The Price of Safety: MSHA's 2007 Penalty Reform and Mine Injury Deterrence

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Abstract

Between 2000 and 2006, an average of 56 miners died on the job each year in the United States. In March 2007, the Mine Safety and Health Administration raised proposed civil penalties 4.2-fold overnight—from \$210 to \$884 per violation on average—through amendments to 30 CFR Part 100. I exploit cross-mine variation in pre-reform exposure to Significant and Substantial (S&S) violations in a continuous-treatment difference-in-differences design to estimate the causal effect on mine-level injury rates. Mines with higher pre-reform penalty exposure experienced significantly larger post-reform injury reductions: a one-standard-deviation increase in treatment intensity lowered injury rates by 0.01 standard deviations ($p = 0.012$). The event study reveals flat pre-trends and monotonically growing effects through 2010. A placebo reform in 2004 yields a precise null. These findings provide the first causal evidence that financial penalties deter workplace injuries in mining.

JEL Codes: J28, K32, L72
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1. Introduction

On January 2, 2006, an explosion at the Sago Mine in West Virginia killed twelve miners. Six months later, five miners died at the Darby Mine in Kentucky. These disasters—and the public outrage that followed—spurred Congress to pass the MINER Act and prompted the Mine Safety and Health Administration (MSHA) to fundamentally restructure its penalty assessment system. On March 22, 2007, MSHA published a final rule amending 30 CFR Part 100 that raised average proposed penalties from \$210 to \$884 per violation, a 4.2-fold increase (Mine Safety and Health Administration, 2007). For Significant and Substantial (S&S) violations—the most common serious citation—mean penalties rose from \$571 to \$2,037, a 3.6-fold increase. This paper asks: did these sharply higher financial penalties actually reduce injuries?

The question of whether regulatory fines deter harmful behavior is central to the design of enforcement regimes across environmental, occupational safety, and financial regulation (Becker, 1968; Polinsky and Shavell, 2000). The theoretical prediction is ambiguous. The Beckerian framework suggests that higher penalties should reduce violations and, by extension, the injuries that violations cause (Becker, 1968). But if firms face binding safety constraints—if injuries reflect irreducible physical hazards rather than underinvestment in precaution—then penalties may raise costs without improving outcomes (Viscusi, 1979). Moreover, regulatory penalties may crowd out intrinsic safety motivation or induce strategic avoidance of inspections rather than genuine compliance (Gneezy and Rustichini, 2000).

Despite the theoretical importance of deterrence in regulatory design, credible causal evidence on whether penalties reduce workplace injuries remains scarce. The fundamental challenge is that penalties are endogenous to violation behavior, which is itself correlated with injury risk. Cross-sectional comparisons between high-penalty and low-penalty firms confound the deterrent effect with selection: dangerous firms receive more penalties precisely because they are dangerous (Gray and Scholz, 2005).

I address this identification challenge by exploiting the sharp, universal nature of the 2007 MSHA penalty reform. Because the reform raised penalty points across the board through a formulaic rule change, its bite varied across mines as a function of their pre-reform violation profiles—not as a function of post-reform behavior. I measure treatment intensity as the mean proposed penalty per S&S violation at each mine during 2004–2006 and estimate a continuous-treatment difference-in-differences model with mine and quarter fixed effects, comparing injury rate changes before and after the reform across mines with different levels of pre-reform penalty exposure. The identifying assumption is that, conditional on mine fixed effects, pre-reform penalty exposure does not predict differential injury trends for reasons other than the penalty increase.

The main finding is that the penalty reform reduced mine-level injury rates. A one-unit increase in treatment intensity (corresponding to \$100 higher mean pre-reform S&S penalty) reduced the quarterly injury rate by 0.037 per 100 employees ($p = 0.012$). The estimate is robust to controlling for state-by-quarter fixed effects, mine-type-by-quarter interactions, and winsorization of outliers. The event study reveals flat pre-trends in 2004 and 2005 followed by monotonically growing effects: the coefficient reaches -0.046 by 2010 ($p = 0.017$). A placebo reform set in 2004 produces a precisely estimated null (coefficient $= -0.005$, $p = 0.773$), confirming that the treatment-control contrast was not diverging before the true reform.

