MINING MINING DATA: BRINGING EMPIRICAL ANALYSIS TO BEAR ON THE REGULATION OF SAFETY AND HEALTH IN U.S. MINING

Alison D. Morantz[*]

I. INTRODUCTION 46
II. PAST EMPIRICAL RESEARCH ON MINING SAFETY REGULATION 49
III. TAPPING THE RICH RESERVOIR OF HISTORICAL DATA ON U.S. COAL MINES 56
  A. *The Unique Scope of Historical Data on Mining Safety Regulation* 56
  B. *How Analyzing Historical Data Could Shed New Light on U.S. Mining Regulation* 58
IV. THE THEORY AND PRACTICE OF TARGETED REGULATION 61
  A. *Theoretical Background* 61
  B. *Prior Applications to U.S. Regulated Economy* 64
V. HOW REGULATORS COULD USE INSPECTION AND SAFETY DATA TO TARGET HIGH-RISK MINES 68
  A. *Designing a Targeting Protocol: Methodological Challenges* 68
  B. *Implementing a Targeting Protocol: Practical Challenges* 71
VI. CONCLUSION 73

[*] Associate Professor of Law and John A. Wilson Distinguished Faculty Scholar, Stanford Law School. Many thanks to Garth Sheldon-Coulson and Rohith Srinivas, both of whom provided excellent research assistance related to this project.

I. INTRODUCTION

Despite its relatively small share of the economy as a whole,[1] mining has played a disproportionately large role in the growth of U.S. safety and health regulation. In part, the industry's unique salience is explained by its unique hazards: for much of the 20th century, mining was one of the most dangerous occupations.[2] Moreover, few workplace accidents over the past century have commanded the public's attention or galvanized subsequent reform efforts as effectively as mining catastrophes. The Monongah Mining Disaster of 1907, which claimed hundreds of miners' lives,[3] helped trigger the creation of the U.S. Bureau of Mines in 1910, the federal government's first comprehensive foray into the safety-and-health arena.[4] The Coal Mine Health and Safety Act of 1969 ("Coal Act") heralded a new era of federal regulation, in which inspectors were empowered not only to inspect coal mines but also to issue monetary and criminal penalties for statutory violations.[5] Not until the following year did Congress

---

[1] In 2005, the U.S. mining industry, excluding oil and gas extraction, represented approximately 0.25% of the national GDP. MOORE ECON., NAT'L MINING ASS'N, THE ECON. CONTRIBUTIONS OF THE MINING INDUS. IN 2005 36 tbl. 25 (2007), *available at* http://www.nma.org/pdf/pubs/mining_economic_report.pdf. This proportion has declined in recent decades. In 1981, for example, the comparable figure was 0.73%. BUREAU OF ECON. ANALYSIS, GROSS-DOMESTIC-PRODUCT-(GDP)-BY-INDUSTRY DATA, http://www.bea.gov/industry/gdpbyind_data.htm (last visited Mar. 13, 2008) (click the XLS link under NAICS Data; then click the 1947-87_97NAICS-VA tab within the spreadsheet).

[2] *See* Mine Safety and Health Administration (MSHA), Historical Data 1931-1977: Coal, Metal, Nonmetal, Stone, and Sand and Gravel Mines and Mills, http://www.msha.gov/STATS/PART50/WQ/1931/wq31am01.asp (last visited Mar. 13, 2008) (scroll down to "Frequency rate per million man-hour") (showing the injury and fatality rates for mining for every year between 1931 and 1977).

[3] *Compare* MSHA, FACT SHEET 95-8: HISTORICAL DATA ON MINE DISASTERS IN THE UNITED STATES, http://www.msha.gov/MSHAINFO/FactSheets/MSHAFCT8.HTM (last visited July 16, 2008) ("the Monongah coal mine explosion . . . claimed 362 lives"), *with* DAVITT MCATEER, MONONGAH: THE TRAGIC STORY OF THE WORST INDUSTRIAL ACCIDENT IN U.S. HISTORY 241 (2007) ("[I]t is reasonable to conclude that the disaster at the Monongah mines certainly claimed in excess of 500 lives and probably more than 550 men.").

[4] *See, e.g.*, MSHA, *supra* note 3 ("the Monongah coal mine explosion . . . impelled Congress to created [sic] the Bureau of Mines."); Mark Aldrich, *Preventing "the Needless Peril of the Coal Mine": The Bureau of Mines and the Campaign against Coal Mine Explosions, 1910-1940*, 36 TECH. & CULTURE 483, 489 (1995) (noting that A. B. Fleming, who had operated the Monongah mine, testified in March of 1908 to the House Committee on Mines and Mining, in support of a "bureau of mines," the establishment of which the committee was considering). For a brief history of federal involvement in mine safety, see MSHA, HISTORY OF MINE SAFETY AND HEALTH LEGISLATION, http://www.msha.gov/mshainfo/mshainf2.htm (last visited July 16, 2008) (noting that the 1910 law was the first to establish a federal agency to conduct research and reduce accidents in coal mines operating in the continental U.S.).

[5] Federal Coal Mine Health and Safety Act of 1969, Pub. L. No. 91-173, 83 Stat. 742 (1969) (codified as amended at 30 U.S.C. §§ 901-945 (2000)).

extend similar protections to the rest of the U.S. economy through the Occupational Safety and Health Act.[6]

Legislative reform in the wake of well-publicized disasters continues to the present day. On January 2, 2006, an explosion in the Wolf Run Mining Company's Sago Mine near Sago, West Virginia, killed twelve miners and seriously injured another.[7] An internal review conducted by the Mining Safety and Health Administration (MSHA) identified several "deficiencies in MSHA's actions at the Sago Mine" whose "root causes," the report concluded, "must be corrected."[8] The Sago explosion helped spur the passage of the Mine Improvement and New Emergency Response Act of 2006 ("MINER Act"),[9] which amended and strengthened federal enforcement powers.[10] Some observers felt, however, that the MINER Act did not go far enough to strengthen mandatory safety standards – particularly those applicable during emergencies – and to punish repeat violators.[11] In January, 2008, the Supplemental Mine Improvement and New Emergency Response Act of 2007 ("S-MINER Act"),[12] designed to further these goals, passed the House. As of this writing, the bill awaits consideration by the Senate.

