# Regulation Enforcement

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**Abstract**

This paper compares the effectiveness of two mechanisms of regulation enforcement: (1) the frequency of inspections and (2) penalties for violations. Mining industry data from 2004-2009 are used to analyze the responses of mines to separate increases in inspections and citation penalties regarding regulations of safety standards. Mines significantly and permanently reduced accidents under increased inspections; however, they did not reduce accidents in response to increased penalties. Analysis suggests that, locally, increasing inspections would increase social welfare.

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# 1 Introduction

In a wide variety of settings, regulations and policies are imperfectly enforceable. Environmental emissions standards, self-reported filing of taxes, and enforcement of drunk driving laws, are a short list of settings in which an agent is requested to comply with well-defined standards, however enforcement of such standards is costly and imperfect. This paper uses data regarding safety regulations and accidents in the mining industry to compare the effectiveness of the two most prominent enforcement mechanisms: (1) the frequency of inspections and (2) the dollar value of penalties for violations. Mining is a meaningful industry to study regulation enforcement due to the significant risk to workers. Understanding mechanisms which effectively enforce safety specifically is also meaningful in light of the trade-off between economic growth and safety discussed by Jones (2016).

There are two channels whereby inspections and citations are hypothesized to affect behavior: (1) a threat effect, a response to the threat of being caught violating a standard or a response to the magnitude of the penalty associated with a citation and (2) a corrective effect, that agents may adjust behavior after being inspected or cited. It is often difficult to determine the mechanism which drives corrective effects (a short list of possible mechanisms includes learning, temporary abatement, and sunk-cost related fallacies), in contrast it is straightforward to understand the mechanism by which threats influence behavior. Because of this, the present paper focuses on threat effects.

Responses to the threat of inspections are identified by an increase in the propensity of the Mine Safety and Health Administration (MSHA) to inspect mines. In October, 2007 the MSHA announced the 100 Percent Plan, an effort to perform all mandated safety inspections (described in what follows), and subsequently increased average inspections. This policy was not accompanied by legislation or safety technology changes, and is assumed to be an exogenous shock to the threat of receiving a citation. It is shown that mines significantly reduced their propensity to have accidents in the wake of the announcement. To justify that the estimated safety improvements were caused by the increase in inspections, inspecting offices are marked by their change in inspecting rates around the announcement of the 100 Percent Plan. Safety improvements are only exhibited by mines for which the local office increased inspections by more than the median, implying the reduction in accidents was a response to the increase in inspections, rather than a response to other contemporaneous factors. Surface mines treated by the policy are estimated to have decreased average accidents per quarter by .146 between the announcement of the policy and December 2009, and underground mines are estimated to have decreased average accidents per quarter by .592. These are reductions in accidents of roughly 40% and 20% respectively (inspecting rates increased by about 40% and 10% respectively). Selection is shown to be driven by increases in staffing of inspecting offices. Implications on conclusions are discussed in what follows. Robustness checks limit the sample to mines which were similar ex ante, confirming results.

Regarding the threat effect of larger penalties, the Federal Mine Safety and Health Act of 1977 (Mine Act) established the issuance of citations for violations of the Mine Act. The MSHA announced increases to citation amounts in March, 2007, taking effect in April, 2007. Analysis indicates that mines did not adjust behavior in response to the increase in penalties. It is suggested that fines act as payment for the right to commit violations in the style of Gneezy and Rustichini (2000). At local levels, penalties may not be large enough to deter violations.

## 1.1 Related Literature

Implications of inspections on regulation enforcement have been studied in other contexts, notably with regards to tax filings. Dubin, Graetz, and Wilde (1990), Slemrod et al. (2001), and Kleven et al. (2011) among others, have shown that receiving an audit, and increases in audit rates, result in increases in personal tax reporting.[1] The primary contribution of the present paper is the comparison of responses to threats of citation amounts, with responses to threats of inspections. In addition, this work considers a large industry in which inspections are frequent and routine, unlike tax filings. Estimates in this setting are more likely to be applicable when considering policies regarding enforcement of environmental regulations and industry standards.

In the context of environmental regulations, Telle (2008) attempts to quantify responses to threats of inspections through estimating the probability of an inspection. In Telle's context, the probability of an inspection relies on endogenous characteristics: risk class and previous compliance. The threat of inspections is endogenously determined. This paper provides estimates of threat effects in a context with exoge-

[1] In similar research, Hansen (2015) uses a regression discontinuity to conclude that having blood alcohol content above the DUI threshold reduces recidivism by 17%.

nous inspection probability, and exploits an exogenous increase in inspections.[2]

Pouliakas and Theodossiou (2013) provide a review of health and safety literature. In discussing the effectiveness of penalties and inspections, they state, "Empirical evidence tends to suggest that the estimated effects of (occupational safety and health) inspections on safety are quite small or non-existent". They cite Shapiro (1999), who references a variety of papers that examine correlations between inspecting rates and safety, and violations and safety.[3] Recent research regarding effectiveness of workplace safety regulations is minimal. Two papers include (1) Haviland et al. (2010), who show in manufacturing that inspections are negatively correlated with accidents in the short run, even for accidents that are not associated with violations, and (2) Kniesner and Leeth (2004), who use over 200 specifications of dynamic models to estimate the effect of regulations on safety for underground coal mines, concluding regulations have essentially no effect. These, and the studies cited by Shapiro, have focused on the corrective response of firms to being inspected or receiving a citation.[4] It is intuitive that forward looking agents would be minimally affected by a past event (unless it provided information). A contribution of this paper is to examine the safety response to an exogenous increase in the threat of receiving a violation. Estimates imply significant and meaningful safety improvements.[5]

In related work, health and safety in the context of compensating wage differentials has been well-researched, see Viscusi and Aldy (2003) for a review of estimates. Various sources have shown that workplace safety is a luxury good, that as non-labor income rises, workers choose safer jobs (Biddle and Zarkin 1988). Other relevant work includes Fishback and Kantor (1995), who show that costs of workplace safety are passed through to workers in the form of lower wages, and Drakopoulos and Theodossiou (2016), who show workers often underestimate job-associated risks. Other work has shown that workers prefer jobs with more amenities and lower wages in

[2]Other relevant research includes Hanna and Oliva (2010), who estimate corrective responses to inspections in the context of environmental regulation.

[3]Specific papers include: Viscusi (1992), Gray and Scholz (1993), Cooke and Gautschi (1991), Robertson and Keeve (1983), Scholz and Gray (1990), Smith (1979), McCaffrey (1983), Ruser and Smith (1991), Gray and Jones (1991), and Bartel and Thomas (1985).

[4]A slightly different strand of research regards discretion in enforcement and includes Jung and Makowsky (2014), who show that state agencies find fewer violations when unemployment is higher.

[5]Corrective effects were estimated using the sample of this paper as well. Consistent with earlier literature, small, short-lived corrective effects were estimated. Estimation is excluded for brevity.

response to tax increases (Powell and Shan 2012). Powell (2012) shows safety is an amenity which is difficult to adjust in response to taxes, and finds large differences in the wage response of jobs to taxes based on their riskiness. This work contributes by comparing the effectiveness of policies designed to improve workplace safety.

In other regulation work, much has been learned regarding the effects of environmental regulations on productivity and firm behavior. Dechezlepêtre and Sato (2017) review the literature, showing environmental regulations have adverse effects on trade, employment, plant location, and productivity in the short run. It is also shown that such regulations induce innovation. Greenstone, List, and Syverson (2012) show that air quality regulations cause a 2.6% decline in total factor productivity among manufacturing firms. Productivity implications of regulations are not analyzed in this paper. Other mining research includes Gowrisankaran, Lutz, and Burgess' (2015) analysis of productivity responses to accidents among coal mines.

This paper proceeds with background information, a description of the data, discussion of methodology, presentation of empirical results, and concludes.

# 2 Background

A natural question regarding the relevance of this paper is the size of the industry studied. According to the Bureau of Labor Statistics, the mining industry employed 731,000 individuals in January, 2016. The raw data used in this paper indicate there were 54,766 worker-days lost due to accidents in 2016. The average number of days lost per accident was 7.96. While mining accounts for a small fraction of U.S. employment, the findings of this work are meaningful beyond the context of reducing accidents in mining. The primary contribution is analysis of the general question regarding which methods best enforce regulations.

What follows draws from the MSHA-Handbook Series - *Citation and Order Writing Handbook for Coal Mines and Nonmetal Mines* and the *Metal and Nonmetal General Inspection Procedures Handbook*. The interested reader is referenced to these.

The Federal Coal Mine Health and Safety Act of 1969 (Coal Act) created the Mining Enforcement and Safety Administration, later renamed the MSHA. The Coal Act dramatically increased the safety and health standards of coal mines, and was later updated through the Mine Act to apply to all mines: coal, metal, and nonmetal. The Mine Act also established that inspectors would issue citations when it was believed a violation of the Mine Act had occurred. The Mine Improvement and New

Emergency Response Act of 2006 (MINER Act) amended the Mine Act. The MINER Act included a variety of adjustments: creation of emergency response plans, changing reporting requirements for accidents, removing liability to individuals involved in rescue teams, and requiring the Secretary of Labor to modify the civil penalty criteria, eventually causing citation dollar amounts to increase in the following year (discussed in what follows).[6] An assumption of this paper is that the MINER Act's passage did not affect safety in mines. Required adjustments were with respect to accident response plans, rather than safety measures preventing accidents, or incentives to avoid accidents. Empirically it will be shown no kinks nor jumps in accidents per quarter occurred due to the passing of the MINER Act. It was hypothesized that the increase in citation rates resulting from the MINER Act would affect mine safety decisions, although estimation suggests a null effect.

The MSHA is required to perform regular inspections at each underground mine four times a year and each surface mine twice a year. Inspections are partitioned into three classifications in this paper, (1) regular inspections, (2) compliance follow-up inspections after violations have been issued, (3) all other inspections which include accident investigations, hazardous condition complaint investigations, and special inspections at extremely hazardous mines (i.e. those with large amounts of explosive gases). From 2004-2009, about 46% of all inspections were regular, and about 13% were compliance follow-up inspections. Inspections other than regular inspections usually address a specific subject or a limited area of a mine, while regular inspections are general. Inspectors are encouraged to vary their inspection routes and starting points from one regular inspection to another. Inspectors vary their inspection

[6] Specifically the MINER Act consisted of the following: section 1 presented the name of the Act, section 2 addressed existence of emergency response plans, section 3 addressed liability for rescue operations, section 4 stated qualifications for mine rescue teams, section 5 required prompt notification of accidents, section 6 created the Office of Mine Safety and Health (designed to develop new safety technology), and section 7 addressed relationships with family members of miners which experienced an accident. Section 8 modified penalties, establishing a criteria for flagrant violations (reckless or repeated failure to make reasonable efforts to eliminate a known violation), and requiring that the Secretary of Labor promulgate new regulations with respect to penalties by the conclusion of the year. Section 9 regarded fine collections, and section 10 addressed the sealing of abandoned areas. Later sections regarded the Techincal Study Panel (which provides recommendations with respect to the utilization of belt air and the composition and fire retardant properties), scholarships for Associate's degrees related to mining, and research for refuges in underground coal mines.

frequency as to the month of the quarter a mine is inspected.

If an inspector believes that a mine has committed a violation of the Mine Act, the inspector issues a citation to the mine operator. Each citation includes a reference to the provision of the Mine Act alleged to have been violated. Also recorded is the chapter and part of the Code of Federal Regulations (CFR) which was violated.

