Harnessing transparency initiatives to improve India's environmental clearance process for the mineral mining sector

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Note to readers

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Executive Summary

This project aims to evaluate the 2006 environmental clearance reforms in India. The Environmental Clearance (EC) process, which requires all major capital investment projects by the private sector or government to seek regulatory approval prior to beginning construction, is the centerpiece of environmental regulation of development in India. While the EC process applies across sectors of the economy, it plays a particularly important role in oversight of the mining sector, where environmental impacts are diffuse and diverse.

In this paper, we pursue two objectives. First, we seek to provide proof of concept for the use of remote-sensing data to monitor mines' environmental compliance. We match a wide set of publicly-available administrative data on mines' clearance applications with satellite data on pollution and vegetation coverage to show how these free, publicly-available data can supplement regulators' site visits in a low-resource environment like India. Using these data, we measure mines' environmental performance as the change in environmental conditions from two years pre-clearance to two years post-clearance. One particular methodological innovation is that we identify the timing of deforestation at individual mines using structural breaks in a time series of vegetation coverage, allowing us to assess compliance with the requirement that mines break ground only after receiving clearance. In a low-resource environment like India, remote-sensed data on environmental outcomes may provide low-cost tools to supplement more expensive forms of monitoring by regulators, like site visits to mines. In India's clearance process, satellite-based tools could be useful both in assessing sites for clearance during the application process and in monitoring compliance with post-clearance conditions.

Next, we use our broad data repository to evaluate the impacts of a set of substantial reforms to the EC process enacted in 2006. These reforms sought to bring greater transparency and accountability to the EC process by subjecting larger projects to additional scrutiny from regulators, independent experts, and the public. The reforms required projects to seek site-specific Terms of Reference (ToRs) for their environmental impact assessments, decentralized smaller projects to state-level clearance bodies, and established expert clearance bodies at both the state and central levels to review clearance applications. We provide suggestive evidence of the impacts of the overall reforms: first, we find that mine proponents appear to have shifted to smaller mine sizes to avoid a costly reform, and next, that mines that applied for clearance after the reform experienced substantially shorter clearance but were more likely to deforest illegally before receiving clearance.

Besides providing descriptive evidence on the impacts of the overall reforms, we use a historical discontinuity in clearance requirements to evaluate one crucial aspect of reform: an expanded requirement that mines hold a public hearing before applying for clearance. A large body of qualitative work suggests that public consultation may be a key component of an effective environmental clearance process (Nadeem and Hameed, 2008). However, we are aware of no prior quantitative work evaluating the impact of public hearings. We evaluate the impact of embedding public hearings in the EC process by exploiting a discontinuity in the historical clearance process for mines at an area of 25 ha. While mines of area above 25 ha were required to hold public hearings under the historical clearance process, mines of area under 25 ha were first required to hold hearings after the 2006 clearance notification. For mines of area above and below the 25 ha cutoff, the only differential change in the EC process around the date of the 2006 notification is the additional requirement of a public hearing for mines under 25 ha. Therefore, we can evaluate the impact of public hearings by estimating a difference-in-difference model comparing mines of area below and above 25 ha that applied before and after the 2006 reform notification. Broadly, we seek to estimate the impact of the expanded public hearing requirement on the costs and benefits of the clearance process. In particular, we measure costs of clearance to mines as the self-reported total mine costs and duration of the EC process, though this measure captures only the period after mines complete the public hearing and submit all materials to the Ministry of Environment, Forests, and Climate Change (MoEFCC). We quantify the benefits of the clearance process as mines' environmental performance, which we proxy as air pollution, water pollution, and extent of vegetative coverage using our remote sensing data.

We find no evidence that the additional public hearing requirements under the 2006 reforms significantly altered either the costs or benefits of the environmental clearance process. We find some significant time trends around the date of the notification: mines that applied for clearance after the 2006 notification experienced about 31% shorter EC duration, were 19 percentage points more likely to illegally deforest before the date of clearance, and had significantly lower increases in some measures of water pollution around the date of clearance. Note that we cannot interpret these times trends as the causal impact of the 2006 EC notification. However, we do not find that the imposition of the public hearing requirement on treatment mines significantly altered any of these time trends, so we can attribute no significant impacts to public hearings.

Why do we fail to find significant results for the impact of public hearings? First, it is important to note that our empirical strategy restricts us to evaluating the relatively short-term impacts of the reformed process, and that we may be limited by low power due to our small sample. Our analysis is also limited in that some of our measures of clearance costs and benefits are imprecisely measured: our measure of clearance duration does not include the public hearing period, mine costs are self-reported and are subject to extensive rounding, and our measures of water quality are often drawn from monitors at a significant distance from mines. Finally, public hearings could have benefits that our data cannot capture. While we have the data to evaluate mines' environmental performance, for example, we lack the data to evaluate the impact of hearings on other potential benefits, like local employment or investment in local infrastructure.

However, our null results could also reflect real weaknesses either in the legislative provisions or implementation of the public hearing requirement. While the EC notification includes a set of requirements designed to ensure that public hearings are informative and accessible, like requiring mines to publicly post the mine's draft Environmental Impact Assessment (EIA) report thirty days in advance, anecdotal evidence suggests that mines frequently fail to comply with these requirements. While we cannot test the claim that these shortfalls in implementation account for the null impacts of public hearings on environmental conditions, strengthening mines' compliance with hearing protocol may help ensure that the public hearings offer a platform for substantive public engagement.

Finally, our extensive data collection process has produced important insights for the role of data in monitoring mines in India. As we have already noted, our analysis has highlighted the potential gains from using free satellite data to measure mines' environmental compliance in a low-cost environment like India. Our work has also highlighted the importance of better synthesizing publicly available data on mines. Within the Indian government, both the Indian Bureau of Mines (IBM) and MoEFCC regulate mining and publish records on mining leases and clearance applications, respectively, but their records are unlinked. Establishing a central mining database that linked mines in IBM and MoEFCC's systems would enable more meaningful public scrutiny of mines throughout their lifetimes, from EC and lease application to mine closure.

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List of Abbreviations

EC	Environmental clearances
MoEFCC	Ministry of Environment, Forests, and Climate Change
EIA	Environmental Impact Assessment
ToR	Terms of reference
EAC	Expert Appraisal Committee
SEAC	State Expert Appraisal Committee
SEIAA	State Environmental Impact Assessment Authority
IBM	Indian Bureau of Mines
SPCB	State Pollution Control Board
BOD	Biochemical oxygen demand
EVI	Enhanced Vegetation Index
NGT	National Green Tribunal

1. Introduction

Alongside dramatic imagery of urban air pollution in cities like Delhi and Beijing, a growing focus on environmental health in economics and epidemiology has prompted a reexamination of environmental policy in many rapidly industrializing countries. The *Lancet* Commission on Pollution and Health estimates that 9 million premature deaths in 2015 were attributable to air, water, and soil pollution globally, with a cost of USD 4.6 trillion, or more than 6 percent of the world's gross domestic product (Landrigan et al., 2018). The study cites about 2.5 million premature deaths from pollution in India alone, the most of any country.

The primary challenge of mitigating the costs of rapid industrial development on health and the environment in India, as in many other low and middle income countries like it, is not in establishing new policies, but rather in implementing existing policies. In the 1970s and 1980s, India adopted a strong policy framework for controlling air and water pollution, forest clearing, and land use change. However, as India's development has accelerated in the last 25 years, enforcement capacity in its main pollution control institutions has been outpaced by the growth of polluting activities (Duflo et al., 2013). Greenstone et al. (2015) presents evidence on the magnitude of this implementation gap and the consequences for human health, finding that reducing ambient air pollution levels to those specified in current law would increase life expectancy by at least 3.2 years of life for 660 million people living in the heavily polluted north of India. While improving the capacity of India's environmental regulatory institutions to carry out conventional monitoring and enforcement strategies requires long-term structural changes, transparency initiatives that provide public access to detailed information about industrial activities present a low cost channel for potentially improving the accountability of polluting firms.

The Environmental Clearance (EC) process, which requires all major capital investment projects by the private sector or government to seek regulatory approval prior to beginning construction, is the centerpiece of environmental regulation of development in India. The crux of the EC process is an Environmental Impact Assessment (EIA), an evaluation of likely effects arising from development projects (Jay et al., 2007). Today, EIA-based clearances processes are a fixture of environmental regulation worldwide. The modern EIA was first instituted in the United States with the National Environmental Policy Act of 1969, which required all federal government agencies to “include in every recommendation for major Federal actions significantly affecting the quality of the human environment, a detailed statement on ... the environmental impact of the proposed action” (Section 102(2)(c)). Following its introduction in the US, the EIA process was codified into requirements of European Communities member states in the mid-1980s, and the World Bank ruled in 1989 that EIA should be done for all borrower country projects under Bank supervision. Other donor agencies, like the Asian Development Bank and OECD, have since followed suit. In total, EIA regulations exist today in more than 100 countries worldwide (Jay et al., 2007).

EIA regulations were established in most Asian countries during the 1980s and 1990s. India enacted its initial EC process in 1986. A few Asian countries, like Myanmar, still have no official EIA regulations in place, while some, like Japan, Hong Kong, and Korea, have robust EIA systems set within a broader environmental planning framework (Wood, 2003). Broadly, environmental clearance processes worldwide take the following steps: (i) screening, or filtering projects into EC processes of varying stringency; (ii) scoping, or determining the set of environmental risks that the EIA report should consider; (iii) preparation of the EIA report; and (iv) official review of the EIA report and decision to either grant or deny an environmental clearance.

In 2006, India enacted a set of key reforms that sought to bring greater transparency and accountability to the EC process by subjecting larger projects to additional scrutiny from regulators, independent experts, and the public. The reforms required projects to seek site-specific Terms of Reference (ToRs) for their environmental impact assessments, decentralized smaller projects to state-level clearance bodies, and established expert clearance bodies at both the state and central levels to review clearance applications. One key provision of the 2006 reforms was to institute a requirement that all projects hold a public hearing after undertaking the EIA and before submitting their clearance application to the ministry. Previously, only large projects had been required to hold a public hearing.

By increasing the scope for public scrutiny of projects, this expanded public hearing requirement help to bring much-needed transparency to the EC process. Indeed, previous work on environmental clearances processes suggests that public involvement may be key to an effective clearance process (Nadeem and Hameed, 2006). Many developed countries incorporate public comments into both EIA drafting and review, and a growing number of developing countries, like India, require that project proponents hold public hearings during the EIA review process (Ahmad and Wood, 2002). In theory, public consultation could improve environmental and social performance at development programs by making project proponents accountable to people. However, simply holding public hearings may not be sufficient to ensure that the public has the opportunity to push for better and cleaner development projects. Several reviews of EIA systems caution that public comment periods are often inaccessible and ineffective in developing countries (Zubair, 2001). In Pakistan, for example, Nadeem and Hameed (2008) write that public hearings on EIAs are often held at fancy hotels in the city, far from those who will actually be affected by the project. In Colombia, public participation is only elicited for projects that directly impact land inhabited by indigenous people (Toro, 2010). Bisset (2000) summarizes the obstacles to effective public consultation in low-income countries: illiteracy, linguistic diversity, gender norms that limit women’s participation, geographic remoteness, and a lack of knowledge on the scale and likely impacts of various development projects.

In this paper, we evaluate the impact of this expanded public hearing requirement in environmental clearances within India's mining sector. A transparent EC process may play a particularly important role in oversight of the mining sector, where environmental impacts tend to be diverse and diffuse. Mines' remote locations make frequent in-person monitoring by regulators prohibitively costly, unlike manufacturing or power generators in accessible industrial clusters. Furthermore, frequent land conflicts spurred by mining may make public consultation particularly important in the mining sector (Rights and Resources, 2016). Thus, we focus our analysis on the role of public hearings for India's the mining sector.

We evaluate the impact of embedding public hearings in the EC by exploiting a discontinuity in the historical clearance process for mines at an area of 25 ha. While mines of area above 25 ha were required to hold public hearings under the historical clearance process, mines of area under 25 ha were first required to hold hearings after the 2006 clearance notification. For mines of area above and below the 25 ha cutoff, the only differential change in the EC process around the date of the 2006 notification is the additional requirement of a public hearing for mines under 25 ha. Therefore, we can evaluate the impact of public hearings by estimating a difference-in-difference model comparing mines of area below and above 25 ha that applied before and after the 2006 reform notification. We seek to evaluate the impact of public hearings on the costs of the environmental clearance process, measured as mine costs and process duration, and on mines' environmental performance.

We find no evidence that the expanded public hearing requirement significantly increased clearance costs to mines. First, while mines that applied after the 2006 EC reforms had about 31% shorter post-EIA duration than did those that applied after the 2006 reforms, we do not find that the public hearing reform significantly altered either clearance duration or mines' stated total costs. Furthermore, we find no evidence that the public hearing requirement significantly altered mines' environmental performance or compliance. While mines that applied for clearance after the 2006 notification deforested about 1.3 years earlier relative to their date of clearance and were 19 percentage points more likely to illegally deforest before receiving clearance, there was no differential change for mines newly under the public hearing requirement. Similarly, we find no evidence that the public hearing requirement altered air or water pollution at mine sites. While we find that nearby biological oxygen demand increased by less after clearance in mines that applied after the 2006 notification, we find no evidence that the public hearing requirement altered mines' air or water pollution.

Overall, while we document that mine outcomes changed significantly around the date of the 2006 EC reform, we find no evidence that the public hearing requirement significantly altered either mine costs or environmental performance. Why do we fail to find significant impacts? First, our null results may also reflect real weaknesses in implementation of the public hearing requirement. Indeed, while the 2006 reforms included broad guidelines to ensure that the hearings are accessible and informative to the public, anecdotal evidence suggests that proponents often fail to comply with these requirements. The hearings may be held at inaccessible locations or times, for example, offering only a symbolic opportunity for consultation. Next, our empirical strategy allows us only to evaluate the short-term impacts of the expanded public hearing requirement, so we may be failing to identify longer-term impacts.

Besides offering the first rigorous evaluations of the 2006 clearance reforms, our report offers a novel contribution by introducing and validating a set of satellite-based monitoring tools for environmental compliance. In particular, we use remote sensing data to measure air pollution and deforestation at mine sites, as well as water pollution in nearby rivers. One particular methodological innovation is that we identify the timing of deforestation at individual mines using structural breaks in a timeseries of vegetation coverage, allowing us to assess compliance with the requirement that mines break ground only after receiving clearance. In a low-resource environment like India's environmental monitoring, remote-sensed data on environmental outcomes could provide low-cost monitoring tools to supplement more expensive monitoring site visits at mines. We provide simple proof of concept for these monitoring tools.

Our analysis has shifted substantially since initially designing a pre-analysis plan. We first explored a partnership with the Gujarat Pollution Control Board based on two interventions: providing regulators with remote sensing-based tools to monitor environmental outcomes and improving transparency by creating a publicly accessible website with detailed information on particular mining projects. Subsequently, we pursued a partnership with the Ministry of Mines to evaluate the ministry's new star rating program, which grants mines ratings based on environmental conditions. However, the turnover of the Secretary of Ministry of Mines earlier this year has made it clear that this partnership will not develop soon enough to allow us to proceed. Thus, we shifted our focus to secondary data-based analysis of the 2006 EC reforms, the most substantial overhaul of India's clearance system since its initiation. While the methodology of our study has shifted from a randomized evaluation to secondary data analysis, however, our project has remained focused on the impact of transparency reforms and the role for satellite-based data tools in monitoring environmental compliance at mines.

The report is organized as follows. Section 2 details the environmental clearance process and 2006 reforms, presents our research hypotheses, and describes the theory of change structuring our empirical analysis. Section 3 situates our analysis in the context of India’s mining sector. Section 4 details the timeline of the 2006 EC reforms. Section 5 describes our identification strategy, data collection process, and sample. Section 6 presents the results of our empirical analysis, including a series of robustness checks and extensions. Section 7 presents policy recommendations and concludes.

