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Environmental Regulations, Air and Water Pollution, and Infant Mortality in India

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Environmental Regulations, Air and Water Pollution, and Infant Mortality in India[*]

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Abstract

Using the most comprehensive data file ever compiled on air pollution, water pollution, and environmental regulations from a developing country, the paper examines the effectiveness of India's environmental regulations. The air pollution regulations were responsible for substantial improvements in air quality. The most successful air regulation resulted in a modest, but statistically insignificant decline in infant mortality. The water regulations had no measurable benefits. Qualitative and quantitative evidence suggests that higher relative demand for air quality prompted the effective enforcement of air pollution regulations, indicating that environmental regulation can succeed in weak institutional settings when there is strong public support.

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Keywords: Air pollution; Water pollution; Benefits of environmental regulations; India

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I. Introduction

Weak institutions are a key impediment to advances in well being in many developing countries. Indeed, an extensive literature has documented many instances of failed policy in these settings and has been unable to identify a consistent set of ingredients necessary for policy success (Banerjee, Glennerster and Duflo, 2008; Duflo et al., 2012; Banerjee, Hanna and Mullainathan, forthcoming). The specific question of how to design effective environmental regulations in developing countries with weak institutions is increasingly important for at least two reasons.[1] First, "local" pollutant concentrations are exceedingly high in many developing countries and in many instances are increasing (Alpert et al., 2012). Further, the high pollution concentrations impose substantial health costs, including shortened lives (Chen, et al., 2013; Cropper, 2010; Cropper, et al., 2012), so understanding the most efficient ways to reduce local pollution could significantly improve wellbeing. Second, the Copenhagen Accord makes it clear that it is up to individual countries to devise and enforce the regulations necessary to achieve their national commitments to combat global warming by reducing greenhouse gas emissions (GHG). Since most of the growth in GHG emissions is projected to occur in developing countries, such as India and China, the planet's wellbeing rests on the ability of these countries to successfully enact and enforce environmental policies.

India provides a compelling setting to explore the efficacy of environmental regulations for several reasons. First, India's population of nearly 1.2 billion accounts for about 17 percent of the world's population. Second, it has been experiencing rapid economic growth of about 6.4 percent annually over the last two decades, placing significant pressure on the environment. For example, Figure 1, Panel A demonstrates that ambient particulate matter concentrations in India are five times the United States level (while China's are seven times the U.S. level) in the most recent years with comparable data, while Figure 1, Panel B shows that water pollution concentrations in India are also higher. Further, a recent study concluded that India currently has the worst air pollution out of the 132 countries analyzed (Environmental Performance Index, 2013). Third, India is widely regarded as havingsub-optimal regulatory institutions: Identifying which regulatory approaches succeed in this context would be of great practical value. More

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[1] There is a large literature measuring the impact of environmental regulations on air quality, with most of the research focused on the United States. See, for example, Chay and Greenstone (2003 and 2005), Greenstone (2003), Greenstone (2004), Henderson (1996), and Hanna and Oliva (2010), etc. The institutional differences between the United States and many developing countries mean that the findings are unlikely to be valid for predicting the impacts of environmental regulations in developing countries.

generally, since the air and water regulations were implemented and enforced in different manners, a comparison of their relative effectiveness can shed light on how to design policy successfully in weaker regulatory contexts. Fourth, India has a rich history of environmental regulations that dates back to the 1970s, providing a rare opportunity to answer these questions with extensive panel data.[2]

This paper presents a systematic evaluation of India's environmental regulations with a new city-level panel data file for the years 1986-2007 that we constructed from data on air pollution, water pollution, environmental regulations, and infant mortality. The air pollution data comprise about 140 cities, while the water pollution data covers 424 cities (162 rivers). Neither the government nor other researchers have assembled a city-level panel database of India's anti-pollution laws, and we are unaware of a comparable data set in any other developing country.

We consider two key air pollution policies, the Supreme Court Action Plans and the Mandated Catalytic Converters, as well as India's primary water policy, the National River Conservation Plan, which focused on reducing industrial pollution in rivers and creating sewage treatment facilities.[3] These regulations resemble environmental legislation in the United States and Europe, thereby providing a comparison of the efficacy of similar regulations across very different institutional settings.

The analysis indicates that environmental policies *can* be effective in settings with weak regulatory institutions. However, the effect is not uniform, as we find a large impact of the air pollution regulations, but no effect of the water pollution regulations. In the preferred econometric specification that controls for city fixed effects, year fixed effects and differential pre-existing trends among adopting cities, the requirement that new automobiles have catalytic converters is associated with large reductions in airborne particulate matter with diameter less than 100 micrometres (μm) (PM) and sulfur dioxide (SO_2) of 19 percent and 69 percent, respectively, five years after its implementation. Likewise, the Supreme Court-mandated Action Plans are associated with a decline in nitrogen dioxide (NO_2) concentrations; however, these policies are not associated with changes in SO_2 or PM. In contrast, the National River

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[2] Previous papers have compiled data sets for a cross-section of cities or a panel for one or two cities, including Foster and Kumar (2008; 2009), which examines the effect of CNG policy in Delhi; Takeuchi, Cropper, and Bento (2007), which studies automobile policies in Mumbai; Davis (2008), which looks at driving restrictions in Mexico; and Hanna and Oliva (2011), which studies a refinery closure in Mexico City.

[3] We also documented other anti-pollution efforts (e.g., Problem Area Action Plans, and the sulfur requirements for fuel), but they had insufficient variation in their implementation across cities and/or time to allow for a credible evaluation.

Conservation Plan—the cornerstone water policy—was not associated with improvements in the three available measures of water quality.

As a complement to these results, we adapt a Quandt likelihood ratio test (Quandt, 1960) from the time-series econometrics literature to the difference-in-differences (DD) style setting to probe the validity of the findings. Specifically, we test for a structural break in the difference between adopting and non-adopting cities' pollution concentrations and assess whether the structural break occurs around the year of policy adoption. The analysis finds evidence of a structural break in adopting cities' PM and SO_2 concentrations around the year of adoption of the catalytic converter policy and no breaks in the time-series that correspond to cities' adoption of the National River Conservation Plan. In addition to these substantive findings, this demonstrates the value of this technique in DD style settings.

We conclude that the striking difference in the effectiveness of the air and water pollution regulations reflects a greater demand for air quality by India's citizens. This conclusion is based on a mix of qualitative and quantitative evidence. Higher demand for clean air is to be expected given the international evidence that ambient air quality is responsible for an order of magnitude greater number of premature fatalities than water pollution. Moreover, the costs of self-protection against air pollution are substantially higher than against water pollution; household technologies to clean dirty water and bottled water are effective and inexpensive, while comparable technologies for protection against air pollution simply do not exist. Additionally, higher demand for clean air is consistent with the greater public discourse on air quality: We find that the *Times of India*, the country's leading English-language newspaper, reports on air pollution three times as much as water pollution. Further, high levels of citizen engagement caused India's Supreme Court, widely considered the country's most effective public institution, to promptly promulgate many air pollution regulations and follow up on their enforcement. In contrast, the water regulations were characterized by jurisdictional opacity about implementation, enforcement that was delegated to agencies with poor track records, and a failure to identify a dedicated source of funds. These differences in promulgation and enforcement are especially striking because there are many similarities between the legislations that govern air and water pollution regulation.

Empirical evidence supports these qualitative findings. We assess whether the effectiveness of air pollution regulations differed with observed proxies for the demand for clean air. We find that the catalytic converter policies were more effective in cities with greater newspaper attention to the problems of air pollution and in cities with higher education levels. In contrast, measured corruption levels, which should not be related to the relative demand for clean air, are not systematically associated with differences in the effectiveness of the catalytic converter policy across cities.

Finally, we tested whether the catalytic converter policy, which had significant effects on air pollution, was associated with changes in measures of infant health. To the best of our knowledge, this is the first paper to relate infant mortality rates to environmental regulations in a developing country context.[4] The data indicate that a city's adoption of the policy is associated with a decline in infant mortality, but this relationship is not statistically significant. As we discuss below, there are several reasons to interpret the infant mortality results cautiously.

The paper proceeds as follows. Section II provides a brief history of environmental regulation in India focusing on the policies that the paper analyzes. Section III describes the data sources and presents summary statistics on the city-level trends in pollution, infant mortality, and adoption of environmental policies in India. Section IV outlines the econometric approach and Section V reports and discusses the results. Section VI presents evidence that the relative success of the air regulations reflected a greater demand for air quality improvements. Section VII concludes.

II. Background on India's Environmental Regulations

India has a relatively extensive set of regulations designed to improve both air and water quality. Its environmental policies have their roots in the Water Act of 1974 and Air Act of 1981. These acts created the Central Pollution Control Board (CPCB) and the State Pollution Control Boards (SPCBs), which are responsible for data collection and policy enforcement, and also developed detailed procedures for environmental compliance. Following the implementation of these acts, the CPCB and SPCBs quickly advanced a national environmental monitoring program (responsible for the rich data underlying our analysis). The Ministry of Environment and Forests (MoEF), created in its initial form in 1980, was established largely to set the overall policies that the CPCB and SPCBs were to enforce (Hadden, 1987).

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[4] See Chay and Greenstone (2003) for the relationship between infant mortality and the Clean Air Act in the United States. Burgess, Deschenes, Donaldson, and Greenstone (2011) estimate the relationship between weather extremes and infant mortality rates using the same infant mortality data used in this paper.

The Bhopal Disaster of 1984 represented a turning point in India's environmental policy. The government's treatment of victims of the Union Carbide plant explosion "led to a re-evaluation of the environmental protection system," with increased participation of activist groups, public interest lawyers, and the judiciary (Meagher, 1990). In particular, there was a steep rise in public interest litigation, and the Supreme Court instigated a wide expansion of fundamental rights of citizens (Cha, 2005). These developments led to some of India's first concrete environmental regulations, such as the closures of limestone quarries and tanneries in Uttar Pradesh in 1985 and 1987, respectively.[5] We discuss the Supreme Court's role in the promulgation and enforcement of air pollution regulations in greater detail in Section VI.

Throughout the 1980s and 1990s, India continued to adopt policies that were designed to counteract growing environmental damage. The paper's empirical focus is on two key air pollution policies, the Supreme Court Action Plans (SCAPs) and the catalytic converter requirements, and the primary water pollution policy, the National River Conservation Plan. These policies were at the forefront of India's environmental efforts. Importantly, there was substantial variation across cities in the timing of adoption, which provides the basis for the paper's research design.

The first policy we focus on is the Supreme Court Action Plans. The Action Plans are part of a broad, ongoing effort to stem the tide of rising pollution in cities identified by the Supreme Court of India as critically polluted. The SCAPs involve the implementation of a suite of policies that could include fuel regulations, building of new roads that bypass heavily populated areas, transitioning of buses to CNG, and restrictions on industrial pollution. Measured pollution concentrations are a key ingredient in the determination of these designations. In 1996, Delhi was the first city ordered to develop an action plan, while the most recent action plans were mandated in 2003.[6] To date, 17 cities have been given orders to develop action plans.

Although the exact form of the SCAPs varies across cities, they are typically aimed at reducing several types of air pollutants. At least one round of plans was directed at cities with

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[5] See *Rural Litigation and Entitlement Kendra v. State of Uttar Pradesh* (Writ Petitions Nos. 8209 and 8821 of 1983), and *M.C. Mehta v. Union of India* (WP 3727/1985).

[6] As documented in the court orders, the Supreme Court ordered nine more action plans in critically polluted cities "as per CPCB data" after Delhi. A year later, the Court chose four more cities based on their having pollution levels at least as high as Delhi's. Finally, a year later, nine more cities (some repeats) were identified based on Respired Suspended Particulate Matter (i.e., smaller diameter particulate matter) concentrations.

unacceptable levels of Respired Suspended Particulate Matter (RSPM), which is a subset of PM characterized by the particles' especially small size. Given the heavy focus on vehicular pollution, it is reasonable to presume that the plans affected NO_2 levels. Finally, since SO_2 is frequently a co-pollutant, it may be reasonable to expect the Action Plans to affect its ambient concentrations. However, there has not been a systematic exploration of the SCAP's effectiveness across cities.[7]

The second policy we examine is the mandatory use of catalytic converters for specific categories of vehicles, which was a policy distinct from the SCAPs. The fitment of catalytic converters is a common means of reducing vehicular pollution across the world, due to the low cost of its end-of-the-pipe technology. In 1995, the Supreme Court required that all new petrol-fueled cars in the four major metros (i.e., Delhi, Mumbai, Kolkata, and Chennai) were to be fitted with converters. In 1998, the policy was extended to 45 other cities. It is plausible that this regulation could affect all three of our air quality indicators.

Just as with the SCAPs, there has not been a systematic evaluation of the catalytic converter policies. Qualitative evidence suggests that the catalytic converter policies were enforced stringently by tying vehicle registrations to installation of a catalytic converter.[8] However, it is not clear that this was indeed successful: Oliva (2011), Davis (2008), and Bertrand et al. (2007) all show that drivers often evade regulations. Moreover, in contrast to the SCAPs, public response to the catalytic converter policy was less favorable for several reasons: Petrol's lower fuel share made the scope of the policy narrower than, for example, the mandate for low-sulfur in diesel fuel; unleaded fuel, which is necessary for effective functioning of catalytic converters was at best inconsistently available until 2000; and the implementation in only a subset of cities created opportunities for purchases of cars in the uncovered cities that would be driven in the covered cities.

Finally, we study the cornerstone of efforts to improve water quality, the National River

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[7] Many believe that the overwhelming approval of Delhi's CNG bus program as part of its Action Plan provides indications of its success. Takeuchi, Cropper, and Bento (2007) show that the imposition of a similar conversion of buses to CNG would be the most effective policy for reducing passenger vehicle emissions in Mumbai.