Each citation fixes a time for the abatement of the violation. If an inspector finds that a violation previously cited has not been abated and that the period of time for abatement should not be further extended, the investigator issues a withdrawal order for the cited equipment or area of the mine affected by the violation. Forced abatement is almost immediate. From 2004-2009, over 50% of citations required operators to abate the offense within a day, and the 95th percentile was 15 days.

## 2.1 Types of Violations

Each violation is marked by the part of the CFR which is violated. Since the passage of the MINER Act, most mining violations are from title 30, "Mineral Resources" however there are a trivial potion from title 42 "Medical Care and Examinations". In the sample of analysis, the following parts of title 30 are violated: 40, 41, 44, 45, 46, 47, 48, 49, 50, 56, 57, 58, 62, 70, 71, 72, 75, 77, and 90. Parts 40-45 reference filing and administrative requirements, parts 46-49 reference education and training (i.e. new miner training), and part 50 regards reporting of employment, production, and accidents. Safety in metal and non-metal (but non-coal) mines is referenced in parts 56-58. Uniform health regulations are detailed in part 62. Coal mine safety and health is covered in parts 70-90.

Appendix table A1 lists the name of each part of title 30 which is violated. A detailed explanation of all possible violations would add minimally. The interested reader is referenced to the CFR. A basic list of safety-related topics of violations is: fire prevention, air quality, use of scaffold, use of ladders, clear walkways, electric equipment, use of personal safety equipment, storage of materials and explosives, illumination, use of drilling equipment or other large machines, and ventilation.

## 2.2 100 Percent Plan

In October 2007 the MSHA announced the 100 Percent Plan, a goal to perform every mandated regular inspection during each calendar year (previously the MSHA had failed to perform all mandated inspections). The MSHA and various news releases indicate that the goals were achieved and all mandated regular inspections were completed. Data indicate that inspections increased following the announcement.

The MSHA cited various factors which contributed to the increase in inspections: "...the willingness and work ethic of dedicated career MSHA employees, the temporary reassignment of MSHA inspectors to areas where they were most needed, the provision for increased overtime for additional hours needed to complete inspections, and better oversight and tracking of inspections by the agency's district offices and headquarters. Nearly 190,000 hours of inspector overtime were logged during FY 2008." There are no records I am aware of that inspecting procedures differed under this policy - except perhaps if inspectors were tired due to overwork.

I am unaware of legislation regarding mine safety, or major developments in safety technology, which occurred contemporaneously. There was a major contemporaneous accident, the Crandall Canyon Mine accident in August 2007 which occurred in Emery, Utah. This incident killed six miners and three rescue workers, receiving national attention. One could argue that other mines improved safety in response to such a major event. The improvements in safety following 2007 are long-term and show no reversion to pre-100 Percent Plan levels. Also, reductions in accidents are strongest for mines which were inspected by the offices where the inspecting rate increased the most. A response to an accident would presumably be exhibited by all mines. It is assumed that this incident is not motivation behind improved safety.

## 2.3 Citation Amounts

Violations are assessed according to a formula that considers five factors: (1) history of previous violations, (2) size of the operator's business, (3) negligence by the operator, (4) gravity of the violation (likelihood of injuries), and (5) good faith in the operator trying to correct the violation promptly, which results in a 10% reduction (30% before the change following the MINER Act). The five factors are determined from the inspector's findings, MSHA records, and information supplied by the operator. A sixth factor, the effect of the penalty on the operator's ability to stay in business, is considered when the operator submits information on the adverse effect of the penalty. The general method whereby fines are calculated is described below, the interested reader is referenced to CFR title 30, chapter 1, subchapter P, Part 11 and 72 FR 13591.

The history of previous violations affects penalties through two channels. (1)

Operators who have 10 or more violations during the previous 15 months are assigned penalty points based on the total number of violations per inspection day. (2) Points are assigned for repeat violations of the same standard by an operator with at least six repeat violations in the previous 15 months, similarly assigned depending on the number of repeat violations per inspection day.

Points are assigned according to size as measured by tonnage of coal for coal mines, and labor hours for non-coal mines.

Penalty points are assigned, increasing in severity, for each of the following categories. (1) Likelihood of injury, marked as one of the following: no likelihood, unlikely, reasonably, highly, and occurred. (2) The number of workers potentially affected. (3) The potential seriousness of injuries measured by potential days lost of work. (4) Negligence, marked as one of the following: none, low, moderate, high, and reckless.

Given the total number of points, there is a mapping to the dollar value of the fine. The MINER Act did not change the core of the process whereby citation amounts are calculated, however did change both the number of points assigned for each characteristic, as well as the mapping from points to dollar values of fines. The Final Rule resulting from the MINER Act regarding citation increases, 72 FR 13591, did not take effect contemporaneously with the Act's passage. A proposed rule regarding the change in citations was made public on September 8, 2006. Six public hearings were made from September to October of 2006. After these hearings, revisions were made, and the final rules were announced on March 22, 2007, taking effect April 23, 2007. Most importantly, the changes were well-publicized and anticipated.

The changes resulting from the MINER Act greatly increased the average dollar value of citations. In an example published with the Final Rule, the average fine to a Peabody coal mine under previous legislation was $68, under the new legislation the average fine would have been $586. Formal estimation does not exploit specific changes in the rules, only that the new rule increased average citations (which is confirmed by the data).[7] Estimation proceeds in a reduced form manner regarding the threat of greater citations.

[7] The Final Rule acknowledges that a small portion of violations, about 5% of those occurring in 2005, would have received lower violations under the new rules.

## 2.4 Types of Mines

There are three types of mines: surface, underground, and facility. In surface mining the earth is stripped back, mining ensues, and the overburden is put back in place after mining is complete. Underground mines access ore or coal either with a sloped decline, vertical shafts, or horizontal excavations into the side of a hill or mountain. Facility mines represent mill operations, preparation plants, or breaker plants. Underground mines are typically considered to be the most dangerous due to difficulties with ventilation, collapses, lighting, and entrapment. The vast majority of observations are of surface mines. In the data, 73.63% of mines are surface, 20.03% are underground, and 6.34% are mining facilities.

Analysis separates underground and surface mines because the 100 Percent Plan had different implications on these mines. Facility mines are excluded due to strong pre-trends and because inspections were minimally affected by the 100 Percent Plan.

# 3 Data

Data on inspections, accidents, violations, and fines, are publicly provided by the MSHA. Data are available at the violation-level, accident-level, inspection-level, and quarterly at the mine level, for variables regarding employment and the current operator. Data regarding fines became available in 1995, although the sample is restricted to 2004-2009. Violations, accidents, and inspections are aggregated to the mine-quarter level. This data source has been used previously, notably by Stoker et al. (2005) in their analysis of productivity. Attention is restricted to observations with at least 3,000 employee hours in the quarter.

Data on inspections includes the number of hours of the inspection and the components of the mine which were inspected (surface area, underground area, outby areas, refuse piles, shafts/slopes, dust samples, and air samples are some examples). Offices are assigned to inspect mines based on geographic location, and the inspector's name is not recorded in the data.

Descriptions of violations are detailed. Recorded variables include the part of the CFR which is violated, the likelihood of injury due to the violation, the potential number of persons affected, and the degree of negligence which resulted in the violation. Accident data are also detailed, including specifics of the injury which are not relevant to the methodology of this paper. For transparency, about 27% of injuries from 2004-2009 are marked as "No days away from work, no restricted activity". These are accidents such as non-severely twisted ankles and dislocated fingers. Of injuries which caused at least 1 day away from work, the median is 21 days and the 99th percentile is 330 days. Some examples of injuries are: falling off ladders and breaking bones, dropping a steel beam on one's foot, and muscle strains from lifting heavy objects. Mines are required to report accidents within 15 minutes of their occurrence, facing penalties for failure to do so. It is assumed accident reporting is representative.

Many mines are operated by more than one company in their histories. Fixed effects are determined by the combination of the mine operator and mine.

## 3.1 Descriptive Statistics

Figure 1 displays the average number of accidents per quarter and regular inspections per quarter for surface and underground mines separately. From 2004 to October of 2007 there were minimal changes in average inspections and accidents per quarter for both surface and underground mines. This is unchanged by the MINER Act's passage in June of 2006, denoted by the first vertical bar, and the implementation of new citation amounts, denoted by the second vertical bar. The only deviation from a near-constant function for inspections is that the inspecting rate for underground mines began to dip in 2005 to around .9 per quarter. The third vertical bar denotes the announcement of the 100 Percent Plan, after which underground mines were inspected almost quarterly and the inspecting rate increases for surface mines. (As does the variance in regular inspections, with an increase in inspections specifically in the first quarter of each year, likely an effort early in each year to ensure compliance with standards). At this point, the rates of accidents in both surface and underground mines began declining. This decreasing linear trend in accidents continued until the fourth quarter of 2009. Appendix figure A1 presents the analog with facility mines, showing negative pre-trends in accidents and a minimal increase in inspecting rates.

Figure 2 plots the average number of violations and the average citation paid by mines of each type. Violations increased with the implementation of the 100 Percent Plan, presumably due to increased inspecting rates, then declined as mines improved safety. Figure 2 also shows that citation amounts jumped meaningfully and discontinuously upward due to the implementation of new citation rules. Neither violations nor accidents kinked nor jumped in response to the jump in citation amounts.

Summary statistics of accidents, inspections, employment, and citations are presented in table 1. The first three columns show average accidents per quarter for surface and underground mines separately, split by the time periods: before the average citation increase, between the policy changes, and after the announcement of the 100 Percent Plan until the end of 2009. For surface mines, average accidents per quarter are respectively .308, .290, and .268. For underground mines the averages are 2.232, 2.263, and 2.054. Citations jump discontinuously upward after the implementation of the new formula.

To understand trends further, mines are partitioned to those "treated" and "untreated" by the policy change. A mine for which the local office increased the inspecting rate following the announcement of the 100 Percent Plan may be thought of as "treated" compared to mines for which the local inspecting office did not change behavior. Each mine is marked by the inspecting office which performed the most regular inspections during the years 2006-2009. The average inspections per quarter for all mines with the same inspecting office is calculated separately for 2008-2009, and for 2006-2007. Figure 3 displays histograms of the differences in these inspecting rates at the inspecting office level. At the mine-quarter observation level from 2004-2009, for surface mines the 25th percentile of the change in inspecting rates is .021, the median difference is .070, and the 75th percentile is .114. For underground mines the 25th percentile is -.008, the median is 0, and the 75th percentile is .042. The medians, .070 and 0, are respectively the cutoffs used to mark an office as "complying". Mines for which the office complies are "treated". Safety improvements are exhibited only by treated mines, and analysis separately estimates effects within each quartile. Larger effects are shown in the top quartile, justifying the claim that the reduction in accidents is a result of increased inspecting rates.

Treatment is defined at the office rather than mine level because average inspecting behavior of a local office is plausibly more representative of the average threat of inspections. Also, increases in staffing of local offices will be shown to be a primary determinant of selection into treatment. Therefore treatment is defined at the office level because this is effectively the level at which treatment is assigned.

Columns four through six of table 1 restrict to treated mines. Columns seven through nine display summary statistics for all other mines. Treated surface mines reduced accidents per quarter from .367 to .348 to .318 over the respective time periods. Non-treated surface mines decreased accidents per quarter from .252 to .235

to .220. The respective percent reductions following the announcement of the 100 Percent Plan are $\frac{.348-.318}{.318} = 9.4\%$ and $\frac{.235-.220}{.220} = 6.8\%$. Figure 4 recreates figure 1, however restricted to treated mines. Treated mines had minimal pre-trends prior to the 100 Percent Plan, then accidents kinked strongly downward. Visually it appears the declining linear trend flattens by the beginning of 2010 for surface mines, and the fourth quarter of 2009 is used as the final time period when estimating the linear trend following the 100 Percent Plan. (Robustness checks vary the final time period of analysis). The plots for non-treated mines are shown in figure 5. The decease in accidents among non-treated mines following the 100 Percent Plan appears to be the result of a pre-trend, and this trend being unaffected by the policy.