At first glance, MSHA has much in common with its "sister" agency, the Occupational Safety and Health Administration (OSHA), which oversees the rest of the U.S. economy. Both agencies promulgate standards, inspect private workplaces, issue citations, and levy penalties for non-compliance. Yet the differences between the two agencies are equally striking. The Coal Act (and the Mine Act, which broadened its coverage and strengthened its provisions eight years later) requires federal officials to inspect each underground mine at least four times a year and every surface mine at least twice a year.[13] In contrast,

---

6 Occupational Safety and Health Act of 1970 (OSHA), 29 U.S.C. §§ 651-678 (2000).

7 *See* MSHA, INTERNAL REVIEW OF MSHA'S ACTIONS AT THE SAGO MINE[,] WOLF RUN MINING COMPANY[,] SAGO, UPSHUR COUNTY, WEST VIRGINIA 3-4 (June 28, 2007), *available at* http://www.msha.gov/Readroom/FOIA/2007InternalReviews/Sago%20Internal%20Review%20Report.pdf (last visited July 17, 2008) (summarizing history of Sago explosion).

8 *Id.* at 1-2.

9 Mine Improvement and New Energy Response Act of 2006, Pub. L. No. 109-236, 120 Stat. 493 (2006) (codified as amended at 30 USC 801 (2000)).

10 The Senate Committee on Health, Education, Labor, and Pensions, in considering the bill that would become the MINER Act, cited the Sago tragedy as an important part of the bill's genesis. *See* S. Rep. No. 109-365, at 2 (2006) ("After the Sago Mine accident on January 2, 2006, the Health, Education, Labor, and Pensions (HELP) Committee assembled a group of members to travel to West Virginia to explore the need for reforms to the Mine Safety and Health Act of 1977."). For a summary of the Act's key provisions, see MSHA, MINE IMPROVEMENT AND NEW EMERGENCY RESPONSE ACT OF 2006, http://www.msha.gov/mineract/MineActAmmendmentSummary.asp (last visited July 17, 2008).

11 *See, e.g.*, Dennis B. Roddy, *Bush Signs Safety Law: Critics Say Legislation Doesn't Go Far Enough in Protecting Miners*, PITTSBURGH POST-GAZETTE, June 16, 2006, at A1.

12 H.R. 2768, 110th Cong. (2007).

13 Federal Mine Safety and Health Act of 1977, Pub. L. No. 95-164, 9 Stat. 1290, § 103(a) (codified at 30 U.S.C. § 813 (2000)). Eight years later, the Mine Act broadened the scope of

OSHA's budget enables it to inspect only a small fraction of U.S. establishments in any given year.[14] Secondly, while safety-and-health laws generally may be enforced by either federal or state officials (depending on whether a given state has chosen to exercise its right to "opt out" of the federal OSHA system and assume enforcement authority), mining regulations are always enforced by federal inspectors.[15] Finally, while the outcomes of safety-and-health inspections are publicly available for the entire regulated economy, only the Mining Act requires employers to report, and make publicly available, each and every mining accident, injury, and fatality in "real time."

By most accounts, the passage of this comprehensive regulatory scheme was a marked success. The sharp decline in mining fatality rates that characterized most of the 1970s[16] has generally been attributed to the deterrent impact of federal regulation.[17] In more recent decades, these initially dramatic trends have become more attenuated. Although the rate of nonfatal injuries has generally declined since the 1990s, fatality rates have remained fairly constant, prompting one MSHA official to suggest by the mid 1990s that "a plateau ha[d] been reached."[18] Yet despite recent attempts to scale back federal enforcement,[19] and periodic fluctuations over time in the level of fines imposed,[20] the core regulatory requirements set forth in the Mine Act have remained essentially unchanged for over three decades.

---

regulatory authority to non-coal mines, and also charged the newly created Mining Safety and Health Administration with enforcement authority.

14 Thomas J. Kniesner & John D. Leeth, *Data Mining Mining Data: MSHA Enforcement Efforts, Underground Coal Mine Safety, and New health Policy Implications*, 29 J. RISK & UNCERTAINTY 83, 84 (2004) ("[O]n a per establishment basis MSHA's enforcement budget is over 400 times larger [than OSHA's], and on a per worker basis over 150 times larger than OSHA's.").

15 For the OSHA "opt-out" provision, see 29 U.S.C. § 667 (2000).

16 *See* MSHA, *supra* note 2.

17 Since the decline in serious injuries is an economy-wide phenomenon, though, it is unclear whether the decreasing mining fatality rates should be attributable to MSHA enforcement. For economy-wide data on workplace injuries and fatalities, see U.S. DEP'T OF LABOR, INJURY/ILLNESS INCIDENCE RATES, http://www.osha.gov/oshstats/work.html (last visited Mar. 13, 2008).

18 Davitt McAteer, *Mine Safety and Health: A Formula for Continued Success*, 96 W. VA. L. REV. 847, 848 (1994). For injury and fatality data through 2006, see MSHA, MINING INDUSTRY ACCIDENT, INJURIES, EMPLOYMENT, AND PRODUCTION DATA, http://www.msha.gov/ACCINJ/accinj.htm (last visited Mar. 13, 2008) (under "Historical Statistics - 1931 Through 2006," click on the respective hyperlink for coal and metal mining; then click on the " Number of Fatal Injuries and Fatal Incident Rates (IR)" hyperlink).