2. Intervention, theory of change, and research hypotheses

2.1 The Environmental clearance process in India and the 2006 reforms

The environmental clearance (EC) process, which requires all development projects to seek regulatory approval before breaking ground, is the centerpiece of environmental regulation in India. The initial EC process, instituted in 1994, required all mines larger than 5 ha to apply for clearance at the central level. Mines would prepare an environmental impact assessment (EIA) based on a standardized set of Terms of Reference (ToRs), would hold a public hearing for mines of area over 25 ha, and would then submit the EIA and public hearing report to MoEFCC. MoEFCC would grant or deny clearance, seeking expert input where necessary.

In 2006, a notification by the Ministry of Environment and Forests dramatically overhauled this process, requiring more scrutiny of the projected environmental and social impacts of projects and greater transparency in the approval process. The reforms decentralized the EC process into a two-tiered system where larger projects (known as Category A) pass through a central process and smaller projects (known as Category B) pass through parallel state-level processes. Within the mining sector, mines with lease areas of 50 hectares or more are considered Category A projects, while mines of area between 5 and 50 hectares are considered Category B projects.[1]

As part of this decentralization, the 2006 EC reforms convened central- and state-level clearance bodies that are responsible for reviewing EC applications; these review bodies are known as Central and State Expert Appraisal Committees (EACs) and they are appointed by MoEFCC (Ghosh, 2013). For Category A applications, EACs comprised of representatives from industry, civil society, and academia consider applications on a monthly basis and issue recommendations to MoEFCC, which makes the final decision to approve or deny a clearance. An EAC is formed for each sector, and the EACs work independently of MoEFCC (Ghosh, 2013). For Category B applications, State Expert Appraisal Committees (SEACs) consider applications, which the State Environmental Impact Assessment Authorities (SEIAAs) then approve or reject. The SEIAAs consist of a Chairperson, Member, and Member Secretary appointed by the state government and approved by MoEF. In some cases, the Member Secretary of the State Pollution Control Board may serve as a Member of the SEIAA.

The 2006 EC reforms also increased the stringency of the EC process by requiring that all Category A and B mines apply for mine-specific Terms of Reference (ToRs) before undertaking the EIA. Finally, all Category A and B mines are required to hold public hearings after completing the EIA and before submitting the application to the ministry for clearance consideration. Our analysis focuses on this requirement for public hearings. In sum, the reformed EC application process takes the following five steps:

1. **Application to MoEFCC or SEIAA.** The project proponent files an application consisting of basic information about the project (Form 1), a pre-feasibility report, and a proposed Terms of Reference (ToR) for the EIA.
2. **Scoping for determination of ToR.** The EAC or SEAC drafts the ToR based on the project characteristics and the proposed ToR, meeting to finalize the ToR.
3. **EIA study and public consultation.** The project proponent undertakes the EIA and submits a draft to the relevant State Pollution Control Board (SPCB), which organizes a public hearing and invites written comments from the public.
4. **Project appraisal by EAC or SEAC**. Project proponent files final EIA and Environmental Management Plan to MoEFCC or SEIAA. EAC or SEAC consider final proposal and make recommendation to MoEFCC or SEIAA to either grant or reject the clearance.
5. **Grant or reject EC.** MoEFCC or SEIAA can either grant or reject EC or request that EAC or SEAC reconsider its recommendation. MoEFCC or SEIAA makes final decision.

When the MoEFCC or SEIAA grants clearance, it assigns cleared projects a set of specific and general conditions with which they are legally bound to comply. The conditions for a limestone mine cleared in Chhattisgarh in 2014 include monitoring nearby groundwater levels and planting a green barrier around the mine's periphery, for example. After clearance, project proponents

[1] Initially mines less of than 5 hectares, which comprised about 70 percent of new mines between 1990 and 2013, were not subject to EC. In 2012, the Supreme Court ruled that EC applied to all mines, and mines of area under 5 ha have sinced been required to seek approval through state-level processes.
http://www.downtoearth.org.in/news/regulating-smallscale-mines-below-5-ha-41892

must submit bi-annual reports detailing compliance with these conditions to MoEFCC or SEIAA. These reports are available to the public by request and should be posted online by either MoEFCC or SEIAA. To our knowledge, mines are not required to hire external contractors to produce these compliance reports, and in practice many mines fail to submit compliance reports.

Figure 1 below summarizes the provisions of the 2006 reforms across categories of mines by size and over time. As the figure indicates, the reforms were only partially implemented during an interim period immediately following the September 2006 reform notification. Please see Section 4 for more details on the timeline of the 2006 reforms.

Figure 1. Schematic summary of regulatory changes of the 2006 EC notification

<table>
<tr><th colspan="4">Regulatory changes of the 2006 EC notification</th></tr>
<tr><th>Mine area</th><th>Pre-notification</th><th>Interim period: 9/14/06-9/13/07*</th><th>Post-notification</th></tr>
<tr><td>5-25 ha</td><td>-Applicant completes EIA based on standardized ToRs
-Applicant submits EIA to MoEFCC
-MoEFCC considers the application, consulting with experts if necessary, and grants or denies clearance</td><td rowspan="2">Category B project:
-In absence of SEIAA and SEAC, cleared by central-level EAC and MoEFCC
-Broadly, MoEFCC has discretion in applying revised EIA rules
-Applicant may receive mine-specific ToRs from EAC
-Applicant completes draft EIA
-Applicant holds a public hearing
-EAC may consider the application and recommend it for clearance, deferral, or rejection
-MoEFCC makes a final decision to grant or deny clearance</td><td rowspan="2">Category B project:
-SEAC issues mine-specific ToRs
-Applicant completes draft EIA
-Applicant holds a public hearing
-SEAC considers the application and recommends it for clearance, deferral, or rejection
-SEIAA makes a final decision to grant or deny clearance</td></tr>
<tr><td>25-50 ha</td><td>-Applicant completes EIA based on standardized ToRs
-Applicant holds a public hearing
-Applicant submits EIA and public hearing records to MoEFCC
-MoEFCC considers the application, consulting with experts if necessary, and grants or denies clearance</td></tr>
<tr><td>> 50 ha</td><td>-Applicant completes EIA based on standardized ToRs
-Applicant holds a public hearing
-Applicant submits EIA and public hearing records to MoEFCC
-MoEFCC considers the application, consulting with experts if necessary, and grants or denies clearance</td><td>Category A project:
-May receive mine-specific ToRs from EAC
-Broadly, MoEFCC has discretion in extent to apply revised EIA rules
-Applicant completes draft EIA
-Applicant holds a public hearing
-EAC may consider the application and recommend it for clearance, deferral, or rejection
-MoEFCC makes a final decision to grant or deny clearance</td><td>Category A project:
-EAC issues mine-specific ToRs
-Applicant completes draft EIA
-Applicant holds a public hearing
-EAC considers the application and recommends it for clearance, deferral, or rejection
-MoEFCC makes a final decision to grant or deny clearance</td></tr>
</table>

*Note: While the interim period is mandated to end on September 13, 2007, Category B projects continued to be processed by MoEFCC at the central level until their corresponding state clearance bodies (SEAC and SEIAA) had been established. Our sample includes all Category B projects cleared at the central level before their state's SEAC and SEIAA were established.

2.2 Public hearings in the EC process

We focus our evaluation on one key aspect of the 2006 EC reforms: the expanded requirement that all mines of area above 5 ha hold a public hearing. During step 3 of the clearance process outlined above, the applicant is required to seek "the concerns of local affected persons and others who have plausible stake in the environmental impacts of the project or activity" (MoEFCC, 2006). This public consultation requirement is designed to provide an official channel for the public to have input on the evaluation and mitigation of social and environmental risks associated with mines before their development. Many point to the public hearing requirement as one of the most central aspects of the 2006 reforms in that it opens up the only valve for public participation in regulation of a sector where public and private interests often do not align. Indeed, conflicts between mining projects and the local community are common and a common cause of delays to development of projects (Rights and Resources, 2016). Mohan and Pabreja (2016) write that the public hearings are the link between the EC process and “democratic participatory governance,” “sustainable development,” and “natural justice” for citizens.

Mine proponents are required to consult with the public via two channels: holding a public hearing near the site of the mine and eliciting written comments from other stakeholders. The mine proponent begins the public consultation process by submitting a written request to the relevant State Pollution Control Board (SPCB) to hold a public hearing. Along with the request, they must provide at least 10 hard copies and electronic copies of the draft EIA report to the SPCB, with a summary given both in English and in the local language. The mine proponent must also forward copies to MoEFCC and to various district-level and regional authorities. Each of these authorities must make the draft EIA public until the public hearing is finished. Similarly, MoEFCC must display the summary of the draft EIA on its website and must have a physical copy of the full report available in its office in Delhi.

Next, the SPCB sets a date and venue for the public hearing within seven days of receiving the project proponent's request. The 2006 notification requires that the hearing be held in “close proximity district-wise,” but we are aware of no more specific regulations on the hearing location. SPCB must advertise the hearing date in one major national newspaper and one regional local language paper with at least 30 days of notice. The hearing itself must be overseen by the District Magistrate, District Collector, or Deputy Commissioner, assisted by a representative of SPCB. After a representative for the project proponent describes the project and the EIA report, everyone present is allowed to ask for clarifications on the project and to give opinions. The public hearing should cover the content of the EIA, which must include a description of the project size, location, baseline environmental characteristics, anticipated environmental impacts and mitigation measures, and social costs and benefits, including any plans for relocation of villagers, improvements in physical infrastructure, and local employment.

The SPCB representative both videotapes the hearing and compiles a written summary of its proceedings. After reading this summary aloud, the District Magistrate signs it and then forwards it to the relevant SPCB; SPCB then passes this summary to MoEFCC for consideration in the project's clearance deliberation. This summary must be translated into both English and the local vernacular and must be displayed by local authorities, district authorities, and by SPCB. In total, the hearing must be completed within 45 days of the project proponent's initial request. The mine proponent must address all concerns raised during the consultation process in revising the draft EIA; the proponent then submits the final EIA report to the MoEFCC for the clearance appraisal process.

In practice, anecdotal evidence suggests that public hearings have provided an imperfect channel for consultation in the clearance process. News coverage suggests that public hearings are often held purely as a formality, with little provision for meaningful engagement by the public.[2] In particular, project proponents may hold the hearings at inconvenient locations or times, may neglect to provide the public with the draft EIA before the hearing, or may fail to substantively incorporate public feedback into the final EIA or project design (Mohan and Pabreja, 2016). In *Jeet Singh Kanwar v. Union of India* (2011), for example, villagers sought to overturn clearance for a thermal power plant on the basis that the project proponent had "flouted" the public consultation requirement. The villagers argued that the EIA summary had been made available in English only one week before the hearing, instead of being made available in both English and the local vernacular 30 days in advance, that the summary of proceedings was not read out to the public, and that the hearing was held 8 km from the project site, precluding many from attending.

In *Adivasi Majdoor Kisan Ekta Sangthan v. MoEF* (2011), villagers contested the environmental clearance of a coal mine and washery in Chhattisgarh on similar grounds. Besides arguing that the hearing was held in a remote and inconvenient location, the appellants claimed that the mine proponent failed to make the summary draft EIA available online or in person in the district official's office and failed to publicize any local language version of the summary. Next, video recordings showed that villagers opposing the project disrupted the proceedings before leaving the premises. The district magistrate issued no notice that the public hearing would continue, but resumed the hearing with only a few supporters of the project present. The National Green Tribunal's (NGT) deliberations remark that all of these supporters "appeared to have been brought and prompted by the proponent," concluding that the event had been "a mockery of public hearing.'" The NGT overturned the mine's environmental clearance on these grounds.

Project proponents' noncompliance with the public hearing requirements often translate into delays later in the clearance process. The Council on Energy, Environment and Water (CEEW), a think tank in India, finds that 9.17% of projects that were delayed in EAC meetings were because of public hearing-related issues, especially for coal mining and industrial projects. The delays often arise because the proponent has not incorporated recommendations from the public hearing or because SPCB has created administrative delays in conducting the hearings. CEEW also cautions that public hearings tend to be held too late in the decision-making process, so they simply become a delay for project proponents and an opportunity for public opposition. We focus our analysis on this public hearing requirement, which, while lauded in the literature as a crucial part of environmental impact assessment, has been so contentious in India's EC process.

2.3 Theory of Change

[2] http://www.livemint.com/Home-Page/MD6bEVXOwDbJEGULhJMsVK/Public-hearing-a-mere-formality.html

We hypothesize that introducing a requirement that mines hold public hearings before receiving clearance could have improved environmental performance at mines by increasing the transparency of the clearance process and subjecting projects to more stringent review by expert committees and the public. In the same sense, this increased transparency could improve mines' compliance with legal requirements of the EC process, like the requirement that mines begin construction only after receiving clearance. The reforms could have increased the regulatory burden of the process by placing additional requirements on mine proponents and lengthening the clearance process. Note that all of these mechanisms depend on strong enforcement of the public hearing requirement, which is difficult to verify and was unlikely to be uniformly true. We will measure mines' environmental performance as the change in air pollution, water pollution, and vegetation coverage at mine sites from two years pre-clearance to two years post-clearance. We measure clearance costs as mines' self-reported total costs and as the duration of the clearance process. We describe each of these outcome variables in more detail in Section 5, and we summarize our hypotheses and outcome measures in Table A2 in Appendix B.

Both prior to and following the 2006 reforms to the EC process, the requirements and procedures to which new mining project proponents were subject varied according to a series of characteristics of the mines (e.g., lease area) and their locations (e.g., whether the project involves forest clearing or is near a sensitive ecosystem). For instance, some EC applicants were subject to a public hearing requirement before and after the 2006 reforms, while others were only subject to the requirements after the reforms or not at all. Moreover the implementation of the reforms was gradual and, in some cases, uneven. See Figure 1 above for these implementation details. In this section we abstract from these details and identify the potential causal channels through which the key elements of the reforms may have contributed to improved environmental and social outcomes in the mining sector.

Figure 2 illustrates the theory of change underlying the hypotheses described above. The theory of change gives a series of hypothesized causal channels through which the public hearing and related reforms may have resulted in improved environmental outcomes at mines. The nature of these causal channels -- in particular, public and expert committees applying scrutiny and firms perceiving reputational and legal risks in failing to meet expectations and changing plans and building capacity -- make testing these causal channels difficult, and so we are largely limited to observing the final outcomes. However, we have collected several intermediate process outcomes, including the duration of consideration by the expert committee for each EC application, which we will interpret as a limited measure of the scrutiny applied to each application. In the figure, the policy (red with dots) initiates a series of newly required actions (blue with checks) by project proponents, regulators, and the Expert Appraisal Committee (EAC), which create hypothesized intermediate (purple) and final (green with stripes) outcomes. Here we describe each of the actions and outcomes, along with the hypothesized causal pathways and assumptions:

A1. The core objective of the 2006 reforms was to require that project proponents collect and provide more detailed and higher quality information about potential risks associated with their proposed projects in order that experts and the public could more thoroughly scrutinize projects prior to their execution. Large mines, for example, were required to file more detailed project specifications at the beginning of the application stage in order that the EAC could provide conditions for the EIA.

> ***Intermediate Outcome (IO) 1.*** The process of collecting additional, detailed information on project risks required by the reformed EC process may have induced improvements in planning, design, and environmental management at mines. The causal channel here can be distinguished from that described in IO 3, where mining project proponents alter their designs, siting, and production processes in anticipation of or in response to scrutiny from regulators, the EAC, or the public. Unlike that kind of deterrence effect, this intermediate outcome results from improved capacity at mine and in mining firms to evaluate and manage environmental risks. This intermediate outcome relies on the assumptions that (i) the information solicited under the reformed EC process required detailed study of environmental and social risks by firms and investment of additional resources in order to do so; and (ii) that the capacity built during the EC stage was sustained during project execution of the project. These assumptions are difficult to verify systematically.

A2. At several points during the approval process, MoEF receive and file the documentation provided by project proponents before it is formally reviewed by the EAC. For smaller projects that go through the state-level EC, this review and processing is carried out by officers in state environmental agencies, often the state pollution control board. This provides bureaucrats with an opportunity to call the project proponent's attention to elements of their application that may preclude approval by the EAC in advance of EAC hearings, or the attention of the EAC to particular aspects of the project design that pose environmental or social risks.