For treated underground mines, average accidents per quarter are 2.611, 2.729, and 2.492 over the respective time periods. For untreated underground mines, average accidents for the three time periods are 1.745, 1.652, and 1.455. Percent reductions are 9.5% and 13.5%.[8] Figures 4 and 5 show similar trends for underground mines as for surface mines. Treated underground mines had no trend in average accidents per quarter prior to the policy change, then accidents per quarter kinked downward after the 100 Percent Plan was announced. Accidents per quarter were trending downward in non-treated mines prior to the policy changes, and this trend was unchanged by the increase in citation amounts and 100 Percent Plan. As with surface mines, the downward trend in accidents among treated underground mines ended in the fourth quarter of 2009. Importantly, the kink in accidents is only exhibited by treated mines, justifying the claim that safety improvements were a response to the threat of increased inspections. It is surprising that data imply mines minimally responded to the increase in citation amounts that is so prominently displayed in figure 2 and table 1. For both surface and underground varieties, treated mines had more accidents and higher employment prior to the policy changes. Possible selection concerns are discussed in section 5.3.

The announcement of the 100 Percent Plan does not cause a discontinuous change in accidents per quarter, rather a sharp decline in the first derivative. The lack of a discontinuous jump is not surprising, safety levels certainly have persistence.

[8] Raw data show smaller effects for reductions in accidents than formal estimation. This is because the main effect of the 100 Percent Plan was a change in the first derivative of accidents. Summary stats include observations immediately following the 100 Percent Plan (when mines had minimally adjusted) resulting in smaller decreases in accidents than the total effect.

Discontinuous jumps would be a red flag that there may be changes in reporting methods or definitions of accidents. Because the change is smooth, it is assumed to be a result of mines improving safety.

# 4 Methodology

Estimation uses the data for the time period 2004-2009 to estimate:

$$Acc_{it} = \beta_1 Cite_{it} + \beta_2 P_{it} + \beta_3 t + \beta_4 \tau_{1t} Cite_{it} + \beta_5 \tau_{2t} P_{it} + \alpha_i + \alpha_{\mathbb{T}} + \Gamma X_{it} + \varepsilon_{it}.$$

The variable $Cite_{it}$ is an indicator for being later than the first quarter of 2007 but before 2008, $P_{it}$ is an indicator for being in 2008 or later. The citation policy began in the quarter following the announcement (namely, the second quarter of 2007), and the 100 Percent Plan began with its announcement, however presumably mines had not yet reacted to the increased threat and a response would be observed in the following quarter (the first quarter of 2008). In the equation, $\tau_{1t}$ denotes time measured in years such that the first quarter of 2007 is 0 and $\tau_{2t}$ denotes time such that the fourth quarter of 2007 is 0. Relevant coefficients estimate the change in the time trend that occurred between the policies, and after the 100 Percent Plan, respectively. Visually from figures 1, 4, and 5, it appears that higher order polynomials for time trends are unnecessary. The term $\alpha_{\mathbb{T}}$ denotes quarter fixed effects to account for seasonality, and $\Gamma$ is a vector for $X_{it}$, a controls vector.[9] This model simultaneously estimates jumps and kinks compared to the pre-policy time period for each policy change. Estimates for the effect of the citation policy change are treated as null effects, and analysis estimates the changes compared to the pre-trend caused by the 100 Percent Plan.

The equation is estimated while limiting the sample of mines according to the quartile of the change of the local inspecting office's inspections per quarter from 2008-2009 compared to 2006-2007. If estimated effects of the 100 Percent Plant are due to correlation of the 100 Percent Plan with an unobserved change, or because the response is a lag response to citation increases, then treated and non-treated mines should exhibit similar estimated coefficients. If instead the 100 Percent Plan only affects $Acc_{it}$ through the increase in inspections, it is expected to see larger effects for

[9]The vector $X_{it}$ includes three lags of linear terms for regular inspections, compliance follow-up inspections, and other inspections, and third-degree polynomials for each of: three lags of the number of hours of non-regular inspections, three lags of the number of hours of regular inspections, employment in logs, and employment in levels.

mines for which local inspecting offices had larger increases in inspecting rates.

A limitation of this analysis is that only local responses to threats of citations and inspections are estimated. For both treated and non-treated mines, responses to the citation rate increase are estimated at ex ante inspecting rates and citation levels. For treated mines, the response to the increase in inspecting rates is estimated at given levels of inspecting rates and with the increased citation levels. It is difficult to draw conclusions about global responses, and only local effects are discussed.

## 4.1 Robustness

It is not assumed accidents are auto-correlated, however including lag accidents on the right side is a possible modeling choice. Doing so would raise an issue in the context of a fixed-effects estimator with a lagged dependent variable. Nickell (1981) shows that there is bias on the lagged dependent variable of order $\frac{1}{T}$. Other regressors which are correlated with the lagged dependent variable will have coefficients that are biased as well. In appendix tables, the lag of accidents is included in the model, which is estimated with OLS as well as a systems GMM Blundell-Bond estimator (1998). Trends in coefficients of interest are unchanged.[10]

There is a judgment call regarding the bandwidth of time for which the post-100 Percent Plan linear trend is estimated. Primary analysis uses the bandwidth of the first quarter of 2008 through the fourth quarter of 2009. Time bandwidths contracting and expanding the final time period by 1 to 4 quarters were used to confirm results are representative, with implications on conclusions discussed in the results section.

Mines were geographically selected into treatment due to the behavior of local inspecting offices. In a similar vein, table 1 indicates that treated mines had almost 50% more accidents per quarter prior to the policy changes. This selection issue is a distraction, however not a major concern. Fixed effects capture time-invariant determinants of selection. The empirical approach is to look at whether there is a break in any pre-existing differences in the level or trend of outcomes around the time of the law's passage.

Robustness checks restrict analysis to subsamples for which treated and non-

[10]Blundell-Bond estimates were computed using the xtdpdsys command in Stata using the one-step estimator that does not weight for cross correlations in residuals. Variables for lags of other inspections and lags of compliance follow-up inspections are assumed to be predetermined variables. No restrictions are imposed on the number of lags used for moments.

treated mines were more similar ex ante, both geographically and in terms of other observables. Checks confirm that results are representative. It will be shown that treatment was in large part determined by inspecting offices increasing their employment of inspectors. If understaffing occurred at random, selection does not influence results. If understaffing was not random, then estimated treatment effects are possibly not representative of average treatment effects. Section 5.3 discusses how selection could influence the interpretation of estimates.

### 4.2 Assumptions

The critical assumptions of this analysis are: (1) any improvements in safety in response to changes in citation amounts, and changes in inspecting rates, occurred immediately following implementation of the two policies and (2) no other factors contemporaneously occurred which induced mines to improve safety.

The public passage of the MINER Act, and the public announcement in September 2006 proposing new criteria for citations, justify the claim that impending policy changes to citation amounts were public information. Following public hearings regarding the proposal, the change in policy was announced in March 2007, a full month prior to taking effect. With this, the change in citation amounts was anticipated. Mines were, presumably, able to prepare any adjustments prior to the rule change or in immediate response to it. The announcement of the 100 Percent Plan in October 2007 was a public announcement to which mines could immediately adjust safety. This assumption of immediate responses is critical in estimating effects of the two policies because they occurred in quick succession.

Results indicate a null effect caused by the increase in citations, and a reduction in accidents caused by the 100 Percent Plan. This reduction in accidents is only exhibited by mines which experienced larger increases in inspecting rates, justifying the assumption that the reduction in accidents is not caused by other factors.

## 5 Results

Table 2 shows estimates for the effects of the increase in average citations and the 100 Percent Plan on accidents per quarter. Discussion begins with surface mines. Column 1 restricts to mines for which the local office was in the top quartile of the change in inspections from 2008-2009 compared to 2006-2007 (.114 or higher). The only significant coefficient is the change in the time trend following the announcement of the 100 percent plan, representing a decline in accidents per quarter of .099 with each year. This suggests that mines increased safety under the threat of inspections, however did not improve safety under the threat of increased citation rates. Column 2 restricts to mines for which the local office was in the second quartile of the change in inspections (between .070 and .114). Again only the linear term for the change in the time trend following the 100 Percent Plan is significant, however of smaller value, -.044. Column 3 pools all treated mines, with a coefficient of -.073 for the change in the time trend caused by the 100 Percent Plan, and no other significant coefficients.

Column 4 restricts to mines for which the local office was below the median (.070) of changes in inspections. The pre-trend prior to the policy changes is significant, of value -.021. The change in the trend with the 100 Percent Plan is -.003 and insignificant. Insignificance remains even when splitting by mines for which the local office is in the bottom quartile (below .021) and the second lowest quartile (between .021 and .070) for the change in inspections.

Estimates regarding underground mines are consistent with this. When restricted to mines for which the local office was in the top quartile for the change in inspections (above .042), there is a change in the linear trend caused by the 100 Percent Plan. The coefficient estimate is -.376 and significant at the 10 percent level. For this specification there is a negative coefficient for the discontinuous jump caused by the 100 Percent plan, of value -.525, however significant only at the 10 percent level. This is treated as a null effect due to the analogous coefficient's insignificance when pooling treated mines, noting that this conservatively estimates the response of mines to the increase in inspections. Mines for which the local office is in the second quartile for the change in inspections (between 0 and .042) exhibit a smaller change in the linear trend caused by the 100 Percent Plan, -.271, again significant at the 10 percent level. When pooling treated mines, the coefficient for the change in the trend of accidents caused by the 100 Percent Plan is -.296, significant at the 5 percent level. No other coefficients are significantly different from 0. The discontinuous jump effect is -.128 and insignificant. For non-treated mines, whether pooled or split by quartile (the break occurs at -.008), there are no significant responses to either policy. For the bottom quartile, there is a positive coefficient for the jump following the citation increase, .695. This is likely a freak-of-nature result caused by estimating the coefficient using only three observations for each mine.

Mines for which local inspecting offices increased the regular inspection rate by more than the median exhibited kinks in safety. The magnitude of the kink is greater for the subset of mines for which local offices were in the top quartile compared to the second quartile. It is posited that, locally, mines improve safety with increased inspecting rates; however do not respond to increases in average citations.

## 5.1 Overall Effect

Extrapolation is necessary to provide a point estimate of the overall effect of the 100 Percent Plan. The estimates presented in table 2 assume the linear trend caused by the announcement of the 100 Percent plan lasted for two years.

Assuming linear trends caused by the 100 Percent Plan lasted for two years, estimates for the overall changes in accidents per quarter caused by the 100 Percent Plan are $2^{*}(-.073) = -.146$ for treated surface mines, and $2^{*}(-.296) = -.592$ for treated underground mines. By comparing these estimates with average accidents per quarter between policy changes (.348 and 2.729 respectively as shown in the fifth column of table 1), the effects were improvements in safety of roughly 42.0% and 21.7% respectively. By inspection of figure 1, these estimates appear representative. Table 1 shows that average quarterly regular inspections increased by .140 and .096 for treated surface and underground mines respectively from between-policy levels of .343 and .881 to the time period after the announcement of the 100 Percent Plan (increases of 40.8% and 10.9% respectively). This implies massive safety responses to a small increase in inspecting rates.

