The Solvable Challenge of Air Pollution in India

Michael Greenstone  
University of Chicago

Santosh Harish  
University of Chicago

Rohini Pande  
Harvard University

Anant Sudarshan  
University of Chicago

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Abstract

More than 660 million people in India breathe air that exceeds National Air Quality Standards and research indicates that bringing air quality in compliance would increase life expectancy by an average of 3.2 years. Despite India’s severe environmental challenges, implementing policies that effectively reduce pollution has proven hard. We review empirical evidence from within and outside India, to distill three elements of reform: (i) ensuring reliable monitoring based on high-quality data, (ii) designing incentive-compatible and economically efficient regulation, and (iii) piloting and evaluating the impact of new ideas. We review a variety of empirical evidence from within and outside India, including Delhi’s recent program to ration driving, third-party industry audits in Gujarat and continuous monitoring of industrial emissions. We argue that these three elements can be effectively combined to reduce pollution, and that India may require market-based approaches for long-term solutions.

JEL Classification: Q52, Q53, Q56, Q58, I18  
Keywords: India, Pollution, Regulation, Transparency, Emissions Trading, Markets, Congestion Pricing

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mgreenst@uchicago.edu, sharish@uchicagotrust.org, Rohini_Pande@harvard.edu, anant.sudarshan@gmail.com
The Solvable Challenge of Air Pollution in India
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1. Introduction

The costs of air and water pollution in India are extraordinarily high. Consequently, the deterioration of environmental quality is likely to significantly hinder economic growth. Recent research has helped us grasp the magnitude of the problem. Greenstone et al (2015) used a combination of ground-level in-situ measurements and satellite-based remote sensing data, and estimated that about 660 million Indians live in areas that exceed the Indian National Ambient Air Quality Standard (NAAQS) for fine particulate (PM2.5) pollution. The authors estimate that achieving India’s own standards could increase life expectancy for urban residents by 3.17 years on average. In a similar vein, the Global Burden of Disease report estimated that ambient particulate matter air pollution accounts for 6% of global deaths and that over 10 percent of premature deaths owe to lower respiratory diseases. To put this in perspective, this is higher than deaths due to tuberculosis and malaria combined (Lim et al. 2012). With regards water pollution, India is estimated to have the worst access to safe drinking water of any country in the world (WaterAid 2016) with over 100 million people living in areas without safe drinking water. Research also shows that river water pollution has a causal impact on diarrhea deaths (Do 2014).

The economic costs of pollution, acting via increased health care expenditures and a less productive workforce, will therefore be significant. Ascribing a monetary value to all the externalities created by pollution is difficult, but an estimate from the OECD suggests ambient air pollution alone may cost India more than 0.5 trillion dollars per year (OECD 2014).

Environmental regulation in India has largely used so-called ‘command and control’ instruments including technology mandates, bans on production processes, and absolute emissions standards. Enforcement options have been restricted to criminal penalties and plant closures. Getting such regulation to work has proved challenging for the government and has simultaneously imposed high costs on industry. A necessary requirement for command-and-control regulation to work is a very well-informed regulator with the willingness and ability to systematically enforce fair penalties in cases of non-compliance. In the main, this has been lacking in India. Duflo et al (2013) show how reliable data can be an elusive goal, and Ghosh (2015) identifies severe weaknesses in the enforcement mechanism.

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1 Greenstone (Department of Economics, University of Chicago), Harish (Energy Policy Institute, University of Chicago), Pande (Kennedy School of Government, Harvard University), Sudarshan (Department of Economics and Energy Policy Institute, University of Chicago). The paper has benefitted from comments by Shekhar Shah and Sanjib Pohit at the National Council for Applied Economic Research. We would like to thank Bhavna Rai for excellent research assistance.

2 Estimated using data from India Water Tool, a collaborative database put together by the World Resources Institute and the Confederation of Indian Industry. See http://www.wri.org/blog/2015/02/3-maps-explain-india%E2%80%99s-growing-water-risks for more detail.
This paper examines environmental regulation in India with a view to identify characteristics of policy instruments that have made success more likely, and laying out a roadmap for regulatory reform. We discuss three necessary ingredients: (i) ensuring reliable monitoring based on high-quality data, (ii) designing incentive-compatible and economically efficient regulation, and (iii) piloting and evaluating the impact of new ideas. We argue that these three elements can be effectively combined for designing more effective long-term policy.

The last of these becomes particularly important in the context of urgent but unfulfilled policy objectives and an existing regulatory framework that is not seen as sufficiently effective. In these settings, iteratively designing and testing new ideas through carefully evaluated pilots could provide an effective roadmap of improvements to the status quo, based on rigorous evidence. Unfortunately, this type of forward-looking evidence-based approach to policy-making has not been common when it comes to environmental protection in India.

One policy innovation that does provide a good case-study of the importance of explicit and rigorous evaluation of innovative ideas is a driving-rationing scheme introduced by the Government of the National Capital Territory of Delhi in 2016. In December 2015, the government of Delhi announced a series of emergency measures to reduce air-pollution (The Hindu, 2015; The Indian Express, 2015). The most ambitious of these was the so-called ‘Odd-Even’ scheme, which mandated that vehicles with odd (even) numbered license plates could be used only on odd (even) numbered dates. The scheme was effective between the hours of 8 am and 8 pm for the first 15 days of January 2016. A second round of the odd-even program was implemented during April 15-30, 2016.

Although the Odd-Even scheme was introduced as a pilot, it was not explicitly designed for rigorous impact evaluation. The scheme witnessed unusually high media coverage involving very divergent assessments of success (e.g. Times of India 2016a; DNA, 2016; The Hindu Business Line, 2017). We undertake a careful assessment of the impact of the driving-restriction on local air pollution, using a difference-in-differences approach, and find that relative to its neighboring areas outside city boundaries, fine particulate concentrations in Delhi’s air were lower by roughly 24-36 microgram/m3 during January, or a reduction of about 13%. These reductions were largest in the mid-morning (11am – 2pm) and we see no gains in air quality at nights (when rationing was not in effect). In contrast, Delhi’s air did not show any quality gains relative to its neighboring cities during the April phase of the program.

The success of Odd-Even in January may have owed in part to the significant public engagement with the program. Greenstone and Hanna (2014) suggest that public interest in command-and-control regulations can enhance their effectiveness. They study a supreme court mandated requirement that catalytic converters be installed in vehicles in various Indian cities and find that this rule gathered a great deal of media attention and resulted in significant reductions in certain air pollutants.

In June 2017, the Maharashtra State Pollution Control Board launched an important new regulatory initiative which seeks to publicly release information on industrial air-pollution in the form of a public star rating for regulated factories.

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3 Vehicles driven by women or cars with more than two passengers were exempt from the policy.
Interestingly, this effort has been launched as a pilot explicitly designed for rigorous impact evaluation and gradual scale-up. Some of the authors of this paper have been involved in the design of this pilot and the goal has been to implement some of the elements of policy design we recommend here. More broadly, global experience with this type of ‘third-way’ regulation suggests these policies may increase the effectiveness of an underlying command-and-control structure at relatively low costs (Blackman et al 2004).

Having said this, even where command and control policy is effective, it is rarely economically efficient. A policy comprising a blanket ban on private vehicle trips on a given day assigns the same penalty to a trip down to the grocery store, as to an urgent hospital visit. Consequently, if fully enforced, the costs to residents may exceed any social damages created by the pollution from their private trip. In the long-run, this type of mandate makes non-compliance more likely and Davis (2008) shows that a program in Mexico City similar to Odd-Even resulted in commuters getting around driving restrictions linked to license plates by purchasing secondary cars, often older and more polluting than the original vehicle stock.