A3. Approximately once each month the EAC for non-coal mining projects meets to consider filed applications at two stages. First, the EAC considers applications for Terms of Reference (TOR), which specifies the detailed evaluation criteria that must be considered in the project's EIA. Second, the EAC considers final applications, following the EIA and public hearing. Representatives from the project proponents attend these meetings in order to receive feedback and answer questions. At both stages, the EAC can request additional information or alterations to the project. The minutes of these meetings are publicly available, and it is clear that they exercised this opportunity to delay clearance in order to seek additional information or changes to project designs frequently during the study period.

> ***IO 2.*** Scrutiny from the ministry and EAC may have led proponents to alter project designs. Here we also consider the possibility that project proponents formed expectations about the project characteristics that lead to delays in EC and designed their projects accordingly to minimize the probability of delay. We have verified in the EAC meeting minutes that resubmission of the EC documents was common at various stages of the process. While we see evidence that the EAC demanded additional information and alteration of designs and not just correction of clerical errors or missing documentation, it is difficult to systematically assess how substantive project revisions were in response to or anticipation of this scrutiny. Related potential outcomes are avoidance or evasion: projects may avoid going through the EC process either by reducing the project size below 5 hectares (a measure that would allow projects to avoid

being subject to EC only until the Supreme Court applied EC to mines of all sizes in 2012) or evade by operating illegally. Given that scrutiny in the process is differentiated by evaluation of the risks posed by projects, we might expect more risky projects to avoid or evade EC.

A4. Beginning in June 2014, application documents were made available in real time on environmentclearance.nic.in. The site also provided a timeline enabling projects and the public to track the progress of individual applications. Over the course of the months that followed, MoEF added documentation for projects cleared prior to 2014. This portal provided the public with a central repository of information about pending and already cleared mining projects.

A5. Following the completion of their EIA, project proponents are required to hold a public hearing in the district where the mine will be established. Proponents are required to advertise the public hearing in local newspapers and to respond to public comment.

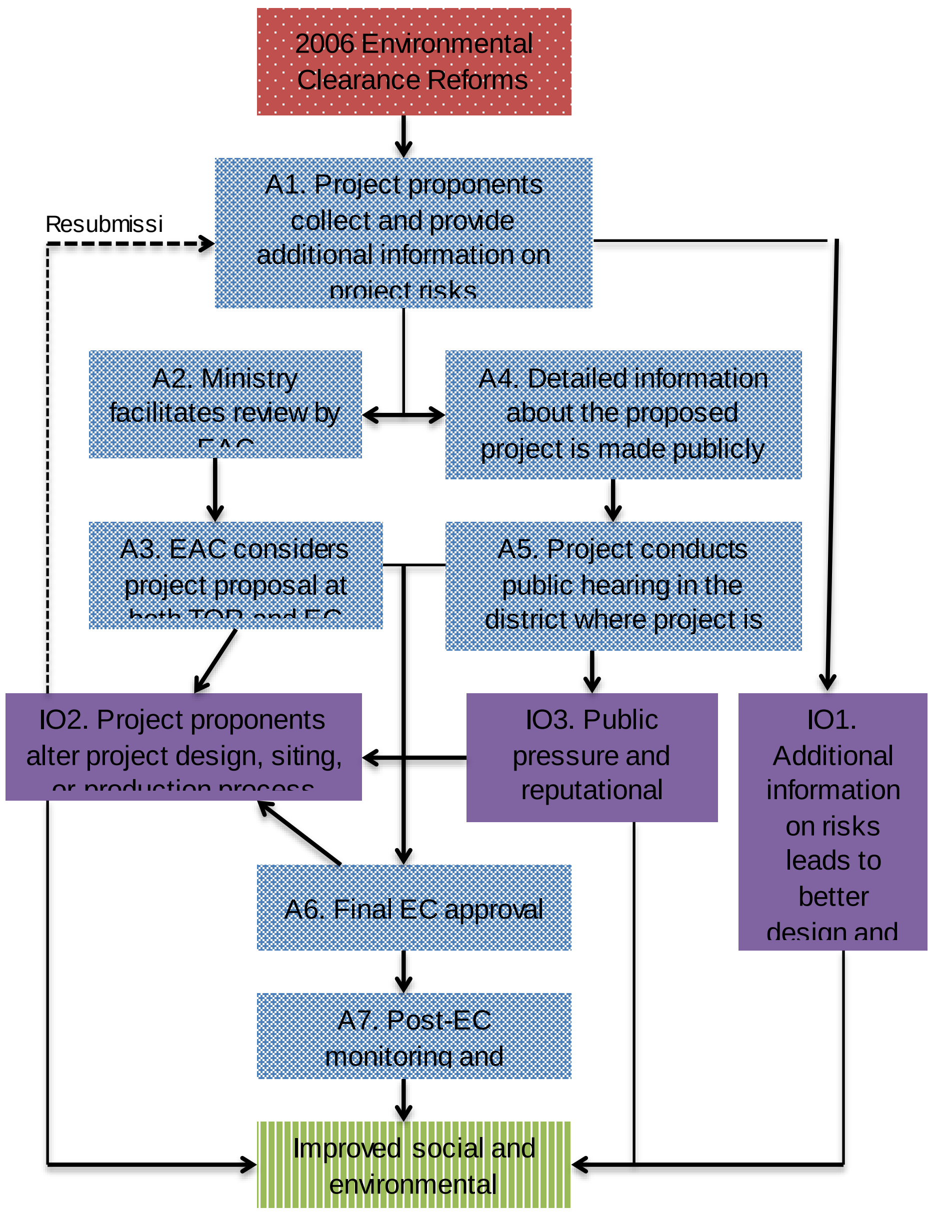
IO 3. Access to additional information about new and expansion mining projects during the EC approval process may have enabled greater scrutiny by the public and the media. This outcome relies on the assumption that the information was, in fact, accessible publicly: for example, that documents were posted to the website promptly, that advertisements of public hearings were made well in advance of hearings in publications that would reach the relevant populations, that public hearings were held in locations and at times that enabled meaningful engagement by affected populations, and that the presentation of information was such that the key issues were accessible to these populations. The accessibility of EC application information has been called into question, particularly prior to the launch of the Ministry's online clearance portal (CEEW 2014). Anecdotal evidence suggests that there is likely substantial regional and project-to-project variation in the quality and accessibility of information made available, though we are unable to observe this systematically. If additional public scrutiny of projects was great enough, we expect that projects may have altered their designs either in response or in anticipation, which is represented in the figure as an arrow pointing toward IO 2.

A6. The EAC scrutinizes applications for a final time following the completion of the EIA and public hearing, but the Minister of Environment holds final approval authority. Again at this stage, scrutiny may induce projects to alter the project design, which may require resubmission of documentation. Theoretically, projects could be rejected, but in the application data we collected a rejection occurred less than once for every one thousand applications.

A7. Following receipt of EC, projects are required to submit compliance self-reports twice annually. Each project is cleared with a set of general and specific conditions, which have legal status. General conditions are applied to all mineral mining projects, while specific conditions are tailored by the EAC and the ministry to the specific risks posed by the project as determined during the review process. Compliance audits may be conducted by the field offices of the MoEF or by the state pollution control boards, but in practice these agencies lacked the staff to carry out these inspections on a regular basis. Compliance performance was often considered by the ministry and EAC in applications for renewal of EC or for expansion of existing projects.

Final Outcomes. The objectives of the reforms were to improve social and environmental outcomes at and around mining sites. The EC process may have increased the benefits and reduced the costs of mining activities for surrounding communities. These benefits may have included employment, direct financial transfers, local tax revenue from economic activity, and in kind transfers like community development programs. The costs may have included displacement of residents, a common practice for many large mining operations, as well as environmental health hazards. The health hazards we consider are air and water pollution.

Figure 2. Theory of Change, 2006 Environmental Clearance Reform



3. Context

Before introducing our data and empirical strategy in more detail, we place the mining sector into economic and social context in India. Mining comprises only a modest share of India's economic activity, but the sector is large by global standards and widespread across the country. According to the United States Geological Survey, India ranks in the world's top six producers of iron, pig iron, aluminum, bauxite, zinc, and coal. In 2014, India's mineral mining sector was comprised of 8,355 mines producing 54 types of minerals. While mineral mining generates only about 2.5 percent of India's annual economic output, mining activity is present throughout the country: 24 of 29 states and about 45 percent of districts had active mining leases in 2014. The median mine was 4.75 hectares, or about 8 Olympic-sized football fields.

The social benefits and costs of mining and other extractive industries are the focus of a large literature in economics on the resource curse. Much of the resource curse literature focuses on the macroeconomic effects of resource wealth, but a growing body of work uses local and regional variation to study microeconomic impacts as well. Aragón and Rud (2013) find that the world's largest gold mine in Peru increased income and household consumption and reduced poverty in communities near the mine. Asher and Novosad (2014) study mining booms in India and find similar spillover effects on local economies. A variety of evidence suggests large external costs from mining activities as well. For instance, Aragón and Rud (2016) find that air pollution from gold mining reduced agricultural productivity at nearby farms by up to 40 percent in Ghana, and Berman et al. (2017) find a causal link between mining and conflict in Africa.

As we will describe in detail in Section 5 below, we have compiled a broad repository of data on non-coal mines granted central-level environmental clearance in India between 2006 and 2016. These data do not include the full universe of mines in India, since we can only collect administrative data on mines cleared at the central level; our data therefore do not include small mines cleared at the state level after the 2006 reforms, any illegal mines, or coal mines. In total, we collect MoEFCC clearance records for 1,318 non-coal mines cleared at the central level since 2006; of these, we can collect a broad set of data on mine and clearance application characteristics for 934 mines. Our data repository for this set of 934 non-coal mines comprises information on mine size and production capacity, mine parent companies, the clearance application process, and environmental conditions at mine sites.[3] We describe the data collection process in detail in Section 5, and here we use this sample of central-level mining clearance applications to describe the landscape of mines passing through the central-level EC process around the time of the 2006 reforms.

We begin with some simple statistics on the clearance process itself. We present these figures in Table 1 below. Consider clearance duration, which we define as the time in days between the date of initial application for EC and the date EC was granted in the form of a clearance letter. While the median project has an EC duration of about 255 days, the distribution is heavily right

[3] Note that the sample with which we evaluate the impact of the 2006 public hearing requirement is a subset of this larger sample; that analysis relies only on mines of area less than 50 ha that applied for clearance before the corresponding state-level clearance bodies had been established.

skewed, with some mines enduring an EC process that takes almost 10 years. Next, 40% of applications in our sample are for new mines, while 12% are for renewal of clearance for existing mines with no area or capacity enhancement, and 48% are for production or capacity enhancements in existing mines. While about 74% of mines in our sample are submitted by parent companies with no previous successful clearances, 18% belong to companies with between 1 and 4 previous clearances, and 8% belong to companies with at least 5 previous clearances.

Next, we give summary statistics on mines themselves. In our sample, 87% of mines are non-riverbed mines (including opencast and underground mines), while 14% are riverbed mines. About 6% of mines in our sample are explicitly identified as violation cases in their clearance letters, meaning that the mine had previously expanded production capacity or begun operations without receiving the required clearance. Next, we find that mine area and production capacity are heavily right-skewed. While the median mine has area of 91 ha, mines' areas range from 3 ha to almost 8000 ha. Similarly, while the median mine has production capacity of 0.3 million tons per annum (MTPA), capacity ranges from 50 TPA to 20 MTPA.

Table 1. Summary statistics for all mines in clearance letter dataset

Numerical variables		Mean	Median	Std. Dev.	Min.	Max.	Obs.
EC duration in days		360.43	254.5	357.98	21	3026	934
Total area of project (ha)		265.84	90.83	536.01	3.04	7978.84	934
Total mine production capacity (MTPA)		1.381	0.30	2.589	0.001	19.6	934
Year of deforestation - clearance year		0.491	0	2.298	-3	4	318
Avg. PM (ug/m3) in clearance year		41.224	39	15.592	20	118	859
Median EVI in clearance year		0.212	0.198	0.0858	0.045	0.527	844
Biochemical oxygen demand (mg/L) in clearance year		2.542	1.7	2.915	0.3	23.4	528
pH in clearance year		7.687	7.8	0.493	6.2	9.15	524
Δ Avg. annual PM		0.636	0	4.206	-18	17	676
Δ Median annual EVI		-0.0153	-0.0099	0.0439	-0.230	0.143	667
Δ Avg. annual biochemical oxygen demand		0.265	0.3	1.773	-7.5	8.3	281
Δ Avg. annual pH		-0.163	-0.05	0.443	-1.45	1.2	268
Numerical variables		Proportion	Obs.				
Cleared before	No previous clearance	0.737	934				
	1-4 previous clearances	0.184					
	≥ 5 previous clearances	0.079					
Application type	New mine	0.398	934				
	Existing mine	0.123					
	Area or capacity enhancement	0.479					
Mine type	Non-riverbed mine	0.865	934				
	Riverbed mine	0.135					
Violation case	Violation	0.056	934				
	Non-violation	0.944					
Deforestation compliance	Complied	0.623	318				
	Deforested illegally	0.377					

Mines also diverge significantly in environmental outcomes, which we first measure as conditions in the year of clearance. There is substantial variation in site levels at clearance.

While the median mine site has average PM2.5 concentrations in the year of clearance of about 39 μg/m^3, some mines have annual average PM concentrations of up to 118 μg/m^3. For reference, the World Health Organization places its guidelines for safe exposure to PM2.5 at an annual average of 10 μg/m^3. The median mine in our sample has median annual Enhanced Vegetation Index (EVI) at clearance of 0.198 on a scale of 0 to 1, corresponding to relative barrenness. The median mine has biochemical oxygen demand (BOD) of 1.7 mg/L in the nearest river, though some mines are near rivers with BOD of 23.4 mg/L; BOD measures the extent of organic pollution in water. The median mine is a near a river with pH of 7.8, just above neutral.

We now consider mines' environmental performance, which we define as the change in conditions from two years pre-clearance to two years post-clearance. At the median mine site, PM2.5 concentrations stay constant, EVI falls slightly, BOD increases, and pH falls slightly from two years pre-clearance to two years post-clearance. However, these trends vary substantially across mines: average PM concentration increased by 17 μg/m^3 around clearance in some mines, while falling by 18 μg/m^3 in others, for example. Finally, we see that mines' compliance with the clearance process is relatively low: while mines are legally required to deforest only after receiving clearance, about 38% of mines deforested before the year of clearance.

4. Timeline

In this section, we provide more details on the timing of the 2006 EC reforms. In January 1994, MoEFCC passed the Environmental Impact Assessment Notification based on Section 3 of the Environmental Protection Act of 1986. The 1994 statutory requirements for clearance, which, as we've described, occurred only at the central level, involved standard ToRs, and did not typically invoke an expert committee, remained in force until the Environmental Impact Assessment Notification of September 14, 2006. We describe the provisions of this notification in detail in Section 2.

The 2006 clearance notification was not immediately enforced. MoEFCC issued a set of Interim Operational Guidelines on October 13, 2006 that remained in effect until September 13, 2007. These interim guidelines allowed some discretion in the evaluation of mining projects applying for clearance between September 14th, 2006 and July 1st, 2007. During this period, new or pending applications were evaluated by the newly formed EAC and, where considered necessary, asked to revise their EIAs to bring them in line with the tighter standards imposed by the 2006 notification. The provisions of the 2006 Notification were fully enforced for all projects applying after July 1, 2007.

Next, while the notification decentralized the clearance process for Category B projects to the state level, to be overseen by newly constituted State Environmental Impact Assessment Authorities (SEIAA) and State Expert Appraisal Committees (SEAC), most states did not establish these bodies for several years following the notification. Table A1 in Appendix A gives the dates on which SEACs were established by state. As we will describe in more detail in the following section, we evaluate the expansion of public hearings using a sample comprised of mines under 50 ha that were cleared at the central level because their corresponding SEIAA and SEAC had not yet been set up.

The potentially uneven implementation of clearance requirements during this interim period makes it challenging to rigorously evaluate the impacts of the 2006 EC reforms with an event-study analysis. However, we have carefully analyzed clearance letters for all mines of area less than 50 ha that applied for clearance during the interim period, and we find that the requirement that all mines of area over 5 ha hold a public hearing was uniformly enforced after the September 2006 notification. As we detail in the next section, we focus our empirical analysis on this requirement. Therefore, we identify September 14th, 2006 as the breakpoint between the old and reformed EC processes. See Figure 1 in Section 2 for a detailed description of the provisions and timeline of the 2006 reforms.

