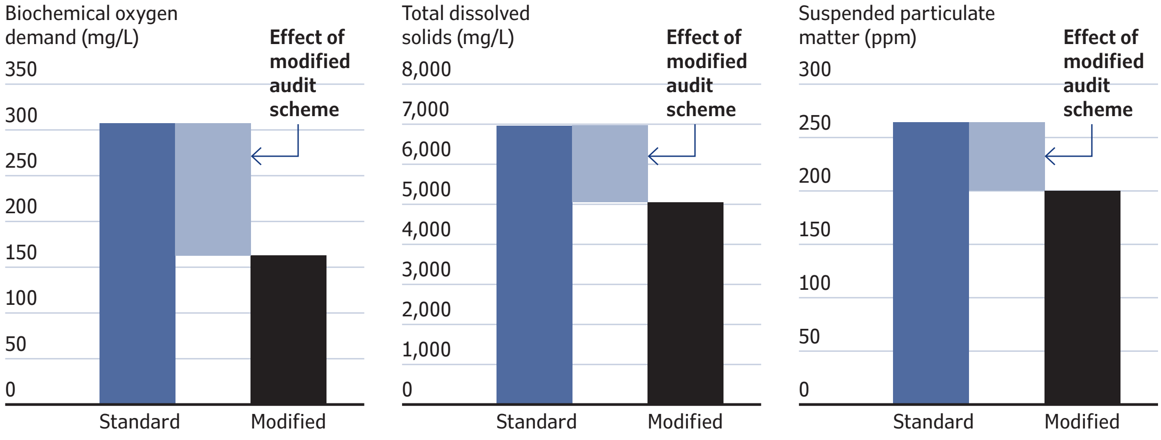


Figure 7 shows the concentration of pollutants at the endline survey for industrial units under the standard and modified audit schemes. The darker blue bars show the average pollution concentration under the standard scheme; the light blue bars the reduction in pollution due to the modified scheme; and the black bars the new, lower average levels of pollution under the modified audit scheme.

It is clear that the modified audit scheme leads to a significant reduction in pollutant concentrations – for example, industries in the standard scheme show average BOD 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 – to around 150 milligrams/litre. The reductions for other pollutants are similar, but 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. GPCB norm for SPM is 150 parts per million; the modified audit scheme therefore reduces the distance between the average plant's emissions and GPCB norm by half.

5.2 Preliminary results of the inspection intervention

5.2.1 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 received 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 GPCB plants before our experiment was about 0.5; 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 group	Control group	Difference
Number of inspections in 2009, annual rate	3.74 [4.20]	1.19 [1.93]	2.56*** (0.21)
Number of inspections in 2010	2.97 [3.99]	1.45 [1.91]	1.53*** (0.20)
Number of inspections in 2011, annual rate	2.69 [3.47]	1.53 [2.25]	1.16*** (0.19)
Total inspections, annual over three years	3.14 [3.52]	1.39 [1.60]	1.75*** (0.18)
Observations	481	480	

Note: *p < 0.10, **p < 0.05, ***p < 0.01

5.2.2 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. This may consequently lead to threats or sanctions to compel the plant to reduce its pollution. The regulator has a range of actions available to move plants towards compliance. First, 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, 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 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 those rates. The actions are listed in rough order of increasing severity.

Table 2: Regulatory interactions during the experiment

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

Note: *p < 0.10, **p < 0.05, ***p < 0.01

The table shows that the inspection treatment greatly increases the number of threatened regulatory actions, but does not significantly increase costly sanctions against plants. We see that GPCB cited plants in the treatment group 0.35 times, versus 0.15 for those in the control group, over the two-year experiment. This is a large and significant difference. Plants in the treatment group also received significantly more citations for water pollution, air pollution and other categories (not shown) such as hazardous waste. GPCB also threatened to close down plants in the treatment group 0.08 times more than those in the control group, about a doubling of the base rate. However, these citations and warnings did not generate more costly actions against plants: while the plants in the treatment group had slightly more costly actions taken against them, this difference is not significant.

There are a couple of possible reasons for this difference. First, the most costly sanctions are reserved for plants that are very highly polluting plants, 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 GPCB relatively little information about heavy polluters.