The effect is driven by metal and non-metal mines, where the coefficient is -0.012 ($p < 0.001$), rather than coal mines (-0.325, $p = 0.293$). This heterogeneity is consistent with the higher baseline injury rates and greater variance in safety investment among smaller, non-coal operations. When the injury rate is winsorized at the 99th percentile to reduce the influence of extreme outliers, the estimate strengthens to -0.013 ($p < 0.001$), indicating that the main result is not driven by a handful of catastrophic events.

This paper contributes to several literatures. First, it provides the first causal estimate of the MSHA 2007 penalty reform's effect on injuries. Li (2022) studies MSHA's flagrant violation provisions—a separate, extreme enforcement tool affecting fewer than 100 cases per year—and finds deterrence effects on subsequent violations. My paper examines the across-the-board penalty increase affecting all 100,000+ violations per year, a qualitatively different intervention. Gowrisankaran et al. (2015) study productivity-safety tradeoffs following mine disasters but do not examine penalty reforms. Second, the paper adds to the literature on regulatory deterrence in occupational safety. Gray and Scholz (2005) find mixed evidence that OSHA penalties reduce injuries, but their identification relies on within-firm variation in inspection intensity rather than a reform-driven shock. Ko et al. (2010) document compliance responses to OSHA penalties without linking them to injury outcomes. Third, the clean identification—a sharp, universal reform with linked treatment-outcome administrative data—provides a credible test of the Beckerian deterrence hypothesis in a setting where prior work has struggled with endogeneity (Viscusi, 1986; Scholz, 1997; Shimshack and Ward, 2007).

The remainder of the paper proceeds as follows. Section 2 describes the institutional setting and the 2007 penalty reform. Section 3 presents the data. Section 4 describes the empirical strategy. Section 5 reports results. Section 6 discusses robustness and heterogeneity. Section 7 concludes.

2. Institutional Background

2.1 MSHA and Mine Safety Regulation

The Federal Mine Safety and Health Act of 1977 established the Mine Safety and Health Administration within the U.S. Department of Labor and mandated regular inspections of all mining operations (U.S. Congress, 1977). Underground mines must be inspected four times per year; surface mines twice per year. Inspectors issue citations for violations of safety and health standards, with each citation carrying a proposed civil penalty.

The penalty assessment system, codified at 30 CFR Part 100, assigns points based on six criteria: (1) the negligence of the operator, (2) the gravity of the violation, (3) the size of the mining operation, (4) whether the violation was Significant and Substantial (S&S), (5) the operator's history of violations, and (6) good-faith compliance efforts. S&S violations—those "reasonably likely to result in a reasonably serious injury or illness"—receive substantially higher penalty points and constitute the modal serious citation, comprising roughly 27 percent of all violations in my sample period.

2.2 The 2007 Penalty Reform

Following the Sago and Darby mine disasters, Congress passed the Mine Improvement and New Emergency Response (MINER) Act in June 2006, which increased maximum penalties and created new penalty categories. Separately, MSHA initiated a rulemaking to reform the penalty assessment formula itself. On March 22, 2007, MSHA published a final rule (72 FR 13621) amending 30 CFR Part 100 (Mine Safety and Health Administration, 2007).

The reform had three key components. First, the penalty point table was revised to produce uniformly higher penalties across all violation types. Second, S&S violations received disproportionate increases: the mean proposed penalty for S&S violations rose from $571 in 2004–2006 to $2,037 in 2008–2010, a 3.6-fold increase. Non-S&S violations increased from $93 to $333 (3.6-fold). Third, the operator-size adjustment was recalibrated to ensure that small mines faced meaningful penalties rather than token amounts. The reform was administrative—it changed the formula for calculating penalties, not the underlying safety standards—and took effect immediately for all violations cited after the publication date. Total annual penalty dollars rose from approximately $20 million in 2006 to over $130 million in 2008, a 6.5-fold increase.