[8] Narain and Bell (2005) write, "In 1995 the Delhi government announced that it would subsidize the installation of catalytic converters in all two- and three-wheel vehicles to the extent of 1,000 Rs. within the next three years (Indian Express, January 30, 1995). Furthermore, the Petroleum Ministry banned the registration of new four-wheel cars and vehicles without catalytic converters in Delhi, Mumbai, Chennai, and Calcutta effective April 1, 1995 (Telegraph, March 13, 1995). This directive was implemented, although it is alleged that some vehicle owners had the converters removed illegally (court order, February 14, 1996)."

Conservation Plan (NRCP). Begun in 1985 under the name Ganga Action Plan (Phase I), the water pollution control program expanded first to tributaries of the Ganga River, including the Yamuna, Damodar, and Gomti in 1993. It was later extended in 1995 to the other regulated rivers under the new name of NRCP. Today, 164 cities on 35 rivers are covered by the NRCP. The criteria for coverage by the NRCP are vague at best, but many documents on the plan cite the CPCB Official Water Quality Criteria, which include standards for BOD, DO, FColi, and pH measurements in surface water. Much of the focus has centered on domestic pollution control initiatives over the years (Asian Development Bank, 2007). The centerpiece of the plan is the Sewage Treatment Plant: The interception, diversion, and treatment of sewage through piping infrastructure and treatment plant construction has been coupled with installation of community toilets, crematoria, and public awareness campaigns to curtail domestic pollution. If the policy has been effective, it should affect several forms of water pollution; but the largest impacts would be expected to be on FColi levels, which are most directly related to domestic pollution.

The NRCP has been panned in the media for a variety of reasons, including poor cooperation among participating agencies, imbalanced and inadequate funding of sites, and an inability to keep pace with the growth of sewage output in India's cities (Suresh et al., 2007, p. 2). However, similar to the air pollution programs, there has never been a systematic evaluation or even a compilation of the data that would allow for one.

III. Data Sources and Summary Statistics

To conduct the analysis, we compiled the most comprehensive city-level panel data file ever assembled on air pollution concentrations, water pollution concentrations, and environmental policies in any developing country. We supplemented this data file with a city-level panel data file on infant mortality rates. This section describes each data source and presents some summary statistics, including an analysis of the trends in the key variables.

A. Regulation Data

India has implemented a series of environmental initiatives over the last two decades. Using multiple sources, we assembled a dataset that systematically documents these policy changes at the city-year level. We utilized print and web documents from the Indian government, including the CPCB, the Department of Road Transport and Highways, the Ministry of Environment and Forests, and several Indian SPCBs. We then exploited information from secondary sources, including the World Bank, the Emission Controls Manufacturers Association, and Urbanrail.net. We believe that a comparable data set does not exist for India.

Table 1 summarizes the prevalence of these policies in the data file of city-level air and water pollution concentrations by year. Columns (1a) and (2a) report the number of cities with air and water pollution readings, respectively. The remaining columns detail the number of these cities where each of the studied policies is in force. The subsequent analysis exploits the variation in the year of enactment of these policies across cities.[9]

B. Pollution Data

Air Pollution Data. This paper takes advantage of an extensive and growing network of environmental monitoring stations across India. Starting in 1987, India's Central Pollution Control Board (CPCB) began compiling readings of NO_2, SO_2, and PM. The data were collected as a part of the National Air Quality Monitoring Program, which was established by the CPCB to identify, assess, and prioritize the pollution control needs in different areas, as well as to aid in the identification and regulation of potential hazards and pollution sources.[10] Individual State Pollution Control Boards (SPCBs) are responsible for collecting the pollution readings and providing them to the CPCB for checking, compilation, and analysis. The air quality data are collected from a combination of CPCB online and print materials for the years 1987-2007.[11]

The full dataset includes 572 air pollution monitors in 140 cities. Many of these monitors operate for just a subset of the sample, and for most cities data is not available for all years.[12] In the earliest year (1987), the functioning monitors cover 20 cities, while 125 cities are monitored by 2007 (see Appendix Table 2 for annual summary statistics). On average, there are 2.3 monitors per city, with 78 percent of cities possessing data from more than one monitor in a given year.[13] Figure 2 maps cities with air pollution data in at least one year.

The monitored pollutants can be attributed to a variety of sources. PM is regarded by the

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[9] Appendix Table 1 replicates Table 1 for all cities in India.

[10] For a more detailed description of the data, see http://www.cpcb.nic.in/air.php (accessed on June 25, 2011).

[11] From the CPCB, we obtained monthly pollution readings per city from 1987-2004, and yearly pollution readings from 2005-2007. The monthly data were averaged to get annual measures.

[12] The CPCB requires that 24-hour samplings be collected bi-weekly from each monitor for a total of 104 observations per monitor per year. As this goal is not always achieved, 16 or more successful hours of monitoring are considered representative of a given day's air quality, and 50 days of monitoring in a year are viewed as sufficient for data analysis. Some cities, such as Delhi, conduct more frequent readings, but we do not include these.

[13] Each monitor is classified as belonging to one of three types of areas: residential (71 percent), industrial (26 percent), or sensitive (2 percent). The rationale for specific locations of monitors is, unfortunately, not known to us at this time so all monitors with sufficient readings are included in the analysis.

CPCB as a general indicator of pollution, receiving key contributions from “fossil fuel burning, industrial processes and vehicular exhaust”. SO_2 emissions, on the other hand, are predominantly a byproduct of thermal power generation; globally, 80 percent of sulfur emissions in 1990 were attributable to fossil fuel use (Smith, Pitcher and Wigley, 2001). NO_2 is viewed by the CPCB as an indicator of vehicular pollution, though it is produced in almost all combustion reactions.

Water Pollution Data. The CPCB also administers water quality monitoring, in cooperation with SPCBs. As of 2008, 1,019 monitoring stations are maintained under the National Water Monitoring Programme (NWMP), covering rivers and creeks, lakes and ponds, drains and canals, and groundwater sources. We focus on rivers due to the consistent availability of river quality data, the seriousness of pollution problems along the rivers, and, most significantly, the attention that rivers have received from public policy. We have obtained from the CPCB, in electronic format, observations from 489 monitors in 424 cities along 162 rivers between the years 1986 and 2005 (see Appendix Table 2).[14] Figure 3 maps the locations of these monitors along India’s major rivers.

The CPCB collects either monthly or quarterly river data on 28 measures of water quality, of which nine are classified as “core parameters”. We focus on three core parameters: Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), and Fecal Coliforms (FColi). We chose them because of their presence in CPCB Official Water Quality Criteria, their continual citation in planning and commentary, and the consistency of their reporting.[15]

These indicators can be summarized as follows. BOD is a commonly-used broad indicator of water quality that measures the quantity of oxygen required by the decomposition of organic waste in water. High values are indicative of heavy pollution; however, since water-borne pollutants can be inorganic as well, BOD is not considered a comprehensive measure of water purity. DO is similar to BOD except that it is inversely proportional to pollution; that is, lower quantities of dissolved oxygen in water suggest greater pollution because water-borne waste hinders mixing of water with the surrounding air, as well as hampering oxygen production from aquatic plant photosynthesis.

Finally, FColi, is a count of the most probable number of coliform bacteria per 100

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[14] From 1986 to 2004, monthly data is available. For 2005, the data is only available yearly.

[15] See *Water Quality: Criteria and Goals* (February 2002); *Status of Water Quality in India* (April 2006); and the official CPCB website, http://www.cpcb.nic.in/Water_Quality_Criteria.php.

milliliters (ml) of water. While not directly harmful, these organisms are associated with animal and human waste and are correlated with the presence of harmful pathogens. FColi is thus an indicator of domestic pollution. Since its distribution is approximately ln normal, FColi is reported as ln(number of bacteria per 100 ml) throughout the paper.

Trends in Pollution Concentrations. Figure 4 graphs national air and water quality trends. Panel A plots the average air quality measured across cities, by pollutant, from 1987 to 2007, while Panel B graphs water quality measured across city-rivers, by pollutant, from 1986 to 2005. Table 2 reports corresponding sample statistics, providing the average pollution levels for the full sample, as well as values at the start and end of the sample.

Air pollution levels have fallen. Ambient PM concentrations fell quite steadily from 252.1 micrograms per cubic meter ($\mu g/m^3$) in 1987-1990 to 209.5 $\mu g/m^3$ in 2004-2007 (Panel A). This represents about a 17 percent reduction in PM. The SO_2 trend line is flat until the late 1990s, and then declines sharply. Comparing the 1987-1990 to 2004-2007 time periods, mean SO_2 decreased from 19.4 to 12.2 $\mu g/m^3$ (or 37 percent). In contrast, NO_2 appears more volatile at the start of the sample period, but then falls after its peak in 1997.

Is there spatial variation in these trends? Appendix Figure 1A provides kernel density estimates of air pollutant distributions across Indian cities for the periods 1987-1990 and 2004-2007. The figure shows that not only have the means of PM and SO_2 decreased, but their entire distributions have shifted to the left over the last two decades. As Table 2 reports, the 10th percentiles of PM and SO_2 pollution both declined by about 10 percent from 1987-1990 to 2004-2007. Particularly striking, however, is the drop in the 90th percentile of ambient SO_2 concentration: 38.2 to 23.0 $\mu g/m^3$, or about 40 percent. In contrast, the NO_2 distribution appears to have worsened, with increases in the mean and 10th and 90th percentiles.

The overall trends in water quality are more mixed. Figure 4 Panel B demonstrates that BOD steadily worsens throughout the late 1980s and early 1990s and then begins to improve around 1997. The improvement, though, did not make up for early losses, as mean BOD increased by about 19 percent over the sample period. FColi drops precipitously in the 1990s, but rises somewhat in the 2000s. The general decrease in FColi is notable, suggesting that domestic water pollution may be abating despite the alarmingly fast-paced growth in sewage generation (Suresh et al., 2007). DO declines fairly steadily over time (a fall in DO indicates worsening water quality) from 7.21 to 7.03 mg/l.

The distributions of the water pollutants across cities and their changes are presented in Appendix Figure 1B, which comes from kernel density estimation. The distribution of BOD has widened over the last twenty years, with many higher readings in the later time period.[16] While the 10th percentile of BOD has dropped slightly, the 90th percentile has increased from 5.78 to 7.85 mg/l between the earlier and more recent periods. In contrast, the FColi distribution has largely shifted to the left. The relatively clean cities show tremendous drops in FColi levels, with the 10th percentile value falling from 3.61 to 1.79, while dirtier cities show more modest declines. Lastly, the DO distribution does not appear to have changed noticeably, with very little difference between the distributions from the earlier and later periods.

C. Infant Mortality Rate Data

We obtained annual city-level infant mortality data from annual issues of *Vital Statistics of India* for the years prior to 1996.[17] In subsequent years, the city-level data were no longer complied centrally; therefore, we visited the registrar's office for each of India's larger states and collected the data directly.[18] Many births and deaths are not registered in India and the available evidence suggests that this problem is greater for deaths, so the infant mortality rate is likely downward-biased. Although the infant mortality rate from the *Vital Statistics* data is about a third of the rate measured from state-level survey measures of infant mortality rates (i.e., the Sample Registration System), trends in the *Vital Statistics* and survey data are highly correlated. While these data are likely to be noisy, there is no reason to expect that the measurement error is correlated with the pollution measures.[19]

Infant mortality rates are an appealing measure of the effectiveness of environmental regulations for at least two reasons. First, relative to measures of adult health, infant health is likely to be more responsive to short and medium changes in pollution. Second, the first year of life is an especially vulnerable one, and so losses of life expectancy may be large.

Since 1987, infant mortality has fallen sharply in urban India (Panel C of Figure 4). As Panel C of Table 2 shows, the infant mortality rate fell from 29.6 per 1,000 live births in 1987-

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[16] The right tail of the 2002-2005 period extends to 100 mg/l, but the figure has been truncated at 20 mg/l to give a more detailed picture of the distribution.

[17] We digitized the city-level data from the books. All data were double entered and checked for consistency.

[18] Specifically, we attempted to obtain data in all states except the Northeastern states (which have travel restrictions) and Jammu-Kashmir. We were able to obtain data from Andhra Pradesh, Chandigarh, Delhi, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, and West Bengal.

[19] Burgess et al. (2011) show that these mortality data are correlated with inter-annual temperature variation, providing further evidence that there is signal in these data.

1990 to 16.7 in 2001-2004. The kernel density graphs of infant mortality from the earlier and later periods further confirm the reduction in mortality rates (Appendix Figure 1C).

D. Demographics Characteristics, Corruption, and Newspaper Pollution References

We additionally collected data on socio-demographic characteristics, corruption, and social activism at the city-level. Socio-demographic data come from two sources.[20] First, we obtained district-level data on population and literacy rates from the 1981, 1991, and 2001 Censuses of India. For non-census years, we linearly interpolated these variables. Second, we collected district-level expenditure per capita data, which is a proxy for income. The data come from the survey of household consumer expenditure carried out by India's National Sample Survey Organization in the years 1987, 1993, and 1999 and are imputed in the missing years.

We used a variety of novel resources to develop measures of demand for clean air and water and the degree of local corruption or institutional quality. First, we collected mentions on “air pollution” and “water pollution” from the *Times of India*, the largest newspaper in India, by state-year. Data prior to 2003 were obtained from the University of Pennsylvania’s searchable library database, while data afterward were obtained from the *Times of India*’s online public searchable database. We interpret the pollution mentions as indicators for the demand for clean air and water but, as we discuss below, note that these measures may also be subject to other reasonable interpretation. Systematic data on the degree of corruption across cities, as well as measures of social activism, are notoriously difficult to obtain, particularly for developing countries (Banerjee, Hanna and Mullainathan, forthcoming). We found and compiled data from two sources. We conducted analogous newspaper searches from the *Times of India,* but in this case searched for “corruption”, “graft”, and “embezzlement”, all of which are intended to provide a proxy for institutional quality. Second, we collected data from Transparency International on public perceptions of corruption by state for 2005.