Table 3 presents estimates of the overall effect while extending and contracting the time bandwidth of estimation by 1 to 4 quarters. This varies from 1 to 3 years the time period while time trends are assumed to be caused by the 100 Percent Plan. Estimated overall effects for surface mines range from -.075 to -.160, and all but the estimate with the shortest time window is greater in absolute value than .124. For underground mines estimated effects range from -.362 to -.675, and all but the two estimates with the shortest time windows are greater in absolute value than .504. This exercise shows qualitative results are not cherry-picked by the time period chosen to estimate the linear trend following the 100 Percent Plan. It is difficult to confirm rigorously for how long the time trend caused by the 100 Percent Plan lasted. For a variety of plausible time windows however, qualitative results are unchanged.

Table A2 reports OLS and Blundell-Bond systems GMM estimates when including lag accidents as a covariate. Qualitative implications are unchanged.

## 5.2 Cost-Benefit Analysis

To quantify the benefits and costs of the 100 Percent Plan I use estimates from previous literature. Miller and Galbraith (1995) estimate, using 1990 dollars, the costs of workplace accidents while accounting for direct medical bills, loss of home production, legal fees, lost work days, and quality of life.[11] The cost of a fatality at work is estimated as $2,500,000. The average cost of a workplace injury that results in at least one day lost of work is estimated as $46,000. The average cost of an injury in which no days are lost is estimated as $650. From 2004-2007, .43% of accidents in surface mines, and .49% in underground mines, resulted in fatalities. Respectively 39.16% and 41.00% resulted in at least one day lost of work. Estimates for the average cost of an accident are: $(.0043)^*(\$2.5 \text{ Million})+.3916^*(\$46,000)+(.6041)^*\$650 = \$29,156$ for surface mines and $(.0049)^*(\$2.5 \text{ Million}) + .4100^*(\$46,000) + (.5851)^*\$650 = \$31,490$ for underground mines.

It is estimated that surface mines decreased average accidents per quarter by .146 due to the increase in inspections, a value saved of $.146^*\$29,156 = \$4,257$ per quarter. For underground mines the estimate is $.592^*\$31,490 = \$18,642$. Average inspections per quarter increased by .140 and .096 for surface and underground mines respectively. An estimate for the dollar cost of additional inspections was not available through a Freedom of Information Act request. If the cost of an additional inspection is less than $\$4,257/.140 = \$30,407$ for surface mines and $\$18,642/.096 = \$194,188$ for underground mines in 1990 dollars, the policy provided a net positive return in social value and, at the margin, increasing inspections would provide positive returns.[12]

[11]I am unaware of more recent work that estimates the costs of accidents while incorporating heterogeneity by accident severity. Miller and Galbraith's estimates are calculated using publicly available data. For example, average medical costs of accidents are calculated using the National Council on Compensation Insurance and the value of lost work is estimated using data on Workers Compensation insurance.

[12]This analysis ignores potential costs of reduced productivity due to improved safety. Output is only observable for coal mines. Unreported analysis replicated table 2 using two measures of production as outcomes: (1) log of coal output, (2) the ratio of the log of coal production to log employment. Treated and non-treated mines exhibit similar trends, generally of null effects, although in some cases treated mines exhibited improvements in productivity relative to non-treated mines.

## 5.3 Selection

It is claimed that the reduction in accidents of treated mines is a response to the increase in inspections. It is also claimed that mines did not respond to the increase in average citations. Selection may influence the interpretation of results.

Similar to the present work, there are many papers which estimate responses to laws for which treatment is not randomly assigned; two examples are the introduction of medicare in 1965 and the imposition of mandatory medical insurance by Massachusetts in 2006 (see for example Finkelstein 2007, Miller 2012a, Miller 2012b, and Kolstad and Kowalski 2012). In such econometric settings, fixed effects capture time-invariant determinants of selection, and the timing and direction of estimated responses imply that effects are a response to the change in policy. Selection regarding the types of agents which are treated may cause quantitative conclusions to not represent an average treatment effect because treatment response may be heterogeneous. In a worst-case scenario, estimated effects are an upper bound on average treatment effects (if treated agents are those with largest average responses). In a best-case scenario, estimated effects are a lower bound (if treated agents are those with smallest average responses). It is argued in what follows that the mechanism driving selection in this paper (increasing staffing of offices) implies that estimated effects are likely a lower bound on average treatment effects.

Through the Freedom of Information Act, the number of inspectors employed by each office in each year is gathered. Let $\ell_{k0}$ denote average employment in office, $k$, in 2006 and 2007, and let $\ell_{k1}$ denote average employment in office $k$ in 2008 and 2009. For each office, let $\iota_{k0}$ denote the average number of quarterly regular inspections per mine in 2006 and 2007 and $N_{k0}$ the mandated average (across surface and underground). The *shortage* of inspectors, $S_k$, prior to the 100 Percent Plan is $\frac{\ell_{k0}}{\iota_{k0}}(N_{k0} - \iota_{k0})$. The *reduction* in the shortage, $R_k$, is $\ell_{k1} - \ell_{k0}$. Let $D_{kw}$ denote the change in average inspecting rates for mines of type $w$ by office $k$ between 2006-2007 and 2008-2009 (the variable defining treatment) and let $d_{kw}$ denote the average inspecting rate from 2006-2007. The following is estimated separately for $w \in$ {Underground, Surface}:

$$D_{kw} = \beta_0 + \beta_1 S_k + \beta_2 R_k + \beta_3 d_{kw} + \varepsilon_k.$$

Predicted values from these regressions represent the predicted increase in the inspecting rate driven by the initial shortage of inspectors, and the reduction in that shortage. Results are shown in table A3. The reduction in the shortage is a strong predictor of the treatment variable, and the initial shortage is never predictive. This implies the main determinant of treatment was the increase in staffing of inspecting offices. The specifications of table 2 are estimated again, however instead data are split by quartile of the predicted values of these regressions. Results are in table A4. Qualitative results for surface mines are somewhat attenuated, however follow similar trends. For underground mines the reduction in accidents is only exhibited by mines in the top quartile of the newly defined treatment. This differs from main results (which show effects in the top two quartiles) however is not a major concern. The purpose of this exercise is to show that qualitative trends are unchanged when isolating variation in treatment caused by staffing.

It is reasonable to think that staffing and inspecting decisions were initially made while prioritizing the most dangerous mines, or mines which would be most responsive. If this is the case, then the increase in staffing would have occurred at mines for which the response to inspections is smallest. Estimated effects would be a lower bound. As stated previously, the worst-case scenario is that estimates are an upper bound on average treatment effects. Focus now turns toward limiting samples of treated and untreated mines to those which are more similar ex ante.

Treatment is defined by inspecting offices' changes in inspecting behavior. This results in geographic selection. The number of treated and non-treated mines are graphed at the county level in appendix figures A2 and A3.

For surface mines, geographic selection shown in figure A2 is apparent. Western states, namely Wyoming, Colorado, Utah, Arizona, Nevada, Oregon, and Idaho, and states in the South (Viginia, West Virginia, Kentucky, and states geographically south of these states) hold high populations of treated mines and minimal non-treated mines. States in the Midwest: Ohio, Michigan, Illinois, Minnesota, Iowa, Missouri, Kansas, Oklahoma, Nebraska, South Dakota, and North Dakota, along with some New England states, contain large quantities of non-treated mines.

For underground mines, figure A3 implies there is minimal geographic selection. Most such mines are in the area of West Virginia, the west part of Virginia, and eastern Kentucky, with both treated and non-treated mines being prevalent.

Geographic selection for surface mines is a distraction, however not believed to be a concern. Minerals mined and mining practices certainly differ depending on location. This will only bias conclusions if geographically determined factors affected safety, or if the elasticity of accidents with respect to inspections or penalties differs between treatment and control regions. Furthermore, geographic selection appears minimal with respect to underground mines, implying that geographic selection does not drive results. To address geographic selection directly, table 2 is replicated, restricted to states which have at least one treated mine and one non-treated mine of the relevant type. Results are in appendix table A5. If anything, estimates are larger on this subsample of treated mines, and remain insignificant for non-treated mines.

A potential concern is that treated mines were those which had more unsafe practices initially. Because of this, operators were able to reduce accidents in response to the threat of increased citations. If non-treated mines had already reduced unsafe practices as much as they feasibly could, they would be unable to meaningfully respond to the threat of increased citations. Such circumstances would result in similar estimates to those presented, however result from a response to citation increases, rather than a response to increases in inspections.

The first point made is that the timing of the kink in accidents per quarter coincides with the increase in inspections, rather than the announced and expected increase in citation amounts. As a robustness check, estimation for non-treated mines is restricted to mines which were more accident-prone and had more employees prior to the policy changes. Such mines are more similar to treated mines ex ante, and also presumably would have been more capable of responding to the incentives of increased citations, should operators have chosen to respond to these incentives.

Specifically, the fourth column of table 2 is replicated while restricting to non-treated mines that averaged positive accidents per quarter prior to the change in citation amounts. Results are presented in table A6. Column 2 further restricts to mines with 5 or more observations prior to the policy change, and column 3 restricts to mines with 15 or more observations prior to the policy change. Columns 4-6 restrict to mines that had total hours worked above the median prior to the policy changes (medians are 5,891 and 15,333 for surface and underground mines respectively), again columns 5 and 6 restrict to mines with at least 5 and 15 observations in the pre-policy period. Estimated coefficients of interest follow the same trends as shown in the fourth column of table 2. These subsamples of non-treated surface mines averaged .433, .431, .448, .375, .376, and .395 accidents per quarter respectively, in fact more than the sample of treated surface mines (see table 1). Average hours worked for these subsamples was higher as well. For underground mines, the average accidents per quarter were: 1.958, 2.008, 2.362, 2.701, 2.780, and 2.994. While often still slightly lower than the rate in treated mines, these subsamples of non-treated mines were more similar to treated mines in propensity to have accidents. Similarly, hours worked are often higher among these subsamples compared to hours worked in treated mines. These subsamples of non-treated mines presumably had accident levels which could be corrected, if mine operators were incentivized to do so. It appears such mines did not respond to the citation amount increase, and selection does not drive results.

# 6 Conclusion

It has been documented that mines significantly reduced accidents in response to increased inspections, however did not reduce accidents under the threat of increased penalties. It is suggested that the response to increased inspections is driven by the threat effect, while the lack of a response to citation penalties may result from penalties acting as "payment" for the right to commit a violation. At present levels, penalties are possibly not high enough to deter violations.

An effort was made to address the possible selection issue. Despite this effort, one may wonder if selection drives results. If so, this does not invalidate the findings of this paper, however at worst would indicate that the results only apply to the subset of the population which responds to threat effects, or the subset of a population which is most prone to commit violations. In most applications of threat effects, these are certainly large populations of interest. Regardless, estimates are an upper bound on average treatment effects. If staffing decisions are made while prioritizing the most dangerous mines, then estimates are a lower bound.

Estimates are only of local responses to inspections and citation penalties. Despite this limitation, the results from this paper may allow for a better understanding of methods of regulation enforcement in other contexts such as environmental regulation and minimum wage compliance. This paper suggests that the strongest improvements in compliance result from responses to threats of monitoring and inspections.