5.2.3 Inspection of treatment plants does 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 saw 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 non-compliance to compliance.

Table 3: Pollution levels in the treatment group

	Type of pollution		
	All (1)	**Water** (2)	**Air** (3)
Inspection treatment assigned (=1)	−0.0997 (0.0810)	−0.120 (0.0810)	−0.0499 (0.0391)
Observations	4,168	2,665	1,503

Note: 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 < 0.05, ***p < 0.01

5.3 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 USD400 per plant per 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) Backchecking: The scheme backchecked 20 per cent of auditors in year 1, and we can assume we would keep this proportion in a scaled-up system. This adds up to a cost of USD180 per plant per 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 collected data on abatement costs in the endline survey, and see no significant differences in abatement investments or operating expenditures. That said, 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 took a different approach and looked 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 found 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 USD7,275 per plant on average, with USD4,537 of these benefits due to reductions in suspended particulate matter in air, and much of the balance – USD1,663 – 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 not precise enough to swamp the estimated benefits from pollution reductions. These limitations constrain us to say that we cannot reject the null hypothesis that the treatment did not change social welfare.

5.4 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. We are currently 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 are therefore 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 probably cleaner to begin with than the plants in our sample: although Schedule I plants are the most polluting, this determination is often on the basis of effluent volume; the concentration of effluent is often lower than in Schedule II plants. GPCB also visits Schedule I plants more frequently. Schedule I auditors, being large and mostly non-profit institutions, may also 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 said 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 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 that of 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?*, building on earlier group incentive literature for moral hazard in teams when monitoring is verifiable (Holmstrom 1982). Rahman offers a contract that includes the principal of randomly altering the client outcome – for example, by adding USD20 to the cash register to check whether the cashier will report a surplus of USD20. 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 that verify true pollution, which by themselves have 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 by Becker (1968), Becker and Stigler (1974) and Mookherjee and Png (1992, 1995) on crime, to literature on financial markets – including 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.

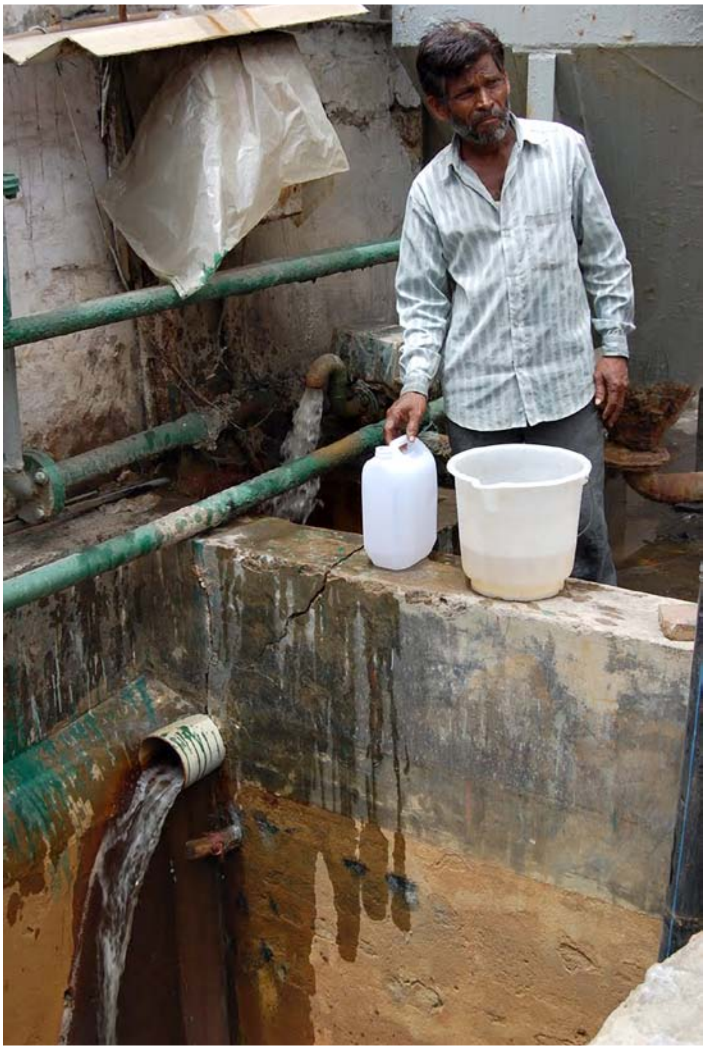
The optimal contract varies greatly across the theoretical settings in the literature discussed above. We draw two main connections between the theory literature and our design. First, while audit probability and punishment are often substitutable, the selection between these instruments will depend 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.