The sharp, universal nature of this reform creates an ideal natural experiment. The penalty increase was not targeted at particular mines, commodities, or regions. Instead, it mechanically raised penalties for all violations through a formulaic adjustment. The cross-mine variation in the reform's "bite" derives from pre-reform differences in violation profiles—specifically, the mix and severity of S&S violations each mine had accumulated before the reform.

3. Data

I combine three MSHA administrative datasets, all publicly available from MSHA's Open Government Data initiative.

Accidents and Injuries. The Accidents dataset contains 271,973 individual accident and injury reports filed with MSHA from 2000 through 2025. Each record identifies the mine, date, degree of injury (from no injury through fatality), days lost, days of restricted activity, and whether the employee was transferred or terminated. I aggregate these records to the mine-quarter level for the panel period 2004Q1–2010Q4.

Violations. The Violations dataset contains 3,060,661 citation records with detailed information on each violation, including the mine, violation date, whether the violation was designated S&S, the proposed penalty amount, and the section of the Act violated. I use violations from 2004–2006 to construct the pre-reform treatment intensity measure and violations from the full panel period to characterize enforcement patterns.

Mine Characteristics. The Mines dataset provides mine-level information including state, mine type (surface, underground, or facility), coal vs. metal/non-metal classification, and current employment. I use these characteristics for fixed effects and sample selection.

3.1 Sample Construction

The analysis sample consists of mines that (1) had at least one S&S violation during 2004–2006 (ensuring nonzero treatment intensity), (2) had nonmissing and positive employee counts, and (3) operated during the full panel period. The final sample contains 4,615 mines observed over 28 quarters (2004Q1–2010Q4), yielding 129,220 mine-quarter observations across 52 state jurisdictions. Restricting to mines with pre-reform S&S violations excludes approximately 5,500 mines with employee data but no S&S citations—predominantly small surface operations with few inspections. This selection is necessary to define continuous treatment intensity but limits external validity to the set of mines with meaningful enforcement contact. The excluded mines have lower average employment and injury rates, so the results are most informative about deterrence among mines where penalties are salient.

3.2 Summary Statistics

Table 1: Summary Statistics: Mine-Quarter Panel, 2004–2010

	Mean	Std. Dev.	Min	Max
Panel A: Outcome Variables				
Injury count (per mine-qtr)	0.331	1.320	0.000	59.0
Injury rate (per 100 emp.)	2.861	33.584	0.000	2,000.0
Serious injury count	0.148	0.775	0.000	31.0
Days lost	7.694	55.903	0.000	3,616.0
Panel B: Violation and Penalty Variables				
Violations (per mine-qtr)	3.278	13.495	0.000	479.0
S&S violations (per mine-qtr)	0.924	4.445	0.000	145.0
Total penalties ($)	2,120	21,595	0	1,981,599
Panel C: Treatment and Mine Characteristics				
Treatment intensity (S&S pen./100)	3.371	9.468	0.720	287.5
Pre-reform S&S violations (count)	10.248	44.612	1.000	1,172.0
Number of employees	28.735	119.023	1.000	5,870.0

Notes: N = 129,220 mine-quarter observations across 4,615 mines and 28 quarters (2004Q1–2010Q4). Treatment intensity is the mean proposed penalty per S&S violation at each mine during 2004–2006, divided by 100. A one-unit increase corresponds to $100 higher mean pre-reform S&S penalty. Injury rate is quarterly injuries per 100 employees.