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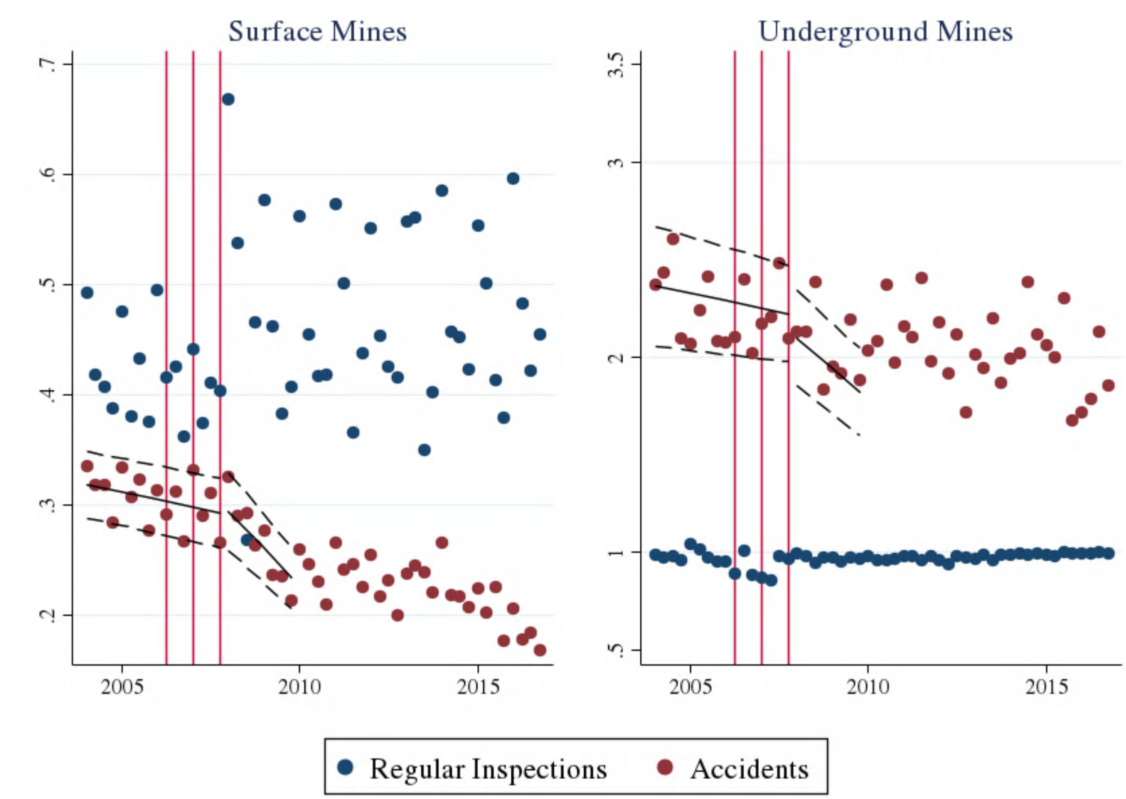
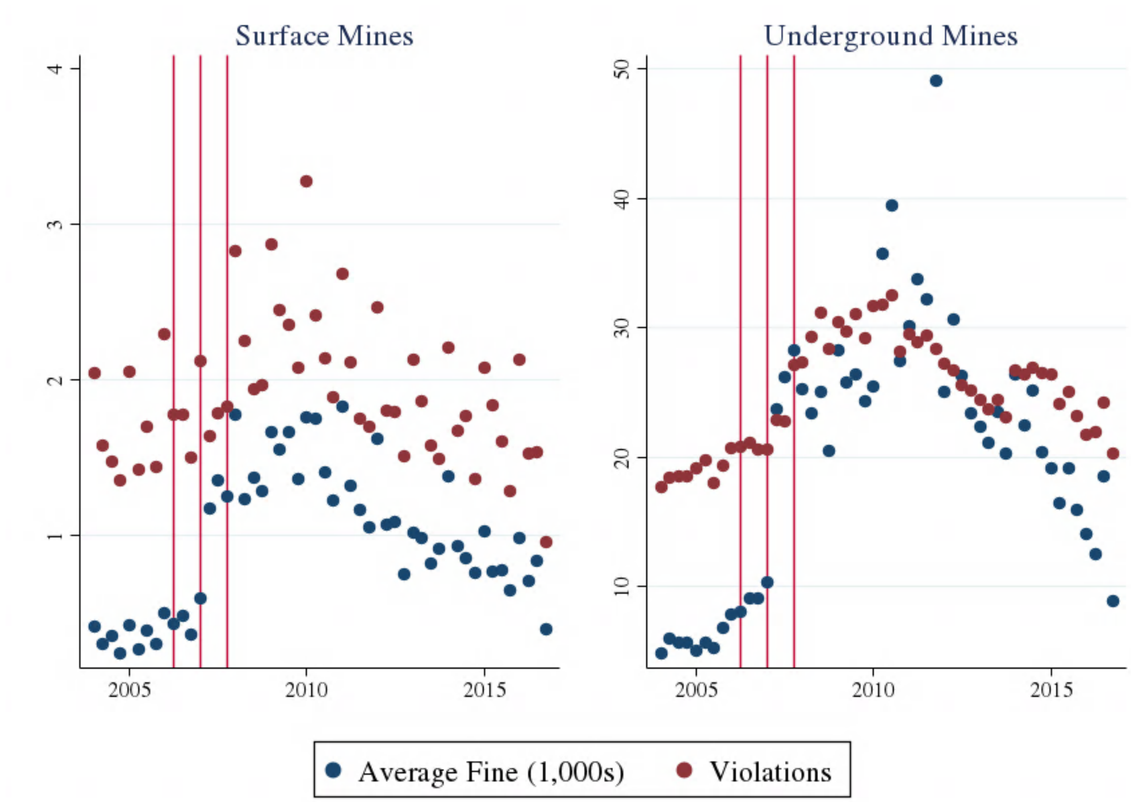
# Figures

Figure 1: Time Trends in Accidents and Inspections.



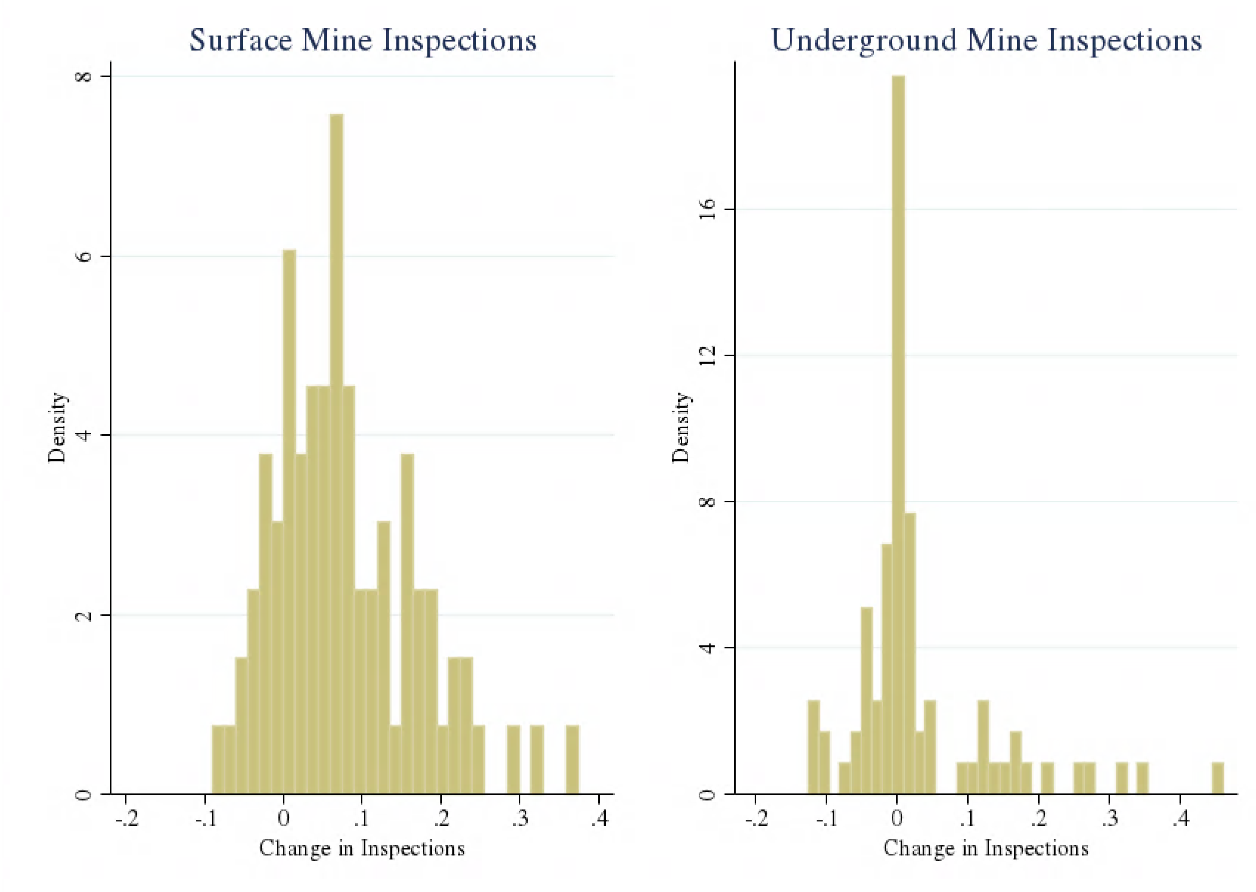

Notes: *Plotted are the average number of accidents per mine-quarter and average number of regular inspections. The first vertical bar denotes June of 2006, when the MINER Act took effect. The second vertical bar denotes March of 2007, the announcement of increased penalty rates for citations caused by the MINER Act, taking effect in the following quarter. The third vertical bar denotes October of 2007, the announcement of the 100 Percent Plan to perform all mandated inspections, quarterly for underground mines, and twice per year for surface mines. Black lines denote fitted values and 95% confidence intervals for trends during the analysis time period, net of controls used in the specification of table 2.*

Figure 2: Time Trends in Citations and Violations



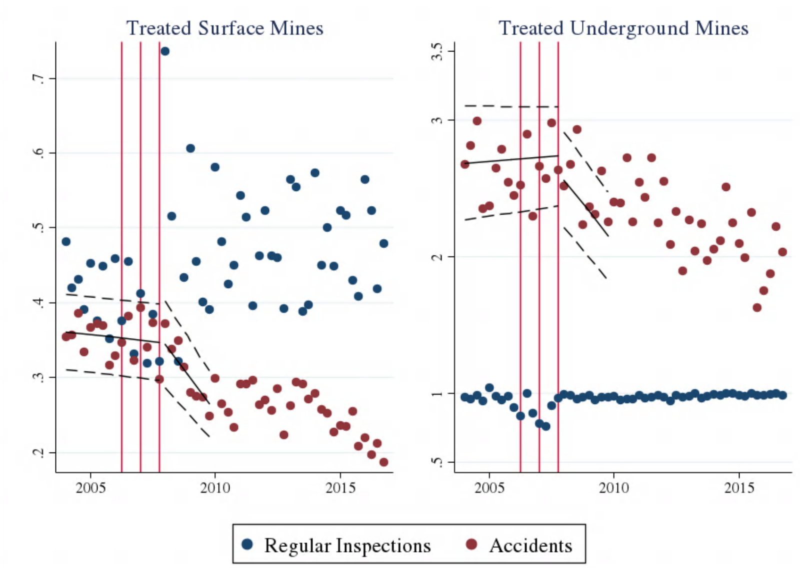

Notes: *Plotted are the average number of violations per mine-quarter and average citation paid. The first vertical bar denotes June of 2006, when the MINER Act took effect. The second vertical bar denotes March of 2007, the announcement of increased penalty rates for citations caused by the MINER Act, taking effect in the following quarter. The third vertical bar denotes October of 2007, the announcement of the 100 Percent Plan to perform all mandated inspections, quarterly for underground mines, and twice per year for surface mines.*