Right: The final outlet sampling point from a chemical plant. From the open pipe, effluent moves into a sump and is then pumped out of the plant. The effluent sample taken here is therefore the most important, as it measures the quality of the waste actually being discharged.
Photo: J-PAL

Below: Sealing a water sample with wax. If a water sample is to be used for legal purposes in court, as opposed to only by the regulator, it must be separated into parts and sealed to rule out tampering.
Photo: J-PAL



Policy recommendations 6

6.1 Recommendations

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

- **Backchecks of audit work:** 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:** GPCB would centrally conduct the assignment of industries to auditors each year on a random basis; and
- **Audit payments:** 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 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 GPCB's current capabilities. GPCB can conduct a random assignment of auditors using Microsoft Excel, and has the capacity to schedule backchecks in a timely manner. Importantly, GPCB oversees enough plants that it could hire full-time 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. 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 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.

6.2 Dissemination

The dissemination plan is to work through both policy and academic channels. In the policy channel, we are working directly with GPCB to permanently adopt the modified environmental audit system, as tested in this study. 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 Abdul Latif Jameel Poverty Action Lab's (J-PAL) website and monthly newsletter, which reaches thousands of individuals in the policymaking community in both developing and industrialised countries.

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.

Appendix A
Sample design

The sample was 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 GPCB, we judged these firms as likely to be audit-eligible. Sample in hand, we conducted randomisation, stratified by region. Treatment assignment was invariant over the experimental period, 2009 and 2010. After assignment, we conducted a detailed survey of plant characteristics and determined final eligibility. The final sample consisted of 473 plants, with 233 in the treatment group and the remainder in the control group.

Appendix B
Survey instruments

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

Audit reports

Audit reports were prepared by audit firms and submitted to GPCB in a format that GPCB specified. We obtained these directly from GPCB. The reports contained information on a mandated set of water pollutants – BOD, COD, TDS, TSS, NH_3-N) and air pollutants (SO_2, NO_X and SPM). For water pollutants, we concentrated our analysis on samples collected at the outlet of the effluent treatment plant, although the reports often contained information on samples collected at other points in the production or treatment process. Air samples were restricted to the boiler stack for maximum comparability; most plants had a boiler.

Backchecks

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

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 included the firm history, revenue, employees and expenditure on: raw materials; labour; auditor fees levied by GPCB; environmental consultants; pollution abatement capital; and pollution abatement variable inputs (in other words, chemicals for water treatment).

Appendix C
Power calculations

We planned for a sample of slightly fewer than 500 plants, with attrition between 10 and 20 per cent. We expected about seven pollutant measurements from each plant. We anticipated an intra-cluster correlation of about 0.1, and a somewhat higher one when restricted to only air or only water parameters.

Under these conditions, and with a standard alpha of 0.05 and power of 0.8, we could identify co-efficients for sub-samples of water or air only as small as 0.2 standard deviations. In GPCB data we examined before the intervention, the standard deviation of final-stage effluent measurements of BOD among small-scale, high-pollution potential plants in Ahmedabad was 707 milligrams per cubic litre. An effect of size 0.2 was therefore 140 milligrams per cubic litre, or about 23 per cent of the mean BOD level among plants that did not output their effluent to a common treatment plant for further treatment.