The economic inefficiencies of command-and-control mean that the net costs of achieving desired environmental objectives can be high. We discuss examples of market-based instruments in different parts of the world and argue that India should now experiment with these methods. Although we focus on local pollution, experience with markets to regulate pollutants might become even more valuable as India attempts to fulfill its INDCs. Using detailed micro-data from a unique survey of over 1000 industrial plants in the states of Gujarat, Maharashtra, and Tamil Nadu, we simulate outcomes from an engineering economic model and find that total abatement costs may reduce by over 70 percent under cap and trade regimes, as opposed to the status quo of command and control. In the case of transport, market-based instruments like congestion pricing, as implemented in cities like London, Singapore, and Stockholm, may be more sustainable over the long term than vehicle rationing.4

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4 Congestion pricing schemes do not directly price emissions and the metric by which their success is measured need not be pollution reduction. However, congestion can be strongly correlated with air pollution and evidence suggests that congestion pricing schemes can have significant impacts on air pollution also (Simeonova 2017).
The remainder of this paper is arranged as follows. In Section 2, we review evidence on the effectiveness of command and control regulations of different kinds on industrial and vehicular pollution. We focus primarily on the Indian experience, borrowing heavily from empirical work we have been involved with over the last decade, with new results around the odd-even program. We discuss monitoring and enforcement of emission standards, programs mandating technology retrofits to reduce pollution, and bans or rationing of the operations of polluters. In Section 3, we use the results of these experiences to discuss three important factors that form the foundation of effective regulation: improved reliability and transparency in monitoring data, interventions that account for incentives of various stakeholders, and ensuring that new policy measures are carefully evaluated, and scaled on the evidence of impact. Section 4 concludes.

2. Experience with Command-and-control Regulation

Command-and-control regulation in India broadly fits into three categories. First, as discussed already, the states may ban or ration certain types of polluting activities. Second, the government may mandate changes in technology e.g. fuel type, pollution control equipment, allowable inputs. Third, and most common, the regulator or the government establishes absolute standards relating to the production of pollutants that need to be adhered to, failing which penalties may be levied. In this section, we will discuss how these programs have fared in India.

2.1. Bans and Rationing of Polluting Activities

One form of command and control regulation involves banning or restricting the operations of specific categories of polluters, independent of individual emissions. By stopping or restricting an economically productive activity, this type of regulation may even impose net social costs, if the externality damages from pollution are lower than the economic value of the restricted activity.

Such restrictions may follow from a failure to satisfactorily regulate pollution in the first instance, for example by failing to ensure that manufacturing plants install and use pollution control equipment. This form of regulation has often been driven by the judiciary, ruling in favor of public interest litigants in cases where regulators have been unable to show that they would be otherwise able to satisfactorily control pollution.

One example of this could be the actions of the Delhi Government in the late nineties, backed by the Supreme Court, to relocate highly polluting industries out of the city proper; the process of relocating industrial units in residential areas in Delhi has also been happening under the pressure of the Supreme Court and is ongoing (Narain and Bell, 2006). The relocation of polluting industries within Delhi city limits, is one of many examples, of Action Plans mandated by the Supreme Court in cities to combat pollution. Supreme Court Action Plans target industries in different ways, including “closure of clandestine units (Faridabad), moving various industries and commercial activities outside of city limits (Jodhpur, Kanpur), installation of electrostatic precipitators in all boilers in power generation stations (Lucknow), surprise inspections (Patna), and promotion of alternative fuels in generators (Hyderabad)” (Harrison et al, 2015).
Plant closures and relocations have typically been options of last resort in the manufacturing sector. However, for vehicular sources of pollution, restrictions on operations and ownership are common. These include compulsory retirement of old vehicles, or restrictions on the use of heavy commercial vehicles during the day in cities. Often, the effectiveness of these environmental policies is difficult to evaluate, as there are too many confounding factors.

In what follows, we exploit a 2016 initiative by the Delhi government that imposed restrictions on driving behavior to provide evidence suggesting that even in the short-term, driving behaviors can change enough to meaningfully reduce air-pollution from transport. Although the literature suggests that in the long-run these impacts may not persist (Davis, 2008; Wang, 2014), this result is important independent of the regulatory mechanism that initiates changes in behavior. If driving behaviors respond to incentives and have discernable, dynamic impacts on air pollution, this opens the door to a productive conversation on the most efficient ways to change vehicle use.

On Dec 1, 2015, the Delhi government announced that the odd-even program for privately owned cars would be launched as a pilot during January 1-15, 2016. The program would be effective between 8 am in the morning to 8 pm in the evening, apart from Sundays. Cars with registration plates from outside Delhi were also required to comply. Despite some exceptions to the rationing, the program was effectively cutting the numbers of cars on the road by nearly 50 percent.

Around the time the odd-even program was being introduced, the Delhi government also announced other measures to reduce air pollution:

- November 6, 2015: Environment Compensation Charge charged for commercial vehicles (light diesel vehicles and three-axle vehicles) entering the city limits. (Supreme Court, 2015a; Department of Environment, 2015) On December 16, 2015, the Charge was doubled (Supreme Court, 2015 b)
- On December 16, 2015, Supreme Court banned the registration of new diesel cars (larger than 2000 cc) till March 3odd-even1, 2016 (Supreme Court, 2015 b)
- From January 1, 2016, Delhi government increased the restriction on entry of trucks during the day. Entry hours were pushed from 9 PM to 11 PM (Department of Environment, 2015)

Our analysis uses data from ten ambient air quality monitors in Delhi and three satellite cities just outside Delhi. Figure 1 shows the location of these monitors which are operated by the Central Pollution Control Board for Delhi and by the Haryana State Pollution Control Board for the neighboring towns of Faridabad, Gurgaon and Rohtak. We compile hourly monitoring data for the six months spanning November 2015 to April 2016.
Temporal and spatial variations in PM2.5 levels imply that a simple comparison of air quality before and during the program may be misleading. We, therefore, focus on difference-in-differences analysis where we examine how difference in air quality in Delhi and neighboring cities changes during the program relative to the time-period before and after. We also consider a ‘triple difference’ variant where we additionally examine whether during program days the impact is concentrated during hours that the program is effective (i.e. between 8 am and 8 pm). More formally, we estimate a regression model that takes the form:

\[ Y_{tm} = \alpha + \beta \cdot 1(m \in \text{Delhi}) + \gamma \cdot 1(t \in \text{odd even}) + \delta \cdot 1(m \in \text{Delhi}) \times 1(t \in \text{odd even}) + \lambda_m + \eta_t + \varepsilon_{tm} \]

\( Y_{tm} \) is the particulate (PM2.5) concentration at time t (on hour h and day d) for monitor m. Explanatory variables include an indicator variable for the treatment area (Delhi), an indicator variable for the days that the odd-even program was in place (termed odd even), and their interaction term. \( \beta \) and \( \gamma \) are the coefficients for the treatment area and period indicator variables. The interaction coefficient \( \delta \) estimates the program impact on particulate concentration. \( \lambda_m \) are \( \eta_t \) capture fixed effects at the monitor level and for each hour.

Our empirical analysis is premised on the assumption that that in the absence of the program, pollution in Delhi and neighboring cities would have evolved similarly. The relatively unexpected nature of the program and short program duration, combined with the geographic proximity of the satellite cities to Delhi, makes this a plausible assumption. In addition, we run 24 models for each hour of the day to get hourly estimates for impact on the concentration of particulates.
The results (in Table 1) show that there was a statistically significant and substantial reduction in PM2.5 concentrations during the days and hours that the odd-even program was implemented in New Delhi in the January round. The estimated reduction from the many specifications we cover ranges from about 24 microgram/m$^3$ to 37 microgram/m$^3$. In percentage terms, we estimate a reduction of 13 percent\(^5\).

From the hourly models, we find large, statistically significant reductions in concentration between 11 am – 2 pm (see Figure 2), which could be attributed to reduction in traffic during the morning peak hours. During other times of the day, our estimates are noisy and we cannot rule out the possibility that they are zero. This may be due to dispersion (wiping out any local improvements in air quality) and other sources of PM2.5 (reducing the significance of reductions from traffic alone). Importantly however, no impacts were observed at night when the odd-even rationing was no longer in force.