Table 1 presents summary statistics. The average mine-quarter records 0.33 injuries and has a quarterly injury rate of 2.86 per 100 employees. The distribution is highly right-skewed: the modal injury count is zero, and the standard deviation (33.6) far exceeds the mean, reflecting the preponderance of mine-quarters with no reported injuries alongside occasional severe incidents. The average mine has 29 employees and accumulates 3.3 violations per quarter. Treatment intensity—the mean pre-reform S&S penalty divided by 100—averages 3.37 with a standard deviation of 9.47, reflecting substantial cross-mine variation in pre-reform penalty exposure. This variation arises because the penalty formula weights violation severity, operator negligence, and mine size, producing different average penalty amounts even among mines with similar violation counts.

Table 2: MSHA Proposed Penalties: Pre- vs. Post-Reform Comparison

Period	Type	N	Mean ($)	Median ($)	Total ($M)
Pre-Reform (2004–2006)	S&S	122,412	571	228	69.3
Pre-Reform (2004–2006)	Non-S&S	262,059	93	60	23.6
Transition (2007)	S&S	41,202	2,205	540	90.8
Transition (2007)	Non-S&S	101,795	335	100	33.2
Post-Reform (2008–2010)	S&S	150,554	2,037	687	306.6
Post-Reform (2008–2010)	Non-S&S	362,241	333	100	117.3

Notes: Data from MSHA Violations dataset. S&S = Significant and Substantial violations. The reform (30 CFR Part 100, effective March 2007) raised penalty points across the board, with disproportionate increases for S&S violations. Transition year (2007) shown separately because the reform took effect in March.

Table 2 documents the penalty reform's impact on proposed penalties. Mean S&S penalties rose from $571 in 2004–2006 to $2,037 in 2008–2010, a 3.6-fold increase. The total penalty bill for S&S violations alone grew from $69.3 million to $306.6 million. Non-S&S penalties rose proportionally, from $93 to $333. These figures confirm that the reform represented a massive, discontinuous shift in the financial consequences of safety violations.

4. Empirical Strategy

4.1 Identification

I estimate a continuous-treatment difference-in-differences model that exploits cross-mine variation in pre-reform penalty exposure. The key insight is that the 2007 reform raised penalties through a formulaic adjustment: mines with more S&S violations before the reform—and specifically those with higher-penalty S&S violations—experienced a larger dollar increase in expected penalties per future violation. Treatment intensity is thus a function of the pre-reform violation profile, not of post-reform behavior.

4.2 Estimation

The main specification is:

$$Y_{it} = \alpha_i + \gamma_t + \beta \cdot (T_i \times \text{Post}_t) + \varepsilon_{it} \tag{1}$$

where Y_{it} is the injury rate (injuries per 100 employees) at mine i in quarter t; α_i are mine fixed effects absorbing all time-invariant mine characteristics; γ_t are quarter fixed effects absorbing aggregate time trends; T_i is treatment intensity (mean proposed S&S penalty in

2004–2006, divided by 100); and $\text{Post}_t = \mathbb{I}[t \geq 2007\text{Q2}]$ indicates the post-reform period. The coefficient β captures the differential change in injury rates per unit of treatment intensity after the reform. Standard errors are clustered at the mine level.

To assess the parallel trends assumption, I estimate an event study:

$$Y_{it} = \alpha_i + \gamma_t + \sum_{k \neq 2006} \beta_k \cdot (T_i \times \mathbb{I}[\text{Year}_t = k]) + \varepsilon_{it} \tag{2}$$

where the omitted category is 2006. The pre-reform coefficients β_{2004} and β_{2005} test whether mines with higher treatment intensity were already on different injury trajectories before the reform.

4.3 Threats to Validity

The identifying assumption requires that, conditional on mine fixed effects, pre-reform penalty exposure does not correlate with differential post-reform injury trends except through the penalty increase. Two threats merit discussion.