5. Evaluation: Design, methods, and implementation

5.1 Evaluating the 2006 EC reform: Exploiting a Cut-off at 25 ha

As we have already described, one crucial provision of the 2006 EC reforms was to expand the requirement that mines hold public hearings from mines of area over 25 ha to all Category B mines, or those of area between 5 and 50 ha. Under the 1994 clearance provisions, only mines of area above 25 ha had been required to hold public hearings. This policy change was enforced on all project proposals that applied for environmental clearance starting September 14th, 2006. See Section 2 for more detail on these clearance requirements and Section 4 for details on the timing of its implementation.

We exploit the sharp cut-offs at mines of 25 ha and around the date of the EC notification in September 2006 to evaluate the impact of requiring that mines hold a public hearing after completing their EIA. In particular, we run a difference-in-difference (DD) regression comparing mines of area below and above 25 ha that applied before and after the 2006 reform notification. Here, we define treatment to be mines of area less than 25 ha, which began holding public hearings only after the 2006 notification, and control to be mines of area over 25 ha, which were required to hold public hearings both before and after the notification. As the 2006 Notification applies identical regulations to all mines with areas between 5 and 50 hectares and bundles them into "Category B" projects, we will restrict our sample throughout this analysis to mines of area between 5 ha, below which mines are not required to get clearance, and 50 ha. For mines just around the 25 ha cut-off, the only differential change in the EC process around the date of the 2006 notification was the additional requirement of a public hearing for mines under 25 ha. Therefore, we can evaluate the impact of holding a public hearing as the differential change in outcomes from pre- to post-notification between treatment (mines of area less than 25 ha) and control (mines of area over 25 ha, which always had to hold public hearings.) By necessity, our sample for this analysis is restricted to mines from states that had not yet set up state-level clearance bodies; once these bodies had been established, mines of area under 50 ha would have been cleared at the state level and would disappear from our sample. We will provide summary statistics for this sample in more detail after describing our data collection process below.

Our identification strategy is robust to any differences between the treatment and control groups that stay constant before and after the notification. However, our results are vulnerable to any differential changes in the composition of treatment and control from the pre-reform to post-reform period. We can account for any differential changes in composition along mines' observable characteristics by including those characteristics as controls in our diff-in-diff model. However, our results would still be vulnerable to any differential changes in unobservable characteristics of mines conditional on these observables between treatment and control.

For example, selection on unobservable characteristics could pose a substantial threat to our DD model. After the announcement of the 2006 notification, mines could have adjusted their area based on their expectations of treatment under the clearance process. There are three likely forms of selection in our sample. First, mines might anticipate significant costs from additional regulatory and public scrutiny under the 2006 reforms and therefore might split into leases of less than 5 ha to escape the clearance process as a whole; this form of selection could be stronger for mines that would otherwise be of area less than 25 ha, both because avoidance might be less costly and because the addition of the public hearing requirement would make the 2006 reforms differentially more costly for mines below 25 ha. Another selection mechanism could arise if mines that would have reported area less than 25 ha before the reform report a larger area post-reform, since the imposition of the public hearing requirement removed the premium to being below 25 ha. Finally, since the 2006 reforms split mines above 50 ha into Category A and below 50 ha into Category B, we might expect to see mines that would otherwise be above 50 ha decreasing in size to avoid what may have been a more costly process for Category A mines.

All three of these mechanisms would likely tend to bias our estimates for the impact of public hearings towards zero. Take EC stringency, which we measure by clearance duration and assume increases with mines' riskiness. Consider the first scenario, where particularly risky mines select out of the clearance process by getting below 5 ha; the loss of higher-risk mines from the treatment group after the notification would mean that average stringency for treatment after the notification falls relative to a world with no selection, reducing our estimates for the impact of public hearings after controlling for area. Similarly, consider the case where particularly risky treatment mines increase in size to cross the 25 ha threshold since there is less of a premium to being below 25 ha. Then, selection would bias upwards the average control stringency relative to the treatment mean stringency after the reform, biasing our estimates for the impact of public hearings towards zero. Finally, consider the third form of selection, where particularly risky mines above 50 ha decrease in size to become Category B mines. Then, selection would bias upwards the average control stringency, biasing down our estimates for the impact of public hearings. In summary, then, these forms of selection could bias down our estimates for the impacts of public hearings. It is reassuring that selection is unlikely to bias our results towards finding false significant impacts of public hearings, but these mechanisms could prevent us from picking up true, significant impacts.

We will document evidence of selection in Section 6 below; we will argue that while we see substantial evidence of mines just above 5 ha splitting into mines of less than 5 ha, therefore avoiding the clearance process as a whole, we see less evidence of selection around the 25 ha cutoff on which we base our analysis. We will take a series of steps to help account for any selection, and we document these robustness checks in Section 6 below.

Broadly, we seek to estimate the impact of the public hearing requirement on the mine-level costs and benefits of the environmental clearance process. First, we measure the regulatory burden of public hearings either as the duration of the clearance process, defined as the time between application and clearance approval in days, or as mines' self-reported total costs. While the benefits of the clearance process could include social benefits like increased employment for local communities, we focus on evaluating the impact of the reform on environmental performance at mines. We proxy for environmental conditions for mines with four outcomes: average annual PM2.5 concentration within 1 km of mines' centroids, biochemical oxygen demand and pH in the nearest river, and median annual vegetation coverage at mine sites. For each of these environmental outcomes, we define our outcome variable for analysis as the change in that outcome from two years pre-clearance to two years post-clearance. Evaluating the impact of public hearings on these differenced environmental outcomes allows us to estimate the impact of public hearings on mines' environmental performance, rather than picking up changes in mine siting over time. In addition to these first-differenced measures of mines' environmental performance, we will assess the impact of public hearings on mines' compliance with the requirement that they deforest only after receiving clearance. We describe the measurement of each of these outcomes in more detail below, and we summarize our primary hypotheses and outcomes in Table A2 in Appendix B.

5.2 Data collection

Our analysis rests on a unique data repository that we have compiled on all mines that applied for environmental clearance (EC) in India from 2006 to 2016. These data cover a range of aspects of these mining projects, including characteristics of mines and project proponents, details of the application process, and satellite-based measurement of environmental outcomes at mine sites. Note that our DD analysis of the impacts of public hearings relies on a small subset of this broader dataset, which is limited to mines of area below 50 ha that applied from states that had not yet established a central-level clearance body. See Section 5.3 for more detail on the sample on which we base our analysis. In total, our full dataset on mines that applied for clearance between 2006 and 2016 comprises 934 mines, while the subset on which we base our analysis includes 134 mines. We present summary statistics for the full sample of 934 mines in Table 1 above, and we present summary statistics for our analysis sub-sample in Table 5 below.

MoEFCC data on clearance applications:

We construct the backbone of this dataset by scraping clearance records from an online application database published by the Ministry of Environment, Forest and Climate Change (MoEFCC). We have scraped data on the roughly 15,000 environmental clearance applications that have been filed since the system's initiation in 1980. Of these, we collect 1,318 records for unique, non-coal mines that applied for clearance between 2006 and 2016. In addition to reporting project name, project location, and the dates of key EC stages of submission, review, and approval, this online portal hosts documents associated with each EC application. However, data available through the MoEFCC portal suffers from several limitations. First, dates associated with key steps in the EC process are not reported for many projects and many associated documents are missing. Even where application dates are reported, they are sometimes inconsistent with the sequence of the legal clearance process or differ from those reported in EC documents associated with the same project.

Based on these inaccuracies, we supplement the MoEFCC portal with data on mine characteristics and application processes drawn from the clearance letters granted to these mining projects. We have scraped all of these letters from attachments available on MoEFCC's online portal. While the contents of the clearance letters change over time, the letters typically contain a range of information on both the dates of key steps in the EC application process, like the date the project applied for clearance or was granted TORs, and on physical mine characteristics, like the mineral mined, mine lease area, production capacity, and method of extraction. These clearance letters are available either as PDF files with text embedding, PDF files without text embedding, or html files. We first convert all of these files to text files and then programmatically extract a wide set of variables, including: key dates in the application time, including the date of EC application and clearance; the state, district, tehsil, and village in which a mine is located; a range of mine characteristics, including the mine proponent, minerals mined, mine production capacity, mine area, and whether an application is for a mine expansion or new mine. To ensure the accuracy of the clearance letter dataset, we supplemented this programmatic variable extraction with manual data entry. Together with the MoEFCC application dataset, this clearance letter dataset provides a robust set of information on mine characteristics and EC applications for all mines in our sample. In total, our final dataset includes 934 mining applications for EC with full information for mine and clearance characteristics scraped from the MoEFCC website.

Complementary information from the Indian Bureau of Mines:

While our clearance dataset gives comprehensive data on the EC application timeline by project, it does not give dates of actual mine operations. To fill this gap, we have purchased a dataset called the All India Directory of Mining Leases from the Indian Bureau of Mines. These data describe details on all mining leases (over 9200) issued since 1992 (Table 2 below lists the variables provided), including the date of mine execution. We hired a data team from the Jameel Abdul Latif Poverty Action Lab to digitize these data, which we initially received as 2000 hard copy pages. We have merged these IBM data with the clearance dataset by mine wherever possible.

Table 2. Variables included in the IBM Directory

Date lease was granted	Duration of lease	Date lease was executed
Date lease will expire	Area of lease	Lease number
Category (A or B)	Primary mineral	Other minerals

Satellite data on environmental outcomes:

Next, we link this dataset on mines' EC applications and mine characteristics with a novel dataset of satellite-based environmental outcomes at mine locations. We commissioned mines' GPS locations from ML Infomaps, an Indian company. Using these coordinates, we link mines to satellite-based measures of air pollution, land cover, and water quality. In particular, we use air pollution satellite data assembled by a group at Dalhousie University, which measure fine particulate matter concentration (in micrograms per meters cubed) at a spatial resolution of 1 km for the years 1998 to 2014. We will use average annual PM concentration in the 1-km cell in which a mine is located as a measure of ambient air quality at mine sites. We are able to link 889 of the 934 mines for which we have full clearance records with data on PM concentrations in the year of clearance.

Next, we assess deforestation at mine sites using the Enhanced Vegetation Index (EVI) from NASA's MODIS satellite.[4] EVI measures vegetation for the entire globe at a spatial resolution of 250m. Values range from 0 to 1, where any value less than 0.2 corresponds to land that is considered to be sparse to barren. EVI values are calculated at 16-day intervals from daily MODIS data. Using these satellite data, we calculate annual maximum, median, and mean EVI at mine sites as a measure of the extent of deforestation at mine sites. We are able to link 882 of the 934 mines in our clearance sample with data on vegetation coverage around the year of clearance. We also use this MODIS EVI data to determine the date of deforestation for each mine, which we identify as the year of a structural break in mine-level timeseries for median EVI. We restrict this structural break to occur within 4 years before or after the date of clearance, which we have scraped from MoEFCC clearance records. We record a non-missing year of deforestation only in cases where a Supremum Wald test of the proposed structural break is significant at the 10% level. Of the 934 mines for which we have full clearance records, we determine deforestation year, or a statistically significant structural break in median EVI, for 324 mining projects.

Finally, we complete this dataset on environmental outcomes at mines with data on water quality near mines drawn from the Central Pollution Control Board's ENVIS database, which includes water quality monitoring data from stations across India. We define water quality at mines as water quality at the nearest site monitor, and we proxy for water quality with biochemical oxygen demand (BOD), a measure of organic pollution, and pH. Greenstone and Hanna (2014) rely on BOD as one of several key measures of water pollution in India. Of the 934 mines in our sample with full clearance records, we have data on nearby BOD for 538 mines and data on nearby pH for 534 mines. One primary concern in our use of water quality data is that the nearest water monitor may be a substantial distance from mines themselves, and may capture water pollutants from other upstream mines. While this measurement error could bias our estimates for the impact of public hearings towards zero, we see little cause to suspect differential measurement error between treatment and control.

[4] Didan, K. 2015. MOD13Q1 MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V006. NASA EOSDIS Land Processes DAAC, USGS Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota (https://lpdaac.usgs.gov), https://doi.org/10.5067/MODIS/MOD13Q1.006

5.3 Validation of Outcome Measures

Next, we validate some of the key environmental outcomes that we will use to assess the impact of the 2006 EC reforms. In particular, we present results from analysis of outcome variables for air pollution and land use change in order to validate that these measures can capture meaningful impacts of mining activity.

Figure 3. Event Study: Median annual Enhanced Vegetation Index (EVI) at mining site (250m Radius), mines obtaining clearance between 2006 and 2015

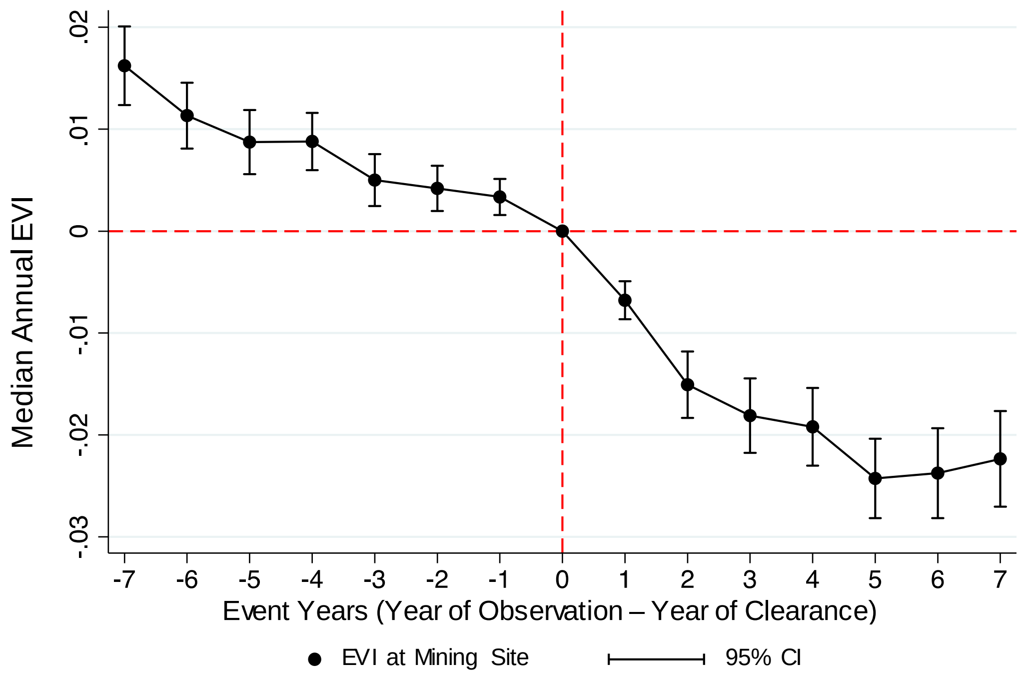


Figure 3 shows event study evidence demonstrating the magnitude of land clearance that occurs at mining sites following clearance. The plot represents time in years relative to the year that mines obtained clearance on the horizontal axis. The vertical axis presents the mean deviation across mines in the annual median enhanced vegetation index (EVI) in a 250 meter radius of the mining site from the level in the year of clearance (event year 0). Ninety-five percent confidence intervals are shown based on standard errors clustered by mine. The figure shows a clear and dramatic drop in vegetation following clearance. The smaller downward trend in years before clearance suggests that, in some cases, land clearing occurs before EC is obtained, which is a focus of firm responses to the lengthening of the EC process following the 2006 reforms in the next section. Table 3 presents reports results from regressions of statistics of mines' distribution of 16-day EVI on an indicator variable for years post-clearance. The specification is:

$$(1) \qquad EVI_{it} = \beta_0 + \beta_1 Post\ Clearance_{it} + \gamma_t + \sigma_i + \epsilon_{it}$$

where γ_t and σ_i are year of clearance and mine fixed effects, respectively. Maximum EVI, shown in column 2, falls by about 14.5 percent on the mean in the years following clearance, holding fixed all time-invariant conditions of mines and common yearly shocks to EVI. The result is highly significant, with a *t*-statistic of more than 24.