This reduction in concentrations could be attributed to three factors: one, reduction in PM from vehicular exhaust of the cars taken off the road; two, reduced congestion and consequently, reduced idling and emissions from all the vehicles (allowed cars as well as buses and other vehicles) on the road; three, reduced resuspension of road-dust due to reduced vehicular volumes.

On the other hand, the results in April look very different. We observe no significant reduction during both the night and the day in the second (April) round of vehicle rationing.

This might owe to several causes. It is possible that compliance decreased in the second round because compliance levels fell as the policy was repeated. Primary traffic surveys by the School of Planning and Architecture along several junctions around the city find that traffic volumes were higher during the second round of the program than the first round, and that there was a large shift to two-wheelers (Hindustan Times, 2016). They contrast this with the January round when commuters chose to carpool or use the public transportation. Compliance levels that fall over time may also be a sign of weak monitoring and enforcement.

It is also possible that despite steady compliance and similar reduction in emissions from cars, measured ambient concentrations (the quantity measured by pollution monitors) may have been affected less in April than January.

A plausible reason for this is greater dispersion during warmer months. Dispersion is faster when atmospheric mixing heights are greater, as is the case in the summers compared to winters (Guttikunda and Gurjar, 2012). For this reason, modest increases and decreases in emission sources on-ground may disperse upwards and not translate into observable changes in pollution concentrations near the ground. On the other hand, in winter when dispersion is minimal, these changes are immediately noticeable. This suggests a limitation of the program itself: it is perhaps more appropriate as an emergency measure during the winters, than as a long-term pollution reduction measure, even if compliance rates are high.

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\(^5\) Percentage reduction is estimated using a variant of the regression models described in the paper with the dependent variable as natural logarithm of PM2.5 concentrations. With these specifications, the coefficient of the triple difference can be directly interpreted as the percentage change. Specifically, this estimate of 13 percent comes from a model using the combined 6-month data, with separate estimates for the two rounds.
The results here analyze regulatory data carefully.

**Figure 2: Delhi Odd-Even Program: Results of the hourly models when run over the six-month period**

![Graph showing change in concentrations during the dates when odd-even was implemented (microgram/m³) over the hours of the day. The graph compares January round and April round, with statistically significant results indicated by circled points.](image)

*Source:* Authors’ calculations.

The difference-in-difference coefficient has been plotted for each hour of the day with the hours with statistically significant results shown as a circled point on the graphs.
Table 1: Delhi Odd-Even Program: Results of the regression model when run on a single pooled dataset with monitor and time (each hour of observation) fixed effects. Results summarized below for the six-month period November 2015 - April 2016

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Six months joint estimate</td>
<td>Six months separate estimates</td>
<td>Jan and April joint estimate</td>
<td>Jan and April separate estimates</td>
</tr>
<tr>
<td>Delhi X OddEvenDatesJan</td>
<td>-14.96</td>
<td>(21.54)</td>
<td>-6.020</td>
<td>(24.29)</td>
</tr>
<tr>
<td>Delhi X OddEvenDatesApril</td>
<td>-3.940</td>
<td>(17.15)</td>
<td>12.84</td>
<td>(13.01)</td>
</tr>
<tr>
<td>Delhi X OddEvenDatesJanXOddEvenHours</td>
<td>-24.42***</td>
<td>(6.446)</td>
<td>-31.69**</td>
<td>(12.93)</td>
</tr>
<tr>
<td>Delhi X OddEvenDatesAprilXOddEvenHours</td>
<td>11.60</td>
<td>(12.27)</td>
<td>-6.794</td>
<td>(15.53)</td>
</tr>
<tr>
<td>DelhiXOddEvenDatesBoth</td>
<td>-8.945</td>
<td>(13.56)</td>
<td>5.702</td>
<td>(13.65)</td>
</tr>
<tr>
<td>DelhiXOddEvenDatesBothXOddEvenHours</td>
<td>-7.072</td>
<td>(8.371)</td>
<td>-18.59*</td>
<td>(9.234)</td>
</tr>
<tr>
<td>Observations</td>
<td>21,197</td>
<td>21,197</td>
<td>7,105</td>
<td>7,105</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.472</td>
<td>0.473</td>
<td>0.486</td>
<td>0.489</td>
</tr>
<tr>
<td>Number of monitors</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Monitor FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Day FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Hour of Day FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Day FE X OddEvenDates FE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

*Source: Authors’ calculations*

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
In the case of similar driving restrictions in Mexico City introduced in 1989, Davis (2008) compares vehicle registrations with new vehicle sales to show that the restrictions led to an increased adoption and use of used cars. Substitution to relatively older vehicles on restricted days for the principal vehicle may lead to a net increase in pollution. In Beijing, where similar car rationing schemes have been in force, Wang et al. (2014) find that non-compliance may have been as high as 48 percent, with car owners who traveled “during peak hours and/or for work trips, and whose destinations were farther away from the city center or subway stations, were more likely to break the driving restriction rules”.

2.2. Mandates on Technology and Process to Reduce Emissions

In addition to setting standards that polluters must adhere to, regulators can mandate technology retrofits to reduce emissions. Technology mandates are extremely common and have had mixed success in India, determined to a significant degree by the difficulty of monitoring equipment installation and ensuring continued maintenance and utilization.

In the nineties, the Delhi Government and the Central Petroleum Ministry pushed the installation of catalytic converters. Like several other interventions, the Supreme Court leaned on these governments to mandate the retrofit (Narain and Bell, 2006). Catalytic converters are an end-of-pipe technology to reduce emissions from the vehicular exhaust, and have been used all over the world. Catalytic converters convert carbon monoxide and unburnt carbon into the more benign carbon dioxide, and convert nitrogen oxides (NOx) into nitrogen gas. In January 1995, the Delhi government introduced subsidies for catalytic converters in all two- and three-wheel vehicles. The petroleum ministry then announced that all new vehicles in the four metros—Delhi, Mumbai, Kolkata and Chennai—needed to have catalytic converters installed. This was then extended to 45 cities in 1998.

Since registrations were linked to the installation of catalytic converters, enforcement was stringent. The impact of the installation of catalytic converters was expected to increase over time, as the fleet composition changed with newer vehicles on the roads. Greenstone and Hanna (2014) study the impact of this program by compiling a comprehensive dataset on air pollution levels across the country. They follow an event-study style approach to investigate the reduction in concentrations of SO$_2$, NO$_2$, and suspended particulate matter in ambient conditions. Their results indicate that five years after implementation of the catalytic converters policy, there were statistically significant declines in PM and SO$_2$, while the decline in NO$_2$ was not significant. Greenstone and Hanna (2014) estimate that the catalytic converter policy resulted in declines of 19 percent, 69 percent, and 17 percent of the 1987–1990 nationwide mean concentrations, for PM, SO$_2$ and NO$_2$ respectively. Similarly, Narain and Krupnick (2007) evaluate a court-mandated shift to CNG and an accompanying ban on diesel fuel, for all public transportation in New Delhi. They find significant decreases in both fine particulate emissions and sulphates.

Not unlike the catalytic converters, the State Pollution Control Boards have also issued mandates to industries to install air pollution control equipment. For example, industries that have a high probability of emitting particulate matter are often required to install bag filters, although their existing air pollution control equipment could
potentially be designed and maintained well enough to ensure that industries comply with the norms. Similarly, all thermal power plants have been required to install flue gas desulphurization units to control their SO2 emissions.

Similarly, Supreme Court Action Plans nearly always included installation of pollution control equipment by industries (Harrison et al, 2015). Using data on pollution abatement and fuel usage from the Annual Survey of Industries, Harrison et al (2015) find that the Action Plans did result in High Pollution industries investing in pollution abatement, but their effect on coal usage was broadly unaffected; overall, they find that changes in coal prices were more effective in reducing SO2 emissions than command and control measures.