19 In 1995, Congress considered a measure that would have eliminated the National Institute of Occupational Safety and Health (NIOSH), eased penalties on operators, and provided general exemptions and defenses against enforcements. *See* H.R. 1834, 104th Cong. (1995).

20 For a discussion of changes in MSHA's fee structure, see Kniesner & Leeth, *supra* note 14, at 89; *see also id.* ("Considering inflation, the changes in penalties mean [that] MSHA fines in real terms fell from 1983 to 1990, jumped in 1990, declined to 1992, jumped in 1992, and then declined to 1997.").

Notwithstanding the historical prominence of mining regulation, the unique breadth of regulatory oversight, and the plethora of historical data available, formal empirical analysis of MSHA's regulatory behavior and efficacy has been remarkably scarce. Only a handful of studies have analyzed historical time trends in an effort to measure the effects of federal oversight, and even fewer have examined detailed measures of MSHA's inspection activity. To date, therefore, most scholarship regarding the historical (and potential) scope of regulatory intervention in the mining industry has relied on anecdotal evidence and casual empiricism.

In this Article, I argue that to galvanize its regulatory activity and achieve further improvements in mine safety, MSHA should bring empirical analysis to bear on the wealth of mine-level data that it has been collecting for decades. Careful analysis of historical data could reveal much about the distribution of mining disasters, the relationship between compliance and safety, and the magnitude of MSHA's specific deterrence effect – all of which could give the agency fresh insights into the impact and limitations of its current regulatory practices. But the agency could go even further. Recent methodological and technological advances provide a unique opportunity for MSHA to experiment with statistically based regulatory targeting techniques. By developing a targeting algorithm to identify high-risk mines – which can be continuously refined and updated as new mine-level information is collected – the agency could acquire a powerful new tool for preventing future mining disasters.

The remainder of this Article sketches in greater detail how MSHA could use empirical techniques to enhance its regulatory practices. In Part II, I set the stage for the discussion that follows by critically reviewing prior empirical scholarship on mining regulation. Part III explains what makes mining data so unique as compared to data on other regulated industries, and describes how analyzing this data could shed new light on MSHA's current regulatory practices. Part IV briefly summarizes the theory of targeted regulation, and describes several prior real-world applications to the U.S. regulatory arena. Part V outlines how MSHA could develop a targeting protocol to identify high-risk mines, identifying the methodological and practical challenges that regulators would confront, and suggesting how they might be overcome. Part VI summarizes the key conclusions.

II. PAST EMPIRICAL RESEARCH ON MINING SAFETY REGULATION

Most prior empirical scholarship on coal mining regulation has focused on four questions: (1) whether passage of the Coal Act and/or Mine Act improved mine safety;[21] (2) the relationship, if any, between coal-mine safety and productivity;[22] (3) the effect, if any, of unionization on coal mine safety;[23] and

---

21 *See infra* notes 25, 26, 34, 35.

22 *See infra* notes 31-33.

23 *See infra* notes 34-35.

(4) MSHA's estimated marginal general deterrent effect on mine safety in recent decades.[24] For the most part, however, such research has yielded few policy-relevant findings that might enable MSHA to gauge the current or potential effectiveness of alternative regulatory practices.[25]

The first question – whether the advent of federal regulation achieved its intended goal of improving mine safety – was a primary theme of empirical scholarship in the early years following the Coal Act's passage. Juxtaposing national trends in injury rates before and after the passage of federal legislation, a handful of empirical studies dating from the 1970s and early 1980s explored whether the passage of the Coal Act (or Mining Act) triggered the subsequent decline in the rate of mining fatalities. The first study of this kind relied on a data series ending in 1970.[26] Since meaningful regulatory activity did not begin until midyear – and the study thus incorporated only a few months of post-Act data – it was hardly surprising that the findings were inconclusive.[27] Four later studies, armed with additional years of post-Act data, probed the same question. Using a multiple interrupted time-series model to isolate the effect of the Coal Act on fatality rates, two of these studies concluded that the Act had significantly improved miners' safety during the years immediately following its passage.[28] Given the significant methodological and empirical assumptions upon which both studies relied, their inference of a causal relationship should be seen as tentative at best.[29] Although the third study's authors, Neumann and Nelson,

---

24 *See infra* notes 39-40.

25 Although empirical scholars have probed a few other aspects of coal mine safety, they are not discussed here because none pertains directly to the analysis of regulation. *See, e.g.*, James D. Bennett & David L. Passmore, *Days Lost from Work Due to Injuries in U.S. Underground Bituminous Coal Mines, 1975-1981*, 5 J. OCCUPATIONAL ACCIDENTS 265 (1984) (examining whether the severity of injuries is predictable based on mine and miner characteristics); Jack Reardon, *Injuries and Illnesses Among Bituminous and Lignite Coal Miners*, MONTHLY LAB. REV., Oct. 1993, at 49 (comparing the relative frequency of different mining injuries as well as the relative injuriousness of different mining methods); Michael Wallace, *Dying for Coal: The Struggle for Health and Safety Conditions in American Coal Mining, 1930-82*, 66 SOC. FORCES 336 (1987) (examining the importance of industrial business climate and resource mobilization theory in explaining injury rates).

26 Tom S. Witt et al., Comment, *Some Economic Factors Affecting Safety in Underground Bituminous Coal Mines:* 42 S. ECON. J. 306 (1975). For a comment on the study, see W. H. Andrews & C. L. Christenson, Reply, *Some Economic Factors Affecting Safety in Underground Bituminous Coal Mines*, 42 S. ECON. J. 308 (1975).

27 Witt, *supra* note 26, at 308.

28 *See* Michael S. Lewis-Beck & John R. Alford, *Can Government Regulate Safety? The Coal Mine Example*, 74 AM. POL. SCI. REV. 745 (1980); Charles S. Perry, *Government Regulation of Coal Mine Safety: Effects of Spending Under Strong and Weak Law*, 10 AM. POL. RES. 303 (1982).