To gain a sense of whether our treatment was likely to have an effect of this magnitude, we collected historical audit reports to estimate the correlation between the frequency of the GBCP inspections and the measured emissions. Specifically, we entered 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 GPCB in the previous six months. The dependent variables in these regressions are the logs of BOD, COD, TDS and suspended solids (SS), all measurements of the quality of wastewater (with 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 GPCB. Table A1 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)

	Type of pollutant			
	BOD	**COD**	**TDS**	**SS**
Visited in last six months	−0.4156 (0.1036)	−0.3382 (0.1009)	−0.5086 (0.0812)	−0.0499 (0.0391)
Observations	0.0604	1,006	1,007	1,005
Mean	5.4640	6.5302	8.654	4.5600
Standard deviation	1.7047	1.6178	1.2936	1.2564

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

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

Appendix D
Descriptive statistics

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

Table A2: Endline measurements, by pollutant

Parameter	Pollutant	Mean	SD	5th percentile	95th percentile
AN	Ammonical nitrogen	18.7	58.3	0.00	47.60
BOD	Biochemical oxygen demand	229.2	590.1	20.00	556.00
COD	Chemical oxygen demand	807.6	1,858.7	84.00	1,971.00
TDS	Total dissolved solids	5,821.1	8,532.5	610.00	19,770.00
TSS	Total suspended solids	145.4	245.8	20.00	350.00
NO_X	Nitrous oxides	14.4	11.6	0.28	35.58
SO_2	Sulphur dioxide	41.4	39.4	3.05	88.50
SPM	Suspended particulate matter	205.0	238.2	35.42	414.00

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 indicate, like Figure 5, that the audit firms in the regular scheme were disproportionately reporting firms as immediately below the standard, relative to the true backcheck distribution.

Table A3: Control report outcome, by report type

Report	Comply	Clump
Audit	0.68	0.28
Backcheck	0.49	0.08

Appendix E
Balance test

Table A4: Audit treatment co-variance balance

	Treatment	Control	Difference
Capital investment INR50m to INR100m (=1)	0.092 [0.29]	0.14 [0.35]	−0.051 (0.033)
Located in industrial estate (=1)	0.57 [0.50]	0.53 [0.50]	0.042 (0.051)
Textiles (=1)	0.88 [0.33]	0.93 [0.26]	−0.030 (0.025)
Dyes and intermediates (=1)	0.038 [0.19]	0.016 [0.12]	0.018 (0.016)
Effluent to common treatment (=1)	0.41 [0.49]	0.35 [0.48]	0.078 (0.049)
Water consumed (kl/day)	510.6 [378.8]	506.4 [633.6]	15.1 (53.1)
Wastewater generated (kl/day)	420.5 [315.9]	394.6 [323.4]	35.4 (31.6)
Lignite used as fuel (=1)	0.71 [0.45]	0.77 [0.42]	−0.024 (0.029)
Diesel used as fuel (=1)	0.29 [0.45]	0.25 [0.43]	0.038 (0.046)
Air emissions from flue gas (=1)	0.85 [0.35]	0.87 [0.33]	−0.0095 (0.033)
Air emissions from boiler (=1)	0.93 [0.26]	0.92 [0.27]	0.016 (0.026)
Bag filter installed (=1)	0.24 [0.43]	0.34 [0.47]	−0.10** (0.046)
Cyclone installed (=1)	0.087 [0.28]	0.079 [0.27]	−0.0010 (0.027)
Scrubber installed (=1)	0.41 [0.49]	0.41 [0.49]	−0.018 (0.050)
Whether audit submitted (=1)	0.82 [0.38]	0.81 [0.39]	0.022 (0.038)
Any inspection conducted (=1)	0.79 [0.41]	0.78 [0.42]	0.016 (0.042)
Any equipment mandated (=1)	0.42 [0.50]	0.49 [0.50]	−0.047 (0.047)
Any citation issued (=1)	0.28 [0.45]	0.24 [0.43]	0.035 (0.045)
Any water citation issued (=1)	0.12 [0.33]	0.12 [0.33]	−0.0031 (0.034)
Any air citation issued (=1)	0.027 [0.16]	0.0052 [0.072]	0.021 (0.013)
Any utility disconnection (=1)	0.098 [0.30]	0.094 [0.29]	0.0029 (0.031)
Any bank guarantee posted (=1)	0.033 [0.18]	0.026 [0.16]	0.0045 (0.017)
Observations	184	191	

Note: *p < 0.10, **p < 0.05, ***p < 0.01

Table A4 presents summary statistics for both 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 co-efficient 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 pooled all the pollutant readings from the audits and backchecks. Our two variables of interest were 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 regressed 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. Panel A, column 1 shows that the audit reports were 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 (column 2) and air pollutants (column 3).