In 2015, the Central Pollution Control Board conducted a survey of over 350 industrial plants in the city of Surat. Using data from this survey, we find that most industries had sophisticated air pollution control devices such as bag filters, which in theory ought to ensure that the plants are comfortably within the emissions norms. Nearly 59 percent of the plants had bag filters, often with other air pollution control devices in addition. However, as Figure 3 shows, these stacks continue to have very high pollution levels, and the mean emissions of the three most common combinations with bag filters exceed the prescribed standard by two-times or more. This suggests that either the bag filters were poorly designed or poorly maintained. This example underscores the problem with technology mandates. They are easier to monitor than ongoing compliance with emissions standards, but unless they are truly ‘plug and play’, they may give a very misleading impression of actual environmental performance.

Figure 3: Distribution of measured concentrations of particulate matter from stacks with the most common configuration of emissions source and air pollution control devices

11

<table>
<thead>
<tr>
<th>Box plot of PM Concentration by Stack Attachments</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Gujarat)</td>
</tr>
</tbody>
</table>

0 500 1,000 1,500
PM Concentration (mg/nm³)
1 2 3 4 5
Source: Baseline Survey
(Gujarat)
Box plot of PM Concentration by Stack Attachments

In Figure 3 the emission sources and air pollution control devices in the chain are as follows:
1- Two emission sources attached each with a cyclone and bag filter;
2- Two emission sources attached, each with a cyclone and scrubber;
3- Two emission sources attached, each with a cyclone, scrubber and bag filter;
4- A single boiler attached with a cyclone and bag filter;
5- A single boiler attached to a cyclone and scrubber

*Source: Central Pollution Control Board and Authors’ calculations*

### 2.3. Monitoring to Enforce Standards

There is a large literature on the effect of inspections on industrial pollution in the developed country context. In the US for example, officials of the US Environment Protection Agency and the state governments have the power to conduct surprise inspections of industrial plants under the Clean Air Act of 1963. Hanna and Oliva (2010) find that, after controlling for plant level heterogeneity, an inspection has a 15 percent reduction in air emissions of a plant. There is also evidence that the threat of an inspection could reduce emissions in plants in the paper and pulp industry (Laplant and Rilstone, 1996) and in electric utilities (Keohane, Mansur and Voynov, 2009). In other words, inspections work in reducing violations, and in reducing emissions from industries.

For industrial emissions, the State Pollution Control Boards in India (SPCB) set a permissible limit on the concentration of pollutants that can be emitted from the stacks (i.e. the chimneys) of each industrial unit. These pollution norms are in terms of concentrations: the mass of pollutants in a unit volume of air leaving a stack. As a result, industries are regulated based on their instantaneous emissions and not their pollutant load over the course of a stipulated duration. This is worth noting because industrial emissions can vary substantially over the course of the day and year depending on industrial operations and whether and the extent to which the installed air pollution control equipment are being run.

Officials from the SPCBs perform inspections of plants, which often but not always include collecting samples. These inspections could either be routine, or as a response to an industrial plant applying for consent to operate, or as a follow-up to a violation discovered in a previous inspection (Duflo et al 2014). A major challenge for the SPCBs is that their manpower is very limited. Bhushan et al (2009) describe how the number of approved employees at the SPCBs has decreased over time, although the number of industries they regulate has increased by two or three-fold.

Duflo et al (2014) documents the results of a field experiment in Gujarat where the number of regulatory inspections in a randomly selected treatment group of industries was raised to the prescribed minimum — about twice that of status quo. They find that the increased inspections only marginal improved compliance and had no effect on the average emissions. The increase in inspections did not increase the detection of extreme polluters or the number of instances of costly penalties on industries. The results of the study suggest that regulators are typically aware of the high polluters and inspections in the status quo already target these.

In addition to the inspections by the SPCBs, some highly polluting plants are required to file audit reports, prepared by certified third party auditors. The auditors are hired and paid by the industries they audit and report to, creating incentives for them to underreport emissions. Duflo et al (2013) discuss a field experiment, once again conducted with the Gujarat Pollution Control Board (GPCB) that sought to investigate
the consequences of the conflict of interest in the third-party audits of industrial emissions, and to test a possible solution to reform this market and create incentives for truthful reporting. The results of the study are discussed below.

In this two-year experiment, audit-eligible industrial plants were randomly allocated into either a treatment group with the altered auditing process, or in the control group with business as usual. The altered auditing process involved the following changes. One, treatment industries were allocated an auditor by GPCB. Two, auditors allocated to treatment industries were paid a flat charge that covered the costs of auditing plus a profit, and were paid through a central pool. Three, the auditors were told that another technical agency may do a follow-up visit to repeat the pollution readings. Follow-up visits were also conducted in the control group.

The experiment had the following major results. Status quo monitoring was found to be corrupted. Between the audit and back-check readings in the status quo, there is a difference of 0.3 standard deviations. 29 percent of status quo audits falsely reported compliance. Second, improving the incentives for accurate reporting improved the quality of monitoring substantially. Treatment auditors reported pollution readings 0.15-0.21 standard deviations (50 to 75 percent) higher than status quo. Auditors in the treatment group were 80 percent less likely to falsely report compliance. Finally, better monitoring reduced industrial emissions. Industries in the treatment group reduced emissions by 0.2 standard deviations, with reductions highest among plants with the highest concentrations.

Emissions monitoring for vehicles shares similar structural challenges. There is literature from around the world showing evidence of “cheating” by emissions testing centers. Oliva (2015) finds that 79 percent emission testing centers in Mexico City accept bribes and substitute emissions readings of failing cars; cheating in this manner is an alternative to maintenance of the vehicles, and given the bribes are low, there is little incentive for users to maintain the vehicle. Hubbard (1998) finds that private centers in California fail vehicles at half the rate at which government run centers do— the probability of failure being lower in independently run garages and for vehicles for whom repair is not covered by warranty. Similarly, Wenzel (2000) compares private centers in California government owned centers in Arizona, and attributes the higher passing rates in California to fraud. The skewed incentives here for both vehicles owners and the testing centers are strikingly similar to those of the third-party auditors studied in Duflo et al (2013).

Vehicle emissions testing could also be unreliable because of variations due to fuel quality, the speed and acceleration of the vehicle, ambient and vehicle temperatures (Wenzel et al, 2000). Although an emission testing is required to be conducted under very specific conditions, even under the best care, emissions variability can be significant (Bishop et al, 1996). Wenzel et al. (2004) find that 5 percent of cars in California and 8 percent in Phoenix that passed the test initially would fail an immediate retest. As with the audits, vehicles and industries share similar challenges in point-in-time testing of emissions.

In India too, vehicles are required to get tested periodically at Pollution Check Centers. When the traffic police stop vehicles, they also check the pollution certificate and any discrepancy can be penalized. However, these checks are meaningful only when the underlying testing is accurate. A recent audit report (CPCB 2013) of the Pollution Check Centers by the Central Pollution Control Board to Delhi’s Department of
Transportation officials was alarming. Manpower at the centers were found to be poorly trained and unaware of protocols for testing, the equipment was not always maintained, and were rarely properly calibrated. The auditing team also documented instances of unauthorized officials passing vehicles, and software being used to generate dummy measurements. The auditing report ends with a call for greater scrutiny of the pollution centers.

As incentives go, monitoring of emissions for vehicles and industries are, for the most part, dependent on third party auditors or agencies to test vehicles. With limited scrutiny and supervising capacity, it is in the best interests of these third-party agencies to underreport emissions and retain their clients. Both industrial and vehicular emissions can have a high variance in emissions, reducing the effectiveness of conventional inspections.

3. Recommendations

In Section 2 we discussed status quo pollution regulation in India, largely based on command and control policy instruments. In what follows we consider the implications of this experience for reforming environmental regulation. We make the case for a policy design process that is centered around three elements:

1. Reliable and transparent data and monitoring.
2. Regulatory design that is incentive compatible and economically efficient.
3. Piloting and evaluating the actual impact of new policies.