IV. Econometric Approach

This section describes a two-stage econometric approach for assessing whether India’s regulatory policies impacted air and water pollution concentrations. The first-stage is an event study-style equation:

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[20] Consistent city-level data in India is notoriously difficult to obtain. We instead acquired district level data, and matched cities to their respective districts.

$$(1)\quad Y_{ct} = \alpha + \sum_{\tau} \sigma_{\tau} D_{\tau,ct} + \mu_t + \gamma_c + \beta X_{ct} + \epsilon_{ct}$$

where Y_{ct} is one of the six measures of pollution in city c in year t. The city fixed effects, γ_c , control for all permanent unobserved determinants of pollution across cities, while the inclusion of the year fixed effects, μ_t, non-parametrically adjust for national trends in pollution, which is important in light of the time patterns observed in Figure 2. The equation also includes controls for per capita consumption and literacy rates (X) in order to adjust for differential rates of growth across districts. To account for differences in precision due to city size, the estimating equation is weighted by the district-urban population.[21]

The vector $D_{\tau,ct}$ is composed of a separate indicator variable for each of the years before and after a policy is in force. τ is normalized so that it is equal to zero in the year the relevant policy is enacted; it ranges from -17 (for 17 years before a policy's adoption in a city) to 12 (for 12 years after its adoption). All τ's are set equal to zero for non-adopting cities; these observations aid in the identification of the year effects and the β's. In the air pollution regressions, there are separate $D_{\tau,ct}$ vectors for the Supreme Court Action Plan and catalytic converter policies, so each policy's impact is conditioned on the other policy's impact.[22]

The parameters of interest are the σ_τ's, which measure the average annual pollution concentration in the years before and after a policy's implementation. These estimates are purged of any permanent differences in pollution concentrations across cities and of national trends due to the inclusion of the city and year fixed effects. The variation in the timing of the adoption of the individual policies across cities allows for the separate identification of the σ_τ's and the year fixed effects.

In the below, the estimated σ_τ's are plotted against the τ's. These event study graphs provide an opportunity to visually assess whether the policies are associated with changes in pollution concentrations. Additionally, they allow for an examination of whether pollution concentrations in adopting cities were on differential trends and whether the time series properties suggest a mean reverting process. These figures will inform the choice of the preferred second-stage model.

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[21] City-level population figures are not systematically available, so we use population in the urban part of the district in which the city is located to proxy for city-level population.

[22] The results are qualitatively similar in terms of sign, magnitude, and significance from models that evaluate each policy separately.

The sample for equation (1) is based on the availability of data for a particular pollutant in a city. For adopting cities, a city is included in the sample if it has at least one observation three or more years before the policy's enactment and four or more years afterward. If a city does not have any post-adoption observations or did not enact the relevant policy, then that city is required to have at least two observations for inclusion in the sample.

The second-stage of the econometric approach formally tests whether the policies are associated with pollution reductions with three alternative specifications. We first estimate:

$$(2a) \quad \widehat{\sigma_\tau} = \pi_0 + \pi_1 1(Policy)_\tau + \epsilon_\tau$$

where $1(Policy)_\tau$ is an indicator variable for whether the policy is in force (i.e., $\tau \geq 1$). Thus, π_1 tests for a mean shift in pollution concentrations after the policy's implementation.

In several cases, the event study figures reveal trends in pollution concentrations that predate the policy's implementation (even after adjustment for the city and year fixed effects). Therefore, we also fit the following equation:

$$(2b) \quad \widehat{\sigma_\tau} = \pi_0 + \pi_1 1(Policy)_\tau + \pi_2 \tau + \epsilon_\tau.$$

This specification includes a control for a linear time trend in event time, τ, to adjust for differential pre-existing trends in adopting cities.

Equations (2a) and (2b) test for a mean shift in pollution concentrations after the policy's implementation. A mean shift may be appropriate for some of the policies that we evaluate. On the other hand, the full impact of some of the policies may emerge over time as the government builds the necessary institutions to enforce a policy and as firms and individuals take the steps necessary to comply. For example, an evolving policy impact seems probable for the Supreme Court Action Plans since they specify actions that polluters must take over several years.

To allow for a policy's impact to evolve over time, we also report the results from fitting:

$$(2c) \quad \widehat{\sigma_\tau} = \pi_0 + \pi_1 1(Policy)_\tau + \pi_2 \tau + \pi_3 (1(Policy)_\tau \times \tau) + \epsilon_\tau.$$

From this specification, we report the impact of a policy five years after it has been in force as $\pi_1 + 5\pi_3$.

There are three remaining estimation issues about equations (2a) through (2c) that bear noting. First, the sample is chosen so that there is sufficient precision to compare the pre- and post-adoption periods. Specifically, for two of the policies it is restricted to values of τ for which there are at least twenty city-by-year observations to identify the σ_τ's. For the catalytic converter regressions, the sample therefore covers τ = -7 through τ = 9 and for the National River

Conservation Plan regressions it includes τ = -7 through τ = 10 (see Appendix Table 4). In the case of the Supreme Court Action Plan policies which were implemented more narrowly, the sample is restricted to values of τ for which there are a minimum of 15 observations for each σ_τ, and this leads to a sample that includes τ = -7 through τ = 3. We demonstrate below that the qualitative results are unchanged by other reasonable choices for the sample. Second, the standard errors for these second stage equations are heteroskedastic consistent. Third, the equation is weighted by the inverse of the standard error associated with the relevant σ_τ to account for differences in precision in the estimation of these parameters.

V. Results

A. Air Pollution

Figure 5 presents the event study graphs of the impact of the policies on PM (Panel A), SO_2 (Panel B), and NO_2 (Panel C). Each graph plots the estimated σ_τ's from equation (1). The year of the policy's adoption, τ = 0, is demarcated by a vertical dashed line in all figures. Additionally, pollution concentrations are normalized so that they are equal to zero in τ = -1, and this is noted with the dashed horizontal line.

These figures visually report on the patterns in the data and help to identify which version of equation (2) is most likely to be valid. It is evident that accounting for differential trends in adopting cities is crucial, because the parallel trends assumption of the simple difference-in-differences or mean shift model (i.e., equation [2a]]) is violated in many cases. This is particularly true in the case of the catalytic converter policies that were implemented in cities where pollution concentrations were worsening. Note, however, that although the trends differ in the cities adopting the catalytic converter policy, the figures fail to reveal symmetry around a mean pollution concentration that would indicate that any of the three measured pollutants follow a mean reverting process. The upward pre-trend in pollution concentrations is also apparent in the case of the Supreme Court Action Plans (SCAPs) and NO_2.[23] In all of these instances with differential trends, equations (2b) and (2c) are more likely to produce valid estimates of the policies' impacts. With respect to inferring the impact of the policies, the figures suggest that the catalytic converter policy was effective at reversing the upward trend in

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[23] Interestingly, the differential trends in SO_2 concentrations between cities that were and were not subject to Supreme Court Action Plans bear some resemblance to a mean reverting process. There is little evidence in Figure 5 that that the SCAP affected SO_2 concentrations.

pollution concentrations, while the SCAPs appear ineffective, with the possible exception of NO_2.

Table 3 provides more formal tests by reporting the key coefficient estimates from fitting equations (2a) - (2c). For each pollutant-policy pair, the first column reports the estimate of π_1 from equation (2a), which tests whether σ_τ is on average lower after the implementation of the policy. The second column reports the estimate of π_1 and π_2 from the fitting of equation (2b) in the second column for each pollutant. Here, π_1 tests for a policy impact after adjustment for the trend in pollution levels (π_2). The third column reports the results from equation (2c) that allow for a mean shift and trend break after the policy's implementation. It also reports the estimated effect of the policy five years after their implementation, which is equal to $\pi_1 + 5\pi_3$.

Reading across Panel A, it is evident that the SCAPs have a mixed record of success.[24] There is little evidence of an impact on PM or SO_2 concentrations. The available evidence for an impact comes from the NO_2 regressions that control for pre-existing trends. In column (8) the estimated impact would not be judged statistically significant, while in column (9) it is of a large magnitude and would be judged marginally significant.

In contrast, the regressions confirm the visual impression that the catalytic converter policies were strongly associated with air pollution reductions. In light of the differential pre-trends in pollution in adopting cities and that the policy's impact will only emerge as the stock of cars changes, the richest specification (equation [2c]) is likely to be the most reliable. It indicates that 5 years after the policy was in force, PM, SO_2, and NO_2 declined by 48.6 $\mu g/m^3$, 13.4 $\mu g/m^3$, and 4.5 $\mu g/m^3$, respectively. The PM and SO_2 declines are statistically significant when judged by conventional criteria, while the NO_2 decline is not. These declines are 19 percent, 69 percent, and 15 percent of the 1987-1990 nationwide mean concentrations, respectively. These percentage declines are large, reflecting the rapid rates at which ambient pollution concentrations were increasing before the policy's implementation in adopting cities—put another way, if the pre-trends had continued then pollution concentrations would have reached levels much higher than those recorded in the 1987-1990 period.

Appendix Table 4 demonstrates that the qualitative results are unchanged by reasonable alternative sample selection rules that determine the number of event years included in the

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[24] Note that for the Supreme Court Action Plans, the analysis lags the policies by one year. The dates we have correspond to Court Orders, which mandated submission of Action Plans. However, a special committee frequently reviewed the SCAPs and only afterwards declared/implemented them.

analysis.[25] Specifically, we fit equation (2c) on a wider range of τ's (i.e., from τ = -9 through τ = 9 for the catalytic converters and τ = -14 through τ = 4 for the SCAPs) and a narrower range τ's (i.e., from τ = -5 through τ = 5 for the catalytic converters and τ = -4 through τ = 4 for the SCAPs). The pattern of the coefficients for the catalytic converters policy is similar to that of Table 3 for both the wider and narrower event year samples. The SCAP is associated with a large and significant decline in NO_2 with the narrower range. With the wider range, the SCAP continues to be associated with a decline in NO_2 but it no longer would be judged to be statistically significant; however, it is associated with a statistically significant decline in PM.

B. Effects of Policies on Water Quality

Panels A-C of Figure 6 present event study analyses of the impact of the National River Conservation Plan (NRCP) on BOD, ln(FColi), and DO, respectively. As in Figure 5, the figures plot the results from the estimation of equation (1). From the figures, there is little evidence that the NRCP was effective at reducing pollution concentrations.

Table 4 provides the corresponding regression analysis and is structured similarly to Table 3. The evidence in favor of a policy impact is weak. BOD concentrations are lower after the implementation of NRCP, but the decline occurs several years prior to the implementation of the plan (Panel A). While NRCP targets domestic pollution, the data fail to reveal an improvement in FColi concentrations (Panel B), which is the best measure of domestic sourced water pollution. The results from the fitting of equation (2c) are reported in column (9) and confirm the perverse visual impression that the NRCP is associated with a worsening in DO concentrations (recall, lower DO levels indicate higher pollution concentrations).[26]

C. Assessing Robustness with a Structural Break Test

The previous subsection presented results from a difference-in-differences (DD) approach that can accommodate differential trends across cities that did and did not adopt the

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[25] There is a tradeoff to including a greater or smaller number of event years or τ's in the second-stage analysis. The inclusion of a wider range of τ's provides a larger sample size and allows for more precise estimation of pre and post adoption trends. But at the same time, it moves further away from the event in question so that other unobserved factors may confound the estimation of the policy effects. Further, it exacerbates the problems associated with estimating the τ's from an unbalanced panel data file of cities. In contrast, the inclusion of fewer τ's results in a smaller sample size (and number of cities) to estimate pre and post trends, but the analysis is more narrowly focused around the policy event. Appendix Table 3 reports on the number of city-by-year observations that identify the σ_τ's associated with each event year.

[26] Appendix Table 4 demonstrates that the qualitative result that the NRCP had little impact on the available measures of water pollution is unchanged by reasonable alternative selection rules for the number of event years to include in the analysis. The table reports on specifications that increase and decrease the number of event years or taus (i.e., changing the event years to include [-9,12] or to include [-5,5]) in the second-stage analysis.

environmental regulations. As is always the case with a non-experimental design, there is a form of unobserved heterogeneity that can explain the findings without a causal explanation. This subsection adapts a structural break test from time-series econometrics and demonstrates that these tests can be used to shed light on the validity of a DD-style design. Structural break tests have generally been limited to settings where this is a single time-series and a control group is unavailable. However as equation (1) and the event-study figures highlight, it is straightforward to collapse a DD framework into a single time-series, even when the policy date varies across units (i.e., cities in our setting) that have been adjusted for unit and time fixed effects. We are unaware of previous efforts to apply structural break tools to a DD setting and believe that these tests can and should be used more broadly with DD designs.[27]

Inspired by Piehl et al. (2003), we adapt the Quandt likelihood ratio (QLR) statistic to determine if there is a structural break in a time-series. Specifically, we take the estimated σ_τ's from the estimation of equation (1) and the most robust second-stage specification (i.e., [2c]) that assumes that the regulations cause a mean shift and trend break in pollution concentrations. Note that the test for whether a policy has any effect in equation (2c) is tantamount to calculating the F-statistic associated with the null hypothesis that $\pi_1 = 0$ and $\pi_3 = 0$. In time-series, this is often referred to as a Chow-test for parameter constancy, but it essentially boils down to an F-test.

The idea is to assess whether there is a structural break in the policy parameters (i.e., π_1 and π_3) near the true date of the policy's adoption. The test does two things: It identifies the date at which there is the largest change in the parameters (defined as the date associated with the largest change in the F-statistic) and produces p-values for whether the change in those parameters is different than zero (i.e., whether there is a break). A failure to find a break or a finding of a break significantly before the measured date of policy implementation would suggest that the policies were ineffective and undermine any findings to the contrary from the DD approach. In contrast, a finding of a policy effect in the years around $\tau = 0$, especially the years after $\tau = 0$, would support the findings of a policy effect from the DD results.