Table 3. Change in median, maximum, and minimum annual EVI, mines obtaining clearance between 2006 and 2015, mine and year of clearance fixed effects

	Median (1)	Maximum (2)	Minimum (3)
Post Clearance (=1)	-0.0206***	-0.0768***	-0.0144***
	(0.00144)	(0.00319)	(0.000962)
Fixed Effects	Mine & Year	Mine & Year	Mine & Year
Observations	15810	15810	15810
Mines (clusters)	930	930	930
Mean of EVI	0.209	0.466	0.122
R^2	0.860	0.608	0.723
Adjusted R^2	0.851	0.583	0.705
Standard errors clustered by mine; * p < 0.1, ** p < 0.05, *** p < 0.01			

Figure 4 presents similar results for annual $PM_{2.5}$ concentrations at mining sites. Rather than using the raw $PM_{2.5}$ level observed at the mining site, the figure shows the difference in PM concentrations between that in a one kilometer radius of the mine and than in the surrounding area, between 1 and 50 kilometers of the mine. Here the effect of mining activity on PM is much less discernible than for EVI. However, beginning two years before clearance there is a modest upward trend in PM relative to that in the surrounding area.

Figure 4. Event Study: Difference between annual PM2.5 concentrations (µg/m3) at mine site (1 km radius) and surrounding area (50 km radius), opencast mines cleared from 2006 to 2015

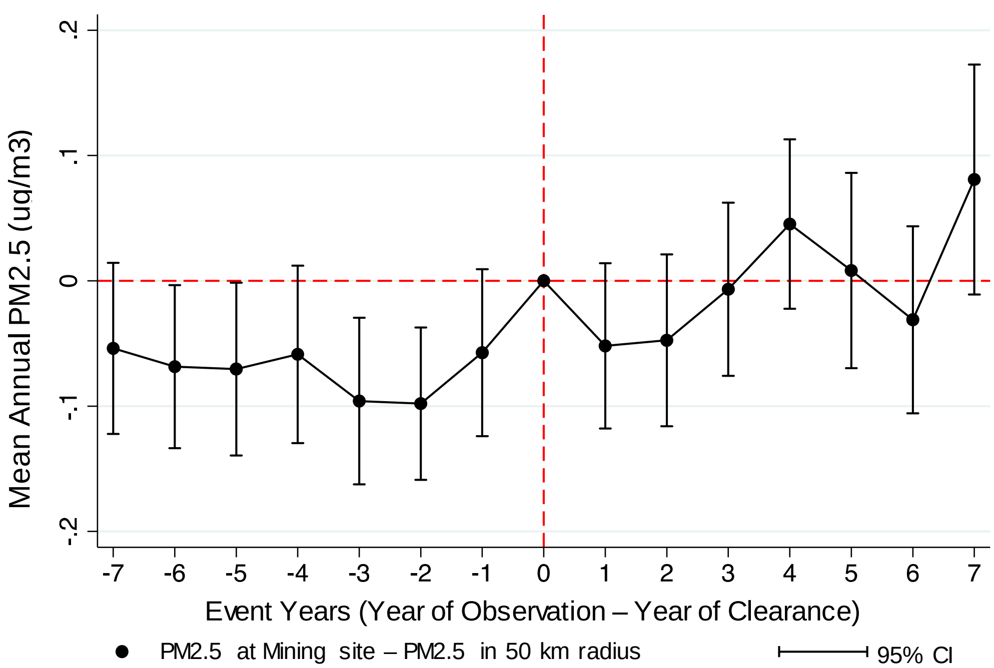


Table 4 presents these results in a regression that estimates the specification in equation 1 above, with various measures of PM on the lefthand side. In Column 3, which corresponds to the radii used in the figure, pollution rises by only one tenth of a percent of the mean and is only marginally significant. As in Table 3, these results will understate the effect of mining on PM if activity occurred before clearance and increased PM.

Table 4. Difference between annual PM2.5 concentrations (µg/m3) at mining site (inner radius) and surrounding area (outer radius), opencast mines obtaining clearance between 2006 and 2015, mine and year of clearance fixed effects

	1-km Inner Radius 25-km Outer Radius (1)	5-km Inner Radius 25-km Outer Radius (2)	1-km Inner Radius 50-km Outer Radius (3)	5-km Inner Radius 50-km Outer Radius (4)
Post Clearance (=1)	0.0283	0.0218	0.0402*	0.0331
	(0.0180)	(0.0158)	(0.0237)	(0.0224)
Fixed Effects	Mine & Year	Mine & Year	Mine & Year	Mine & Year
Observations	13374	13374	13374	13374
Mines (Clusters)	743	743	743	743
Mean of PM (ug/m3)	37.50	37.50	37.50	37.50
R^2	0.435	0.470	0.588	0.615
Adjusted R^2	0.401	0.438	0.563	0.592

Standard errors clustered by mine; * p < 0.1, ** p < 0.05, *** p < 0.01

5.4 Analysis Sample and Power

While our full sample includes 934 mines that applied for clearance between 2006 and 2016, our identification strategy restricts us to estimating the impact of the 2006 reform off of a much smaller sample of mines. Again, we evaluate the impact of requiring mines to hold public hearings by estimating a DD specification around the date of the 2006 reform for mines above and below 25 ha. Thus, we restrict our analysis to mines of area between 5 ha, below which mines are not required to apply for clearance, and 50 ha. Again, all of these mines are subject to the same clearance requirements as Category B mines under the reformed EC process.

Next, we restrict our sample to mines that applied for clearance before their state established a state-level clearance body, the State Environmental Appraisal Committee (SEAC). After each state established its SEAC, Category B mines no longer apply to the central MoEFCC and thus do not appear in our sample, which is based on the MoEFCC application database. In other words, the upper time limit on application date for inclusion in our sample varies by state. While most states had established their clearance body by the end of 2008, Goa established its body in 2010, Jharkhand in 2011, Orissa in 2012, and Uttarakhand in 2013 (see Table A1 in Appendix A). In our sample, 120 of 134 mines had applied for clearance by the end of 2008. Only 9 mines in our sample applied for clearance in 2009 and 5 in 2010. In total, our evaluation sample comprises 134 mines, of which 68 are treatment (area < 25 ha) and 66 are control (area > 25 ha). We present summary statistics on mine characteristics for this sample in Table 5 below. We have tried our analysis excluding these 14 observations and find that doing so does not alter our null results for the impact of public hearings.

While we have no scope to expand this sample, since we are limited by secondary data availability and by the restrictions of our empirical strategy, this sample may offer limited power to estimate the impacts of the 2006 reform. If holding a public hearing reduced clearance duration by 20%, a sample of 134 would provide power of only about 33%. See Figure A1 in Appendix C for our calculated power at a range of sample sizes.[5] Thus, our fairly small sample may prevent us from detecting even economically significant impacts of requiring that mines hold a public hearing.

6. Impact analysis and results of the key evaluation questions

6.1 Descriptive Evidence on the 2006 Reforms: Selection

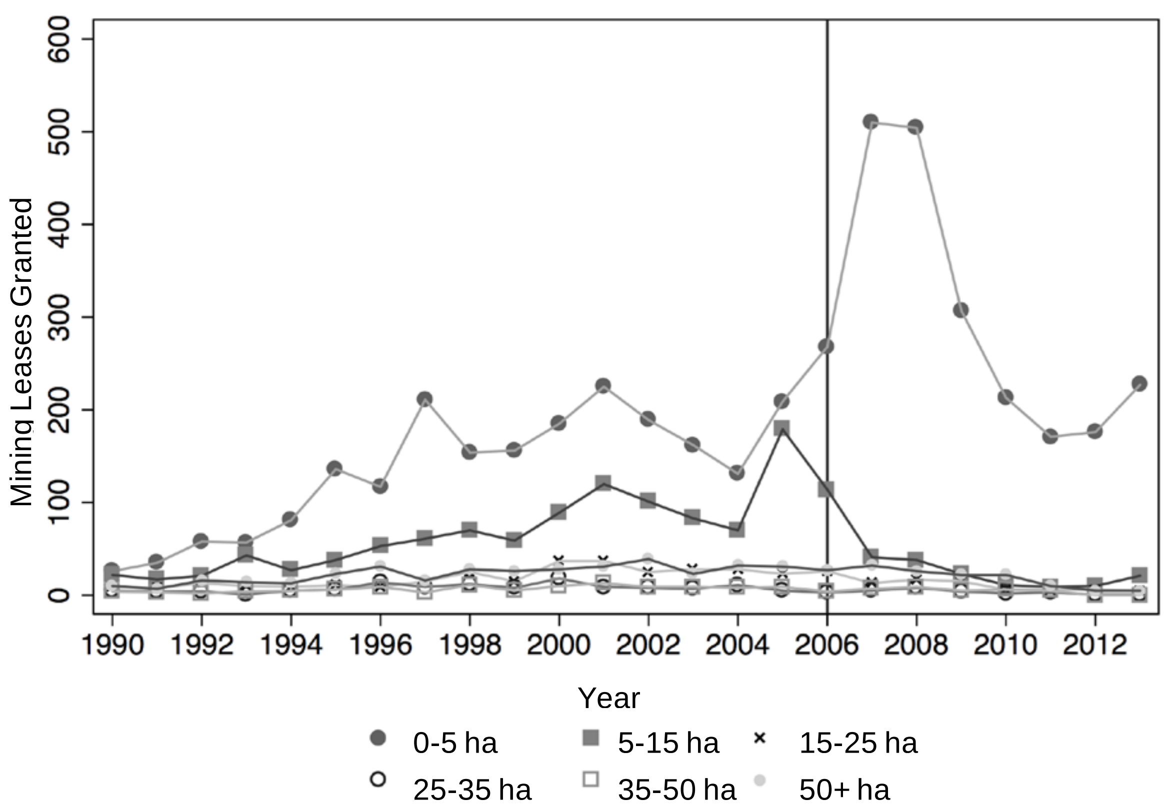
We begin our analysis of the 2006 reforms with simple descriptive analysis of mine application trends. While we cannot provide a robust analysis of the impacts of the 2006 reforms as a whole, visible selection in mine application trends suggests that mine proponents perceived the reforms to be substantial and costly. We will argue that we see most evidence of relatively small treatment mines (i.e. between 5 and 15 ha) selecting out of the clearance process as a whole, rather than of selection between treatment and control around the 25 ha public hearing cut-off.

Consider Figure 5 below, which uses data from the IBM Registry of Mining Leases to plot the number of mining leases granted in each year from 1990 to 2013 by lease area for six groups: less than 5 hectares (dark circles); 5 to 15 hectares (dark squares); 15 to 25 hectares (x marks); 25 to 35 ha (open circles); 35 to 50 ha (open squares); and greater than 50 hectares (light, small circles). The figure illustrates that the EC reforms initiated in September 2006 appear to have had a large, immediate, and permanent effect on the size of new mines established. In particular, there appears to be a large increase in applications for leases of area less than 5 ha--which were not subject to EC until a ruling of the Supreme Court in 2012--between 2005 and 2007. Over the same years, there was a marked fall in the number of leases granted to mines of area between 5 and 15 ha. We see no visible change in application trends for any categories of mines with area above 15 ha.

[5] We calculate power via simulation. We expand our sample by three times, then take 1000 random draws of treatment and control observations to fill various sample sizes. We run our primary difference-in-difference regression on each of these 1000 random samples per sample size to estimate power for a given sample size.

These trends are strongly consistent with one of the selection stories that we outlined above, namely that mining firms anticipated significant costs from additional regulatory and public scrutiny under the 2006 reforms and therefore split mines just above the 5 ha cut-off into mines of area below that cut-off to avoid a more stringent clearance process. Indeed, the number of leases granted between 5 and 15 ha fell by 73 between 2006 and 2007, while the number of leases granted of 5 ha or less rose by 242; these figures would be consistent with mines of around 15 ha splitting into about 3 mines of area around 5 ha. These results provide strong evidence that mine proponents saw the 2006 reforms as costly.

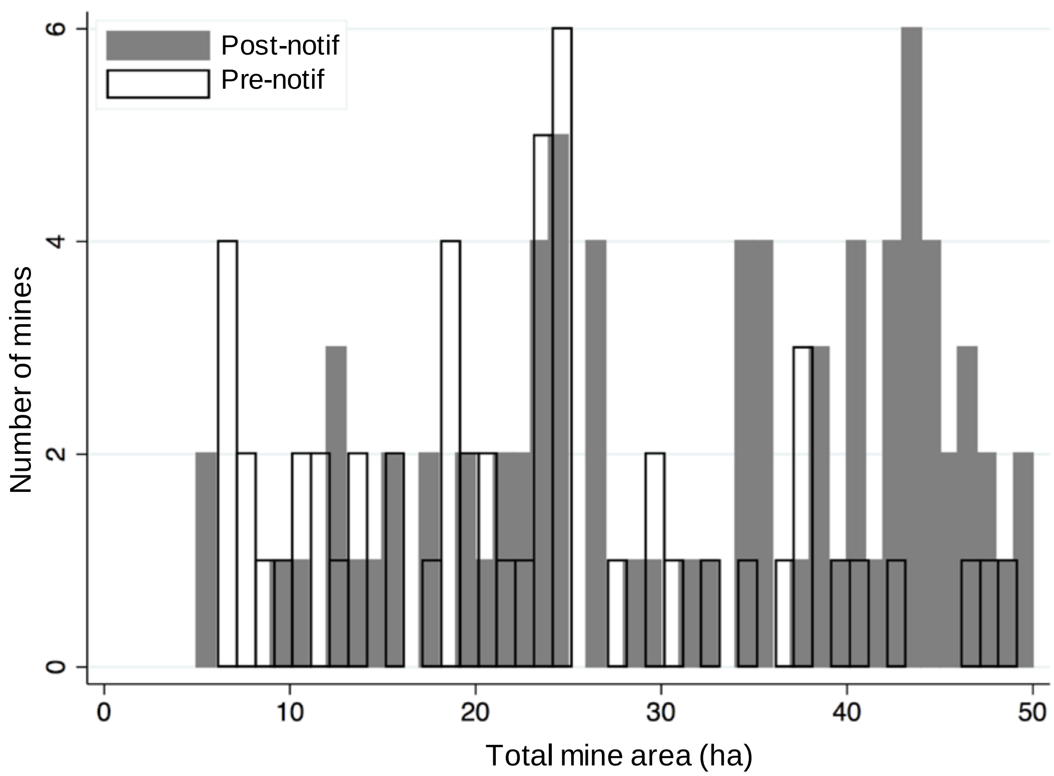
Figure 5. New mining leases granted by lease area, 1990-2013



On the other hand, Figure 5 does not suggest any visible selection between area categories for mines either of area between 15 and 25 ha or over 25 ha; leases granted stay broadly steady for these groups around the date of the 2006 notification. These results suggest that there is limited selection for mines of area close to the 25 ha cut-off: we neither see that mines below 25 ha grew larger and crossed the 25 ha threshold nor that mines of area between 15 and 25 ha or above 25 ha split into mines of area below 5 ha. Note, also, that do we not see visible evidence of selection on time, with mines seeking to get clearance before the 2006 reforms were announced. We are aware of no evidence that mines knew about the reform before it happened, and the figure shows no visible breaks from generally increasing application trends over time until 2006 itself. Note, also, that we see little visible evidence of spatial selection among mines after the 2006 reform. Figure A23 in Appendix J maps active mining leases across districts using IBM data; the spatial pattern remains similar between 2006 and 2013.

While so far we have looked for selection in the IBM lease directory, which covers all mining leases granted in India, we now evaluate the prevalence of selection in our sample. Figure 6 below plots a histogram of clearance applications' mine area before and after the 2006 notification. Several trends appear: first, there appears to be a substantial decrease in mass at low areas and a substantial increase in mass at high areas after the 2006 reforms. These shifts are consistent with two selection stories, namely that small mines would select below 5 ha to escape the clearance process as a whole and that mines above 50 ha might select under that cut-off to attempt to move into the state-level clearance process.