3.1. Reliable Data and Transparency

The availability of data that is both reliable and transparent plays an important role in enabling efficient regulation. Although these are two distinct concepts, making data transparent to the public may also have the indirect benefit of forcing regulators to improve the reliability of disclosed information. In health care for example, Marshall et al (2003) argue that disclosure initiatives in the United Kingdom also improved the quality of report cards issued by hospitals. In what follows we begin by discussing the role that environmental disclosure and ratings initiatives may play in improving environmental outcomes. We then turn to mechanisms to improve the quality of monitoring data.

In the United States, following the Clean Air Act amendments of 1990, regulation that required reliable monitoring became more common. These included the use of market based instruments such as the acid rain trading regime, which sought to efficiently cut emissions at the minimum possible cost. They also included new transparency and disclosure initiatives, including significant expansions to the Toxic Release Inventory, and public disclosure programs around safe drinking water. The United States was not the only country to move in this direction. Perhaps the most innovative disclosure regime came from Indonesia, which initiated a ratings regime for industrial water pollution in 1995 called The Program for Pollution Control, Evaluation and Rating (PROPER). Research suggests that PROPER resulted in improved environmental performance of firms (Blackman et al 2004) through a mix of improving the information available to firm management, and making data public. Similar evidence
from a disclosure scheme in China called GreenWatch found similar results (Wu et al 2004).

Public ratings may also create competition among plants on environmental performance and there is evidence that when a firm is seen as being better for the environment, it also does better on the stock market (Klassen and McLaughlin 1996).

It is important to note that the process of disclosing data on the environmental performance of plants also removes an important information asymmetry. In an opaque monitoring framework, as is the norm in India, the regulator knows the relative performance of plants while the regulated entity does not. A rich literature on the power of peer comparisons in developing (Sudarshan 2017) and developed (Allcott and Rogers 2014) country households suggests that making this information available may be a particularly important mechanism of change. In examining Indonesia's PROPER initiative Blackman et al (2004) argue that more informed managers played an important role in driving improved environmental performance and similarly Wang et al (2004) provide evidence of the effectiveness of disclosure, in a setting where any overt participation of environmental civil society organizations is absent.

Nevertheless, while some of the impacts of disclosure on behavior may owe to learning, there is significant evidence suggesting that public pressure and reputation are also important. Greenstone and Hanna (2014) make the case that command and control regulation is likely to be more effective in the presence of significant public engagement. Indeed even the release of data on ambient air or water pollution – which is not tied to an individual violator – can lead to the involvement of the judiciary and civil society organizations.

In November 2014, the Centre for Science and Environment, a civil society group collected individual exposure data from eight prominent individuals identifying dangerously high levels of air pollution in the capital city of New Delhi. This data was used as part of an individual petition filed by the lawyer Harish Salve, requesting the court to introduce surcharges on the entry of commercial vehicles into Delhi. These legal proceedings resulted in additional fees on heavy vehicles entering the city. The Chief Justice adjudicating the case observed, “My grandson wears a mask. He looks like a ninja. When I asked him why he was wearing a mask, he said it was due to pollution...This is one case where newspapers should report as to what transpired in the court during the hearing”.

One of the most well-known directions passed under India’s Air Act (1981) also came about because of public pressure as opposed to proactive regulatory action. A Supreme Court judgment in 1997, delivered in response to a Public Interest Litigation filed by the lawyer M.C Mehta, required 500 plants near the Taj Mahal to reduce damages from air pollution through closing down, relocating, or changing the fuels they burned.

There are limited examples of transparency initiatives run by the state in India and China, especially in the context of environmental performance. In India, possibly
the first such initiative was launched on the 5th of June in the state of Maharashtra where large industrial plants will now be publicly rated on a 1-5 star scale based on how much particulate air pollution they emit. The pilot targets large plants with capital investments exceeding 25 crore INR and belonging to the Cement, Chemicals, Metal Works, Paper, Pharmaceuticals, Power, Sugar and Distilleries or Textiles sector. Data from the last four times a plant was tested for particulate emissions is used to generate a star rating, by using the median test value to assign a star based on the scale in Table 2.

Table 2: Maharashtra Star Rating Initiative

<table>
<thead>
<tr>
<th>Rating</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Rating Key</th>
<th>Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 star</td>
<td>250</td>
<td>-</td>
<td>Very Poor</td>
<td>★★★★★★★★★★★★★</td>
</tr>
<tr>
<td>2 star</td>
<td>150</td>
<td>250</td>
<td>Poor</td>
<td>★★★★★★★★★★★★★</td>
</tr>
<tr>
<td>3 star</td>
<td>100</td>
<td>150</td>
<td>Moderate</td>
<td>★★★★★★★★★★★★★</td>
</tr>
<tr>
<td>4 star</td>
<td>50</td>
<td>100</td>
<td>Good</td>
<td>★★★★★★★★★★★★★</td>
</tr>
<tr>
<td>5 star</td>
<td>0</td>
<td>50</td>
<td>Very Good</td>
<td>★★★★★★★★★★★★★</td>
</tr>
</tbody>
</table>

Source: Maharashtra Pollution Control Board, see http://www.mpcb.gov.in/star_rating/landing

Higher quality data may also have secondary benefits for regulators because this not only allows existing regulation to be implemented better, but also opens new options. The United States Acid Rain SOx Trading Market which began in 1995 was a direct outcome of investments in monitoring made by the regulator previously. Although these SOx markets cap emissions of sulphates, they were in fact motivated by non-compliance with fine particulate standards. To comply with local SOx standards, many power plants constructed tall stacks emitting sulphates which traveled long distances, combining with other chemicals to produce fine particles deposited elsewhere. This type of regulatory motivation necessary requires widespread data on both fine particulate and sulphate ambient concentrations, as well as modeling tools necessary to link emissions of one pollutant in one location to non-compliance with another pollutant elsewhere.

The Indian government has recently taken a set of wide-ranging actions designed to increase the quality of regulatory data. Continuous emissions monitoring systems (CEMS) are instruments that attach to the chimney stack of factories and supply real-time data on the emissions being generated. In so doing, they allow for dramatic improvements in the quality of data available to regulators. In 2013, the Central Pollution Control Board released the first ever specifications for CEMS devices (CPCB, 2013), outlining allowable technology as well as auditing and maintenance procedures. Interestingly these specifications were designed to produce data that could also underpin market based regulatory frameworks such as cap and trade regimes. Following this initial standards document, which focused only on particulate emissions, the CPCB has since released a more general specification. With these regulatory instructions, in February 2014 the CPCB passed an order mandating the installation of continuous

ambient and plant pollution levels, including the 2014 disclosure of industrial emissions for around 13,000 enterprises.

7 The new star rating program can be accessed at: http://www.mpcb.gov.in/star_rating/browseRating
monitoring systems for air and water pollutants in seventeen categories of highly polluting industries

Nevertheless, it is unclear how large the impacts of higher quality information might be within the status quo regulatory framework. The ways in which improved data is used in decision-making will also be influenced by forces such as institutional constraints, inadequately skilled manpower, and an inability to enforce penalties. These may act as binding constraints that prevent better data from automatically leading to better environmental outcomes. Unfortunately, very little evidence exists on the value of information in developing country contexts. Because the costs of monitoring technology are not trivial⁸, identifying their impact on emissions is critical to evaluating the value of such technology mandates. Gathering data to examine the impacts of better information within command and control regulatory regimes represents an important research question.

Technology also does not obviate the need for incentive compatible monitoring regimes. For example, like any other metering device, CEMS also require calibration and auditing. These tasks must be carried out by trained regulatory staff, or accredited third party regulators. The lessons from Duflo et al (2013) thus apply to the use of modern monitoring technology also, and suggest that technology mandates by themselves may not even fulfill the minimal goal of better information unless used within incentive compatible and monitored contexts.