This test is implemented in two steps. First, equation (2c) is re-estimated redefining a new "policy implementation" date each time and the F-statistic associated with the null

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[27] Based on our investigation, the closest use of a structural break test in a non-time series setting is Ludwig and Miller's (2007) application within a regression discontinuity framework as a robustness check for the existence and timing of a discontinuity.

hypothesis that $\pi_1 = 0$ and $\pi_3 = 0$ is calculated. We test for break dates within a window of the middle 50 percent of the event years in each time-series. There needs to be a sufficient amount of data outside the window, so, for example, the possible break dates are limited to $\tau = -3$ through $\tau = 6$ (out of the total available years that range from $\tau = -7$ through $\tau = 9$) for the effect of the catalytic converter policy on PM.

Second, the QLR test selects the maximum of the F-statistics to test for a break at an unknown date. The maximum of a number of F-statistics does not converge to any known distribution. Andrews (1993) provides critical values that are asymptotically correct, but we instead run a Monte Carlo simulation to compute the critical values due to our small sample. Specifically, to compute the small-sample critical values, we first generated data with the variance set equal to the variance of the actual data, but without a break in the data. We then compute the QLR test over the simulated data to obtain the maximum F-statistics. We replicate this 100,000 times to obtain the distribution of the QLR statistics under a null of hypothesis of no break.

Figure 7 and Table 5 (Panel A) report on the results of the QLR test for the catalytic converter policy, which the previous section found to be the most effective policy. For PM, Panel A of Figure 7 plots the F-statistics associated with the test of a break for each of the event years. It is evident that this test selects $\tau = 2$ as the event year with the most substantive break. Table 5 reports that the null hypothesis of no break at $\tau = 2$ can be rejected at the 1 percent level. This break corresponds to the reversal of the upward trend in PM observed at $\tau = 2$ in Figure 5.

The results from the other two structural break tests are also broadly supportive of the previous subsection's findings. With respect to SO_2, Panel B of Figure 7 reveals that the largest F-statistics are concentrated in the period $\tau = -2$ through $\tau = 1$. The QLR statistic (i.e., the biggest F-statistic) occurs at $\tau = -1$ and is easily statistically significant at the 1 percent level (Table 5). A comparison of this figure and Figure 5 reveal that the QLR test, which is only designed to test for a single break, picks the arrest of the upward trend in SO_2 as a more important change than the downward trend that is first evident in $\tau = 1$. Overall, the test suggests that the case for the catalytic converter policy reducing SO_2 concentrations is not as strong as the case for a relationship between the policy and reduced PM concentrations. Finally, Panel C of Figure 7 and Table 5 fail to provide evidence of a structural break in NO_2 concentrations, which is consistent with Table 3 where the null of zero effect cannot be rejected.

For comparison, Panel B of Table 5 provides the QLR test statistics for the National River Conservation Policy. The null of no structural break cannot be rejected for the BOD or Ln(Fcoli) time series, which is consistent with the results in Table 4. There is a significant break in DO, but it occurs three years prior to the event; this is consistent with the observed *worsening* of DO that, according to the event study analysis in Figure 6, begins about three years prior to the program implementation. Finally, we note that we could not conduct the QLR test for the SCAPs due to the limited number of event years for these policies.

D. Effects of Catalytic Converter Policy on Infant Mortality

The catalytic converter policy is the most strongly related to improvements in air pollution. This subsection explores whether the catalytic converter policy is associated with changes in human health, as measured by infant mortality rates.

Specifically, we fit equation (1) and equations (2a) - (2c), where the infant mortality rate is the outcome of interest. Several estimation details are noteworthy. First, despite a large data collection exercise (including going to each state to obtain additional registry data), there are fewer cities in the sample.[28] Second, the dependent variable is constructed as the ratio of infant deaths to births, and equation (1) is weighted by the number of births in the city-year. Third, it is natural to consider using the catalytic converter induced variation to estimate the separate impacts of each of the three forms of air pollution on infant mortality in a two-stage least squares setting. However, such an approach is invalid in this setting because, even when the exclusion restriction is otherwise valid, there is a single instrument for three endogenous variables.

Figure 8 and Table 6 report the results. In light of the differential pre-existing trend, the column (3) specification is likely to be the most reliable. It suggests that the catalytic converter policy is associated with a reduction in the infant mortality rate of 0.86 per 1,000 live births. However, this estimate is imprecise and is not statistically significant.

VI. Why Were the Air Pollution Policies More Effective than the Water Pollution Policies?

The previous section's results' analysis indicates that India's air pollution policies were more successful than the water pollution ones. The question that naturally arises is why? India has an extensive history of both types of policies, and, in fact, the National Water Act—giving

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[28] When the air pollution sample is restricted to the sample used to estimate the infant mortality equations, the catalytic converter policy is associated with substantial reductions in PM and SO_2 but not of NO_2 concentrations.

the government the rights and official structure in which to regulate water pollution—was passed seven years *before* the Air Act. This section presents qualitative and quantitative evidence that suggests that the difference is largely a reflection of the greater demand for clean air.

A. Qualitative Evidence

There are several reasons why the demand for better air quality may exceed that for water. First, the costs of air pollution may be higher: The Global Burden of Disease study (Lim et al., 2012) suggests that outdoor PM and ozone air pollution are responsible for about 3.4 million premature fatalities annually. In contrast, the estimated number of annual premature fatalities due to unimproved water and sanitation (i.e., about 340,000) is an order of magnitude smaller. Further, recent evidence indicates that the mortality impacts of poor air quality at the high concentrations observed in many Indian cities may be worse than previously recognized (Chen et al., 2013).

The second, and related, reason may be a difference in avoidance costs. The argument starts with the observation that middle and upper income groups are the most likely to engage in public activism on environmental issues, and these groups may find it relatively easy to avoid water pollution through the purchase of clean, bottled water. In fact, the revenue generated from bottled water sales in India in 2010 exceeded $250 million dollars and was "expected to grow at a 30% rate in the next 7 years."[29] Further, it is common for middle-class households to use boiling and other techniques for cleaning water. In contrast, it is nearly impossible to completely protect oneself against air pollution because people spend time outdoors for leisure, travel to work, etc., and air pollution can penetrate buildings and affect indoor air quality.

Third, air pollution appears to have been a greater source of concern in public discourse, suggesting relatively greater demand for air quality. We collected data from the *Times of India*, which is the most widely read English-language newspaper in India (and the world), on the number of mentions of air and water pollution. Figure 9 demonstrates that air pollution was mentioned about three times as frequently as water pollution between 1986 and 2007.[30] While this finding is consistent with higher demand for air quality, it is possible that the greater mentions reflect differences in water or air pollution concentrations or some other factor.

Fourth, the implementation and enforcement of the water pollution regulations, compared

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[29] http://www.researchandmarkets.com/research/f9deab/indian_bottled_wat, accessed on August 14, 2012.

[30] Interestingly, this finding still holds even when reports from Delhi, which had especially poor air quality, are dropped.

to the air pollution regulations, suggest a relatively lower demand for water quality. For starters, the lines of authority under the NRCP for the designation of water quality standards and their enforcement were muddled and unclear. No single organization was accountable for ensuring success: Although the NRCP was originally developed and launched by the MoEF, implementation and enforcement were split among a wide variety of institutions that frequently lack the power necessary for successful enforcement, including the CPCB, the State Pollution Control Boards, and local departments for public health, development, water, and sewage (Ministry of Environment and Forests, 2006). Additionally, the recommended solutions to high water pollution concentrations involve the construction of sewage treatment plants and other expensive capital investments, but the legislation did not provide a dedicated source of revenues and funding responsibility jumped around across levels of government during this period.[31] Further, state and local bodies have been accused of financial mismanagement, including diversion, underutilization, and incorrect reporting of funds (Ministry of Environment and Forests, 2006). The weak institutional support for the NRCP was evident in the failure to achieve basic “process” goals, such as construction of necessary sewage treatment plants.[32]

In principle, air pollution laws had many of the same jurisdictional and enforcement issues, but the key difference is that they often had the forceful support of India’s Supreme Court. This difference is a critical one because the Supreme Court has the role of determining when there have been serious infringements of fundamental and human rights. The avenue for such determinations is India’s public interest litigation that can compel the Supreme Court to deliver economic and social rights that are protected by the constitution but are otherwise unenforceable. Notably, a public interest litigation suit can be introduced by an aggrieved party, a third party (e.g., a non-governmental organization), or even the Supreme Court itself. In many instances, the Supreme Court’s rulings have been motivated by executive inaction.

India’s Supreme Court became heavily involved in environmental affairs with its order

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[31] Under the first river Action Plan in 1985, the central government was responsible for 100 percent of policy funding. In 1990, it was decided that the cost would be split between central and state administrations. This division was revoked in 1997, returning the full cost to the Union government. One final change was made in 2001, allocating 30 percent of the financial burden to states, a third of which was levied on local bodies themselves (Suresh et al., 2007, p. 3).

[32] For example as of March 2009, 152 out of 165 towns officially covered under NRCP have been *approved* for Sewage Treatment Plant capacity building, but construction has been initiated in only 82. Additionally, as of March 2009, there has not been any spending of federal or state monies on the NRCP in fifteen NRCP towns (National River Conservation Directorate, 2009). Furthermore, the Centre for Science and Environment (CSE) calculates that the 2006 treatment capacity was only 18.5 percent of the full sewage burden (Suresh et al., 2007, p. 11)

that Delhi develop an action plan to address pollution in 1996.[33] The Court followed that order with a directive to create an authority "to advise the court on pollution and monitor implementation of its order." Following the success of the Delhi efforts, new initiatives to address pollution were pushed forward by non-governmental organizations, public sentiment, prominent Indian citizens, and the Supreme Court. These efforts ultimately led to further action by the Supreme Court, including requirements for city-level Supreme Court Action Plans, the mandatory installation of catalytic converters for designated cities, and other regulatory and enforcement efforts.

In summary, the air pollution regulations had the powerful Supreme Court's backing and this brought substantial bureaucratic effort to bear on the problem.[34] In contrast, the implementation and enforcement of the water pollution regulation appeared to lack widespread public support and was left to a mix of central and state government institutions without the tools, accountability, and resources that are generally critical for effective governance. Our read of the history is that the Supreme Court's decision to focus on air pollution, and largely ignore water pollution, reflects the higher level of demand for government provision of improved air quality that manifested itself as public activism and citizen suits filed in the Supreme Court under the aegis of India's public interest litigation.[35]

B. Quantitative Evidence

This subsection quantitatively assesses the hypothesis developed in the previous subsection that the greater success of air pollution policies was due to higher demand for improvement in air quality. This exercise is conducted by dividing the sample of cities into those with above and below the median value of variables that can be interpreted as demand shifters for air quality. Given that corruption is often cited as a barrier to the efficient delivery of government services in developing countries, we also test whether the air pollution policies were more effective in cities with above, versus below, median values of variables designed to measure the degree of local corruption (see, for example, Banerjee, Hanna, and Mullainathan, forthcoming).

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[33] It has been suggested that the mandate for an action plan to address pollution in Delhi was partially due to Justice Kuldeep Singh reading a book published by the influential NGO Centre for Science and Environment, entitled *Slow Murder: The Deadly Story of Vehicular Pollution in India* (Narain and Bell, 2005, p. 10).

[34] A former CPCB chairman summed up the need for Supreme Court intervention: "When it comes to doing things, it is not up to the CPCB, even in the area of air pollution." (Sharma and Roychowdhury, 1996, p. 128).

[35] As just one prominent example, see Court Order on April 5th, 2002, Supreme Court of India. Writ Petition (Civil) No. 13029 of 1985. M.C. Mehta vs. Union of India and Others.

Table 7 reports the results from the estimation of equation (2c) for the success of the catalytic converter policy.[36] In columns (1) and (2), the samples are restricted to cities with education levels that are above and below the median, respectively; we assume that education is a proxy for higher demand for air quality due to higher knowledge on the health effects of air quality and/or higher income. Columns (3) and (4) repeat this exercise, but this time we divide cities by the number of mentions of air pollution (measured at the state-level) in the *Times of India*. We interpret the newspaper mentions as a measure of demand for clean air, although it would be inappropriate to definitively rule out that the mentions reflect other factors that cannot be classified as demand shifters (e.g., newspaper mentions may provide new information that in turn increase demand for air quality). Columns (5) - (8) repeat this exercise for two different measures of corruption: The sample is divided in half by the number of mentions of corruption in the *Times of India* and Transparency International's corruption rankings, respectively.

The results are consistent with the hypothesis that differences in the demand for air quality drive the effectiveness of the air pollution policies. Turning first to literacy, columns (1) and (2) reveal that the catalytic converter policy is associated with larger 5-year reductions in PM and SO_2 concentrations in cities with higher literacy rates, although 95% confidence intervals overlap in both cases. Similarly, we find larger policy impacts in cities with more frequent mentions of air pollution in the *Times of India* (Columns [3] and [4]). In contrast, columns (5) – (8) fail to reveal a consistent pattern, suggesting that the available measures of corruption are unrelated to the effectiveness of the catalytic converter policy.[37]

VII. Conclusion

Using the most comprehensive data file ever compiled on air pollution, water pollution, environmental regulations, and infant mortality for a developing country, this paper tests for the impacts of key air and water pollution regulations in India. We find that air regulations were in part responsible for observed improvements in air quality over the last two decades. The most successful air regulation resulted in a modest, but statistically insignificant decline in infant mortality. In contrast to the air findings, the results indicate that the National River Conservation

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[36] As in the main analysis, all regressions are estimated by OLS and include indicators for the Supreme Court Action Plans in the first stage, and have robust standard errors in the second stage.

[37] Table 7's results are unchanged qualitatively if cities are divided by the per-capita *Times of India* mentions of air pollution and corruption, rather than the raw number of mentions.