Figure 6. Distribution of mine area in our sample



There is also some evidence of selection about the 25 ha cut-off, which we do not see in the IBM data and which could pose a threat to our identification. In particular, we see some slight bunching just below the 25 ha cut-off before the 2006 reforms; this bunching appears to be reduced after the 2006 reform, which would be consistent with mines no longer selecting to be below 25 ha once the expansion of the public hearing removes the associated premium. However, it is important to keep in mind that this apparent bunching is based on only a handful of mines in our sample. In particular, only about 2 additional mines in our sample fall just below the 25 ha cut-off in our data before the notification than after the notification. Rather, the primary visible changes in the distribution is the major increase in mass between around 35 and 50 ha. As we proceed with our diff-in-diff analysis of the impacts of public hearings, we recognize that selection may compromise our results. We will seek to account for this selection as much as possible.

6.2 Impacts of the 2006 EC Reform

As we describe in Section 5 above, our primary empirical analysis exploits a discontinuity in the historical clearance process for mines of area above and below 25 ha to evaluate the impact of requiring that mines hold a public hearing after compiling the EIA and before submitting that EIA to MoEFCC for clearance. Under the 1994 system for environmental clearance, mines of area less than 25 ha were not required to hold public hearings, while those above 25 ha were. The 2006 reforms bundled all mines of area between 5 and 50 ha as "Category B" projects, requiring all of them to hold public hearings after compiling an EIA. For mines above and below the 25 ha cut-off, this differential change in the public hearing requirement was the only regulatory change to the EC process around the date of the 2006 notification.We exploit these cut-offs in clearance requirements at 25 ha and around the date of the EC notification in September 2006 to evaluate the impact of the public hearing requirement.

Identifying mines of area less than 25 ha as treatment mines and mines of area greater than 25 ha as control, we estimate the following difference-in-difference regression:

$$(2) \quad Y_i = \beta_0 + \beta_1 Treatment_i + \beta_2 Post_i + \beta_3 Post * Treatment_i + \beta_4 Log\ area_i + \beta_5 Mine\ characteristics_i + \beta_6 Queue\ length_i + \beta_7 Cleared\ before + \epsilon_i$$

where Y_i is a mine-level outcome, $Treatment_i$ is an indicator specifying that mine *i* has area under 25 ha, and $Post_i$ indicates that a given mine applied for clearance after the 2006 EC notification. Then, $\beta_1$estimates the differential in mine outcomes for mines below 25 ha relative to mines above 25 ha before the 2006 notification, β_2 estimates the gap in mine outcomes for control mines (area above 25 ha) that applied after the 2006 notification relative to those that applied before, and β_3 estimates the differential change in mine outcomes around the date of the 2006 notification for treatment mines, or those with area below 25 ha. We can interpret β_3 as the impact of the expanded public hearing requirement under the 2006 EC reforms. Note that we restrict our analysis to mines of area between 5 and 50 ha. Mines of area below 5 ha are not required to apply for environmental clearance, and mines of area greater than 50 ha are classified as "Category A"' projects and are subject to a different clearance process.

Besides modeling mines' clearance outcomes as a function of mines' treatment status and application date, we include controls for mine characteristics, the number of applications awaiting clearance (queue length), and parent company characteristics. We include those characteristics that previous analysis has shown are significant determinants of EC stringency and mines' environmental risks (See Table A3 in Appendix D for simple regressions of clearance duration and environmental conditions on mine characteristics.) We define *Queue Length* as the number of non-coal mining projects that submitted their EC application before project *i* and have not yet been granted clearance. Queue length will be the same for all projects that applied for clearance at the same time as project *i*. When the clearance system is burdened with a larger volume of clearances to process, we would expect each clearance to be processed more slowly. Here, *Mine characteristics* represents the characteristics of project *i* that define its environmental and social risks. In particular, it includes log area, log production capacity, a categorical variable indicating whether an application is for lease renewal, an area or capacity enhancement, or a new mine, and an indicator that a mine is a riverbed mine. Finally, *Cleared Before* is a dummy taking value 1 if the parent company of project *i* has already had a successful environmental clearance prior to submitting the application for clearance of project *i*. We hypothesize that companies with a successful previous clearance are "known" in the EC system and might be processed more quickly.

The validity of our DD analysis rests on the fulfillment of the parallel trends assumption, which requires that the difference between the treatment and control groups would stay constant over time in the absence of treatment, i.e. the imposition of the public hearing requirement for the treatment group. We seek to validate this assumption by visualizing the trends in mines' outcomes by treatment and control groups over time. We present these figures as Figures A2 to A9 in Appendix E. Here, we plot trends in moving averages by month, calculated as the average of two months prior to two months after a given month. The trends appear to be largely parallel before the 2006 notification except for the year of deforestation relative to clearance, the probability of compliance with the deforestation requirements, and BOD in the nearest river. All of these outcomes have a relatively high proportion of missing data, so their timeseries are highly irregular.

Even if we see parallel trends in mine outcomes before the date of the 2006 reform, the reforms themselves could induce violations of the parallel trends assumption. In particular, while our difference-in-difference analysis is robust to any differences between the treatment and control groups that stay constant before and after the notification, it is vulnerable to any differential changes in composition for treatment and control. As we documented in Sections 5 and 6.1 above, the 2006 reforms could have induced substantial selection between treatment and control. This selection could lead to compositional changes in treatment and control both on observable and unobservable mine characteristics. Table 5 below assesses the extent of differential compositional changes on key mine characteristics.

We regress each mine characteristic Y_i on a simple diff-in-diff specification as follows:

$$(3) \qquad Y_i = \alpha + \beta_1 Treatment_i + \beta_2 Post_i + \beta_3 Post * Treatment_i + \epsilon_i$$

The coefficient β_3 evaluates differential compositional changes on a given characteristic. Table 5 below reports pre-reform means for treatment and control, as well as coefficients β_1, β_2, and β_3. We give p-values for each of these coefficients in parentheses below. We find evidence of differential compositional changes for application type, with a higher proportion of treatment mines applying as new mines and a lower proportion of treatment mines applying for area or capacity enhancements after the 2006 reforms. We also find evidence of differential changes on date of application, with treatment mines differentially applying for clearance later after the 2006 reforms. We attempt to control for these compositional changes as much as possible by including controls for observable mine characteristics as controls in our regressions. Even as we control for selection and other differential compositional changes on observable characteristics, however, our results may still be vulnerable to selection on unobservable characteristics. We discuss this selection in more detail in section 6.3. For now, we proceed under the assumption that the parallel trends assumption holds and our diff-in-diff model is valid.

Table 5. Assessing compositional changes on observable mine characteristics

	Pre-reform means		DD estimates (p-values below)		
	Control	Treatment	Treatment	Post	Post*treatment
Queue length	161.125	155.564	-5.561	15.635	-17.854
			(0.669)	(0.216)	(0.282)
Application type					
New mine	0.375	0.154	-0.221	-0.015	0.344
			(0.108)	(0.910)	(0.050)
Existing mine	0.188	0.103	-0.085	-0.047	0.152
			(0.428)	(0.646)	(0.266)
Area/capacity enhancement	0.438	0.744	0.306	0.062	-0.496
			(0.034)	(0.652)	(0.007)
Log prod cap (MTPA)	0.218	0.216	-0.002	0.108	-0.207
			(0.983)	(0.272)	(0.112)
Riverbed mine	-0.000	0.026	0.026	0.020	0.023
			(0.615)	(0.685)	(0.719)
Mine in multiple districts	0.000	-0.000	-0.000	0.020	-0.020
			(1.000)	(0.424)	(0.543)
Proponent cleared before	0.250	0.077	-0.173	0.050	0.114
			(0.155)	(0.670)	(0.458)
Violation	0.000	0.026	0.026	-0.000	0.009
			(0.481)	(1.000)	(0.848)
Date of EC application	5/31/2006	4/25/2006	-36.402	467.328	319.193
			(0.669)	(0.000)	(0.004)

Note: Robust standard errors are given in parentheses. Significant coefficients are denoted with stars as follows: *** p$<$0.01, ** p$<$0.05, and * p$<$0.1. The sample is restricted to mines of area less than 50 ha. *Post notif* is a dummy variable indicating a mine applied for clearance after the date of the EC notification on September 14, 2006. *Treatment* is a dummy variable indicating that a mine has area below 25 ha. Columns 1 and 2 give the control and treatment pre-reform means. For each mine characteristic Y_i, we run the following regression: $Y_i = \beta_1 Treatment + \beta_2 Post + \beta_3 Treatment * Post.$ Column 3 gives β_1, column 4 gives β_2, and column 5 gives β_3. P-values are given in parentheses below these coefficients.

We now turn to estimating the impact of the public hearing requirement. We start by visualizing our DD regressions. Figures A10 through A15 in Appendix F plot the kernel densities for each of these outcome variables in our treatment and control samples separately for the pre- and post-notification periods. Each figure is overlaid with vertical lines for treatment and control means for each outcome. Visually, we can interpret the differential change in these outcome distributions for treatment and control around the date of the notification as the impact of the change in public hearing requirements for treatment mines. In many cases, there appears to be a differential pre-post change between treatment and control; this differential shift is readily visible for PM concentrations at clearance in Figure A13, for example.

Tables 6 through 8 present the results of our primary difference-in-difference analysis of the impact of public hearings, which we estimate as the differential impact of the 2006 reforms for treatment mines (area less than 25 ha) relative to control mines (area greater than 25 ha). In Table 6, we begin by estimating the impact of the public hearing requirement on the costs of the EC process. We measure costs as duration of the EC process (columns 1 and 2) or as the total mine cost stated in each mine's clearance letter (columns 3 and 4). First, we find that clearance duration fell significantly for mines that applied for clearance after the 2006 notification, falling by about 31%. Note that we can only interpret this average change as a time trend, not as a causal impact of the 2006 notification reforms. We find no significant differential pre-post trend for treatment mines, i.e. no impact of the public hearing requirement.

Table 6. Impacts of the 2006 public hearing reform on clearance costs

	(1)	(2)	(3)	(4)
	Log duration		Total mine costs	
Treatment	-0.134	-0.203	52.208	17.132
	(0.17)	(0.17)	(71.18)	(65.37)
Post notif.	-0.414***	-0.373***	90.286	78.854
	(0.15)	(0.14)	(68.63)	(63.92)
Treatment * post notif.	0.177	0.266	-104.800	-98.435
	(0.21)	(0.20)	(80.53)	(73.22)
Log area	-0.102	-0.016	42.537	-20.646
	(0.13)	(0.13)	(34.83)	(33.97)
Queue length		0.002		-0.495
		(0.00)		(0.38)
Log prod cap (TPA)		-0.122***		52.730***
		(0.03)		(10.61)
Application type (Base = new mine)				
Existing mine		0.211		40.281
		(0.17)		(62.18)
Area/capacity enhancement		0.261**		1.269
		(0.13)		(41.16)
Mine type (Riverbed = 1)		0.576		-70.783
		(0.37)		(89.47)
Letter lists more than 1 district		0.565***		-101.260***
		(0.12)		(37.88)
Cleared before		-0.211		-4.291
		(0.14)		(53.91)
Violation		0.240		182.082***
		(0.16)		(40.49)
Nr. observations	134	134	124	124
R^2	0.077	0.325	0.049	0.277
Adj. R^2	0.049	0.258	0.017	0.199

Note: Robust standard errors are given in parentheses. Significant coefficients are denoted with stars as follows: *** p<0.01, ** p<0.05, and * p<0.1. The sample is restricted to mines of area less than 50 ha. *Post notif* is a dummy variable indicating that a mine applied for clearance after the date of the EC notification on September 14, 2006. *Treatment* is a dummy variable indicating that a mine has area below 25 ha.

It is important to approach these null results with caution, since they could simply reflect weaknesses in our measures of process costs. First, our measure of EC application duration does not actually include the time spent on the public hearing. Most mine applications lack data on the date that projects first applied for ToR, so we calculate duration as the time between when a project submits its EIA to MoEFCC and the date on which it receives clearance. The public hearing occurs before the project proponent submits its EIA to the ministry, so it is not included in our measure of duration. Thus, even if the public hearing requirement increases the total duration of the application process, we might not expect to see significant impacts on the measure of duration to which we have access. However, this measure of duration could pick up increases in duration that arise because the public hearing produces additional information that slows consideration by the EAC, for example. We attempt to rectify this mis-measurement by running our primary regression on ToR duration, measured from the date of ToR submission to clearance. However, dates of ToR application are available for only 26 mines, only one of which applied for clearance before the 2006 reforms, making this analysis impossible.

Table 7. Impacts of the 2006 public hearing reform on deforestation at mines

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Δ median EVI			Deforest year (rel. to clear)		Prob. of compliance	
Treatment	0.002	0.004	0.004	-0.342	0.173	-0.207	-0.099
	(0.02)	(0.02)	(0.02)	(1.09)	(1.00)	(0.15)	(0.16)
Post notif.	-0.004	-0.001	0.000	-1.782***	-1.338**	-0.283***	-0.190*
	(0.02)	(0.02)	(0.02)	(0.59)	(0.65)	(0.09)	(0.11)
Treatment * post notif.	0.016	0.013	0.012	1.195	0.174	0.260	0.075
	(0.02)	(0.02)	(0.02)	(1.15)	(1.24)	(0.19)	(0.20)
Log area	-0.002	-0.000	0.001	1.782*	2.297***	0.304*	0.366**
	(0.01)	(0.01)	(0.01)	(0.93)	(0.82)	(0.16)	(0.15)
Log prod cap (TPA)		-0.002	-0.002		-0.822***		-0.117***
		(0.00)	(0.00)		(0.19)		(0.03)
Application type (Base = new mine)							
Existing mine		0.001	-0.003		-0.454		0.040
		(0.01)	(0.01)		(1.01)		(0.17)
Area/capacity enhancement		0.000	-0.000		-0.361		-0.019
		(0.01)	(0.01)		(0.65)		(0.14)
Mine type (Riverbed = 1)		-0.010	-0.008		-2.632***		-0.754***
		(0.01)	(0.02)		(0.55)		(0.22)
Cleared before		-0.002	-0.003		0.586		0.229
		(0.01)	(0.01)		(0.49)		(0.14)
Queue length			-0.000		0.003		-0.001
			(0.00)		(0.01)		(0.00)
Letter lists more than 1 district			0.004		1.191**		0.182
			(0.01)		(0.58)		(0.14)
Violation			0.044**		4.241***		0.548***
			(0.02)		(0.59)		(0.11)
Nr. observations	116	116	116	70	70	70	70
R^2	0.031	0.041	0.067	0.132	0.406	0.147	0.350
Adj. R^2	-0.004	-0.040	-0.042	0.079	0.280	0.095	0.213

Note: Robust standard errors are given in parentheses. Significant coefficients are denoted with stars as follows: *** p<0.01, ** p<0.05, and * p<0.1. The sample is restricted to mines of area less than 50 ha. *Post notif* is a dummy variable indicating that a mine applied for clearance after the date of the EC notification on September 14, 2006. *Treatment* is a dummy variable indicating that a mine has area below 25 ha.

Instead, we seek to evaluate the costs of the clearance process as mines' total costs, with they self-report in the EIA and which are included in mine clearance letters. Columns 3 and 4 of Table 6 present the results of our primary diff-in-diff specification of mine costs. Again, we estimate no significant impact of the public hearing requirement on mines' total costs. Here, our predictive power may be limited by imprecise outcome data. Mines self-report costs, which are often rounded up to values like 5 crore Rupees, or 50 million Rupees. Downward bias due to measurement error may therefore contribute to our null result for the impact of public hearings.