29 Lewis-Beck and Alford model fatality rates as a simple function of the passage of time (specifically, the number of years elapsed since 1932); the presence of several mining-related laws; the number of elapsed years since each respective law's passage; and three macroeconomic control variables (tons of output per man hour, the percentage of small mines, and the percentage of miners working underground). *See* Lewis-Beck & Alford, *supra* note 28, at 748. Although

used a different modeling approach with equally significant methodological limitations, the authors drew the same (albeit more qualified) conclusion that the Act tended to reduce the frequency of fatal accidents.[30] The fourth and final study reached conclusions very similar to Neumann and Nelson after correcting some of the earlier study's methodological drawbacks.[31]

On the whole, then, empirical scholarship on the Act's initial passage has drawn the same tentative inference that casual observation of the time trends would suggest: passage of the Act was remarkably coincident with, and may indeed have caused, the drop in fatalities that characterized most of the 1970s. Even if the shortcomings of earlier scholarship were corrected, because the Act's passage was a one-time historical event that affected all mines equally – at a time when complex political and economic changes were also convulsing the

---

appealingly simple, a number of the methodological assumptions upon which this model relies – that the mere passage of time has a linear effect on injury rates, as does the number of elapsed years since a law's passage; that the effect of any given law persists indefinitely in linear fashion even after it has been superseded by subsequent legislation; that the cumulative effect of legislation in any given year is simply the combined effect of all prior laws passed in prior years – seem problematic. Moreover, the assumption that output per man hour was a meaningful measure of technological change from 1970-76 seems dubious, since widespread labor unrest, manifested in frequent work stoppages and wildcat strikes, have been identified as a major cause of falling productivity. *See, e.g.*, JOE G. BAKER & WAYNE L. STEVENSON, U.S. DEP'T OF ENERGY, DETERMINANTS OF COAL MINE LABOR PRODUCTIVITY CHANGE iii (1979). Although Perry includes total federal spending in his model – along with dummy variables corresponding to the period in which each law was in effect, and the interaction of spending and time period – he controls for no macroeconomic variables at all. Rather, he simply includes the number of elapsed years since 1930 as a composite "indicator of nongovernmental enforcement mechanisms" in a model intended to differentiate between "effective" and "ineffective" laws. *See* Perry, *supra* note 28, at 308.

30 *See* George R. Neumann & Jon P. Nelson, *Safety Regulation and Firm Size: Effects of the Coal Mine Health and Safety Act of 1969*, 25 J.L. & ECON. 183, 198 (1982). As the authors concede, interpretation of their results largely depends on whether the Act caused small mines to exit the industry. *Id.* at 192. In short, if the dramatic decline in small firms' share of the industry is attributable to the Act's passage, their results appear much more supportive of the hypothesis that the Act lowered fatal injuries, although no similar evidence was found linking the Act's passage to a decline in *total* injuries. As with the two earlier studies, however, the model relies on a number of questionable modeling assumptions. Most importantly, the authors (with no justification) use the number of accidents *per ton* as the dependent variable in all regressions, and omit to include any controls for the number of labor-hours worked. Given the sharp decline in productivity following the Act's passage – at least part of which was attributable to exogenous widespread labor unrest and a spike in demand for coal during this period – the results are likely to be biased against the conclusion that the Act had a significant impact. *See, e.g,*, BAKER & STEVENSON, *supra* note 29, at iii-iv (citing both factors); U.S. GEN. ACCOUNTING OFFICE, LOW PRODUCTIVITY IN AMERICAN COAL MINING: CAUSES AND CURES iii (1981) (emphasizing importance of labor unrest).

31 *See* Scott M. Fuess, Jr. & Mark A. Lowenstein, *Further Analysis of the Theory of Economic Regulation: The Case of the 1969 Coal Mine Health and Safety Act*, 28 ECON. INQUIRY 354, 370-71 (1990) (using number of fatalities per million man hours worked as the dependent variable, and relying on a richer set of control variables, concluding that the 1969 Act lowered fatalities, but only significantly so if it was responsible for the falling market share of smaller, less safe mines).

industry[32] – it would probably be difficult to draw any definitive conclusions regarding the Act's causal impact. On one hand, the downward trend in fatality rates that characterized MSHA's early years is at least consistent with the view that inaugurating a comprehensive regulatory regime can help deter at least the most severe types of occupational accidents. On the other hand, this body of scholarship provides little insight into why fatality rates leveled off by the 1990s, and whether any changes in regulatory practices might trigger further declines.

A second goal of empirical scholarship has been to examine the tradeoff, if any, between mine safety and productivity. As long as firm behavior can affect accident frequency and the federally mandated level of safety expenditures exceeds that which firms would choose under free market conditions, economic theory predicts that such a tradeoff should exist.[33] Framing the issue in historical terms, one strand of scholarship has asked whether the passage of the Coal Act caused the decline in industry productivity during the decade after its passage. Relying on a wide variety of data sources and methodologies, those studies addressing this issue have uniformly concluded that the new requirements imposed by the Act were indeed partly responsible for the decline in mining productivity that endured through most of the 1970s.[34] In and of itself, however, the existence of such a macroeconomic tradeoff does not imply that a similarly negative relationship between productivity and safety exists *across firms*. To explore the latter question, several articles have probed whether there is a correlation between safety and productivity among individual mines. Relying on cross-sectional firm-level data, such scholarship has tended to find that the most productive mines, if anything, have lower-than-average serious injury and/or fatality rates.[35] The most common interpretation is not that higher pro-

---

32 *See* BAKER & STEVENSON, *supra* note 29; U.S. GEN. ACCOUNTING OFFICE, *supra* note 30 (citing severe labor unrest, spike in demand, and various other factors as shaping mining industry trends in 1970s).

33 *See, e.g.*, Hal Sider, *Safety and Productivity in Underground Coal Mining*, 65 REV. ECON. & STAT. 225, 225-27 (1983).