Plan—the cornerstone of India's water policies—failed to lead to improvements in any of the three available measures of water pollution.

India, like many developing countries, is widely considered to have weak regulatory institutions, so the success of the air policies is noteworthy. A range of qualitative and quantitative evidence suggests that citizens' higher relative demand for air quality, especially those with the means to file public interest litigation suits, were critical to the air regulations' success. This demand and activism prompted the Supreme Court, which is widely considered the country's most efficacious institution, to become active in the implementation and enforcement of the air regulations.

There are several broader implications. First, the results demonstrate that environmental regulations and presumably other government interventions can succeed, even in weak institutional settings, when demand and/or public support is strong enough. Second, the results suggest that no matter what climate deals are worked out internationally, India may be unlikely to significantly reduce greenhouse gas emissions until climate change becomes an urgent issue domestically. This would pose challenges for addressing climate change because India is projected to be a major contributor to the growth in greenhouse gas emissions in the coming decades. Third, the paper has left unanswered the fundamental questions of the magnitudes of the marginal benefits and costs of regulation-induced emissions reductions and whether the benefits exceed the costs. Currently, there is very limited information on the costs and benefits of environmental regulations in developing countries and this is a rich area for future research.

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Table 1: Prevalence of Air and Water Policies

Year	*Air*			*Water*	
	All Cities (1a)	SCAP (1b)	Cat Conv (1c)	All Cities (2a)	NRCP (2b)
1986	--	--	--	104	0
1987	20	0	0	115	0
1988	25	0	0	191	0
1989	31	0	0	218	0
1990	44	0	0	271	0
1991	47	0	0	267	0
1992	58	0	0	287	0
1993	65	0	0	304	10
1994	57	0	0	316	10
1995	42	0	2	317	38
1996	68	0	4	316	39
1997	73	1	4	326	43
1998	65	1	22	325	43
1999	74	1	26	320	43
2000	66	1	24	303	39
2001	54	1	19	363	43
2002	63	1	22	376	41
2003	72	11	25	382	42
2004	78	15	24	395	41
2005	93	16	24	295	38
2006	112	16	24	--	--
2007	115	16	24	--	--

Notes:

1. Columns (1a) and (2a) tabulate the total number of cities in each year, while columns (1b), (1c), and (2b) tabulate the number of cities with the specified policy in place in each year.

2. We subject the full sample to two restrictions before analysis, both of which are applied here. (1) If there is pollution data from a city after it has enacted a policy, then that city is only included if it has at least one data point three years or more before policy uptake and four years or more after policy uptake. (2) If there is no post-policy pollution data in a city (or if that city never enacted the policy), then that city is only included if it has at least two pollution data points.

3. In this table, a city is counted if it has any pollution data in that year. A city is only included in the subsequent regressions if it has pollution data for the specific dependent variable of that given regression. Thus, the above city counts must be interpreted as maximums in the regressions. Most city-years have available data for all pollutants studied here.

4. The data were compiled by the authors from Central Pollution Control Board's online sources, print sources, and interviews.

Table 2: Summary Statistics

Period	Mean	10th Percentile	90th Percentile	Mean	10th Percentile	90th Percentile	Mean	10th Percentile	90th Percentile
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Air Pollution									
		PM			SO_2			NO	
Full Period	223.2	90.5	378.4	17.3	4.0	35.4	26.8	10.0	48.7
	(114.0)			(15.2)			(18.0)		
	1370			1344			1382		
1987-1990	252.1	101.6	384.3	19.4	4.4	38.2	25.5	8.5	42.6
	(126.4)			(13.3)			(21.5)		
	120			116			117		
2004-2007	209.4	92.0	366.6	12.2	4.0	23.0	25.6	10.4	47.0
	(97.1)			(8.1)			(14.0)		
	420			381			417		
Panel B: Water Quality									
		BOD			Ln(FColi)			DO	
Full Period	4.2	0.8	7.0	5.4	1.9	9.0	7.1	5.7	8.5
	(8.0)			(2.7)			(1.3)		
	5948			4985			5919		
1986-1989	3.5	0.9	5.8	6.4	3.6	9.7	7.2	6.0	8.5
	(6.9)			(2.3)			(1.2)		
	644			529			648		
2002-2005	4.1	0.9	7.9	5.3	1.8	9.1	7.0	5.5	8.4
	(7.9)			(2.9)			(1.5)		
	1509			1339			1487		
Panel C: Infant Mortality									
		IM Rate							
Full Period	23.5	3.4	46.3						
	(22.1)								
	1246								
1987-1990	29.6	4.8	56.2						
	(31.5)								
	357								
2001-2004	16.7	2.7	36.2						
	(14.1)								
	216								

Notes:

1. This table provides summary statistics on air and water quality. Standard deviations are provided below the mean in parantheses.
2. Infant mortality data are restricted to those cities which have at least one air or water pollution measurement in the full sample.
3. Pollution data were drawn from Central Pollution Control Board's online and print sources. Infant mortality data were taken from the book *Vital Statistics of India* as well as various state registrar's offices.

Table 3. Trend Break Estimates of the Effect of Policy on Air Pollution

	PM			SO_2			NO_2		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Supreme Court Action Plans									
π_2: Time Trend		-3.8	-3.6		0.2	0.2		1.2**	1.4**
		(2.4)	(2.8)		(0.1)	(0.1)		(0.4)	(0.4)
π_1: 1(Policy)	-16.2	4.9	7.5	-0.5	-1.5*	-1.4	1.9	-4.4	-1.7
	(9.4)	(15.8)	(20.6)	(0.4)	(0.7)	(0.9)	(2.0)	(2.7)	(3.1)
π_3: 1(Policy) * Time Trend			-1.5			-0.1			-1.6
			(7.1)			(0.3)			(1.1)
5-Year Effect = $\pi_1 + 5\pi_3$			-0.2			-1.7			-9.8*
p-value			0.99			0.21			0.06
N	11	11	11	11	11	11	11	11	11
Panel B: Catalytic Converters									
π_2: Time Trend		-0.3	7.8***		0.1	2.0***		-0.3	0.9*
		(1.8)	(2.5)		(0.3)	(0.3)		(0.3)	(0.4)
π_1: 1(Policy)	11.9	14.7	5.6	2.5	1.5	-0.5	2.2	4.5	3.2
	(8.8)	(17.4)	(12.8)	(1.7)	(3.3)	(1.5)	(1.4)	(2.8)	(2.2)
π_3: 1(Policy) * Time Trend			-10.8***			-2.6***			-1.5***
			(2.9)			(0.3)			(0.5)
5-Year Effect = $\pi_1 + 5\pi_3$			-48.6**			-13.4***			-4.5
p-value			0.04			0.00			0.25
N	17	17	17	17	17	17	17	17	17
Equation (2a)	Y	N	N	Y	N	N	Y	N	N
Equation (2b)	N	Y	N	N	Y	N	N	Y	N
Equation (2c)	N	N	Y	N	N	Y	N	N	Y

Notes: This table reports results from the estimation of equations (2a), (2b), and (2c). Panel A reports on the estimated impact of the Supreme Court Action Plans for PM (columns (1) – (3)), SO2 (columns (4) – (6)), and NO2 (columns (7) – (9)). Panel B reports on the same exercise, except for the catalytic converter policy. Rows denoted "5-Year Effect" report $\Pi_1 + 5\Pi_3$, which is an estimate of the effect of the relevant policy 5 years after implementation from equation (2c). The p-value of a hypothesis test for the significance of this linear combination is reported immediately below the 5-year estimates. Asterisks denote significance at the 90% (*), 95% (**), and 99% (***) levels. See the text for further details.

Table 4. Trend Break Estimates of the Effect of the National River Conservation Plan on Water Pollution

	BOD			Ln(Fcoli)			DO		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
π_2: Time Trend		-0.1	-0.9**		0.0	-0.1		0.0	0.1***
		(0.2)	(0.3)		(0.0)	(0.1)		(0.0)	(0.0)
π_1: 1(Policy)	-1.1	-0.1	1.1	-0.1	-0.1	0.0	0.0	0.2	0.0
	(1.0)	(1.9)	(1.7)	(0.2)	(0.4)	(0.4)	(0.1)	(0.2)	(0.1)
π_3: 1(Policy) * Time Trend			1.0**			0.1			-0.1***
			(0.4)			(0.1)			(0.0)
5-Year Effect = $\pi_1 + 5\pi_3$			5.9*			0.5			-0.6***
p-value			0.06			0.45			0.01
N	18	18	18	18	18	18	18	18	18
Equation (2a)	Y	N	N	Y	N	N	Y	N	N
Equation (2b)	N	Y	N	N	Y	N	N	Y	N
Equation (2c)	N	N	Y	N	N	Y	N	N	Y

Notes: This table reports estimates of the impact of the National River Conservation Plan on three measures of water pollution from the fitting of equations (2a), (2b), and (2c). The three measures of water pollution are BOD (columns (1) – (3)), Ln(Fcoli) (columns (4) – (6)), and DO (columns (7) – (9)). The row denoted "5-Year Effect" reports $\Pi_1 + 5\Pi_3$, which is an estimate of the effect of the relevant policy 5 years after implementation from equation (2c). The p-value of a hypothesis test for the significance of this linear combination is reported immediately below the 5-year estimates. Asterisks denote significance at the 90% (*), 95% (**), and 99% (***) levels. See the text for further details.

Table 5: Structural Break Analysis

	Year of Maximum F (1)	QLR Test Statistic (2)
A. Catalytic Converter Policy		
PM^2	2	15.8
SO^2	-1	30.2
NO	-2	9.1
B. National River Conservation Plan		
BOD	-3	4.9
Ln(Fcoli)	-2	3.5
DO	-3	18.8

Notes: This table provides the QLR test statistic, as well as the corresponding year of the break in the data, for equation (2c). Asypmtotic critical values are invalid due to the small sample sizes. Instead, we conducted a monte carlo analysis to generate the appropriate small sample critical values. The critical value corresponding to a 99 percent confidence level is 13.98.

Table 6. Trend Break Estimates of the Effect of the Catalytic Converter Policy on Infant Mortality

	(1)	(2)	(3)
π_2: Time Trend		-0.4**	-0.3
		(0.2)	(0.2)
π_1: 1(Policy)	-1.6	1.7	3.5**
	(1.0)	(1.5)	(1.5)
π_3: 1(Policy) * Time Trend			-0.9**
			(0.4)
5-Year Effect = $\pi_1 + 5\pi_3$			-0.9
p-value			0.61
N	16	16	16
Equation (2a)	Y	N	N
Equation (2b)	N	Y	N
Equation (2c)	N	N	Y

Notes: This table reports estimates of the impact of the Catalytic Converter Policy on infant mortality rates from the fitting of equations (2a), (2b), and (2c). The row denoted "5-Year Effect" reports $\Pi_1 + 5\Pi_3$, which is an estimate of the effect of the relevant policy 5 years after implementation from equation (2c). The p-value of a hypothesis test for the significance of this linear combination is reported immediately below the 5-year estimates. Asterisks denote significance at the 90% (*), 95% (**), and 99% (***) levels. See the text for further details.

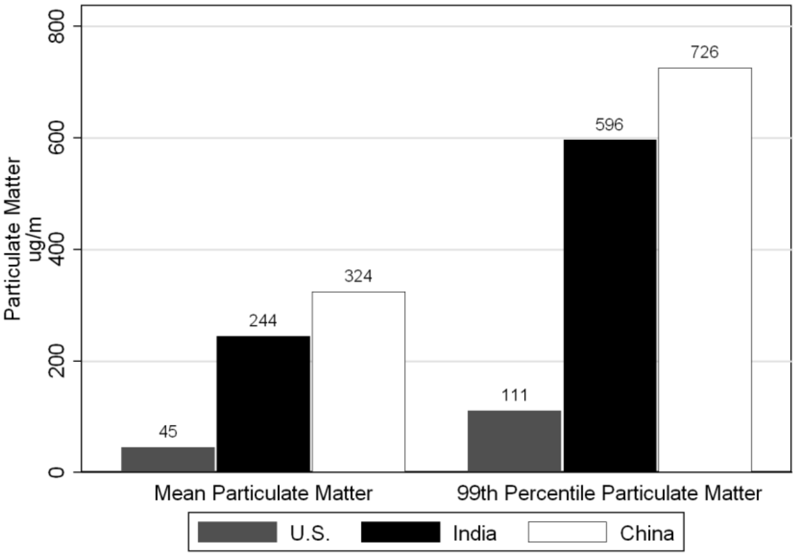
Table 7: Heterogeneity of Effect of Catalytic Converter Policy

	Urban Literacy		Air Pollution Mentions		Corruption Mentions		Transparency International	
	High (1)	Low (2)	High (3)	Low (4)	High (5)	Low (6)	High (7)	Low (8)
Panel A: PM								
5-Year Effect = $\pi_1 + 5\pi_3$	-57.9**	-39.6	-42.8*	-18.2	-38.5**	-85.7*	-61.5*	-47.2**
p-value	0.04	0.20	0.08	0.61	0.05	0.06	0.06	0.04
Panel B: SO_2								
5-Year Effect	-15.1***	-10.1***	-20.5***	12.7***	-13.0***	-11.1	-6.2***	-19.4***
p-value	0.00	0.01	0.00	0.00	0.00	0.11	0.01	0.00
Panel C: NO_2								
5-Year Effect	-1.9	-0.9	-4.2	4.5	0.4	-3.7	1.6	-5.3
p-value	0.76	0.85	0.31	0.51	0.93	0.68	0.80	0.31

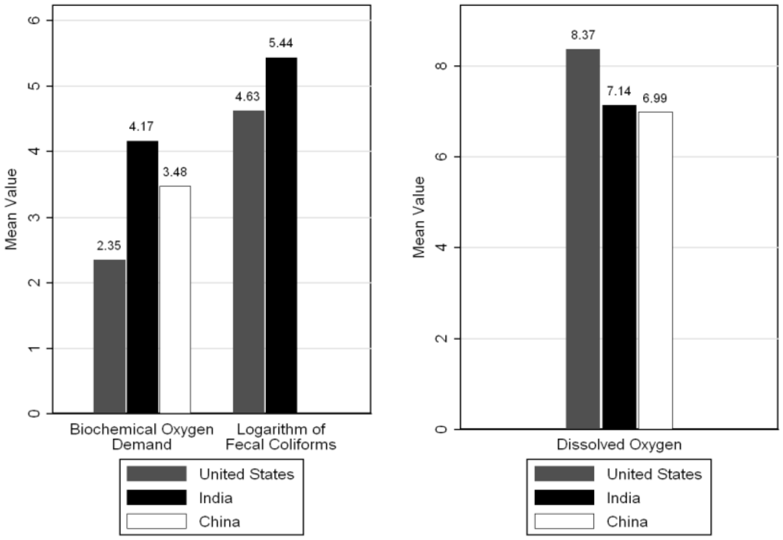
Notes: This table explores the heterogeneity of the treatment effect for the Catalytic converter policy. We report estimates from fitting equation (2c), our prefered specification. Asterisks denote significance at the 90% (*), 95% (**), and 99% (***) levels.