Table 8. Impacts of the 2006 public hearing reform on air and water pollution at mines

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Δ PM (ug/m3)			Δ BOD (mg/L)			Δ pH		
Treatment	0.014	-0.357	-0.262	0.631	0.477	0.444	-0.014	-0.014	-0.013
	(1.32)	(1.27)	(1.27)	(0.54)	(0.66)	(0.66)	(0.11)	(0.13)	(0.13)
Post notif.	-1.400	-1.034	-1.056	-1.281**	-1.410**	-1.255**	0.026	0.036	0.018
	(0.89)	(0.87)	(0.84)	(0.56)	(0.62)	(0.61)	(0.11)	(0.11)	(0.12)
Treatment * post notif.	0.620	0.827	0.851	0.112	0.179	0.165	-0.089	-0.094	-0.090
	(1.25)	(1.25)	(1.24)	(0.63)	(0.65)	(0.65)	(0.15)	(0.16)	(0.16)
Log area	1.120	1.438*	1.485*	0.165	0.061	0.058	-0.119	-0.083	-0.084
	(0.85)	(0.86)	(0.88)	(0.35)	(0.44)	(0.45)	(0.09)	(0.09)	(0.10)
Log prod cap (TPA)		-0.403**	-0.448**		0.114	0.112		-0.031*	-0.030*
		(0.18)	(0.19)		(0.12)	(0.12)		(0.02)	(0.02)
Application type (Base = new mine)									
Existing mine		0.009	0.111		0.655	0.655		-0.006	-0.005
		(0.78)	(0.82)		(0.42)	(0.41)		(0.12)	(0.12)
Area/capacity enhancement		0.586	0.648		-0.102	-0.053		0.025	0.019
		(0.63)	(0.63)		(0.41)	(0.40)		(0.09)	(0.10)
Mine type (Riverbed = 1)		1.364	1.332		-0.198	-0.186		-0.002	-0.002
		(3.91)	(4.12)		(0.31)	(0.31)		(0.05)	(0.05)
Cleared before		-1.666***	-1.405*		-0.248	-0.262		-0.053	-0.051
		(0.63)	(0.72)		(0.41)	(0.41)		(0.10)	(0.11)
Queue length			0.010			-0.004			0.000
			(0.01)			(0.01)			(0.00)
Letter lists more than 1 district			-4.952***			0.000			0.000
			(0.78)			(.)			(.)
Violation			0.697			0.000			0.000
			(1.15)			(.)			(.)
Nr. observations	132	132	132	80	80	80	72	72	72
R^2	0.032	0.132	0.158	0.187	0.208	0.211	0.034	0.076	0.077
Adj. R^2	0.001	0.068	0.073	0.144	0.107	0.097	-0.023	-0.058	-0.074

Note: Robust standard errors are given in parentheses. Significant coefficients are denoted with stars as follows: *** p<0.01, ** p<0.05, and * p<0.1. The sample is restricted to mines of area less than 50 ha. *Post notif* is a dummy variable indicating that a mine applied for clearance after the date of the EC notification on September 14, 2006. *Treatment* is a dummy variable indicating that a mine has area below 25 ha.

Next, we consider the impact of the expanded public hearing requirement on the benefits of the environmental clearance process, for which we proxy with mines' environmental performance. Broadly, we find no evidence that the public hearing requirement significantly altered mines' environmental performance. First, consider the extent of vegetation coverage at mines, given in Table 7: in particular, we evaluate the impact of the hearings on the pre- to post-clearance change in EVI, a satellite-based measure of the extent of vegetation coverage, the timing of deforestation relative to clearance, and compliance with the requirement that mines only deforest the mine site after receiving clearance. We find no evidence that the public hearing requirement significantly changed mine's pre- to post-clearance EVI trends, nor do we find any significant change in these trends for control mines that applied for clearance after the 2006 reform.

Now consider proponents' compliance with the requirement that they only deforest the mine site after receiving clearance, given in columns 4 through 7 in Table 7 above. While we don't find any significant impact of the public hearing requirement on mines' deforestation compliance, we find that mines that applied for clearance after the 2006 notification were in general less likely to comply. In particular, we find that mines that applied for clearance after the 2006 reforms deforested an average of about 1.3 years earlier relative to clearance and were therefore 19 percentage points more likely to illegally deforest before the year of clearance. This shift, which we cannot interpret causally, is somewhat surprising given that the clearance process appears to have sped up following the 2006 notification. While we find this overall time trend, however, we find no evidence that the expanded public hearing requirement significantly altered mines' probability of deforesting early.

Finally, we find no evidence that the public hearing requirement significantly altered air or water pollution at mine sites. See Table 8 above, where we present estimates for the impact of hearings on changes in PM concentrations in columns 1 and 2, on changes in BOD in nearby rivers in columns 3 and 4, and on changes in pH in nearby rivers in columns 5 and 6. We do find some limited evidence that mines' water pollution changed post-notification: biological oxygen demand in rivers near mines increases significantly less around the date of clearance for mines that applied after the 2006 notification, suggesting that the reforms could have reduced water pollution from mines. In particular, we find that BOD in the nearest river increased by 1.255 mg/L less among mines that applied for clearance after the 2006 notification, relative to a mean post-clearance increase of 0.604 mg/L among pre-reform mines. However, we cannot confidently interpret this change as a causal impact of the 2006 notification. We find no parallel changes in mines' impact on air pollution or pH in nearby rivers. Furthermore, we find no evidence that the expanded public hearing requirement for treatment mines significantly altered mines' air and water pollution. That is, treatment status does not significantly alter the pre- to post-notification time trend for any of our measures of air or water pollution.

6.3 Robustness checks and extensions

Next, we provide robustness checks to help account for any bias induced by selection into treatment or control. While our difference-in-difference analysis is robust to any differences between the treatment and control groups that stay constant before and after the notification, it is vulnerable to any differential changes in composition for treatment and control, as we describe in Section5V above. Selection into treatment or control could create such differential changes. As we document in Section 6.1, we see evidence of substantial selection on mine size around the 5 ha cut-off for clearance. In particular, it appears that mines that would otherwise have area between 5 and 15 ha split into mines of area below 5 ha to avoid a more costly clearance process. We see less evidence of selection of mines around the 25 ha cut-off, though we cannot rule out that this form of selection exists as well.

We account for compositional changes induced by selection on observable mine characteristics, like area, production capacity, and application type, by including those characteristics as regression controls. However, our specification remains vulnerable to any differential compositional changes on unobservable characteristics between treatment and control conditional on these observables. For example, we might find that particularly risky mines of area of 8 ha are more likely than less risky mines of the same size to select out of the clearance process by splitting into two 4 ha mines. To minimize any bias from selection about the 5 ha clearance cutoff, therefore, we can show some robustness of our results to selection by estimating our primary specification on a sample of mines with area between 15 and 35 ha and between 10 and 40 ha, rather than between 5 and 50 ha. We present these results in Appendix Tables A8 through A10. In general, we do not find that restricting our sample to a smaller area ranges alters our null results for the impacts of the expanded public hearing requirement. The only exception is our estimate for the impact of public hearings on total mine costs, which becomes large and statistically significant on a sample between 10 and 40 ha; we take this result to be an aberration and not robust indication of a treatment effect.

Next, we experiment with alternative specifications. While the 2006 reforms' primary differential change for mines above and below 25 ha was the expansion of the public hearing requirement, we might expect that other components of the 2006 reform would imply differential increases in stringency for larger mines. For example, the 2006 reforms also began requiring mines to apply for mine-specific ToRs for the environmental impact assessment. If mine-specific ToRs imposed differential increases in stringency for larger mines, we might expect to see both a level change for treatment mines relative to control and a change in the slope on our area control in the post period. We would expect any such change in slope to bias upward our estimate for the average gap between mines above and below 25 ha. First, we have made a set of scatterplots with lines of best fit visualizing the relationship between mine area and mine outcomes before and after the notification. These scatterplots, given in Figures A16 to A22 in Appendix G, show some slight changes in slope for certain outcomes. We next test for any such change in regressions, running the following variant of our primary diff-in-diff specification:

$$(4) \quad Y_i = \beta_0 + \beta_1 Treatment_i + \beta_2 Post_i + \beta_3 Post * Treatment_i + \beta_4 Log\ area_i + \beta_5 Post * Log\ area_i + \beta_6 Mine\ characteristics_i + \beta_7 Queue\ length_i + \beta_8 Cleared\ before + \epsilon_i$$

We find that allowing an interaction between log area and the post dummy does not change our null results for a level change associated with public hearings. We present these results in Tables A4 through A6 in Appendix H. We then test whether any other mine characteristics have a substantially different impact on EC stringency post-reform by regressing clearance duration on a specification including a post interaction for each mine characteristic that we include in our primary regressions. We present these results in Table A7 in Appendix I. We find that the relationship between EC stringency and a number of application characteristics changed significantly post-reform. We find, for example, that while riverbed mines had significantly shorter durations than non-riverbed mines pre-reform, they had significantly longer duration post-reform. Violation mines, on the other hand, had significantly longer durations pre-reform, but shorter durations post-reform. Our estimate for the impact of public hearings on duration falls in magnitude when we include these interactions between mine characteristics and the post dummy, remaining statistically insignificant.

Finally, we corroborate our null results for the impact of public hearings on vegetation cover at mine sites by trying the same analysis other measures of landcover drawn from the MODIS satellite, Land Cover Type Yearly L3 (MCD12Q1).[6] Using these data, we calculate the change in the percentage of land within a 500 m radius of a mine site that is natural, cropland, barren, and a mixture from two years before clearance to two years after clearance. Table A11 in Appendix K presents the results of running our primary DD specification using these measures as outcome variables. As with EVI, we find no evidence that the public hearing requirement significantly altered the distribution of land types at mine sites.

7. Discussion

In this paper, we have pursued two objectives. First, we have provided proof of concept for the use of remote-sensing data to monitor mines' environmental compliance. We have matched a broad set of publicly-available administrative data on mines' clearance applications with remote sensing data on air pollution and vegetation to demonstrate how these free, publicly-available data can supplement monitoring in a low-resource environment like India. Using these data, we measure mines' environmental performance as the change in environmental conditions from two years pre-clearance to two years post-clearance. One particular innovation that we have demonstrated is to identify the timing of deforestation at individual mines using structural breaks in time series of vegetation coverage. This tool allows us to assess compliance with the requirement that mines break ground only after receiving clearance.

Next, we have used our broad data repository to evaluate the impacts of a set of substantial reforms to the EC process enacted in 2006. These reforms sought to bring greater transparency and accountability to the EC process by subjecting larger projects to additional scrutiny from regulators, independent experts, and the public. We have provide descriptive evidence of the impacts of the overall reforms: first, we find that mine proponents appear to have shifted to smaller mine sizes to avoid a costly reform, and next, that mines that applied for clearance after the reform experienced substantially shorter clearance but were more likely to deforest illegally before receiving clearance.

Next, we have used a historical discontinuity in clearance requirements to evaluate one crucial aspect of reform: an expanded requirement that mines hold a public hearing before applying for clearance. We evaluate the impact of embedding public hearings in the EC process by exploiting a discontinuity in the historical clearance process for mines at area of 25 ha. Overall, we have found no evidence to suggest that public hearings significantly altered either the costs of the clearance process, as measured by mine costs and the duration of the process, or its

[6] Friedl, M. 2010. MCD12Q1 Land Cover Type Yearly L3 Global 500 m SIN Grid. NASA EOSDIS Land Processes DAAC, USGS Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota (https://lpdaac.usgs.gov), https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd12q1.

benefits, which we measure as the impacts of mines on air pollution, water pollution, and forest cover.

We must maintain a certain degree of caution in interpreting these results. As we noted earlier, for example, our measures of clearance costs may be imprecise: mine capital costs are imprecisely estimated, and our measure of duration does not include the public hearing itself. This imprecision may somewhat compromise the internal validity of our results; that is, it may obscure true impacts of the public hearing reform. Next, we cannot assess the full range of benefits that we might expect to arise from the public hearing requirement. While we can assess its impact on environmental outcomes, we might expect forced public consultation to increase mines' other benefits to nearby communities, like increasing local employment or investments in local schools or health centers, for example.

Next, the external validity of our analysis may be limited in that our estimates only apply to the short-term impacts of the expansion of public hearings under the 2006 reform. We are limited to analyzing these impacts off of mines that applied for clearance before state-level clearance bodies were established, so we are unable to estimate any impacts of the reform on mines that applied for clearance longer after the reforms took effect. Finally, our results likely have limited external validity to public hearing reforms in other contexts. The impacts of any policy reform will depend crucially on the details of its implementation. For a public hearing reform, these important details could include the method of advertising hearings to the public, how public comments are incorporated into project plans, and people’s expectations of the regulation’s stringency, for example. Our estimates for the impacts of the India’s 2006 environmental clearance reform likely would have only limited relevance to a similar reform undertaken elsewhere, where the details of implementation might differ in key ways.

8. Specific findings for policy and practice

While inconclusive, our results point to a broad set of policy recommendations for regulators of mining in India and beyond. Our null results for the impact of public hearings reaffirm that ensuring that new policies work as intended requires not just establishing them, but also implementing them well. In India, anecdotal evidence suggests that the public hearings may be ineffectual tools for public consultation because they are often inaccessible to affected populations and are held as mere formalities. Enforcing particular details, like advertising the hearings well in advance, holding the hearings at convenient locations and times, and making information on environmental risks clear and accessible, may be crucial to ensuring effective public engagement in the clearance process.

Since 2006, India’s central government has made a series of reforms to the public hearing regulations to address some of these alleged shortcomings. For example, a 2009 amendment to the EIA Notification instituted a requirement that SPCB also notify the public in areas where newspapers are not available by beating drums and announcing the hearing by radio and television (Ghosh, 2013). In addition, while SPCBs had often held multiple public hearings at the same place and on the same day, MoEFCC issued a memorandum in 2009 directing that public hearings be held at the same location only if there is sufficient time between the hearings (Ghosh, 2013). While these reforms could help to make public hearings productive settings for public engagement, ensuring that they fulfill this potential will require monitoring that public hearings are systematically implemented. Next, other analysts have issued recommendations for more sweeping changes to the role of public hearings. For example, the Council on Energy, Environment and Water (2014) recommends that ensuring effective public participation in India's EC process could require holding two public hearings, first during the process of determining appropriate ToRs and then again after the EIA report is prepared. They argue, also, that the public hearings should involve an NGO or other civil society representation to ensure that the hearings are accessible.

Indeed, ensuring that public hearings are run in an accessible manner will likely require improving monitoring and increasing the costs of non-compliance with procedural statutes. As we have seen, the National Green Tribunal occasionally overturns clearances on the basis of non-compliant public hearings. However, it is likely that many purely symbolic public hearings go undetected. The notes from consideration of mining projects at EAC meetings suggest that public hearing compliance is only cursorily verified during the clearance deliberation process; in particular, the notes typically state only that "The issues raised during Public Hearing were discussed during the meeting." In some cases, the EAC appears to have given the public hearing more detailed scrutiny. For example, the meeting notes for January 15-16, 2015 detail that participants in one mine's public hearing commented on the "effect on the agricultural land due to mining activity, accidents due to transporation of mineral, effect on children" and other risks; the EAC concluded that the mine proponent should submit a revised plan to better accommodate these concerns. Strengthening mechanisms like these to hold mine proponents accountable for public hearing results may be a crucial part of ensuring that they provide a venue for substantive public engagement.

Next, our analysis has revealed the value of using low-cost tools like remote-sensing data to monitor compliance. India's regulatory environment has relatively low capacity for site monitoring; indeed, our analysis has revealed that there is high non-compliance with clearance regulations. We find that a remarkable 38% of mines appear to have illegally deforested at the mine site before the year of clearance. Among the sample of mines of 50 ha or less on which we base our DD analysis of public hearings, we find that non-compliance actually became more common among mines that applied for clearance after the 2006 reforms. Besides this form of illegal mining within the clearance process, there is likely substantial illegal mining that never passes through the clearance process. In a low-capacity environment like India, satellite monitoring may provide a useful complement to traditional, higher-cost forms of monitoring. In particular, our work has provided proof of concept for the use of satellite data to measure air pollution, water pollution, and to identify the timing of deforestation. In the clearance process, this form of monitoring could provide useful inputs into clearance deliberations and post-clearance monitoring.

Finally, our data collection process has pointed to the importance of better synthesizing publicly available data on mines. Within the Indian government, both IBM and MoEFCC regulate mining and publish records on mining leases and clearance applications, respectively, but their records are unlinked. Establishing a central mining database that linked mines in IBM and MoEFCC's systems would enable more meaningful public scrutiny of mines throughout their lifetimes, from EC and lease application to mine closure.