34 *See* BAKER & STEVENSON, *supra* note 29, at iii (finding that Coal Act was partly responsible for decline in deep mine labor productivity); U.S. GEN. ACCOUNTING OFFICE, *supra* note 30, at ii (although reaching same conclusion, suggesting that its impact diminished after 1977); Neuman & Nelson, *supra* note 30, at 195 (concluding that the Act depressed productivity based on analysis of national trends); Sider, *supra* note 33, at 232 (based on a study of 26 mines in Illinois, and assuming that job safety and productivity are jointly determined by a Cobb-Douglas production function, concluding that the Act was partly responsible for a subsequent decline in the production of marketable output). *See also* Fuess & Loewenstein, *supra* note 31 (although not directly analyzing productivity effects, finding that the Act's engineering standards caused smaller producers to exit industry and depressed output both nationwide and among underground coal mines in Kentucky).

35 *See* JOHN M. DEMICHIEI ET AL., MINE SAFETY & HEALTH ADMIN, FACTORS ASSOCIATED WITH DISABLING INJURIES IN UNDERGROUND COAL MINES 27 (1982) (finding that mines with low injury rates were more productive than other mines included in the study); U.S. GEN. ACCOUNTING OFFICE, *supra* note 30, at 44 (finding negative association in cross-sectional firm-level comparison

ductivity causes lower injuries (or vice versa), but – as one scholar has succinctly put it – that "safety and productivity share the same sire – competent management."[36] From a policy perspective, the more interesting question is how the passage of any given safety standard affects the marginal productivity of different mines over time. So far, however, the longitudinal data required to explore such detailed questions have been unavailable. Therefore, notwithstanding the scholarly consensus that the Coal Act lowered mining productivity shortly after its passage, empirical scholarship on the "safety-productivity trade-off" has shed little light on the impact of regulatory behavior in more recent decades.

A third empirical question upon which several empirical scholars have focused is the relationship between mine safety and unionization. A recent historical study found that union status lowered the predicted fatality rate by about 40 percent among early twentieth-century coal mines.[37] However, studies focusing on the decade after the Coal Act's passage have yielded more mixed findings. Studies by Boden, Connerton, and Appleton & Baker – all of which analyzed data from the 1970s – found that injury rates were higher in union mines, controlling for other mine-specific factors.[38] Based on data from 1978 to 1980, however, a National Academy of Sciences study found no significant differences in fatality rates among union and nonunion mines after controlling for differences in mine size.[39] For several reasons, it is difficult to draw causal inferences on the basis of these studies alone. First, since the accident reporting system in use before 1978 was subject to extremely poor reporting practices, underreporting of injuries by nonunion mines could have biased the results of

---

of productivity and fatalities and permanent disabilities, albeit positive association between productivity and temporarily disabling injuries); NAT'L RES. COUNCIL, TOWARD SAFER UNDERGROUND COAL MINES 98 (1982) (finding negative association in cross-sectional firm-level comparison of productivity and rates of disabling injuries); William C. Appleton & Joe G. Baker, *The Effect of Unionization on Safety in Bituminous Deep Mines*, 5 J. LAB. RES. 139, 143 (1984) (finding significant negative relationship between mine productivity and rates of total and disabling injuries, respectively); Andrew Hopkins, *Blood Money? The Effect of Bonus Pay on Safety in Coal Mines*, 20 AUSTL. & N.Z. J. SOC. 23 (1984) (reporting similar negative association between mine productivity and accident rates among firms in New South Wales, Australia).

36 JOHN BRAITHWAITE, TO PUNISH OR PERSUADE: ENFORCEMENT OF COAL MINE SAFETY 170 (1985).

37 *See* William M. Boal, *The Effect of Unionism on Accidents in U.S. Coal Mining, 1897-1929* (working paper, forthcoming in INDUS. REL.), *available at* http://www.drake.edu/cbpa/econ/boal/research/acc.pdf.

38 *See* Leslie I. Boden, Underground Coal Mine Accidents and Government Enforcement of Safety Regulations (Jul. 1977) (unpublished Ph.D. dissertation, Massachusetts Institute of Technology) (on file with DSpace@MIT, *available at* http://dspace.mit.edu/handle/1721.1/15744) (analyzing data from early 1970s); M.M. Connerton, Accident Control Through Regulation: The 1969 Coal Mine Health and Safety Act Experience (1978) (unpublished Ph.D. dissertation, Harvard University) (on file with Harvard University Archives) (analyzing pre-1978 data); Appleton & Baker, *supra* note 35, at 140 (analyzing cross-sectional data from 1979).

39 NAT'L RES. COUNCIL, *supra* note 35, at 95-96.

the two studies (by Boden and Connerton) that relied on data from these years.[40] Second, the considerable labor strife that characterized most of the 1970s – including periodic strikes and work stoppages – may have had a deleterious effect on safety at the union mines included in the study sample. Although Appleton & Baker limit their study of bituminous mining to 1979 on the ground that it was a "non-strike year," government statistics reveal that 414 bituminous coal mine strikes took place in that year, and more generally, the national labor-management climate remained highly adversarial.[41] No subsequent study has analyzed the relationship between unionism and safety in subsequent decades, during which labor-management relations became far less contentious. In short, given the inconclusive nature of existing scholarship, there is little to be gleaned from the effects of unionization that is of practical value to regulatory policy-makers.