Figure 1: Comparison of Pollution Levels in India, China, and the U.S.

Panel A: Air Pollution Levels



Panel B: Water Pollution Levels



Notes:

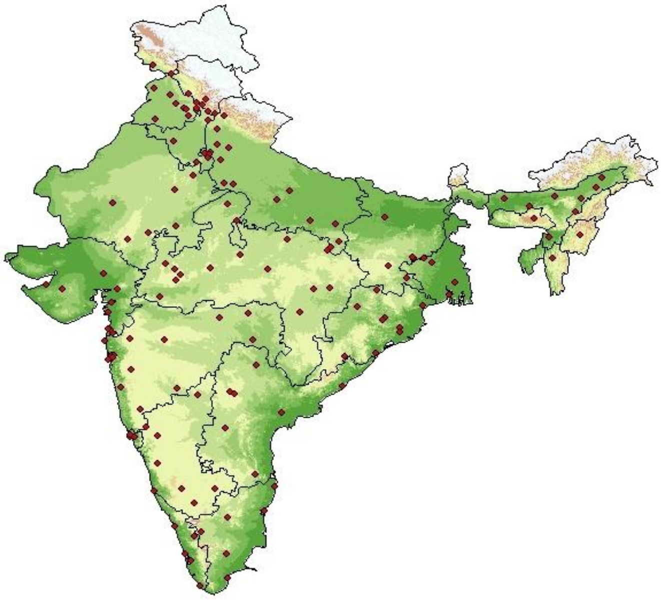
1. In Panel A, the air pollution values are calculated from 1990-1995 data. For India, only cities with at least seven years of data are used. In Panel B, water pollution values for India and the United States are calculated from 1998-2002 data. For India, only city-rivers with at least seven years of data are used. Pollution values for China are calculated across six major river systems for the year 1995 and are weighted by number of monitoring sites within each river system. Fecal coliform data for China were unavailable.

2. "Particulate Matter" refers to all particles with diameter less than 100 µm, except in the case of the United States, where particle size is limited to diameter less than 50 µm.

3. Units are mg/l for Biochemical Oxygen Demand and Dissolved Oxygen. For Logarithm of Fecal Coliforms, units are the most probable number of fecal coliform bacteria per 100 ml of water or MPN/100 ml. An increase in Biochemical Oxygen Demand or Fecal Coliforms signals higher levels of pollution, while an increase in Dissolved Oxygen signals lower levels of pollution.

4. Indian pollution data (both air and water) were drawn from the Central Pollution Control Board's online and print sources. Data for the United States (both air and water pollution) were obtained from the United States Environmental Protection Agency. Air pollution data for China came from the World Bank and China's State Environmental Protection Agency. Doug Almond graciously provided these data. Chinese water pollution data come from the World Bank; Avi Ebenstein graciously provided them.

Figure 2: Air Quality Monitors Across India

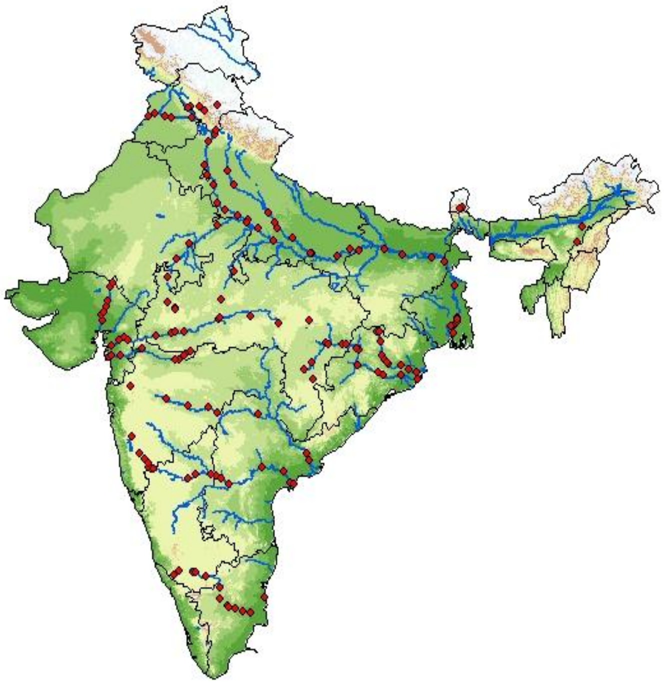


Notes:

1. Dots denote cities with monitoring stations under India's National Ambient Air Quality Monitoring Programme (NAAQMP).

2. Geographical data are drawn from MIT's Geodata Repository. Monitoring locations are determined from CPCB and SPCB online sources and Google Maps.

Figure 3: Water Quality Monitors on India's Major Rivers



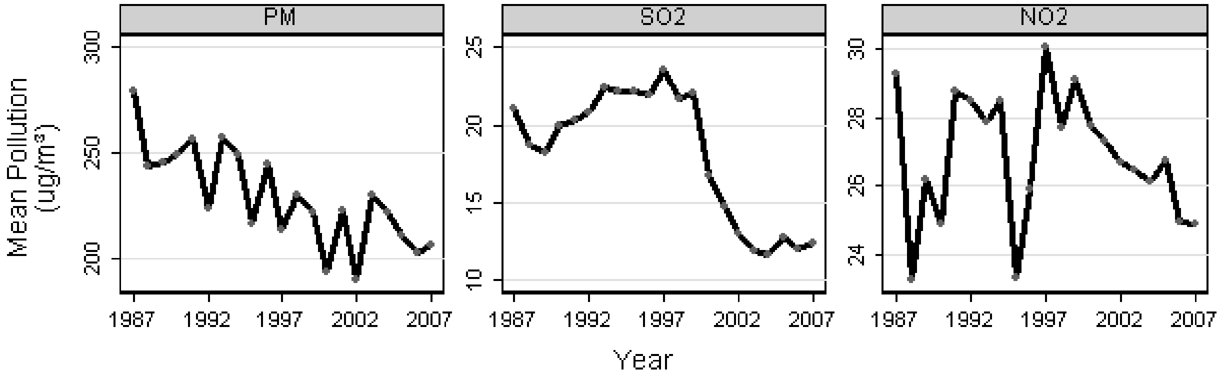
Notes:

1. Dots denote cities with monitoring stations under India's National Water Monitoring Programme (NWMP). Only cities with monitors on major rivers are included, as geospatial data for smaller rivers is unavailable.

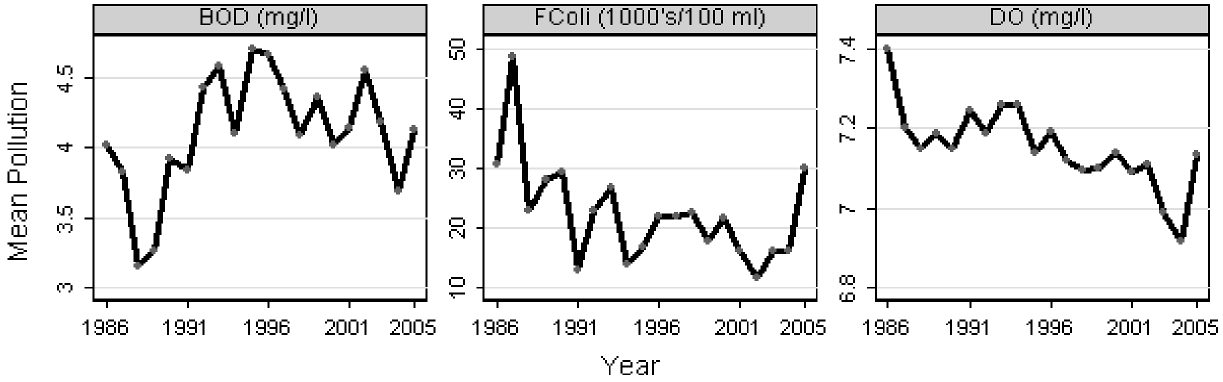
2. Geographical data are drawn from MIT's Geodata Repository. Monitoring locations are determined from CPCB and SPCB online sources and Google Maps.

Figure 4: Trends in Air and Water Quality

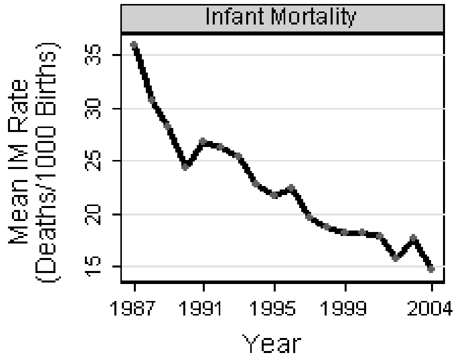
Panel A: Air Pollution



Panel B: Water Quality



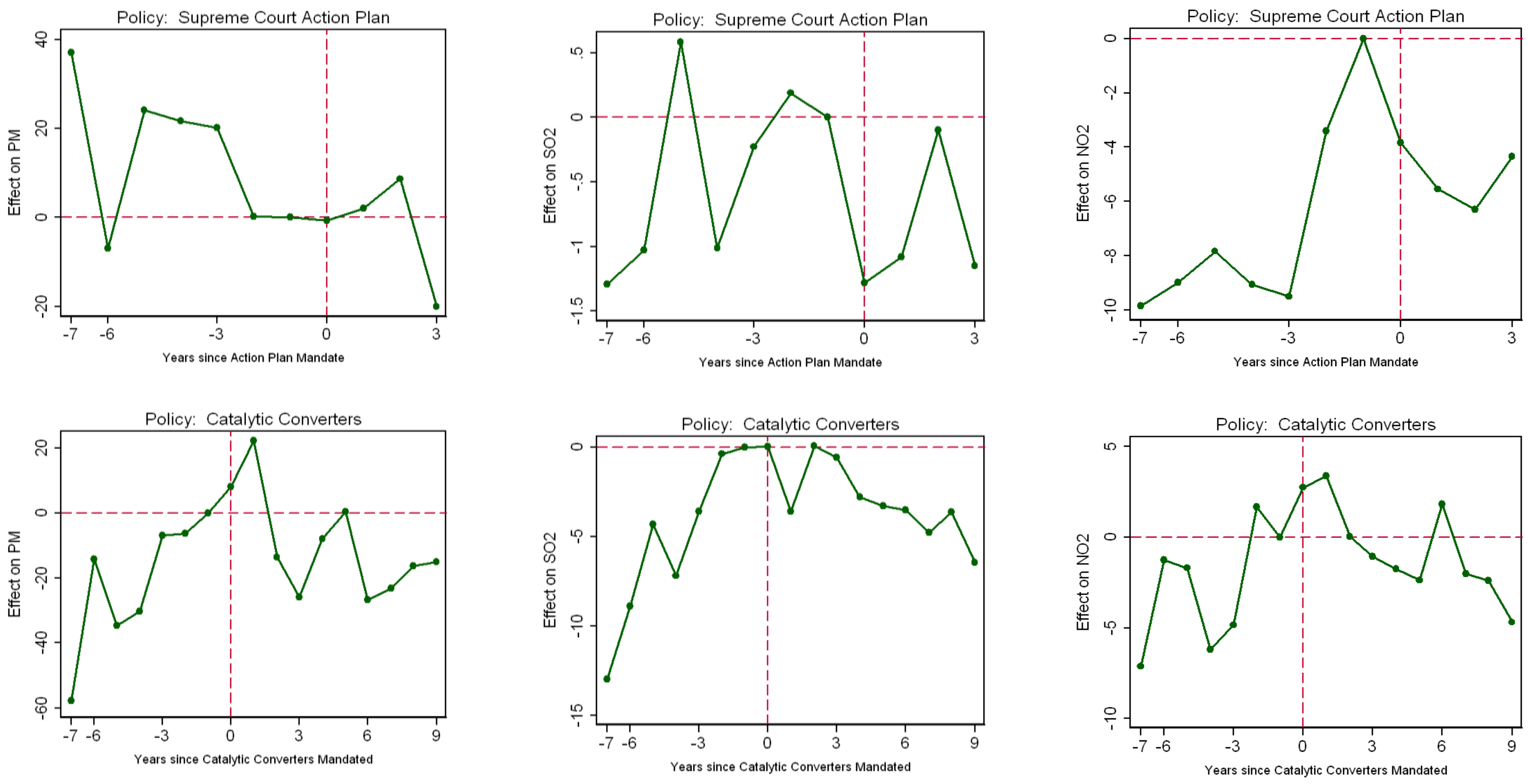
Panel C: Infant Mortality



Notes:

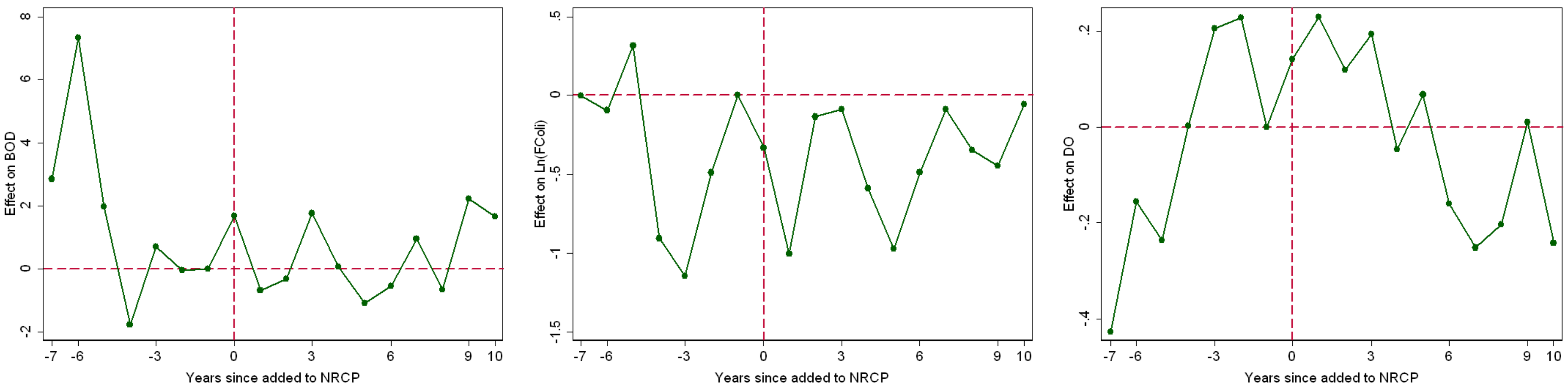
1. The figures depict annual mean pollution levels. There are no restrictions on the sample. Annual means are first taken across all monitors within a given city, and then across all cities in a given year.
2. Infant mortality data are restricted to those cities which have at least one air or water pollution measurement in the full sample.
3. Pollution data were drawn from Central Pollution Control Board's online and print sources. Infant mortality data were taken from the book *Vital Statistics of India* as well as various state registrar's offices.