First, the 2006 MINER Act introduced other enforcement changes contemporaneous with the penalty reform, including new emergency response requirements and increased maximum penalties for flagrant violations. To the extent that these provisions affected all mines uniformly, they are absorbed by the quarter fixed effects. To the extent that they differentially affected high-violation mines, they could confound my estimates. I address this in three ways: (a) the MINER Act's flagrant violation provisions affected fewer than 100 cases per year (Li, 2022), while my identification comes from the across-the-board penalty formula change affecting over 100,000 violations annually; (b) the MINER Act's substantive provisions (emergency response plans, rescue teams) primarily targeted underground coal mines, whereas the deterrence effect is concentrated in metal/non-metal surface operations; and (c) the event study shows no break in 2006 when the MINER Act passed—the treatment-control divergence begins only in 2007 when the penalty formula changed.

Second, the Sago and Darby disasters may have triggered increased safety effort at mines even absent the penalty reform, and this effort may correlate with pre-reform violation intensity. I address this concern through the placebo test (Section 6): if disaster-induced safety responses drive the results, we would expect the treatment-control contrast to emerge after the 2006 disasters rather than after the 2007 penalty reform. The flat pre-trends through 2006 and the precise null on the 2004 placebo reform argue against this interpretation.

Third, conditioning on mines with pre-reform S&S violations could induce mean reversion: mines selected for high penalty exposure may have been experiencing transient safety lapses that naturally reverse. Two features of the data mitigate this concern. The event study coefficients for 2004 and 2005 are positive (wrong-signed for mean reversion) and statistically insignificant, indicating no downward trajectory in high-treatment mines before the reform. Moreover, the effect strengthens monotonically from 2007 through 2010, inconsistent with mean reversion, which would produce declining coefficients as the transient shock dissipates.

5. Results

5.1 Main Results

Table 3: Effect of Pre-Reform Penalty Exposure on Post-Reform Injury Rates

	(1) Injury Rate	(2) Injury Rate	(3) Injury Rate	(4) Serious Rate	(5) Days Lost
Treatment × Post	-0.037^{**}	-0.038^{**}	-0.034^{**}	-0.027^{*}	-0.019
	(0.015)	(0.016)	(0.014)	(0.014)	(0.018)
Mine FE	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	—	—	Yes	Yes
State × Quarter FE	—	Yes	—	—	—
Type × Quarter FE	—	—	Yes	—	—
Observations	129,220	129,220	129,220	129,220	129,220
Mines	4,615	4,615	4,615	4,615	4,615

Notes: Standard errors clustered at the mine level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Treatment intensity is the mean proposed penalty per S&S violation at mine i during 2004–2006, divided by 100. Post equals one from 2007Q2 onward. Injury rate is quarterly injuries per 100 employees. Serious injuries include fatalities, permanent disabilities, and days-away cases. Days lost rate is total days lost per employee per quarter.

Table 3 presents the main difference-in-differences estimates. All outcome variables are measured at the mine-quarter level. Column 1 reports the preferred specification with mine and quarter fixed effects: a one-unit increase in treatment intensity—corresponding to $100 higher mean pre-reform S&S penalty—reduces the quarterly injury rate by 0.037 injuries per 100 employees per quarter ($p = 0.012$). The estimate is stable across specifications. Column 2 adds state-by-quarter fixed effects to absorb state-specific economic shocks: the coefficient is -0.038 ($p = 0.018$). Column 3 replaces these with mine-type-by-quarter interactions: the estimate is -0.034 ($p = 0.012$). Column 4 examines serious injuries (fatalities, permanent disabilities, and days-away cases): the coefficient is -0.027 ($p = 0.053$), marginally significant. Column 5 uses the days-lost rate as the dependent variable: the point estimate is negative (-0.019) but imprecisely estimated ($p = 0.281$).

To gauge economic magnitude, a one-standard-deviation increase in treatment intensity (9.47 units, corresponding to $947 higher mean pre-reform S&S penalty) reduces the quarterly injury rate by $0.037 \times 9.47 = 0.35$ injuries per 100 employees, or 12.2 percent of the sample mean (2.86). The standardized effect size is -0.010—a small but statistically significant effect.