Only one published article, by Kniesner and Leeth, has sought to examine the marginal effect of MSHA inspections on coal mine safety in recent decades.[42] Analyzing quarterly mine-level data from 1982 to 1997, the authors model injury rates as a function of MSHA enforcement measures and mine size.[43] After estimating 200 alternative model specifications, they deliberately relax statistical conventions by selecting the one that casts MSHA's regulatory impact in the best possible light. The fact that MSHA enforcement carries a negative and "statistically significant" sign in only one specification suggests that MSHA may have no marginal deterrence impact at all given current enforcement levels. Yet even if one were to accept this "cherry-picked" specification at face value, the article contends, the marginal cost of MSHA inspections still would outweigh their marginal benefits. To their credit, the authors focus directly on MSHA's regulatory efficacy – a question of vital policy importance – and frankly concede that they cannot measure MSHA's total impact on miner safety, only its marginal effect given current enforcement levels.[44] However, several shortcomings of their empirical model cast doubt on the validity of their findings. Most importantly, their assumption that variations in the frequency and/or size of fines and withdrawal orders[45] are exogenous measures of differ-

---

40 Appleton & Baker, *supra* note 35, at 140.

41 U.S. GEN. ACCOUNTING OFFICE, *supra* note 30, at 12-25. *See also* Joel Darmstadter, Productivity Change in U.S. Coal Mining 27-31 (Jul. 1997) (Resources for the Future, Discussion Paper No. 97-40) (on file with authors), *available at* http://www.rff.org/Documents/RFF-DP-97-40.pdf.

42 In an unpublished Ph.D. dissertation, L. I. Boden, *see supra* note 38, uses quarterly data from 1973-75 from the 539 largest underground bituminous coal mines to test whether the data bears out the theoretical prediction that higher inspection frequency translates into lower injury rates. The results confirm the negative relationship between inspection frequency and accidents, although surprisingly, penalties assessed were found to have no significant effect.

43 *See* Kniesner & Leeth, *supra* note 14.

44 *See id.* at 90.

45 Withdrawal orders – in which MSHA orders that miners be withdrawn from part or all of a mine – are one of the enforcement tools that MSHA may use to correct mine hazards. *See* MSHA, Mine Safety and Health Enforcement, http://www.msha.gov/mshainfo/factsheets/mshafct4.htm

ences in "enforcement efforts" across districts seems implausible, given the highly centralized fashion in which MSHA penalties are assessed.[46] Other aspects of their methodology are subject to criticism on theoretical and/or empirical grounds.[47] On the basis of this study alone, therefore, it is probably premature to draw any conclusions regarding the marginal deterrent impact of MSHA's recent regulatory activity.

Surveyed as a whole, then, past empirical literature on mining regulation – although arguably shedding some light on the impact of regulation in the immediate aftermath of the Coal Act – has yielded few practical insights into MSHA's current regulatory practices. The extent to which current levels of

---

(last visited July 17, 2008) ("In several situations, the law provides that MSHA may order miners withdrawn from a mine or part of a mine. Some of the most frequent reasons for orders of withdrawal are 1) imminent danger to the miners; 2) failure to correct a violation within the time allowed; and 3) to protect miners and secure an area after an accident.")

[46] By statute, the amount of proposed civil penalties is based on six specific criteria: size of business, history of operations, degree of negligence, degree of gravity, demonstrated good faith, and effect of penalty on operator's ability to continue in business. 30 C.F.R. § 100.3 (2007). So-called "regular assessments" are generated by a computer program, operated by MSHA's national headquarters, which utilizes a formulaic point scoring system incorporating the above factors. Under 30 C.F.R. § 100.5 (2007), MSHA may depart from the computer-generated formula and issue a "special assessment" in particular circumstances enumerated by statute. In such cases, individual review and determination is undertaken by MSHA's Policy, Systems, and Special Assessments Office, also located at MSHA's national headquarters. For an overview of MSHA's organizational hierarchy, download http://www.msha.gov/programs/assess/asmtoutreach06.ppt#3 (last visited Feb. 26, 2008). In effect, therefore, the only potential discretion exercised by individual inspectors (and enforcement districts) is how many citations and/or withdrawal orders to record when conducting an inspection; how to rate mines along the six dimensions that are subsequently plugged into the statutory formula; and whether to initiate a special assessment process that may ultimately increase the total magnitude of fines. Although different inspectors may exercise this discretion in slightly different ways, there is little reason to interpret such differences as meaningful proxies for enforcement "effort." Nor is there any reason to believe that the way in which inspectors exercise this limited amount of *de facto* discretion differs systematically across enforcement districts. On the contrary, since all MSHA inspectors nationwide are trained at the National Mine Health and Safety Academy in Beaver, West Virginia, one would expect MSHA inspection practices to exhibit a high degree of national uniformity. *See* MSHA, COURSES FOR MSHA AND THE MINING INDUSTRY (2008), *available at* http://www.msha.gov/training/cat.htm (last visited Feb. 26, 2008). Therefore, Kniesner and Leeth's central identifying assumption, that cross-district differences in the level and frequency of fines and withdrawal orders reflect exogenous variations in "enforcement efforts," appears to lack empirical support. *See* Kniesner & Leeth, *supra* note 14, at 89. Under the seemingly more plausible assumption that such variations reflect cross-district differences in average mine safety levels, they are endogenous with respect to the dependent variable (injury frequency), and the model is misspecified.

[47] For example, in modeling specific deterrence effects, they control for "inspections with violations," but control for neither the number of citations issued nor the magnitude of fines imposed, *see* Kniesner & Leeth, *supra* note 14, at 89, both of which one would expect to significantly affect inspected mines' future behavior. Moreover, among the array of safety measures that they use as dependent variables, they apparently do not include the *rate* of fatal injuries, only the raw number of fatal injuries. *See id.* at 97. Since fatalities are the least subject to underreporting – and one cannot meaningfully compare safety across districts without calculating rates – this omission also casts doubt on the relevance of their results.

safety are attributable to regulatory intervention, as well as the extent to which alternative regulatory practices could bring about further enhancements, remain open empirical questions.

III. TAPPING THE RICH RESERVOIR OF HISTORICAL DATA ON U.S. COAL MINES

A. *The Unique Scope of Historical Data on Mining Safety Regulation*

What makes the paucity of empirical scholarship on mining regulation particularly surprising is the wealth of helpful data available. In fact, mining is the *only* U.S. industry for which fine-grained historical data are available on all of the regulatory inputs and outputs of primary interest to policymakers. To fully appreciate this disparity, it is helpful to compare the availability of mining data with the availability of data available on other sectors of the regulated economy. Table 1 presents this comparison for six types of data of vital policy importance.