Figure 5. Event Study of Air Pollution Policies


Panel A. PM *Panel B. SO2* *Panel C. NO2*

Notes: The figures provide a graphical analysis of the effect of the Supreme Court Action Plans and mandated Catalytic Converter policies on air pollution. The figures plot the estimated σ_τ's against the τ's from the estimation of equation (1). Each pair of graphs within a panel are based on the same regression. See the text for further details.

Figure 6. Event Study of Water Pollution Policy



Panel A. BOD

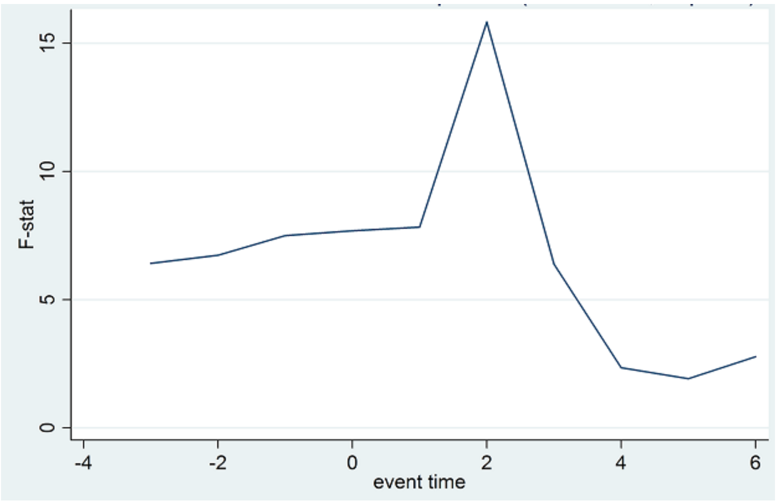
Panel B. Ln(Fcoli)

Panel C. DO

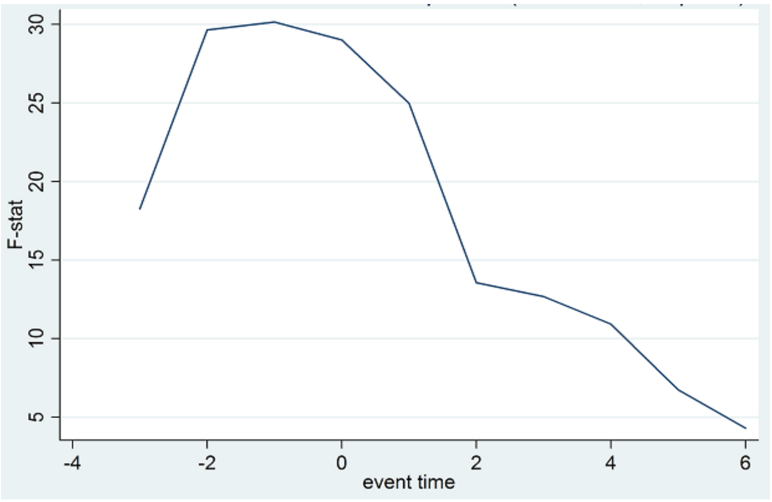
Notes: The figures provide a graphical analysis of the effect of the National River Conservation Plan policy on water pollution. The figures plot the estimated σ_τ's against the τ's from the estimation of equation (1). See the text for further details.

Figure 7: F-Statistics from QLR Test for Catalytic Converter Policies

Panel A: Particulate Matter



Panel B: SO



Panel C: NO

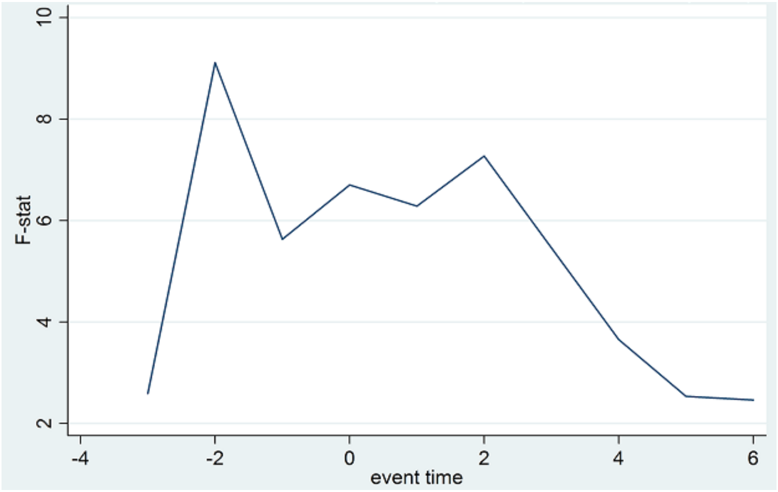
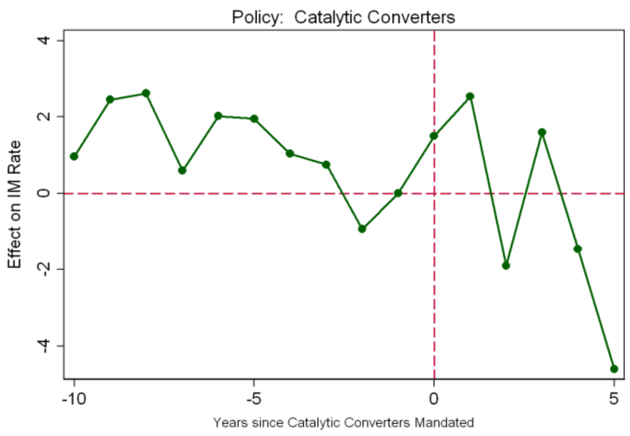
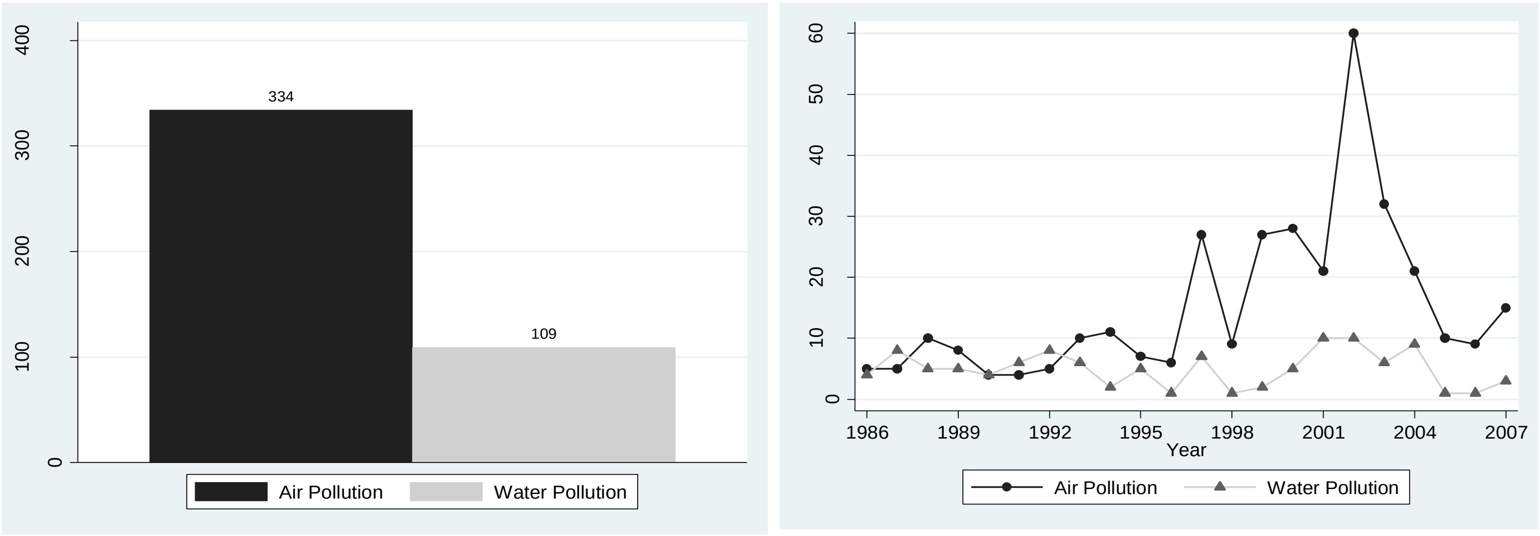


Figure 8. Event Study of Catalytic Converters and Infant Mortality



Notes: The figure provides a graphical analysis of the effect of the Catalytic Converter policy on the infant mortality rate. The figure plots the estimated σ_τ's against the τ's from the estimation of equation (1). See the text for further details.

Figure 9: Total Nationwide References to Air and Water Pollution in Times of India, 1986 – 2007



Source: Author Compilation from the Times of India

Appendix Table 1: Summary Statistics, by Year

	Panel A: Air Quality			*Panel B: Water Quality*			*Panel C: Infant Mortality*
Year	PM	SO$_2$	NO$_2$	BOD	Ln(Fcoli)	DO	IMR
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1986	--	--	--	4.0	6.1	7.4	--
	--	--	--	111	100	110	--
1987	279.3	21.0	29.3	3.8	6.5	7.2	35.9
	20	17	18	122	101	119	87
1988	243.6	18.7	23.2	3.2	6.3	7.2	30.6
	25	25	25	190	162	195	87
1989	245.7	18.2	26.2	3.3	6.7	7.2	28.2
	31	31	31	221	166	224	87
1990	249.1	19.9	24.9	3.9	6.6	7.2	24.4
	44	43	43	273	205	275	96
1991	256.2	20.3	28.8	3.8	5.6	7.2	26.9
	47	46	45	264	212	268	80
1992	223.5	20.9	28.5	4.4	6.1	7.2	26.2
	58	57	57	287	206	286	76
1993	257.2	22.5	27.9	4.6	5.9	7.3	25.3
	66	64	63	306	246	307	79
1994	249.3	22.2	28.5	4.1	5.7	7.3	22.8
	58	65	65	327	256	324	78
1995	216.0	22.2	23.3	4.7	5.1	7.1	21.8
	42	41	43	327	285	327	78
1996	244.9	21.9	25.9	4.7	4.9	7.2	22.3
	70	68	68	328	279	326	58
1997	213.6	23.6	30.0	4.4	4.9	7.1	19.6
	76	72	72	338	290	335	59
1998	229.8	21.7	27.7	4.1	4.9	7.1	18.7
	68	66	66	329	282	334	58
1999	221.5	22.1	29.1	4.4	4.9	7.1	18.2
	77	75	75	326	265	324	55
2000	193.5	16.7	27.8	4.0	4.9	7.1	18.1
	68	71	71	313	270	311	52
2001	223.0	14.7	27.3	4.2	5.1	7.1	17.8
	57	69	70	377	321	367	63
2002	189.4	13.0	26.7	4.6	5.2	7.1	15.7
	67	77	77	389	335	380	61
2003	230.3	11.9	26.5	4.2	5.1	7.0	17.6
	76	76	76	393	349	382	62
2004	221.4	11.6	26.1	3.7	5.1	6.9	14.6
	82	85	85	417	370	417	30
2005	210.6	12.7	26.7	4.1	5.9	7.1	--
	97	86	93	310	285	308	--
2006	202.9	12.0	25.0	--	--	--	--
	116	104	115	--	--	--	--
2007	206.7	12.4	24.9	--	--	--	--
	125	106	124	--	--	--	--

Notes:

1. The figures depict annual mean pollution levels. There are no restrictions on the sample. Annual means are first taken across all monitors within a given city, and then across all cities in a given year.

2. Number of city-year observations is reported below the mean in each year.

3. Units are ug/m^3 for all air pollutants; mg/l for BOD and DO; Ln(MPN/100 ml) for Fcoli; and Deaths per 1000 Births for infant mortality.

4. Pollution data were drawn from Central Pollution Control Board's online and print sources. Infant mortality data were taken from the book *Vital Statistics of India* as well as various state registrar's offices.