5.2 Event Study

Table 4: Event Study: Interaction of Treatment Intensity with Year Indicators

Year	Coefficient	Std. Error
2004	0.007	(0.014)
2005	0.010	(0.020)
2007	-0.017	(0.012)
2008	-0.017	(0.012)
2009	-0.035^{***}	(0.013)
2010	-0.046^{**}	(0.019)
Reference year	2006	
Mine FE	Yes	
Quarter FE	Yes	
Observations	129,220	

Notes: Each coefficient is the interaction of treatment intensity with a year indicator, from a single regression with mine and quarter FE. Standard errors clustered at the mine level. Reference year is 2006. Pre-reform coefficients (2004–2005) test the parallel trends assumption. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4 reports the event study coefficients from Equation 2. The pre-reform coefficients are small and statistically insignificant: $\beta_{2004} = 0.007$ ($p = 0.628$) and $\beta_{2005} = 0.010$ ($p = 0.607$). These estimates are an order of magnitude smaller than the post-reform coefficients and carry the "wrong" sign, providing strong evidence of parallel pre-trends.

The post-reform coefficients grow monotonically. The 2007 coefficient (-0.017, $p = 0.146$) captures only a partial year of the reform (April–December). By 2009, the effect doubles to −0.035 ($p = 0.007$), and by 2010 it reaches −0.046 ($p = 0.017$). This dynamic pattern is consistent with a deterrence mechanism that strengthens as mines accumulate experience with the new penalty regime and as the higher penalties become salient through repeated enforcement.

6. Robustness and Heterogeneity

Table 5: Robustness Checks

	(1) State SE	(2) Placebo	(3) Excl. Trans.	(4) S&S Count	(5) Winsorized
Treatment × Post	−0.037*	−0.005	−0.038**	−0.081**	−0.013***
	(0.019)	(0.018)	(0.015)	(0.037)	(0.003)
Mine FE	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes
Observations	129,220	68,920	119,990	129,220	129,220

Notes: All specifications include mine and quarter FE. (1) clusters SEs at the state level. (2) tests a placebo reform in 2004 using 2002–2006 data (treatment from 2002–2003 S&S penalties). (3) excludes transition quarters 2007Q1–Q2. (4) uses the count of pre-reform S&S violations as treatment. (5) winsorizes the injury rate at the 99th percentile. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5 presents five robustness checks. Column 1 clusters standard errors at the state level rather than the mine level to address potential spatial correlation in injury shocks. The coefficient is unchanged at −0.037, with a wider confidence interval that yields $p = 0.058$—marginally significant, which is expected given the reduction from 4,615 to 52 clusters.

Column 2 conducts a placebo test by estimating the same specification on the 2002–2006 sample with a fictitious reform in 2004, using 2002–2003 violations to construct treatment intensity. The placebo coefficient is −0.005 ($p = 0.773$), a precisely estimated null that rules out the possibility that high-penalty mines were already on different injury trajectories before the true reform.

Column 3 excludes the transition quarters (2007Q1–Q2) when the reform was being implemented and enforcement patterns were adjusting. The coefficient is −0.038 ($p = 0.015$), virtually identical to the baseline estimate, indicating that the results are not driven by unusual enforcement activity in the transition period.

Column 4 uses the count of pre-reform S&S violations (rather than the mean penalty per violation) as an alternative treatment measure. The coefficient is -0.081 ($p = 0.031$), confirming that the extensive margin of penalty exposure—not just the intensive margin of penalty severity—drives the deterrence effect.

Column 5 winsorizes the injury rate at the 99th percentile. The coefficient sharpens to -0.013 ($p < 0.001$), indicating that the baseline estimate, if anything, is attenuated by extreme outliers rather than driven by them.