Table A5: **Pollution reports on report type and treatment**

	Type of pollution		
	All	**Water**	**Air**
Panel A: Report between 75% and 100% of standard			
Audit report × audit treatment	−0.085*** (0.034)	−0.212*** (0.044)	−0.143*** (0.046)
Audit report (=1)	0.270*** (0.025)	0.297*** (0.034)	0.230*** (0.033)
Audit treatment (=1)	−0.034 (0.017)	−0.013 (0.025)	0.011 (0.024)
Control mean	0.232	0.259	0.191
Panel B: Report below standard			
Audit report × audit treatment	−0.234*** (0.039)	−0.166*** (0.05)	−0.345*** (0.056)
Audit report (=1)	0.288*** (0.023)	0.273*** (0.033)	0.311*** (0.032)
Audit treatment assigned (=1)	0.058* (0.034)	0.0075 (0.048)	0.145*** (0.041)
Control mean	0.701	0.674	0.741
Observations	2,236	1,378	858

Note: *p < 0.10, **p < 0.05, ***p < 0.01
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 reported the results from a single cross-section of endline survey data on the pollution outcome. The outcome variables were 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 calculated by normalising the reported pollution by the mean and backcheck of the true backcheck distribution. On average, the treatment plants reduced pollution by a statistically significant 0.211 standard deviations. This effect was 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 did not change in response to the experimental treatments, so these reductions in concentrations represented reductions in the total emitted effluent load, rather than a dilution of constant pollutant loads. A quantile regression indicated that most of the effect was from the dirtiest plants.

Table A6: Pooled pollution concentrations on treatment status: inspection control only

			Type of pollution
	All	**Water**	**Air**
Panel A: Pollution concentrations			
Audit treatment assigned (=1)	−0.211** (0.01)	−0.300* (0.159)	−0.053 (0.057)
Control mean	0.076	0.114	0.022
Panel B: Regulatory compliance			
Audit treatment assigned (=1)	0.027 (0.027)	0.039 (0.039)	0.0018 (0.028)
Control mean	0.573	0.16	0.656
Observations	1,439	860	579

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

Appendix F **Study methodology**

The research design was a randomised controlled trial, which lends itself to straightforward empirical analysis using ordinary least squares. We also used quantile regressions to examine heterogeneity in the firms' responses to the treatment.

References

Becker, G.S., 1968. Crime and punishment: An economic approach. *Journal of Political Economy*, Vol 76, p.169.

Becker, G. and Stigler, G., 1974. Law enforcement, malfeasance, and the compensation of enforcers. *Journal of Legal Studies* 3, pp.1–19.

Bolton, P., Freixas, X., and Shapiro, J., 2009. *The credit ratings game.* National Bureau of Economic Research working paper No. w14712.

Brandon, C., and Homman, K., 1995. *The cost of inaction: Valuing the economy-wide cost of environmental degradation in India.* Asia Environment Division, World Bank.

Bolton, P., Freixas, X. and Shapiro, J., 2012. The credit-ratings game. *The Journal of Finance*, 67(1), pp.85–111.

Chen, Y., Ebenstein, A. and Li, H., 2013. 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*, 110(32), pp.12,936–12,941

Dasgupta, P., 2004. Valuing health damages from water pollution in urban Delhi, India: A health production function approach. *Environment and Development Economics*, 9(01), pp.83–106.

Duflo, E., Greenstone, M., Pande, R., and Ryan, N., 2012. *Truth-telling by third-party auditors and the response of polluting firms: Experimental evidence from India.* MIT.

Dranove, D., and Zhe Jin, G., 2010. *Quality disclosure and certification: Theory and practice.* National Bureau of Economic Research working paper No. w15644.

Farhi, E., Lerner, J. and Tirole, J., 2010. *Fear of Rejection: Tiered Certification and Transparency.* Mimeo.

Hanna, R., and Greenstone, M., 2011. *Environmental regulations, air and water pollution and infant mortality in India.* National Bureau of Economic Research working paper No. w17210.

Hanna, R., and Oliva, P., 2011. *The effect of pollution on labor supply: Evidence from a natural experiment in Mexico City.* National Bureau of Economic Research working paper No. w17302.