Appendix Table 2: Pollution Policy Coverage in India

	Air		*Water*
Year	Supreme Court Action Plans (1)	Catalytic Converters (4)	National River Conservation Plan (6)
1986	--	--	25
1987	0	0	25
1988	0	0	25
1989	0	0	25
1990	0	0	25
1991	0	0	25
1992	0	0	25
1993	0	0	25
1994	0	0	97
1995	0	0	160
1996	0	4	160
1997	0	4	160
1998	1	4	160
1999	1	49	160
2000	1	49	160
2001	1	49	160
2002	1	49	160
2003	12	49	160
2004	17	49	160
2005	17	49	160
2006	17	49	--
2007	17	49	--

Notes:

1. This table describes the incidence of each policy across all of India.
2. Policy data were drawn from a variety of sources that are detailed in the text.

Appendix Table 3: Distribution of Air and Water Policies, by Relative Year

	Air		*Water*
Relative Year	Supreme Court Action Plans (1)	Catalytic Converters (4)	National River Conservation Plan (6)
-17	1	0	0
-16	6	0	0
-15	6	0	0
-14	10	0	0
-13	12	0	0
-12	12	0	0
-11	11	5	0
-10	14	8	0
-9	13	10	13
-8	10	19	14
-7	15	20	26
-6	16	22	30
-5	16	23	37
-4	16	18	37
-3	16	18	41
-2	16	26	39
-1	16	26	36
0	16	20	42
1	15	26	42
2	16	24	42
3	16	19	39
4	11	22	43
5	1	25	43
6	1	24	43
7	1	24	39
8	1	24	42
9	1	24	39
10	1	4	38
11	0	4	11
12	0	4	11

Notes:

1. This table describes the prevalence of policies in the dataset by year *relative to policy uptake* . Thus, a value of '-17' in the first column signifies '17 years before a policy is implemented'. We use relative year ('tau') as the year variable in event study regressions and figures.
2. Cities which enact a policy are subjected to the same inclusion rules as in event study analysis. That is, a city is only included here if it has at least one pollution data point 3 years or more before policy uptake as well as at least one data point 4 years or more after policy uptake.
3. In this table, a city is counted if it has *any* pollution data in that year. In analyses, a city is only used if it has pollution data for the specific dependent variable in a given regression. Thus, the above city counts must be interpreted as maximums among our regressions. Most city-years have available data for all pollutants studied here.
4. Since infant mortality data is only available up to the year 2004, the table above is not representative for analysis which uses infant mortality as the dependent variable.
5. Policy data are drawn from a variety of sources detailed in the text.

Appendix Table 4: Robustness Checks with Varying Taus

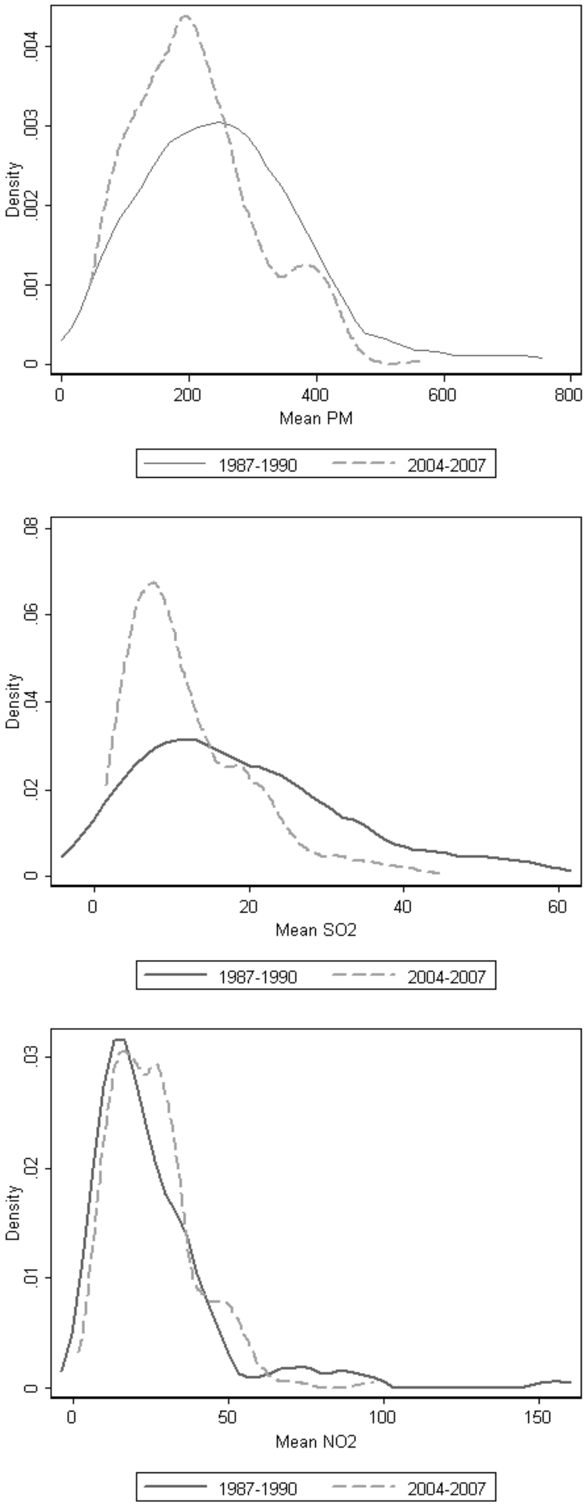
	Narrow Tau Range			Wide Tau Range		
	(1)	(2)[2]	(3)[2]	(4)	(5)[2]	(6)[2]
Panel A. Supreme Court Action Plans						
	PM	SO	NO	PM	SO	NO
5-Year Effect	23.6	-0.5	-20.8***	-61.2**	1.4	-4.1
p-value	0.38	0.88	0.00	0.01	0.62	0.22
N	9	9	9	19	19	19
		[2]	[2]		[2]	[2]
Panel B. Catalytic Converters						
	PM	SO	NO	PM	SO	NO
5-Year Effect	-54.1*	-9.2*	-6.5	-30.0	-14.9***	-3.2
p-value	0.09	0.08	0.27	0.17	0.00	0.32
N	11	11	11	19	19	19
Panel C: National River Conservation Plan						
	BOD	Ln(Fcoli)	DO	BOD	Ln(Fcoli)	DO
5-Year Effect	2.0	0.1	-0.4	15.5***	1.3	-0.4
p-value	0.56	0.94	0.19	0.00	0.11	0.21
N	11	11	11	22	22	22

Notes:

1. This table provides robustness checks for the prefereed econometric specification (Equation 2c).

2. Note that for the Supreme Court Action Plan, Narrow Tau Range, the effect is calcuated at 4 years out (rather than 5 years) due to limited data

Appendix Figure 1A: Kernel Density Graphs of Air Quality



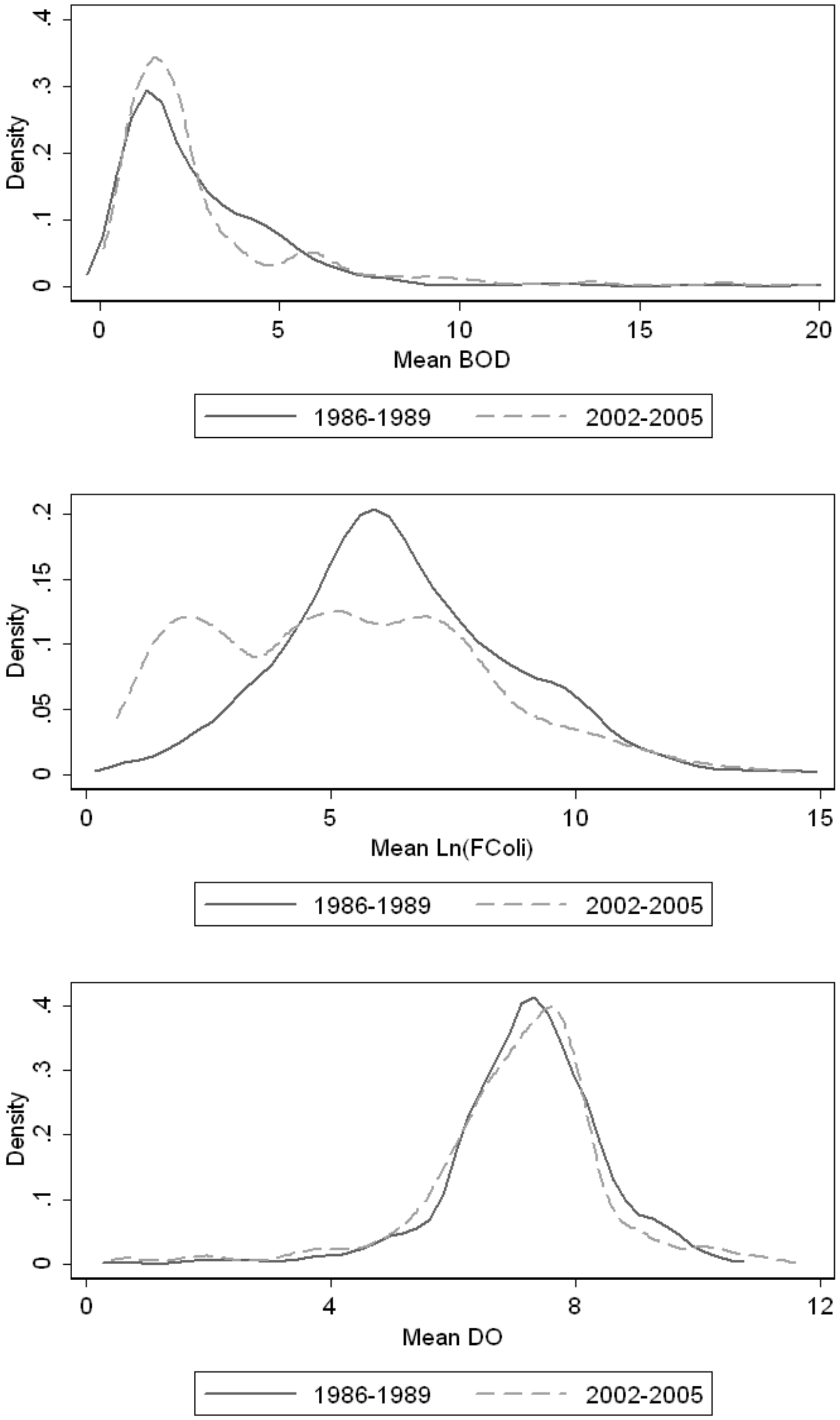
Notes:

1. The graphs provide the distribution of air pollution for the early (1987-1990) and later (2004-2007) periods of our sample. They are constructed using an Epanechnikov kernel function.

2. Units are µg/m³ for all pollutants.

3. The data were drawn from Central Pollution Control Board's online and print sources.

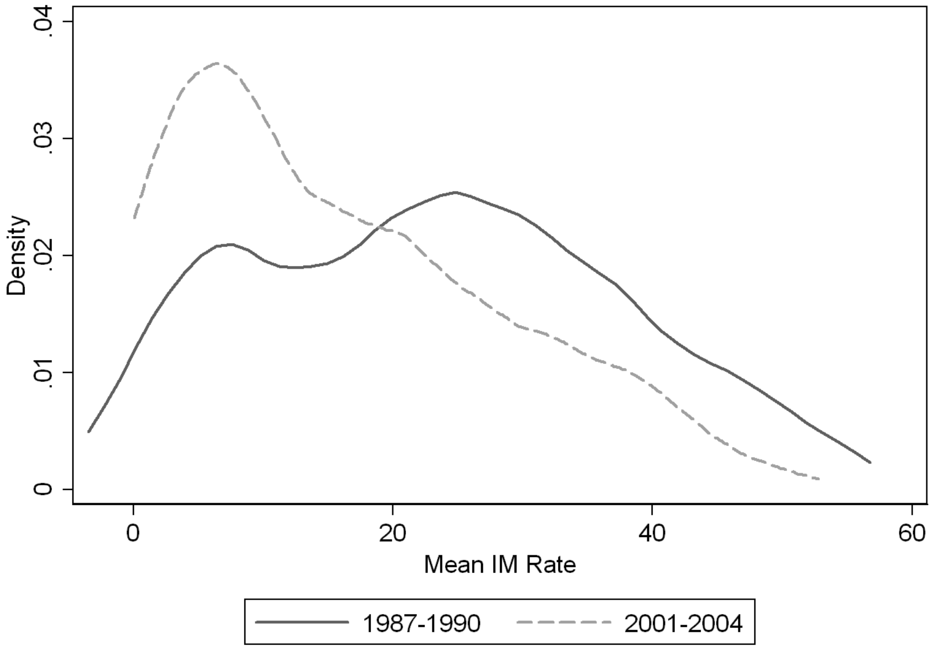
Appendix Figure 1B: Kernel Density Graphs of Surface Water Quality



Notes:

1. The graphs provide the distribution of water pollution for the early (1986-1989) and later (2002-2005) periods of our sample. They are constructed using an Epanechnikov kernel function.
2. Units are mg/l for BOD and DO, and Ln(MPN/100 ml) for FColi.
3. The right tail of the BOD distribution extends to 100 mg/l but is truncated to provide a more detailed picture of the distribution.
4. The data were drawn from Central Pollution Control Board's online and print sources.

Appendix Figure 1C: Kernel Density Graphs of Infant Mortality



Notes:

1. The graph provides the distribution of infant mortality for the early (1987-1990) and later (2001-2004) periods of our sample. They are constructed using an Epanechnikov kernel function.

2. Infant mortality data are restricted to those cities which have at least one air or water pollution measurement in the full sample.

3. Units of infant mortality rate are Deaths per 1000 Births.

4. The right tail of the IM distrbution extends above 100 but is truncated to provide a more detailed picture of the distribution.

5. The data were drawn from the book *Vital Statistics of India* as well as various state registrar's offices.