Besides these recommendations for policymakers, our research process has pointed to a set of important learnings for other researchers. Like policymakers, researchers can benefit from using low-cost satellite data to measure outcome variables. Our research is the most recent contribution to a growing body of work in economics that uses remote sensing data to measure a range of environmental and economic outcome variables. These data allow for novel analysis in that they are low-cost, cover a wide geographic scale, and are available at unusually granular spatial resolution (Donaldson and Storeygard, 2016). Besides pointing to the value of using satellite data, our research process reveals the challenges of working with policymakers in real-world environments. We pursued a number of intervention partnerships with pollution and mining regulators in India, none of which came to fruition. Our experience reveals the importance of preparing contingency plans for the obstacles that inevitably arise in real-world research.

Appendix A: Dates of SEAC established by state

Table A 1. Date each State's SEAC Established

State name	Date SEAC was established
Andhra Pradesh	7/4/07
Arunchal Pradesh	3/27/08
Assam	5/1/13
Bihar	2/7/11
Chhattisgarh	1/9/08
Goa	4/15/10
Gujarat	6/12/07
Haryana	4/21/08
Himachal Pradesh	10/11/07
Jammu & Kashmir	1/8/08
Jharkhand	2/7/11
Karnataka	6/11/07
Kerala	11/3/11
Madhya Pradesh	1/8/08
Maharashtra	4/21/07
Manipur	11/3/11
Meghalaya	7/23/07
Orissa	8/17/12
Punjab	11/19/07
Rajasthan	7/30/08
Sikkim	7/8/08
Tamil Nadu	3/3/08
Telangana	4/27/15
Uttar Pradesh	7/12/07
Uttarakhand	3/8/13
West Bengal	4/13/07

Appendix B: Research Hypotheses and Outcomes

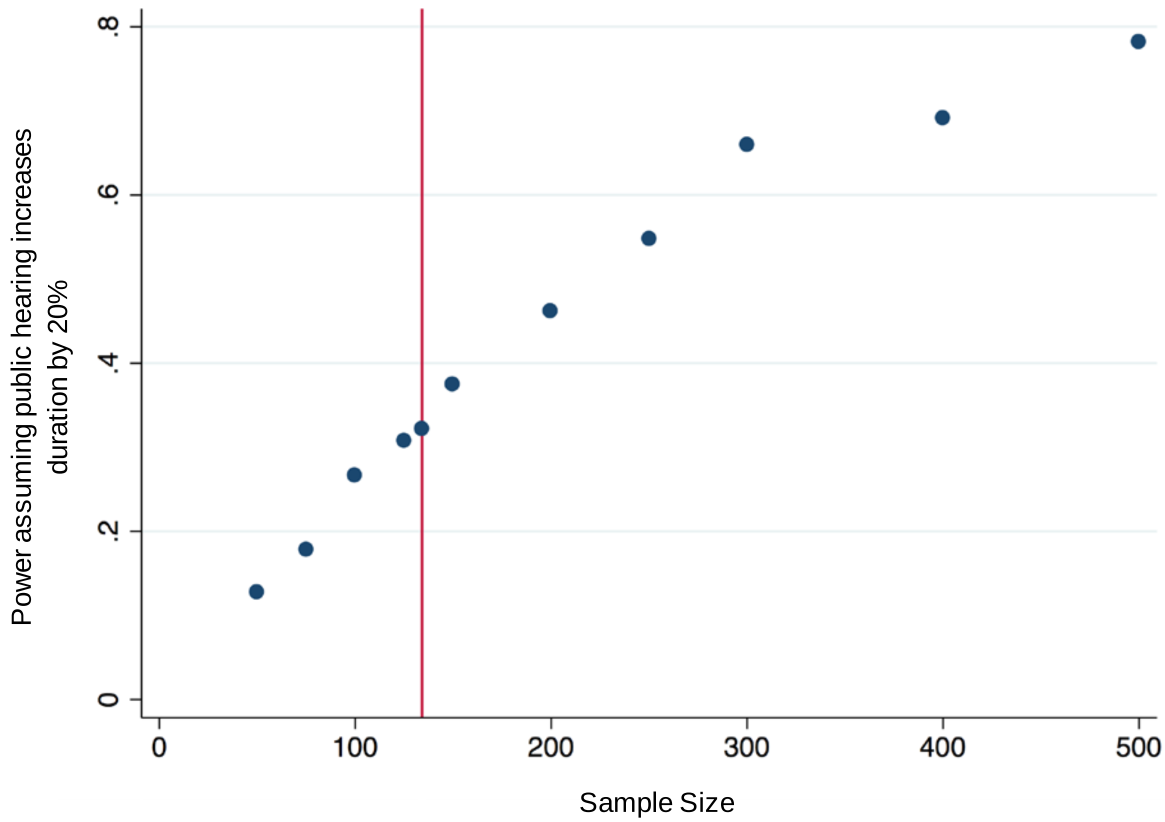
Table A 2. Variables Included in

Hypothesis	Outcome		Measurement	Variable construction
The public hearing requirement could improve mines' environmental performance by subjecting projects to more stringent review by expert committees and the public.	Δ average annual PM2.5 concentrations at mine sites		We use PM2.5 data assembled by the Atmospheric Composition Analysis Group at Dalhousie University. The data is given in micrograms per meters cubed at a spatial resolution of 1 km for the years 1998 to 2014. We measure ambient PM2.5 concentrations at mine sites as average annual PM concentration in the 1-km cell in which a mine is located.	We define our variable as the change in average annual PM2.5 concentrations from two years before clearance to two years after clearance.
	Δ annual average Biochemical oxygen demand (BOD) in nearest river		We use BOD data, measured in mg/L, drawn from India's Central Pollution Control Board's ENVIS database. BOD is a measure of organic pollution. We measure a mine's water pollution as average annual BOD at the nearest water monitor.	We define our BOD variable as the change in average annual BOD from two years before clearance to two years after clearance.
	Δ annual average pH in nearest river		We use pH data drawn from India's Central Pollution Control Board's ENVIS database. We measure a mine's water alkalinity as average annual pH at the nearest water monitor.	We define our pH variable as the change in average annual pH from two years before clearance to two years after clearance.
	Δ annual median Enhanced Vegetation Index (EVI) at mine sites		We draw data for EVI, which measures vegetation coverage at a spatial resolution of 250 m, from NASA's MODIS satellite. Values range from 0 to 1, where any value less than 0.2 corresponds to land considered to be sparse or barren. We measure vegetation coverage at mines as annual median EVI.	We define our vegetation coverage variable as the change in annual median EVI from two years before clearance to two years after clearance.
Increased public scrutiny could also improve mines' compliance with	Year of deforestation relative to		We identify the year of deforestation as the year of a structural break in mine-level timeseries for annual	We define our variable as the year of deforestation minus the year of

legal requirements of the EC process.	year of clearance		median EVI. We restrict this structural break to occur within 4 years before or after the date of clearance. We record a non-missing year of deforestation only in cases where a Supremum Wald test of the proposed structural break is significant at the 10% level.	clearance. Then, non-negative values proxy for compliance with the requirement that mines begin construction only after receiving clearance.
	Indicator for compliance with deforestation requirement		We define this variable based on the previous outcome, the difference between year of deforestation and year of clearance. We code non-negative values for deforestation year as compliance with the deforestation requirement.	
But by increasing public scrutiny of mining EC applications, the public hearing requirement could increase the costs of clearance for mines.	Duration of the clearance process		We calculate duration of the clearance process as the time in days between the date that an applicant submitted a final EIA to MoEFCC for consideration by the EAC and MoEFCC and the date the clearance letter was issued. We calculate this duration based on dates manually extracted from clearance letters.	This duration measure is not ideal for measuring the impact of public hearings, since it does not include the public hearing itself. So while it could capture heightened scrutiny by the EAC or MoEFCC due to additional information gathered in the public hearing, it does not capture time spent on the public hearing itself.
	Mines' total costs		We manually extract data on mine cost from clearance letters.	This data is fully self-reported and seems to often be reported with a high degree of rounding and estimation.

Appendix C: Power Calculations

Figure A1. Calculated power assuming treatment effect on duration of 20%.



The red vertical line indicates our true sample size of 134.

Appendix D: Regressions of EC duration and environmental performance on mine characteristics

Table A3. Regressions of EC duration and environmental performance on mine characteristics

	(1) Log duration	(2) Δ PM (ug/m3)	(3) Δ Median EVI	(4) Deforestation year rel. to clearance	(5) Prob. of compliance
Queue length	0.002*	0.013*	0.000	-0.007	-0.001
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
Log area	0.104***	0.020	0.001	0.432***	0.064**
	(0.02)	(0.15)	(0.00)	(0.12)	(0.03)
Log prod cap (TPA)	-0.069***	0.025	-0.002**	-0.391***	-0.055***
	(0.01)	(0.09)	(0.00)	(0.09)	(0.02)
Application type (Base = new mine)					
Existing mine	0.042	-0.173	-0.008	0.447	0.093
	(0.08)	(0.49)	(0.01)	(0.48)	(0.10)
Area/capacity enhancement	0.089*	0.072	0.005	-0.323	-0.119*
	(0.05)	(0.32)	(0.00)	(0.29)	(0.06)
Mine type (Riverbed = 1)	0.132*	-0.284	0.004	-1.479***	-0.413***
	(0.08)	(1.04)	(0.01)	(0.47)	(0.14)
Letter lists more than 1 district	0.569*	-3.046***	-0.002	3.184***	0.403***
	(0.31)	(0.45)	(0.01)	(0.60)	(0.06)
Cleared before	-0.100*	-0.139	-0.002	-0.207	0.005
	(0.05)	(0.39)	(0.00)	(0.29)	(0.07)
Violation	0.687***	4.061***	0.020***	3.885***	0.429***
	(0.15)	(1.22)	(0.01)	(0.39)	(0.08)
Nr. observations	934	676	667	318	318
R^2	0.379	0.261	0.078	0.103	0.078
Adj. R^2	0.366	0.243	0.054	0.065	0.038

Significant coefficients are denoted with stars as follows: *** p$<$0.01, ** p$<$0.05, and * p$<$0.1. All regressions include year fixed effects.

Online Appendix E: Trends in Mines' Outcomes Over Time

http://www.3ieimpact.org/media/filer_public/2018/11/22/tw81017-online-appendix-e-trends-mines-outcomes.pdf

Online Appendix F: Visualizing Difference-in-Difference Regressions

http://www.3ieimpact.org/media/filer_public/2018/11/22/tw81017-online-appendix-f-visualizing-diff-in-diff-regressions.pdf

Online Appendix G: Mine Area and Mine Outcomes Before and After Treatment

http://www.3ieimpact.org/media/filer_public/2018/11/22/tw81017-online-appendix-g-mine-area-mine-outcomes.pdf

Online Appendix H: Alternative Specifications: Public Hearings

http://www.3ieimpact.org/media/filer_public/2018/11/22/tw81017-online-appendix-h-alternative-specifications-public-hearings.pdf

Online Appendix I: Alternative Specifications: Additional Factors

http://www.3ieimpact.org/media/filer_public/2018/11/22/tw81017-online-appendix-i-alternative-specifications.pdf

Online Appendix J: Active Mine Leases by District

http://www.3ieimpact.org/media/filer_public/2018/11/22/tw81017-online-appendix-j-active-mine-leases-district.pdf

Online Appendix K:

http://www.3ieimpact.org/media/filer_public/2018/11/22/tw81017-online-appendix-k.pdf

References

Adivasi Majdoor Kisan Ekta Sangthan v. MoEF, 2012. Appeal No. 3/2011, National Green Tribunal, New Delhi, India. Available at: <https://indiankanoon.org/doc/19333350/>

Ahmad, B. and Wood, C. (2002). A comparative evaluation of the eia systems in egypt, turkey and tunisia. *Environmental impact assessment review*, 22(3):213–234.

Aragón, F. M. and Rud, J. P. (2013). Natural Resources and Local Communities: Evidence from a Peruvian Gold Mine. *American Economic Journal: Economic Policy*, 5(2):1–25.

Aragón, F. M. and Rud, J. P. (2016). Polluting Industries and Agricultural Productivity: Evidence from Mining in Ghana. *The Economic Journal*, 126(597):1980–2011.

Asher, S. and Novosad, P. (2014). Digging for Development: Mining Booms and Local Economic Development in India. *Mimeo*.

Berman, N., Couttenier, M., Rohner, D., and Thoenig, M. (2017). This Mine is Mine! How Minerals Fuel Conflicts in Africa. *American Economic Review*, 107(6):1564–1610.

Bisset R., 2000. Methods of consultation and public participation. In: Lee N, George C, editors. *Environmental Impact Assessment in Developing and Transitional Countries: Principles, Methods and Practice.* New York: John Wiley and Sons.

Council on Environment, Energy, and Water (CEEW) (2014). State of Environmental Clearances in India: Procedures, Timelines and Delays across Sectors and States

Donaldson, D. and Storeygard, A. (2016). The View from Above: Applications of Satellite Data in Economics. *Journal of Economic Perspectives*, 30(4):171-198.

Duflo, E., Greenstone, M., Pande, R., and Ryan, N. (2013). Truth-telling by Third-party Auditors and the Response of Polluting Firms: Experimental Evidence from India. *The Quarterly Journal of Economics*, 128(4):1499–1545.

Ghosh, S. (2013). Demystifying the Environmental Clearance Process in India. *National University of Juridical Sciences Law Review*, 6(3):433–480.

Greenstone, M., Nilekani, J., Pande, R., Sudarshan, A., Sugathan, A., and Ryan, N. (2015). Lower Pollu- tion, Longer Lives: Life Expectancy Gains if India Reduced Particulate Matter Pollution. *Economic and Political Weekly*, 50(8):40–46.

Jay, S., Jones, C., Slinn, P., and Wood, C. (2007). Environmental impact assessment: Retrospect and prospect. *Environmental impact assessment review*, 27(4):287–300.

Landrigan, P. J., Fuller, R., Acosta, N. J. R., Adeyi, O., Arnold, R., Basu, N. N., Balde´, A. B., Bertollini, R., Bose-O'Reilly, S., Boufford, J. I., Breysse, P. N., Chiles, T., Mahidol, C., Coll-Seck,

A. M., Crop- per, M. L., Fobil, J., Fuster, V., Greenstone, M., Haines, A., Hanrahan, D., Hunter, D., Khare, M., Krupnick, A., Lanphear, B., Lohani, B., Martin, K., Mathiasen, K. V., McTeer, M. A., Murray, C. J. L., Ndahimananjara, J. D., Perera, F., Potocˇnik, J., Preker, A. S., Ramesh, J., Rockstro ̈m, J., Salinas, C., Samson, L. D., Sandilya, K., Sly, P. D., Smith, K. R., Steiner, A., Stewart, R. B., Suk, W. A., Schayck, O. C. P. v., Yadama, G. N., Yumkella, K., and Zhong, M. (2017). The Lancet Commission on Pollution and Health. *The Lancet*, vol. 391, no. 10119, pp. 462-512.

Ministry of Environment and Forests, 2006. *Notification, Published in the Gazette of India, Extraordinary, Part-II, and Section 3, Sub-section (ii).* New Delhi, India. Available at: <http://envfor.nic.in/legis/eia/so1533.pdf>

Mohan, M. R. and Pabreja, H. (2016). Public Hearings in Environmental Clearance Process: Review of Judicial Intervention. *Economic and Political Weekly*, 51(50):68–75.

Nadeem, O. and Hameed, R. (2008a). A critical review of the adequacy of EIA reports—Evidence from Pakistan. *World Academy of Science and Technology*, 23(2006):64–70.

Nadeem, O. and Hameed, R. (2008b). Evaluation of environmental impact assessment system in Pakistan. *Environmental Impact Assessment Review*, 28:562–571.

Panigrahi, J. and Amirapu, S. (2012). An Assessment of EIA Systems in India. *Environmental Impact Assessment Review*, 35: 23-36.

Rights and Resources (2016). Land Disputes and Stalled Investments in India. 57

Toro, J., Requena, I., and Zamorano, M. (2010). Environmental impact assessment in colombia: critical analysis and proposals for improvement. *Environmental Impact Assessment Review*, 30(4):247–261.

Wood, C. (2003). Environmental impact assessment in developing countries. *International Development Planning Review*, 25(3):301–321.

Zubair, L. (2001). Challenges for environmental impact assessment in sri lanka. *Environmental Impact Assessment Review*, 21(5):469–478.