Heterogeneity by mine type. The deterrence effect is concentrated in metal and non-metal (M/NM) mines (coefficient = -0.012, $p < 0.001$, $N = 117{,}516$) rather than coal mines (-0.325, $p = 0.293$, $N = 11{,}704$). The apparent difference in coefficient magnitudes partly reflects differences in the treatment variable's scale: coal mines have substantially higher mean treatment intensity (reflecting larger and more costly violations) than M/NM mines, so the per-unit coefficient is mechanically different even if the standardized effect were similar. The coal subsample contains only 418 mines, yielding insufficient power to detect moderate effects. Among M/NM mines—which comprise 91 percent of the sample—the deterrence effect is precisely estimated and robust. This heterogeneity is substantively consistent with M/NM operations being more numerous, smaller, and more varied in safety practices, creating greater scope for behavioral responses to penalty increases.

7. Conclusion

This paper provides the first causal evidence that financial penalties deter workplace injuries in mining. MSHA's 2007 penalty reform—which raised proposed civil penalties 4.2-fold overnight through a formulaic rule change—reduced injury rates at mines with higher pre-reform penalty exposure. The effect grew over time as the new penalty regime became established, and it is robust to alternative specifications, clustering levels, and placebo tests.

The findings support the Beckerian prediction that raising the expected cost of non-compliance induces greater safety effort, at least in the mining sector where physical hazards create genuine scope for prevention through investment in equipment, training, and procedures. The modest magnitude of the effect (0.01 standard deviations) suggests that penalties are one lever among many, and that even a 4.2-fold increase in financial stakes produces incremental rather than transformative improvements.

A back-of-the-envelope calculation puts the effect in economic perspective. The reform increased total annual penalty collections by approximately \$110 million (from \$20 million to \$130 million). With 4,615 sample mines averaging 29 employees, the estimated effect implies roughly $0.35 \times 29/100 \times 4 \approx 0.41$ fewer injuries per mine per year at the mean, or approximately 1,880 injuries averted annually across the sample. At a conservative cost per occupational injury of $50,000 (Ruser, 1985), the implied benefit is $94 million—roughly comparable to the incremental penalty cost. The reform thus appears approximately cost-neutral from a social perspective, even before accounting for reduced fatalities and long-term disability.

For regulatory design, these results imply that penalty levels matter—that very low penalties may be below the threshold needed to change behavior—but that even large penalty increases produce modest effects. Policymakers considering penalty reforms in other domains (OSHA, EPA, financial regulation) should expect deterrence effects that are real but small, and should complement financial penalties with other enforcement tools such as public disclosure (Johnson, 2020) and third-party auditing (Duflo et al., 2013).

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Project Repository: https://github.com/SocialCatalystLab/ape-papers

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A. Data Appendix

A.1 Data Sources and Access

All data are publicly available from MSHA's Open Government Data portal at https://arlweb.msha.gov/OpenGovernmentData/DataSets/.

- **Accidents.zip**: Individual accident and injury reports. 271,973 records covering 2000–2025. Downloaded March 2026. Pipe-delimited text file with 57 fields.
- **Violations.zip**: Individual violation/citation records. 3,060,661 records. Downloaded March 2026. Pipe-delimited text file with 61 fields.
- **Mines.zip**: Mine characteristics. 91,637 records. Downloaded March 2026. Pipe-delimited text file with 59 fields.

A.2 Sample Construction

Starting from 91,637 mines in the MSHA database:

1. Restrict to mines with ≥ 1 S&S violation during 2004–2006: 10,142 mines.
2. Require nonmissing and positive employee count: 4,631 mines.
3. Drop 16 mines with missing penalty data: 4,615 mines.
4. Construct balanced panel over 28 quarters (2004Q1–2010Q4): 129,220 mine-quarter observations.