Figure 3: Changes in the Inspecting Rate by Inspecting Offices



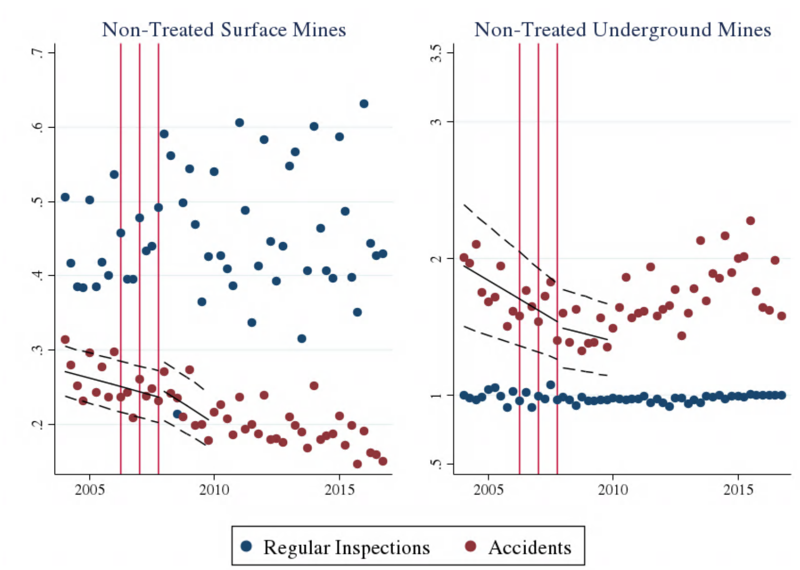

Notes: *Observations are at the inspecting office level. Plotted is the increase in regular inspections per quarter from 2006-2007 to 2008-2009 for mines of the respective type.*

Figure 4: Time Trends in Accidents and Inspections in Treated Mines.




Notes: *Identical to figure 1, restricted to treated mines as defined in the text.*

Figure 5: Time Trends in Accidents and Inspections in Non-Treated Mines.




Notes: *Identical to figure 1, restricted to non-treated mines as defined in the text.*

# Tables

Table 1: Summary Stats - Threat Effects

| | All Data | | | Treated | | | Non-Treated | | |
|---|---|---|---|---|---|---|---|---|---|
| | Before | Mid | After | Before | Mid | After | Before | Mid | After |
| Surface | | | | | | | | | |
| Accidents | .308 | .290 | .268 | .367 | .348 | .318 | .252 | .235 | .220 |
| | (1.082) | (1.274) | (1.139) | (1.325) | (1.630) | (1.435) | (.772) | (.784) | (.741) |
| Inspections | .422 | .397 | .467 | .418 | .343 | .483 | .426 | .449 | .451 |
| | (.499) | (.494) | (.509) | (.500) | (.479) | (.509) | (.499) | (.502) | (.507) |
| Hours Worked | 15,700 | 15,722 | 15,982 | 18,135 | 18,294 | 18,698 | 13,327 | 13,226 | 13,331 |
| | (36,288) | (41,331) | (44,068) | (43,476) | (50,957) | (54,009) | (27,324) | (28,874) | (31,242) |
| Citation | 386 | 1,256 | 1,479 | 473 | 1,650 | 1,860 | 301 | 874 | 1,108 |
| | (2,624) | (10,092) | (14,323) | (3,193) | (13,329) | (18,449) | (1910) | (5,290) | (8,538) |
| N | 63,729 | 15,602 | 35,867 | 31,457 | 7,684 | 17,718 | 32,272 | 7,918 | 18,149 |
| Underground | | | | | | | | | |
| Accidents | 2.232 | 2.263 | 2.054 | 2.611 | 2.729 | 2.492 | 1.745 | 1.652 | 1.455 |
| | (3.929) | (3.893) | (3.567) | (4.503) | (4.564) | (4.150) | (2.966) | (2.658) | (2.436) |
| Inspections | .961 | .935 | .973 | .938 | .881 | .977 | .990 | 1.006 | .967 |
| | (.332) | (.364) | (.188) | (.356) | (.412) | (.181) | (.295) | (.272) | (.196) |
| Hours Worked | 45,174 | 46,955 | 49,826 | 49,641 | 51,573 | 54,400 | 39,432 | 40,892 | 43,555 |
| | (68,651) | (70,733) | (75,417) | (72,257) | (74,833) | (78,977) | (63,265) | (64,504) | (69,778) |
| Citation | 6,971 | 26,000 | 24,817 | 7,431 | 28,903 | 28,298 | 6,380 | 22,189 | 20,045 |
| | (27,878) | (73,866) | (61,024) | (30,765) | (81,875) | (66,051) | (23,646) | (61,641) | (53,013) |
| N | 7,617 | 1,841 | 4,917 | 4,284 | 1,045 | 2,843 | 3,333 | 796 | 2,074 |

Notes: *Data are 2004 through 2009. "Before" is prior to the second quarter of 2007, "After" is following the fourth quarter of 2007, "Mid" is all other time periods. The fourth through sixth columns are restricted to mines for which the inspecting office increased inspections per quarter by .070 or more in 2008-2009 compared to the prior two years (0 for underground mines). The seventh through ninth columns are restricted to all other mines.*

Table 2: Threat Effect Analysis: Increases in Citation Amounts and Inspections

| | Accidents | | | | | |
|---|---|---|---|---|---|---|
| Percentile Restriction | [75,100] | [50,75) | [50,100] | [0,50) | [25,50) | [0,25) |
| Panel A | Surface Mines | | | | | |
| Time | -0.001 | 0.009 | 0.005 | -0.021*** | -0.030*** | -0.013 |
| | (0.011) | (0.011) | (0.008) | (0.006) | (0.007) | (0.009) |
| Time*Between Policies | 0.002 | -0.158 | -0.088 | 0.085* | 0.069 | 0.095 |
| | (0.060) | (0.097) | (0.058) | (0.045) | (0.053) | (0.072) |
| Time*Post 100 Percent | -0.099*** | -0.044** | -0.073*** | -0.003 | 0.013 | -0.019 |
| | (0.036) | (0.020) | (0.020) | (0.014) | (0.018) | (0.020) |
| Between Policies | -0.054 | 0.055 | 0.005 | -0.012 | -0.010 | -0.010 |
| | (0.039) | (0.054) | (0.034) | (0.025) | (0.030) | (0.040) |
| Post 100 Percent Plan | 0.009 | -0.031 | -0.015 | 0.039** | 0.038 | 0.036 |
| | (0.047) | (0.031) | (0.030) | (0.019) | (0.024) | (0.030) |
| N | 22,056 | 22,698 | 44,754 | 42,063 | 21,000 | 21,063 |
| Clusters | 1,596 | 1,716 | 3,312 | 3,170 | 1,489 | 1,681 |
| Panel B | Underground Mines | | | | | |
| Time | 0.064 | -0.076 | -0.023 | -0.084 | -0.000 | -0.127 |
| | (0.109) | (0.068) | (0.056) | (0.066) | (0.067) | (0.090) |
| Time*Between Policies | 0.863 | -0.125 | 0.405 | -0.451 | 0.190 | -0.825 |
| | (0.668) | (0.449) | (0.388) | (0.352) | (0.379) | (0.523) |
| Time*Post 100 Percent | -0.376* | -0.271* | -0.296** | 0.012 | 0.007 | 0.014 |
| | (0.218) | (0.142) | (0.120) | (0.124) | (0.168) | (0.154) |
| Between Policies | -0.485 | 0.081 | -0.211 | 0.354* | -0.222 | 0.695** |
| | (0.428) | (0.282) | (0.249) | (0.193) | (0.208) | (0.284) |
| Post 100 Percent Plan | -0.525* | 0.159 | -0.128 | 0.028 | -0.341* | 0.195 |
| | (0.298) | (0.183) | (0.164) | (0.158) | (0.192) | (0.223) |
| N | 2,961 | 3,789 | 6,750 | 4,883 | 1,894 | 2,989 |
| Clusters | 259 | 302 | 561 | 466 | 199 | 267 |

Notes: *Restricted to 2004 to 2009. Columns are restricted to mines based on the percentile of the change in the main inspecting office's inspections per quarter in 2008-2009 compared to 2006-2007. Percentile restrictions are denoted in the column headings. Quartile breaks for surface mines are: .021, .070, and .114. Quartile breaks for underground mines are: -.008, 0, and .042. Unreported covariates described in the text. Standard errors clustered by mine-operator, *** p<0.01, ** p<0.05, * p<0.1.*

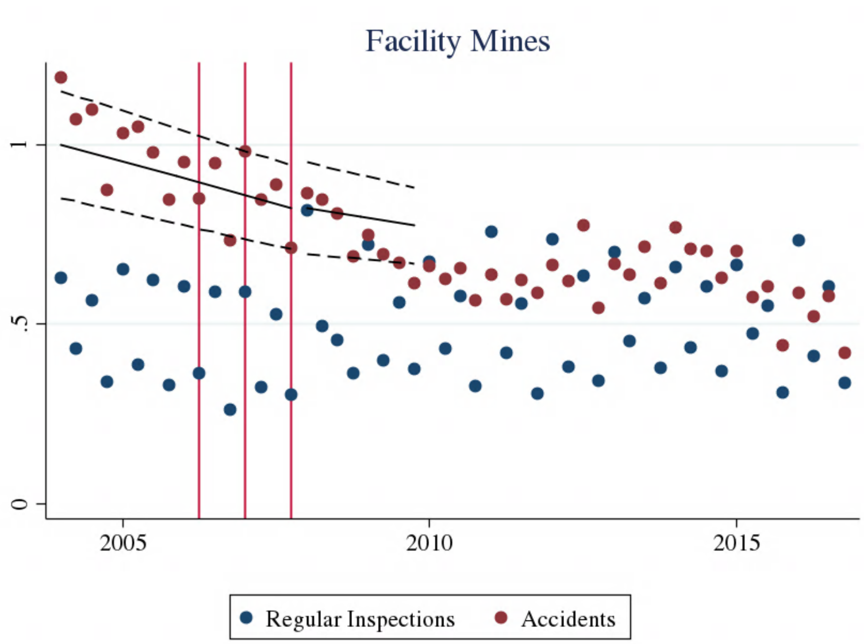
Table 3: Robustness of Analysis of Threat Effects - Time Window

| | 2008 Q4 | 2009 Q1 | 2009 Q2 | 2009 Q3 | 2009 Q4 | 2010 Q1 | 2010 Q2 | 2010 Q3 | 2010 Q4 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Surface Mines | | | | |
| Time*Post 100 Percent Plan | -0.075* | -0.104*** | -0.089*** | -0.089*** | -0.073*** | -0.055*** | -0.055*** | -0.058*** | -0.052*** |
| | (0.044) | (0.036) | (0.027) | (0.023) | (0.020) | (0.016) | (0.015) | (0.014) | (0.013) |
| Post 100 Percent Plan | -0.017 | 0.000 | -0.007 | -0.007 | -0.015 | -0.034 | -0.033 | -0.027 | -0.027 |
| | (0.037) | (0.034) | (0.032) | (0.031) | (0.030) | (0.030) | (0.029) | (0.027) | (0.026) |
| Estimated Effect | -.075 | -.130 | -.134 | -.156 | -.146 | -.124 | -.138 | -.160 | -.156 |
| | | | | | Underground Mines | | | | |
| Time*Post 100 Percent Plan | -0.362 | -0.354** | -0.380*** | -0.368*** | -0.296** | -0.224** | -0.217** | -0.236** | -0.225*** |
| | (0.237) | (0.171) | (0.135) | (0.134) | (0.120) | (0.107) | (0.096) | (0.092) | (0.086) |
| Post 100 Percent Plan | -0.160 | -0.103 | -0.071 | -0.077 | -0.128 | -0.174 | -0.161 | -0.151 | -0.165 |
| | (0.198) | (0.188) | (0.175) | (0.166) | (0.164) | (0.160) | (0.168) | (0.165) | (0.165) |
| Estimated Effect | -.362 | -.443 | -.570 | -.644 | -.592 | -.504 | -.543 | -.649 | -.675 |