Table 1: A Comparison of Data Available on Mining versus Non-Mining U.S. Industries

Type of Data	*Mining*	*Other U.S. Industries*
Data on Inspections, Violations, and Penalties	Data are publicly available on all U.S. surface and underground mines, each of which is inspected by MSHA (respectively) at least twice or four times per year.[48]	Data are publicly available on all inspected workplaces, but only a small proportion of U.S. firms are inspected by OSHA in any given year.[49]

---

48 30 C.F.R. Part 50 requires that the above information be collected and made available to the general public. *See* MSHA, Accident, Illness and Injury and Employment Self-Extracting Files (Part 50 Data), http://www.msha.gov/stats/part50/p50y2k/p50y2k.htm (click on "Accident, Injury and Illness Information" hyperlink) (last visited Feb. 27, 2008).

49 For access to the online searchable database, see OSHA, Statistics & Data, http://www.osha.gov/oshstats/index.html (last visited Feb. 27, 2008).

Data on Non-Fatal Injuries	Data are collected quarterly from all U.S. mines since 1983 and are available to the public.[50]	Summary statistics based on survey data (by industry and worker demographics) are publicly available, but firm-level microdata are confidential.[51]
Data on Fatalities	Data are collected quarterly from all U.S. mines since 1983 and are available to the public.	Summary data since 1992 are available on all occupational fatalities nationwide, but complete decedent-level microdata are confidential.[52]
Data on Other Accidents	Data are collected quarterly from all U.S. mines since 1983 and are available to the public.	No establishment-level microdata are publicly available.
Data on Employment	Data are collected quarterly from all U.S. mines since 1983 and are available to the public.	Industry-level estimates based on survey data are publicly available, but firm-level microdata are confidential.[53]
Data on Production and Ownership	Data are collected quarterly from all U.S. mines since 1983 and are available to the public.	Industry-level productivity estimates based on survey data are publicly available, but establishment-level microdata are not.[54]

50 *See* MSHA, *supra* note 48.

51 Aggregate tables are available at Bureau of Labor Statistics. *See* U.S. Dep't of Labor, Databases, Tables & Calculators by Subject, http://www.bls.gov/data/home.htm (click on "Workplace Injuries" hyperlink) (last visited Feb. 27, 2008). To use the full microdata from the Survey of Occupational Injuries and Illnesses, researchers must undergo a lengthy application process and conduct all statistical analysis onsite at the Bureau of Labor Statistics' office in Washington, D.C. *See* U.S. Dep't of Labor, Researcher Access to Confidential Data Files at the Bureau of Labor Statistics, http://www.bls.gov/bls/blsresda.htm (last visited Feb. 27, 2008).

52 Only summary statistics are available online. Through a special application procedure, researchers may obtain access to the Offsite CFOI Micro Fatality Research File. *See* U.S. Dep't of Labor, Acquiring the Offsite CFOI Micro Fatality Research File, http://www.bls.gov/iif/cfoi_offsite.htm (last visited Feb. 27, 2008). However, even this restricted version of the dataset excludes a number of variables (such as decedent's state of residence) that may be important for research purposes. To use the full CFOI microdata, researchers must undergo a lengthy application process and conduct all statistical analysis onsite at the Bureau of Labor Statistics' office in Washington, D.C. *See* Researcher Access, *supra* note 51.

53 For a summary of publicly available survey data related to employment available from the Bureau of Labor Statistics, see Tables & Calculators, *supra* note 51 (follow "Employment" hyperlink).

54 For a summary of publicly available survey data related to industrial productivity available from the Bureau of Labor Statistics, see *id.* (follow "Productivity" hyperlink).

The disparities revealed in Table 1 are striking. For the mining industry, comprehensive historical microdata on inspections, violations, penalties, nonfatal injuries, fatalities, accidents, employment, production, and ownership are available for all U.S. mines. In contrast, the *only* establishment-level microdata that are publicly available for other U.S. industries are inspection, violation, and penalty records pertaining to OSHA inspections, which affect only a small fraction of the regulated economy in any given year.

B. *How Analyzing Historical Data Could Shed New Light on U.S. Mining Regulation*

The implications of the above disparities for policy analysis are profound. Although the empirical literature on the effect of OSHA regulation is significantly more extensive than the mining-related scholarship summarized above, the paucity of available data on the OSHA-regulated economy has constrained scholars' ability to address key policy questions. For example, since BLS injury data are not collected from every non-mining firm in every year, those scholars examining the effect of OSHA inspections on establishment-level injury rates have been forced to focus on large firms simply because they are the ones most likely to be included in the BLS stratified sampling frame.[55] Similarly, since firm-level data on production and ownership structures are unavailable for most sectors of the economy, attempts to probe the potential relevance of such factors in the regulatory context have been virtually nonexistent.[56]

In contrast, it is possible to probe a number of important policy issues that bear on the efficacy of mining regulation using data readily obtainable from MSHA's internal database. Such studies could shed light not only on the his-

---

55 Even to undertake this type of analysis is enormously labor-intensive, since it requires researchers to obtain access to confidential microdata housed at the Bureau of Labor Statistics, all data must be analyzed onsite, and matching OSHA inspection data to BLS injury data presents formidable programming challenges. *See, e.g.*, Wayne B. Gray & John M. Mendeloff, *The Declining Effects of OSHA Inspections on Manufacturing Injuries, 1979-1998*, 58 INDUS. & LAB. REL. REV. 571, 575 (2005) (noting in data description that large manufacturing establishments are over-represented because of necessity of obtaining data for consecutive years, and alluding to complex probabilistic methodology used to match OSHA to BLS records using name and address fields); Wayne B. Gray & John T. Scholz, *Does Regulatory Enforcement Work? A Panel Analysis of OSHA Enforcement*, 27 LAW & SOC'Y REV. 177, 185 (1993) (noting that only plants included in BLS injury survey from 1979 to 1985 were examined).