Holmstrom, B., 1982. Moral hazard in teams. *The Bell Journal of Economics*, 98, Supplement: pp.23–54.

Maria, A., 2003. *The Costs of Water Pollution in India.* Presented at the Conference on Market Development of Water and Waste Technologies through Environmental Economics, Delhi. Mimeo, Ecole Nationale Superieure des Mines de Paris.

Mookherjee, D. and Png, I.P.L., 1992. Monitoring vis-a-vis investigation in enforcement of law. *American Economic Review*, Vol 82(3), pp.556–65.

Mookherjee, D. and Png, I.P.L., 1995. Corruptible law enforcers: How should they be compensated? *Economic Journal*, Vol. 105(428), pp.145–59.

Morgan, J. and Stocken, P.C., 2003. An analysis of stock recommendations. *RAND Journal of Economics*, Vol 34(1), pp.183–203.

Olken, B.A., 2005. *Monitoring corruption: Evidence from a field experiment in Indonesia.* National Bureau of Economic Research working paper No. w11753.

Olken, B.A., 2007. Monitoring corruption: Evidence from a field experiment in Indonesia. *Journal of Political Economy* 11, 2, pp.200–249.

Olken, B.A., and Pande, R., 2011. *Corruption in developing countries.* National Bureau of Economic Research working paper No. w17398.

Olken, B.A. and Pande, R., 2012. Corruption in Developing Countries. *Annual Review of Economics*, Vol. 4, pp.479–509.

Rahman, D., 2012. But who will monitor the monitor? *American Economic Review*, 102(6), pp.2,767–97.

Publications in the 3ie Impact Evaluation Report series

The following reports and other 3ie publications are all available from
www.3ieimpact.org/publications/3ie-impact-evaluations/

The promise of preschool in Africa: A randomised impact evaluation of early childhood development in rural Mozambique, 3ie Impact Evaluation Report 1.
Martinez, S., Naudeau, S. and Pereira, V. (2012)

A rapid assessment randomised-controlled trial of improved cookstoves in rural Ghana, 3ie Impact Evaluation Report 2.
Burwen, J. and Levine, D.I. (2012)

The GoBifo project evaluation report: Assessing the impacts of community-driven development in Sierra Leone, 3ie Impact Evaluation Report 3.
Casey, K., Glennerster, R. and Miguel, E. (2013)

Does marginal cost pricing of electricity affect groundwater pumping behaviour of farmers? Evidence from India, 3ie Impact Evaluation Report 4.
Meenakshi, J.V., Banerji, A., Mukherji, A. and Gupta, A. (2013)

Impact evaluation of the non-contributory social pension programme 70 y más in Mexico, 3ie Impact Evaluation Report 5.
Rodríguez, A., Espinoza, B., Tamayo, K., Pereda, P., Góngora, V., Tagliaferro, G., Solís, M. (2013)

The impact of daycare on maternal labour supply and child development in Mexico, 3ie Impact Evaluation Report 6.
Angeles, G., Gadsden, P., Galiani, S., Gertler, P., Herrera, A., Kariger, P. and Seira, E. (2013)

Social and economic impacts of Tuungane: final report on the effects of a community-driven reconstruction programme in eastern Democratic Republic of Congo, 3ie Impact Evaluation Report 7.
Humphreys, M., Sanchez de la Sierra, R., van der Windt, P. (2013)

Paying for performance in China's battle against anaemia, 3ie Impact Evaluation Report 8.
Zhang, L., Rozelle, S. and Shi, Y. (2013)

No margin, no mission? Evaluating the role of incentives in the distribution of public goods in Zambia, 3ie Impact Evaluation Report 9.
Ashraf, N., Bandiera, O. and Jack, K. (2013)

Truth-telling by third-party audits and the response of polluting firms: Experimental evidence from India, 3ie Impact Evaluation Report 10.
Duflo, E., Greenstone, M., Pande, R. and Ryan, N. (2013)

Impact Evaluation Series

International Initiative for Impact Evaluation
c/o Global Development Network
2nd Floor, West Wing, ISID Complex
Plot No. 4, Vasant Kunj Institutional Area
New Delhi – 110070
India

3ie@3ieimpact.org
Tel: +91 11 4323 9494

www.3ieimpact.org