Notes: *Reported are point estimates for two coefficients from the specification in the third column of table 2, estimated with the final time period of the sample period changed as denoted in the column heading. "Estimated Effect" is calculated by multiplying the Time*Post 100 Percent Plan coefficient by the number of years past the beginning of 2008 the time period covers, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.*

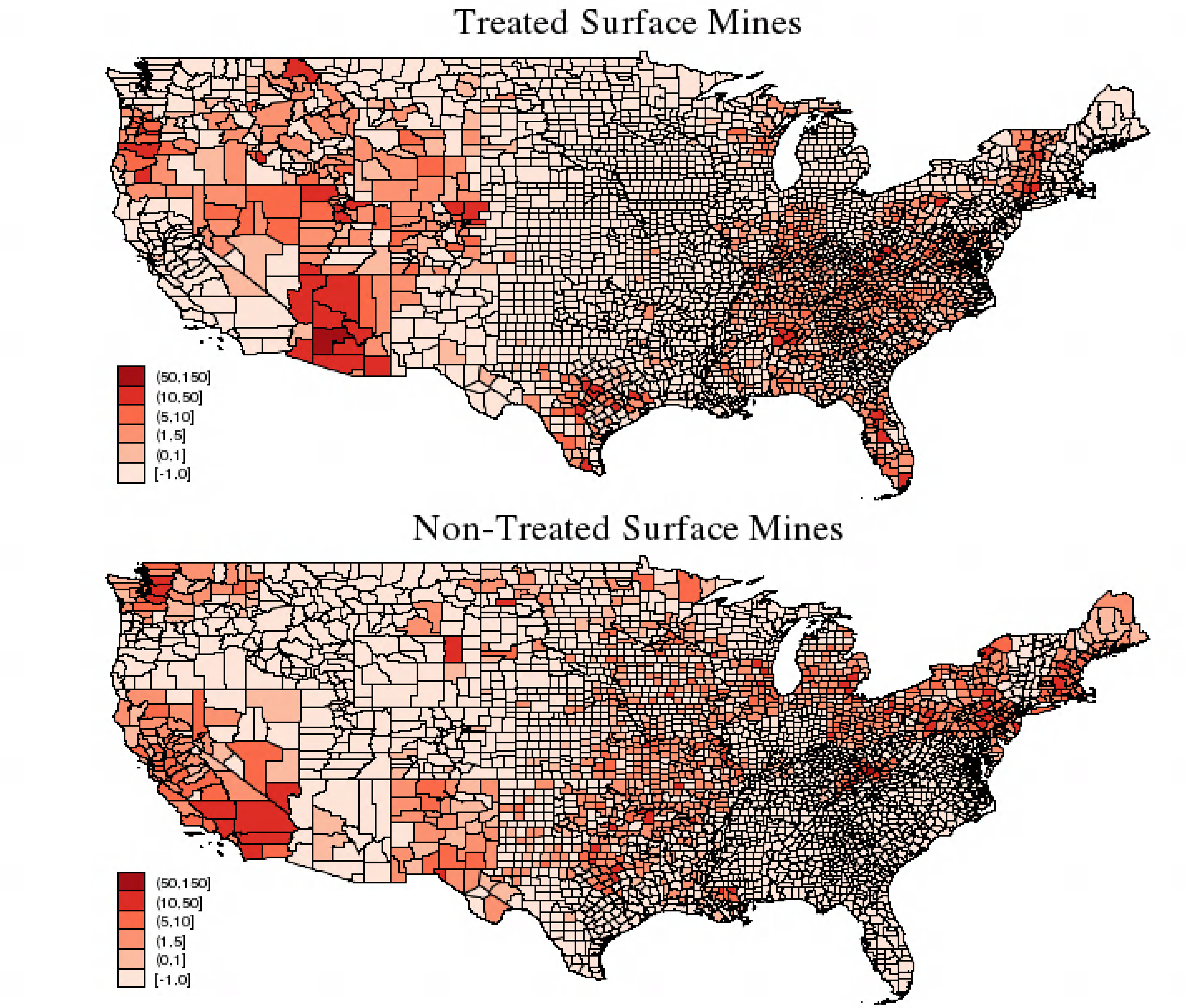
# Appendix A

Figure A1: Time Trends in Accidents and Inspections: Facility Mines



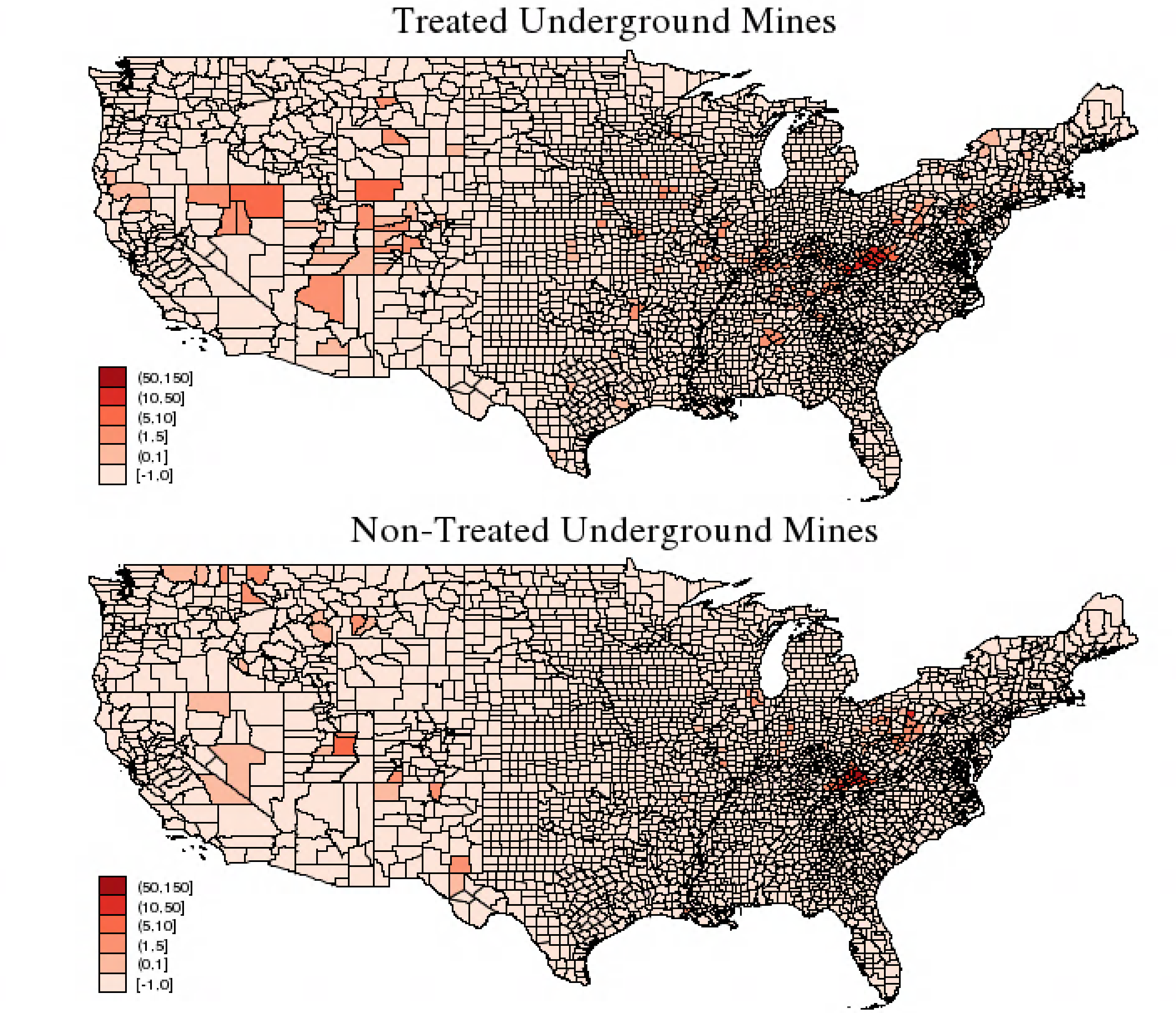

Notes: *Identical to figure 1 from the text, however restricted to mining facilities.*

Figure A2: Geographic Selection into Treatment: Surface Mines




Notes: *Treatment is defined in the text. Plotted are the number of treated and non-treated mines at the county level.*

Figure A3: Geographic Selection into Treatment: Underground Mines




Notes: *Treatment is defined in the text. Plotted are the number of treated and non-treated mines at the county level.*

Table A1: Parts of the CFR Violated

| Part | Name | N |
|---|---|---|
| 40 | Representative of Miners | 29 |
| 41 | Notification of Legal Identity | 1,405 |
| 44 | Rules of Practice for Petitions for Modification of Mandatory Safety Standards | 13 |
| 45 | Independent Contractors | 366 |
| 46 | Training and Retraining of Miners Engaged in Shell Dredging... | 8,766 |
| 47 | Hazard Communication | 7,978 |
| 48 | Training and Retraining of Miners | 4,208 |
| 49 | Mine Rescue Teams | 342 |
| 50 | Notification, Investigation, Reports, and Records of Accidents... and Coal Production | 12,125 |
| 56 | Safety and Health Standards - Surface Metal and Nonmetal Mines | 279,480 |
| 57 | Safety and Health Standards - Underground Metal and Nonmetal Mines | 28,784 |
| 58 | Health Standards for Metal and Nonmetal Mines | 125 |
| 62 | Occupational Noise Exposure | 5,387 |
| 70 | Mandatory Health Standards - Underground Coal Mines | 1,715 |
| 71 | Mandatory Health Standards- Surface areas of Underground Coal Mines | 1,575 |
| 72 | Health Standards for Coal Mines | 3,704 |
| 75 | Mandatory Safety Standards - Underground Coal Mines | 338,924 |
| 77 | Mandatory Safety Standards- Surface areas of Underground Coal Mines | 95,384 |
| 90 | Mandatory Health Standards - Coal Miners who have Evidence of... Pneumoconiosis | 47 |

Notes: *Parts of Title 30 of the CFR Chapter I which are violated from 2004-2009.*

Table A2: Threat Effect Analysis with Lag Accidents

| | Treated Mines | | Non-Treated Mines | |
|---|---|---|---|---|
| | OLS | Blundell Bond | OLS | Blundell Bond |
| Panel A | | Surface Mines | | |
| Time | 0.004 | 0.036*** | -0.020*** | -0.036*** |
| | (0.007) | (0.008) | (0.006) | (0.006) |
| Time*Between Policies | -0.071 | -0.082 | 0.080* | 0.041 |
| | (0.057) | (0.057) | (0.044) | (0.044) |
| Time*Post 100 Percent | -0.060*** | -0.137*** | -0.001 | -0.039*** |
| | (0.018) | (0.018) | (0.014) | (0.014) |
| $Acc_{it-1}$ | 0.138*** | 0.134*** | 0.070*** | 0.095*** |
| | (0.031) | (0.005) | (0.021) | (0.005) |
| N | 44,754 | 44,754 | 42,063 | 42,063 |
| Clusters | 3,312 | 3,312 | 3,170 | 3,170 |
| Panel B | | Underground Mines | | |
| Time | -0.024 | -0.036 | -0.091 | -0.192*** |
| | (0.051) | (0.059) | (0.059) | (0.056) |
| Time*Between Policies | 0.477 | 0.242 | -0.472 | -0.364 |
| | (0.384) | (0.418) | (0.345) | (0.364) |
| Time*Post 100 Percent | -0.232** | -0.245** | 0.049 | 0.107 |
| | (0.105) | (0.116) | (0.111) | (0.112) |
| $Acc_{it-1}$ | 0.125*** | 0.137*** | 0.131*** | 0.173*** |
| | (0.033) | (0.012) | (0.026) | (0.014) |
| N | 6,750 | 6,750 | 4,883 | 4,883 |
| Clusters | 561 | 561 | 466 | 466 |