We stress that better monitoring is not restricted to improved data collection from pollution sources. Effective policy depends very heavily on the information regulators possess on the cumulative outcome of all emissions sources, whether this be river water quality in the case of effluents or air quality in the case of air pollutants. Recent developments in the use of networks of low cost and mobile ambient monitoring instruments allow dramatically increased insight into the spatial distribution of air pollution.

Similarly, networks of water pollution monitors provide insight into effluent discharge upstream and downstream of industry clusters and may allow a reconciliation of measured discharge into the ambient compared to self-declared or monitored discharge from individual plants. This becomes particularly important when limits are placed on the volume and concentration of effluent discharge into the ambient, since these mandates may create incentives to send water pollutants into sewer lines or ground-water instead.

Lastly, satellite data provides important information on ambient air pollution across large and often unmonitored geographies. Using all these sources in making and evaluating policy is critical to achieving targeted outcomes.

In the case of small mobile sources of pollution such as vehicles, individual source monitoring can be infeasible and policy often focuses on targeting driving behavior based on information on the spatial distribution of pollutants. Such policy instruments can be usefully informed by spatially disaggregated information on air pollution levels using mobile pollution monitoring networks, to identify the presence of hotspots and to

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⁸ In Surat in Gujarat, the authors of this paper are conducting a trial of the effect of continuous emissions monitoring systems on particulate emissions in collaboration with the Gujarat Pollution Control Board. Plants in this pilot are largely small-scale, coal burning textile units and the costs of CEMS ranged from about 1 to 5 lakhs INR per stack in 2016.
estimate population exposures (Apte et al., 2011; Apte et al., 2017). The Odd-Even program is a good example of a targeted intervention aimed at changing driving behavior, both motivated by and evaluated using ambient air monitoring data.

As with CEMS, regulators need to ensure that ambient monitors are well-calibrated and functional and that these data are accessible to the public through traditional and new media outlets. Wide public release can both play an important role as a health advisory system and increase pressure on polluters to comply with regulatory standards (Afsah et al. 2013; Tietenberg 1998; Wang et al. 2004).

3.2. Effective and Incentive Compatible Regulation

Environmental regulation based on high quality monitoring can be effective but this does not imply it is economically efficient. Command and control regulatory instruments are common but often impose high costs on the regulated entity. As already discussed, environmental regulation is based primarily on technology mandates, fixed emissions standards and enforcement based on relatively inflexible penalty structures. Surprisingly, these tools are deployed across both transport and industrial emission sources although the number of sources, costs of monitoring and flexibility in pollution reduction options differ widely between the two.

Broadly speaking, economically efficient regulation requires identifying the source of negative externalities, quantifying the full social costs of externalities from these sources, and putting in place rules that ensure that polluters must pay a price equal to this full social cost when undertaking polluting activities. Ensuring that this price is paid requires enforcement mechanisms to ensure regulatory constraints bind and monitoring technology that is sufficiently reliable to quantify emissions accurately. In practice, these goals are difficult to achieve. Externalities are spatially differentiated and in theory every emitting source might impose different social costs from pollution (Muller and Mendelsohn, 2009). Some types of monitoring may be expensive or infeasible and therefore it may become necessary to use proxy measures. This includes the regulation of ‘suspended particulate matter’ in industry stacks as a catch-all proxy for a distribution of fine particles of different sizes and chemical composition, each with differing health impacts. Enforcing different types of rules and behaviors may also not be equally easy. For instance, it can be easier to monitor the presence or absence of a specific piece of pollution abatement equipment in a plant or vehicle, than real-time emissions and driving patterns.

Nevertheless, although first-best regulatory mechanisms may be difficult to always achieve, in many cases command and control regulation falls far short of this ideal. We have identified specific weaknesses of status-quo environmental regulation in Section 2, but even measured by the minimal standard of reaching pre-defined environmental goals, it is hard to disagree with the conclusion that command and control regulation has largely been a failure in India.

In what follows we identify a few necessary amendments to improve the efficiency and effectiveness of environmental regulation in India. We begin with enforcement mechanisms since incentive compatible regulation requires penalties for non-compliance.
In India, criminal penalties including imprisonment and plant closures are the primary penal actions available to regulators.\(^9\) Ghosh (2015) and Greenstone et al (2015) argue that the absence of civil fines in India’s Air Act and Water Act significantly reduces the effectiveness of regulation. Efficient penalties need to be proportional to the extent of violation and impose low implementation costs on the regulator. Criminal penalties do badly on both counts. They are highly inflexible, and can be excessively severe punishments for minor violations. They also impose high costs on the regulator, both directly because they require filing and winning a criminal case in court, and indirectly since severe actions such as plant closures can be politically difficult to implement, imposing high costs on the local economy.

These characteristics make it less likely that penalties will be enforced, especially for modest violations, and in turn encourages widespread non-compliance. Gray and Shimshack (2011) summarize evidence showing that the regular enforcement of penalties, combined with regular monitoring, reduces violations in both penalized and non-penalized entities and reduces overall emissions.

China has relied on financial penalties since the early 1980s. While there are national standards for various pollutants, and non-compliance could invite legal sanction, this is extremely rare (Wang and Wheeler, 2005). Instead, industries are charged a levy for non-compliance, which is proportional to the exceedance; since 1993, Chinese regulators have also been levying charges for air emissions or water discharges within the standards for some pollutants (Wang and Wheeler, 2005). As a result, pollution levels become an economic choice for industries, as a response to the levies imposed on them. Specifying a model of endogenous enforcement, Wang and Wheeler (2005) determine the elasticity of pollution with levy rates and find that a statistically significant, strong marginal deterrence for the pollution levy: for water pollution and SO\(_2\) emissions, estimated elasticities are about -1. Since 2002, there has also been an SO\(_2\) Emissions Trading Pilot Scheme, and as listed in Table 3 at the end of the paper, seven regional trading pilots for CO\(_2\) were experimented with between 2011 and 2015.

High quality monitoring and the use of flexible financial penalties might therefore significantly improve the performance of status-quo regulation. Unfortunately, by themselves this is not sufficient to overcome the high costs and low flexibility of command-and-control regulation. Over the last two decades, the Indian government has reviewed environmental regulation through the appointment of multiple task forces, high-level committees, and external consultants (Ministry of Environment Forests & Climate Change, 2014). Several expert committees have emphasized the need to use market-based regulation and fiscal instruments that align incentives and reduce costs of complying with regulations, following the “polluter pays” principle (Ministry of Environment Forests & Climate Change, 2014).

India has rarely used markets as a means of regulation, with the Renewable Energy Certificates and the Bureau of Energy Efficiency’s Perform, Achieve and Trade scheme being notable exceptions. These schemes were introduced by India’s Ministry of Power, and there exist no similar examples in the sphere of environmental regulation.\(^10\)

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\(^9\) India’s Air and Water Act do allow for criminal fines but these are capped at extremely low levels and have not been regularly updated, thus rendering them essentially toothless.

\(^10\) India does have a cess on coal that was raised to INR 400 per tonne in the 2016-17 budget. This number is too low to be seen as meaningful environmental regulation. Mittal (2012) use
Outside India however, there exists significant experience with the use of market-based instruments, especially cap and trade markets in both local air pollutants and carbon dioxide. Table 3 at the end of the paper summarizes evidence from a number of cap and trade markets across the world.

The primary motivation for market-based instruments is that they minimize the costs of attaining any given level of emissions. The economic theory underpinning this claim is clear but there have been limited empirical studies quantifying cost reductions relative to a well-defined counter-factual. The evidence that has been gathered points to significant benefits from environmental markets. In evaluating the US SOx markets of 1995 (expanded in 2000), Carlson et al (2000) estimate savings of 45-55% compared to a uniform standard regulating emissions rates. Burtraw et al (1998) and Muller and Mendelsohn (2009) estimate that the improvements in public health and reduced acidification from these markets outweigh the costs by an order of magnitude. Fowlie et al (2012) carry out a direct comparison of command and control regulation with a cap and trade scheme. By matching firms, regulated under the RECLAIM NOx trading market in Los Angeles with nearby firms subject to command and control, the authors show that emissions from firms under RECLAIM were on average 24 percent lower than those regulated under command and control.