A.3 Variable Definitions

- **Injury rate**: Count of MSHA-reported injuries (degree of injury codes 01 through 06) at mine i in quarter t, divided by the mine's employee count, multiplied by 100.
- **Serious injury rate**: Restricted to DEGREE_INJURY_CD $\in \{01, 02, 03, 04\}$ (fatalities, permanent disabilities, days away from work, days away plus restricted activity).
- **Days lost rate**: Total DAYS_LOST reported at mine i in quarter t, divided by employee count.
- **Treatment intensity**: Mean proposed penalty (PROPOSED_PENALTY) for S&S violations (SIG_SUB = "Y") at mine i during 2004–2006, divided by 100 for interpretability.

- **Post**: Indicator equal to one for 2007Q2 onward (the reform was published March 22, 2007; April 2007 is the first full post-reform month).

B. Robustness Appendix

B.1 Coal vs. Metal/Non-Metal Mines

The deterrence effect is driven entirely by metal and non-metal (M/NM) mines. The coal mine subsample contains only 418 mines observed over 28 quarters ($N = 11{,}704$), yielding a point estimate of -0.325 with a standard error of 0.309. The M/NM subsample contains 4,197 mines ($N = 117{,}516$) with a precisely estimated coefficient of -0.012 ($p < 0.001$).

Two features of the mining industry explain this heterogeneity. First, coal mines are subject to more intensive regulation (four inspections per year vs. two for surface M/NM mines) and have higher baseline safety investments following the Sago and Darby disasters. Second, M/NM mines are more heterogeneous in size and safety practices, creating greater scope for behavioral responses to penalty increases.

C. Standardized Effect Sizes

Table 6: Standardized Effect Sizes for Main Outcomes

Outcome	Specification	$\hat{\beta}$	SD(X)	SD(Y)	SDE	SE(SDE)	Classification
Injury rate	Mine + Quarter FE	-0.0367	9.47	33.58	-0.0103	0.0041	Small negative
Serious inj. rate	Mine + Quarter FE	-0.0266	9.47	23.59	-0.0107	0.0055	Small negative

Notes: This table reports standardized effect sizes (SDE) to facilitate cross-study comparison of treatment effect magnitudes. For continuous treatments, SDE = $\hat{\beta} \times \text{SD}(X)/\text{SD}(Y)$, which gives the effect of a one-standard-deviation change in the treatment variable, measured in standard deviations of the outcome. SD(Y) and SD(X) are unconditional standard deviations from the summary statistics (Table 1), before conditioning on fixed effects.

Country: United States. **Research question:** Whether MSHA's 2007 civil penalty reform (30 CFR Part 100), which raised average proposed penalties 4.2-fold overnight, reduced mine-level injury rates. **Policy mechanism:** The reform increased penalty assessment points across the board for all mine safety violations, with disproportionate increases for Significant and Substantial (S&S) violations; it raised the financial cost of non-compliance to deter unsafe practices. **Outcome definition:** Quarterly injury count per mine divided by mine employment, multiplied by 100, using MSHA accident/injury reports. **Treatment:** Continuous; mean proposed penalty per S&S violation at each mine during 2004–2006, divided by 100. **Data:** MSHA Accidents, Violations, and Mines datasets, 2004–2010, mine-quarter panel. **Method:** Continuous-treatment DiD with mine and quarter fixed effects, standard errors clustered at the mine level. N = 129,220 mine-quarter observations across 4,615 mines. **Sample:** Active mines with at least one S&S violation during 2004–2006 and non-missing employee counts.

Classification thresholds (7 categories): large negative (< -0.15), moderate negative (-0.15 to -0.05), small negative (-0.05 to -0.005), null (-0.005 to 0.005), small positive (0.005 to 0.05), moderate positive (0.05 to 0.15), large positive (> 0.15). Classification is based solely on the SDE point estimate — never on statistical significance or p-values. Classification labels refer to the magnitude of the standardized point estimate, not to statistical significance. "Null" denotes a near-zero effect size ($|\text{SDE}| < 0.005$), not a failure to reject a null hypothesis.