Notes: *The left, and right, two columns are respectively the specifications of columns 3 and 4 of table 2, with the inclusion of lag accidents. Post variables are not reported only to save space. For Blundell-Bond, all three lags of compliance follow-up inspections and other inspections are treated as predetermined.*

Table A3: Determinants of Selection into Treatment

| | Change in Inspecting Rate | |
|---|---|---|
| | Surface | Underground |
| Reduction in Shortage | 0.007** | 0.010*** |
| | (0.003) | (0.003) |
| Shortage of Inspectors | -0.003 | 0.007 |
| | (0.003) | (0.008) |
| N | 88 | 79 |
| R-squared | 0.487 | 0.447 |

Notes: *Each observation is an inspecting office. The outcome variable is the change in inspections per quarter of mines of the relevant type from 2008-2009 compared to 2006-2007 (the variable defining treatment in table 2). Independent variables are estimates for the number of inspectors needed to reach mandated targets in 2006-2007 and the reduction in this shortage by 2008-2009 (described in the text). Regressions include a linear term for average inspecting rates from 2006-2007. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*

Table A4: Threat Effect Results using Staffing-Predicted Treatment

| | Accidents | | | | | |
|---|---|---|---|---|---|---|
| Percentile Restriction | [75,100] | [50,75) | [50,100] | [0,50) | [25,50) | [0,25) |
| Panel A | | | Surface Mines | | | |
| Time | -0.004 | 0.014 | 0.002 | -0.019*** | -0.024*** | -0.018 |
| | (0.009) | (0.012) | (0.008) | (0.006) | (0.007) | (0.012) |
| Time*Between Policies | -0.019 | -0.059 | -0.034 | 0.032 | -0.013 | 0.039 |
| | (0.052) | (0.068) | (0.042) | (0.061) | (0.061) | (0.118) |
| Time*Post 100 Percent | -0.057*** | -0.052** | -0.051*** | -0.024 | -0.013 | -0.022 |
| | (0.019) | (0.026) | (0.015) | (0.017) | (0.018) | (0.027) |
| Between Policies | -0.029 | -0.009 | -0.021 | 0.012 | 0.038 | 0.014 |
| | (0.033) | (0.044) | (0.028) | (0.033) | (0.037) | (0.059) |
| Post 100 Percent Plan | -0.008 | -0.006 | -0.009 | 0.035 | 0.038* | 0.030 |
| | (0.028) | (0.032) | (0.022) | (0.027) | (0.021) | (0.054) |
| N | 22,555 | 19,479 | 42,034 | 44,783 | 25,557 | 19,226 |
| Clusters | 1,647 | 1,473 | 3,120 | 3,362 | 1,898 | 1,464 |
| Panel B | | | Underground Mines | | | |
| Time | 0.090 | -0.105 | 0.002 | -0.104 | -0.135 | -0.070 |
| | (0.093) | (0.076) | (0.062) | (0.064) | (0.102) | (0.079) |
| Time*Between Policies | 0.812 | 0.375 | 0.573 | -0.586 | -0.259 | -0.770 |
| | (0.588) | (0.512) | (0.356) | (0.406) | (0.645) | (0.509) |
| Time*Post 100 Percent | -0.539** | -0.047 | -0.327** | -0.070 | 0.064 | -0.175 |
| | (0.222) | (0.146) | (0.137) | (0.112) | (0.178) | (0.131) |
| Between Policies | -0.651** | -0.264 | -0.434* | 0.542** | 0.281 | 0.726** |
| | (0.308) | (0.329) | (0.224) | (0.234) | (0.304) | (0.328) |
| Post 100 Percent Plan | -0.488 | -0.175 | -0.348** | 0.210 | 0.175 | 0.246 |
| | (0.321) | (0.172) | (0.172) | (0.168) | (0.248) | (0.210) |
| N | 2,804 | 3,392 | 6,196 | 5,437 | 2,242 | 3,195 |
| Clusters | 241 | 324 | 565 | 462 | 204 | 258 |

Notes: *Identical to table 2, however split by quartiles of predicted values from regressions of table A3.*

Table A5: Threat Effect Results Limiting Geographic Selection

| | Accidents | | | | | |
|---|---|---|---|---|---|---|
| Percentile Restriction | [75,100] | [50,75) | [50,100] | [0,50) | [25,50) | [0,25) |
| Panel A | | | Surface Mines | | | |
| Time | 0.011 | 0.014 | 0.015 | -0.021*** | -0.032*** | -0.012 |
| | (0.020) | (0.012) | (0.010) | (0.006) | (0.008) | (0.010) |
| Time*Between Policies | -0.046 | -0.123 | -0.099 | 0.096** | 0.089 | 0.095 |
| | (0.105) | (0.111) | (0.081) | (0.048) | (0.057) | (0.076) |
| Time*Post 100 Percent | -0.197*** | -0.046** | -0.101*** | -0.007 | 0.013 | -0.027 |
| | (0.058) | (0.021) | (0.026) | (0.016) | (0.020) | (0.022) |
| Between Policies | -0.080 | 0.028 | -0.011 | -0.020 | -0.022 | -0.015 |
| | (0.070) | (0.059) | (0.046) | (0.027) | (0.032) | (0.042) |
| Post 100 Percent Plan | 0.032 | -0.040 | -0.019 | 0.041** | 0.039 | 0.039 |
| | (0.095) | (0.035) | (0.046) | (0.021) | (0.026) | (0.032) |
| N | 10,272 | 18,146 | 28,418 | 38,408 | 18,674 | 19,734 |
| Clusters | 784 | 1,340 | 2,124 | 2,905 | 1,332 | 1,573 |
| Panel B | | | Underground Mines | | | |
| Time | 0.061 | -0.159* | -0.053 | -0.135* | -0.034 | -0.204** |
| | (0.128) | (0.084) | (0.074) | (0.072) | (0.081) | (0.097) |
| Time*Between Policies | 0.777 | 0.052 | 0.569 | -0.244 | 0.362 | -0.595 |
| | (0.762) | (0.560) | (0.487) | (0.360) | (0.387) | (0.545) |
| Time*Post 100 Percent | -0.534** | -0.357** | -0.446*** | 0.186 | 0.088 | 0.254* |
| | (0.265) | (0.181) | (0.162) | (0.129) | (0.187) | (0.152) |
| Between Policies | -0.394 | -0.049 | -0.332 | 0.263 | -0.253 | 0.620** |
| | (0.486) | (0.402) | (0.324) | (0.200) | (0.198) | (0.306) |
| Post 100 Percent Plan | -0.500 | 0.204 | -0.177 | -0.056 | -0.270 | 0.084 |
| | (0.325) | (0.255) | (0.210) | (0.169) | (0.198) | (0.246) |
| N | 2,592 | 2,439 | 5,031 | 4,279 | 1,770 | 2,509 |
| Clusters | 239 | 211 | 450 | 424 | 191 | 233 |

Notes: *Identical to table 2, restricted to states with at least 1 treated mine and 1 non-treated mine. For surface mines* ***excluded*** *states are: Alaska, Alabama, Delaware, Florida, Georgia, Hawaii, Iowa, Maine, North Carolina, Nebraska, New Hampshire, New Jersey, Oregon, Rhode Island, South Carolina, Utah, the Virgin Islands, and Vermont. For underground mines* ***included*** *states are Arkansas, California, Colorado, Illinois, Indiana, Kentucky, Maryland, Montana, Nevada, Pennsylvania, Texas, Utah, Virginia, and West Virginia.*

Table A6: Threat Effects for Non-Treated Mines: Limited Sample Analysis

| | | | | | | |
|---|---|---|---|---|---|---|
| | Accidents | | | | | |
| Panel A | Surface Mines | | | | | |
| Time*Between Policies | 0.131** | 0.131** | 0.098 | 0.115** | 0.115** | 0.089 |
| | (0.065) | (0.065) | (0.064) | (0.058) | (0.058) | (0.058) |
| Time*Post 100 Percent Plan | -0.003 | -0.001 | -0.007 | -0.002 | -0.001 | -0.005 |
| | (0.020) | (0.020) | (0.021) | (0.018) | (0.018) | (0.019) |
| Between Policies | -0.041 | -0.040 | -0.027 | -0.015 | -0.014 | -0.006 |
| | (0.036) | (0.036) | (0.037) | (0.032) | (0.032) | (0.033) |
| Post 100 Percent Plan | 0.029 | 0.029 | 0.028 | 0.052** | 0.052** | 0.050* |
| | (0.028) | (0.028) | (0.029) | (0.025) | (0.025) | (0.026) |
| N | 28,749 | 28,542 | 26,137 | 31,556 | 31,193 | 28,542 |
| Clusters | 1,959 | 1,887 | 1,588 | 2,119 | 1,997 | 1,677 |
| Pre-Period Outcome Mean | 0.433 | 0.431 | 0.448 | 0.375 | 0.376 | 0.395 |
| Pre-Period Mean Employment | 18,907 | 18,910 | 20,130 | 19,291 | 19,356 | 20,377 |
| Panel B | Underground Mines | | | | | |
| Time*Between Policies | -0.496 | -0.497 | -0.593 | -0.712 | -0.689 | -0.819 |
| | (0.384) | (0.385) | (0.428) | (0.523) | (0.525) | (0.551) |
| Time*Post 100 Percent Plan | 0.003 | -0.009 | -0.001 | -0.059 | -0.070 | -0.045 |
| | (0.137) | (0.137) | (0.148) | (0.177) | (0.178) | (0.188) |
| Between Policies | 0.385* | 0.374* | 0.483** | 0.489* | 0.465* | 0.593** |
| | (0.210) | (0.210) | (0.236) | (0.279) | (0.280) | (0.297) |
| Post 100 Percent Plan | 0.011 | 0.001 | -0.007 | 0.040 | 0.029 | 0.025 |
| | (0.169) | (0.169) | (0.191) | (0.235) | (0.235) | (0.251) |
| N | 4,488 | 4,383 | 3,507 | 3,238 | 3,161 | 2,733 |
| Clusters | 412 | 368 | 256 | 296 | 265 | 212 |
| Pre-Period Outcome Mean | 1.958 | 2.008 | 2.362 | 2.701 | 2.780 | 2.994 |
| Pre-Period Mean Employment | 43,568 | 45,068 | 57,839 | 61,271 | 63,397 | 73,996 |

Notes: *Identical to the fourth column of table 2 with restrictions on the sample. Coefficients for the general time trend are excluded for brevity. The first three columns restrict to mines with positive accidents prior to the policy changes, columns 4 through 6 restrict to mines with above median employment prior to the policy changes. Columns 2 and 5 also restrict to mines with more than 5 observations prior to the policy changes. Columns 3 and 6 instead restrict to mines with more than 15 observations prior to the policy changes.*