Absolute emission norms, as in status quo, also do not provide any incentive for industries to reduce emissions above and beyond the minimum they are expected to even if the marginal costs of additional abatement are negligibly small in comparison with the externalities they impose. An addition advantage of economic instruments such as trading is that polluters have dynamic incentives to continue abating their emissions and innovate of cleaner equipment and processes (Jaffe and Stavins, 1995).

An area of concern is that markets are likely to be effect if supported by strong monitoring and enforcement infrastructure. In developing countries in general, institutional readiness becomes a potential barrier for trading to be as efficient and cost-effective as it could be in theory. Coria and Sterner (2008) review the lessons from the trading program in Santiago launched in 1997 (the first application of emissions trading outside the OECD countries) and find that while on the one hand, the program was riddled with challenges due to suboptimal design, the cap set on the pollutants were adhered to from the very beginning and with time the volume of transactions increased. Coria and Sterner (2008) point out that “it took the United States some three or four decades of experimentation to learn how to design the institutions for a trading scheme”, and that the Chilean experience compares rather favorably. Putting in place the infrastructure, such as continuous emissions monitoring systems, and increasing public disclosure create the enabling ecosystem where market-based incentives could work more effectively.

An intriguing pilot project initiated by India’s Ministry of Environment and Forests and the Central Pollution Control in Surat, Gujarat presents an opportunity to introduce India’s first cap and trade scheme, a city-level market in particulate matter from coal burning plants. If taken to implementation this project would represent a dramatic step forward in the regulatory instruments used to tackle industrial air

CEA data to estimate specific coal consumption estimates of about 0.7 kg per kWh across Indian coal plants. At 65 INR per USD this works out to a price of about 0.5 cents per kWh, an order of magnitude below most estimates of the pollution externalities from burning coal.
pollution in India. Some of the authors of this paper have worked on the design of this market. Using a bottom up engineering model of pollution reduction, in conjunction with data from a survey of textile plants in the city of Surat, we estimated that the industry costs of compliance under a cap and trade market in Surat would fall by over 70 percent relative to status-quo command-and-control emissions standards. Other research has come to similar conclusions, with Gupta (2002) showing that reducing particulate emissions by 50 percent using market-based instruments would allow for cost-savings between 26 percent to 169 percent for different industry sectors, relative to command-and-control regulation.

Other than industry, the other major regulated source of air pollution is transport emissions. Markets in transportation emissions are harder to execute because of monitoring and enforcement concerns where a very large number of individual agents is involved. One market based instrument in the transport sector is congestion pricing. Although the targeted outcome variable in congestion pricing schemes is not air pollution, because emissions are correlated with congestion, a reduction in the latter can lead to improved air quality. Evidence from Sweden (Simeonova et al, 2017) shows that even in a relatively low pollution setting, congestion pricing schemes can create locally detectable reductions in ambient pollution.

3.3. Piloting and Evaluating New Ideas

Evidence-based innovation is always an asset to improved policy-making. However, the need to reform environmental regulation in India is particularly urgent because we observe both poor environmental quality (Greenstone et al 2015) and severe short-comings in the current regulatory framework (Ministry of Environment, Forests, and Climate Change, 2014). New ideas are therefore much-needed. At the same time, because environmental regulation is nothing but complicated, carefully testing pilots becomes critical before introducing new or different rules. This allows us to cleanly identify what is not working in the status-quo, and provides a transparent assessment of the value of new ideas.

The star rating scheme for polluting plants in Maharashtra is a good example of introducing a new idea with a view to careful evaluation. Another example comes from Duflo et al (2013), who worked with the Gujarat State Pollution Control Board to reform the third-party auditing procedures used by the state to monitor polluting industries. Figure 4, extracted from the original paper, provides a snapshot of the initial conditions observed by the researchers, with both significant rates of non-compliance by plants and wide-spread falsification of data clearly visible. Figure 3 also shows wide-spread non-compliance with the regulatory standard (150 milligram/Nm3) even amongst plants with installed pollution control equipment.
Figure 4: Readings for particulate matter emissions in the stack

The figure shows distributions of pollutant concentrations for particulate matter in stacks during the midline survey of the project. Panel A shows the distributions of readings at control plants from audits and backchecks, respectively. Panel B shows readings at treatment plants from the same two sources. The regulatory maximum concentration limit of 150 milligram/nm3 for spm is marked with a vertical line, and the area between 75% and 100% of the limit is shaded in gray.


Introducing innovative ideas without a well-defined evaluation plan can lead to significant uncertainty about what has been achieved after the fact. With the Odd-Even program, for example, the differences in the results between the January and April rounds raises questions that may have been clarified at the outset had the program been explicitly designed to be evaluated and data collected accordingly.

4. Conclusion

While reviewing existing environmental regulation in India, the TSR Subramanian Committee bluntly notes that “the legislations are weak, monitoring is weaker, and enforcement is weakest”. In this paper, we assert the need for greater investments in monitoring that yields reliable data, taking advantage of advances in technology and reduced costs of monitoring equipment, and considering the incentives of third party agencies tasked with the monitoring. We argue that compliance and hence enforcement may improve if regulations are designed in a manner that is compatible with the incentives of the regulated entities.

We also make the case that market based instruments, like congestion pricing or cap-and-trade, may be more sustainable options in the long term than command and control regulation in India. This is because these regulatory mechanisms seek to reduce
to a minimum the costs of cutting total emissions into the ambient. As such, they seem particularly well suited to bridge India’s perceived conflict between improving environmental performance whilst maintaining robust levels of economic growth. Finally, regardless of the type of regulation, it is essential that new interventions need to be piloted and rigorously tested. We illustrate how this could be done using high frequency data to study Delhi’s recent ‘Odd-Even’ driving rationing scheme.

<table>
<thead>
<tr>
<th>COUNTRY / REGION</th>
<th>NAME</th>
<th>YEAR</th>
<th>POLLUTANT</th>
<th>EFFECTS / TARGET</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEXICO</td>
<td>PILOT ETS</td>
<td>EXPECTED 2017</td>
<td>CO₂</td>
<td>PLANS TO LINK WITH WESTERN CLIMATE INITIATIVE (WCI) MARKET</td>
</tr>
<tr>
<td>CHINA</td>
<td>NATIONAL EMISSIONS TRADING SCHEME</td>
<td>EXPECTED 2017</td>
<td>CO₂</td>
<td>7 EXISTING REGIONAL PILOTS WITH HIGH COMPLIANCE, OVER 4 MILLION TONS OF QUOTA TRADE TO DATE</td>
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<td>BEIJING</td>
<td>EMISSIONS TRADING PILOT</td>
<td>2011-2015</td>
<td>CO₂</td>
<td>IN FIRST PERIOD, EMISSIONS FELL 4.5% AND THE COST OF CUTTING EMISSIONS FELL BY 2.5%</td>
</tr>
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<td>SHANGHAI</td>
<td>EMISSIONS TRADING PILOT</td>
<td>2011-2015</td>
<td>CO₂</td>
<td>EMISSIONS FELL 3.5% FROM 2011 TO 2013</td>
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<tr>
<td>SHENZHEN</td>
<td>EMISSIONS TRADING PILOT</td>
<td>2011-2015</td>
<td>CO₂</td>
<td>EMISSION FELL 11.7% FROM 2010 TO 2013</td>
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<td>TIANJIN</td>
<td>EMISSIONS TRADING PILOT</td>
<td>2011-2015</td>
<td>CO₂</td>
<td>INTENSITY TARGET OF 15% ABOVE 2010 LEVELS</td>
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<td>HUBEI</td>
<td>EMISSIONS TRADING PILOT</td>
<td>2011-2015</td>
<td>CO₂</td>
<td>INTENSITY TARGET OF 17% ABOVE 2010 LEVELS</td>
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<td>CO₂</td>
<td>INTENSITY TARGET OF 20% ABOVE 2010 LEVELS</td>
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<td>GUANGDONG</td>
<td>EMISSIONS TRADING PILOT</td>
<td>2011-2015</td>
<td>CO₂</td>
<td>INTENSITY TARGET OF 19% ABOVE 2010 LEVELS</td>
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<tr>
<td>Country</td>
<td>Scheme</td>
<td>Start Year</td>
<td>Scope</td>
<td>Target Reduction</td>
</tr>
<tr>
<td>------------------</td>
<td>------------------------------------------------------------------------</td>
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<tr>
<td>SOUTH KOREA</td>
<td>KOREAN EMISSIONS TRADING SCHEME (KETS)</td>
<td>2015-PRESENT</td>
<td>ALL GHGS</td>
<td>TARGETS 4% REDUCTION BELOW 2005 LEVELS BY 2020</td>
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<td>KAZAKHSTAN</td>
<td>KAZAKHSTAN EMISSION TRADING SYSTEM</td>
<td>2013-PRESENT</td>
<td>CO₂</td>
<td>TARGETS 15% REDUCTIONS BELOW 1992 GHG LEVELS BY 2020</td>
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<td>SWITZERLAND</td>
<td>SWISS ETS</td>
<td>2008-PRESENT</td>
<td>CO₂</td>
<td>N/A</td>
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<td>NEW ZEALAND</td>
<td>NEW ZEALAND EMISSIONS TRADING SCHEME</td>
<td>2008-PRESENT</td>
<td>ALL GHGS</td>
<td>ENABLED NEW ZEALAND TO MEET EMISSION TARGET FOR THE FIRST COMMITMENT PERIOD OF THE KYOTO PROTOCOL</td>
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<td>JAPAN</td>
<td>JAPAN VOLUNTARY EMISSIONS TRADING SCHEME (JVETS)</td>
<td>2005-PRESENT</td>
<td>CO₂</td>
<td>25% CUT BELOW 1990 LEVELS BY 2020</td>
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<td>TOKYO</td>
<td>TOKYO CAP-AND-TRADE PROGRAM</td>
<td>2010-PRESENT</td>
<td>CO₂</td>
<td>IN 2012, EMISSIONS WERE REDUCED BY 22% BELOW BASE YEAR LEVELS</td>
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<tr>
<td>EUROPEAN UNION</td>
<td>EU ETS</td>
<td>2005-PRESENT</td>
<td>CO₂</td>
<td>21 % CUT BELOW 2005 LEVELS BY 2020</td>
</tr>
<tr>
<td>AUSTRALIA</td>
<td>NEW SOUTH WALES GREEN HOUSE GAS ABATEMENT SCHEME (NSW GGAS)</td>
<td>2003-2012</td>
<td>ALL GHGS</td>
<td>DISCONTINUED TO AVOID DUPLICATION WITH THE COMMONWEALTH'S CARBON PRICE</td>
</tr>
<tr>
<td>CHILE</td>
<td>SANTIAGO AIR EMISSIONS TRADING</td>
<td>1995-PRESENT</td>
<td>TOTAL SUSPENDED PARTICULATES</td>
<td>LOW TRADING VOLUME; DECREASE IN EMISSIONS SINCE 1997 NOT DEFINITIVELY TIED TO TP SYSTEM</td>
</tr>
<tr>
<td>Country</td>
<td>Program</td>
<td>Start</td>
<td>End</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>-------</td>
<td>-----</td>
<td>-------------</td>
</tr>
<tr>
<td>CANADA</td>
<td>ODS ALLOWANCE TRADING</td>
<td>1993-PRESENT</td>
<td></td>
<td>CFCS, METHYL CHLOROFORM, HCFCs, METHYL BROMIDE LOW TRADING VOLUME, EXCEPT AMONG LARGE METHYL BROMIDE ALLOWANCE HOLDERS</td>
</tr>
<tr>
<td></td>
<td>PILOT EMISSIONS REDUCTION TRADING (PERT)</td>
<td>1996-PRESENT</td>
<td></td>
<td>NOX, VOCS, CO, CO₂, SO₂</td>
</tr>
<tr>
<td>ALBERTA</td>
<td>CLIMATE CHANGE AND EMISSIONS MANAGEMENT ACT</td>
<td>2007-PRESENT</td>
<td></td>
<td>ALL GHGS</td>
</tr>
<tr>
<td></td>
<td>REGULATORY FRAMEWORK FOR AIR EMISSIONS</td>
<td>2007-PRESENT</td>
<td></td>
<td>ALL GHGS</td>
</tr>
<tr>
<td>BRITISH COLUMBIA, CALIFORNIA, MANITOBA, ONTARIO, QUEBEC</td>
<td>WESTERN CLIMATE INITIATIVE (WCI)</td>
<td>2013-PRESENT</td>
<td></td>
<td>GHGS</td>
</tr>
<tr>
<td>UNITED STATES</td>
<td>LEADED GASOLINE PHASEDOWN</td>
<td>1982-1987</td>
<td></td>
<td>LEAD IN GASOLINE AMONG REFINERIES</td>
</tr>
<tr>
<td></td>
<td>WATER QUALITY TRADING</td>
<td>1984-1986</td>
<td></td>
<td>POINT-NONPOINT SOURCES OF NITROGEN &amp; PHOSPHOROUS</td>
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<td></td>
<td>CFC TRADES FOR OZONE</td>
<td>1987-PRESENT</td>
<td></td>
<td>PRODUCTION RIGHTS FOR SOME CFCS, BASED ON DEPLETION POTENTIAL</td>
</tr>
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<td></td>
<td>PROTECTION HEAVY DUTY ENGINE TRADING</td>
<td>1992-PRESENT</td>
<td></td>
<td>NOX AND PARTICULATE EMISSIONS</td>
</tr>
<tr>
<td>Program</td>
<td>Start</td>
<td>Pollutant</td>
<td>Emission Reduction</td>
<td>Source</td>
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<td>------------------------------------------------------------------------</td>
<td>-------------</td>
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<td>--------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td><strong>RECLAIM PROGRAM</strong></td>
<td>1994-PRESENT</td>
<td>SO₂, NOₓ</td>
<td>NOₓ emissions fell by 60%; SOₓ emissions by 50 per cent.</td>
<td>Authors’ compilation.</td>
</tr>
<tr>
<td><strong>ACID RAIN PROGRAM</strong></td>
<td>1995-PRESENT</td>
<td>SO₂</td>
<td>Reduction credits</td>
<td>SO₂ reductions achieved ahead of schedule; savings of $1 billion/year</td>
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<tr>
<td><strong>9 NORTHEASTERN STATES</strong></td>
<td>2005-PRESENT</td>
<td>CO₂</td>
<td>10% cut below 2009 levels by 2018</td>
<td></td>
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<tr>
<td><strong>C27 EASTERN STATES</strong></td>
<td>2003-PRESENT</td>
<td>SO₂, NOₓ</td>
<td>61% reduction from 2003 levels; sharp reductions in compliance costs</td>
<td></td>
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<tr>
<td><strong>CALIFORNIA</strong></td>
<td>2013-PRESENT</td>
<td>CO₂, N₂O, SULFUR HEXAFLUORIDE, PFC</td>
<td>Target is 17% reduction from 2012 levels by 2020</td>
<td></td>
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</tbody>
</table>

Source: Authors’ compilation.
References


Do, Quy-Toan, Shareen Joshi, and Samuel Stolper. 2014. “Pollution Externalities and Health: A Study of Indian Rivers.”


Hanna, R., Oliva, P. 2010. The Impact of Inspections on Plant-Level Air Emissions. The B.E. Journal of Economic Analysis & Policy, 10 Iss. 1 (Contributions), Article 19.


Lim, Stephen S., Theo Vos, Abraham D. Flaxman, Goodarz Danaei, Kenji Shibuya, Heather