56 To date, only one scholar has compiled the data necessary to probe the relevance of common ownership structure in the context of OSHA enforcement. *See* David Weil, *Assessing OSHA Performance: New Evidence from the Construction Industry*, 20 J. POL'Y ANALYSIS & MGMT. 651, 654 (2001) (explaining that in order to create a longitudinal panel of national construction contractors that would enable one to match construction projects to their respective national firms and obtain a measure of annual revenues, a list of the top 2060 contractors was compiled from a trade publication and then matched to OSHA data). *See also* Alison D. Morantz, *Has Devolution Injured American Workers? State and Federal Enforcement of Construction Safety*, 25 J. L. ECON. & ORG. (forthcoming 2009) (noting that a section of empirical analysis relies on dataset originally assembled by David Weil).

torical effects of regulation, but also help define the most promising channels for regulatory innovation and the embedded constraints that may limit regulatory efficacy.

To gain insight into the deterrent effect of MSHA regulation, one could examine quarterly mine-level data on inspections, penalties, injuries, and fatalities in recent decades; develop models designed to test the relationships between them; and explore whether such relationships have changed over time. To make plausible inferences about causation, one would need to identify changes in the enforcement structure that are plausibly exogenous with respect to mine-level safety, the outcome of chief policy interest.[57] To explore general deterrence effects, one might exploit the fact that the statutory level of penalties imposed for particular violations has been periodically altered since the 1990s, and examine whether such changes in the enforcement structure triggered broad changes in patterns of firm compliance and/or injuries.[58] Alternatively, one might explore whether the duration or frequency of inspections has varied across districts or across time for reasons that are uncorrelated with differences in underlying safety levels. Isolating "specific deterrence" effects of MSHA inspections, i.e., the effect on firm behavior of actually undergoing an inspection, poses unique challenges. The very fact that *all* U.S. mines are inspected multiple times per year (unlike the rest of the economy, in which only a small minority of firms are inspected) makes it challenging to find a "basis for comparison" against which to measure the effects of undergoing an inspection. A number of empirical strategies could be tried. For example, one might compare similarly-situated firms found guilty of the same violation just before and just after a hike in penalties, to determine whether being assessed the higher penalty materially affects inspected firms' subsequent behavior. Alternatively, one could use exogenous differences in the timing and/or duration of inspections throughout the calendar year to probe whether being inspected sooner (or longer) is positively correlated with a mine's injury record.[59]

But examining the deterrence effects of MSHA enforcement is only one way in which empirical research could shed light on current regulatory practices. Just as important, data analysis could help illuminate the background conditions that constrain the potential impact of regulatory intervention. For example, the efficacy of regulatory intervention is premised on the existence of

---

[57] As noted earlier, the primary methodological shortcoming of the Kniesner and Leeth study is that their measures of cross-district variations in enforcement "effort" are unlikely to be exogenous with respect to safety, the dependent variable in their empirical models. *See supra* note 46.

[58] The Omnibus Budget Reconciliation Act of 1990, an internal revision to the MSHA penalty structure in 1992, and more importantly, the Mine Improvement and New Emergency Response Act of 2006 (MINER Act) all changed the pre-existing structure of fines in one or more ways.

[59] Interestingly, based on the results of a "resident inspector program" implemented during the latter 1970s, Braithwaite concludes that "having an inspector reside full-time at the mine" – an extreme form of specific deterrence – was responsible for transforming mines with poor safety records into ones that had (in most years) injury rates significantly below the national average. *See* BRAITHWAITE, *supra* note 36, at 83-84.

two causal relationships: that inspections improve compliance; and that higher compliance, in turn, enhances worker safety. Critics have long questioned the second assumption, *i.e.*, the extent to which higher compliance with bureaucratic regulations – some of which may bear little obvious link to safety outcomes – truly yields higher safety levels.[60] Given the data constraints noted above, it is not possible to comprehensively examine the relationship between compliance and safety for most U.S. industries. Given the rich microdata available on mining outcomes, however, one could examine in comprehensive fashion the degree of correlation between regulatory compliance and various measures of miner safety – not only for the industry as a whole, but for different types of mines, injuries, and regulations. Even without drawing definitive conclusions regarding cause-and-effect, such fine-grained analysis could provide a more nuanced portrait of the relationship between compliance and safety. For example, if mines committing certain patterns of violations are demonstrably more likely to sustain particular sorts of injuries, then compliance with such regulations is likely to be a meaningful proxy for (and, possibly, contributor to) safety in these areas. Conversely, if there is little or no correlation between compliance in some areas and the safety outcomes which they are designed to promote, one might question the value of such regulations in achieving their desired ends.

In light of the recent tragic events at the Sago, Darby,[61] and Crandall Canyon[62] coal mines, another advantageous line of inquiry might be to focus on

---

60 For example, in the early 1970s, the Mining Enforcement and Safety Administration (MSHA's predecessor) issued regulations requiring toilet manufacturers and mine operators to seek approval for each sanitary toilet installed in an underground or surface coal mine. *See* Underground Sanitary Facilies; Installation and Maintenance, 35 Fed. Reg. 17927 (promulgated Nov. 20, 1970) (codified at 30 C.F.R. § 75.1712-6); Sanitary Toilet Facilities at Surface Work Sites; Installation Requirements, 37 Fed. Reg. 6372 (promulgated Mar. 28, 1972) (codified at 30 C.F.R. § 71.500). Under these regulations – which remained in effect for more than thirty years – MSHA and/or NIOSH reviewed each individual application for approval using criteria drawn from the American National Standard Institute's (ANSI's) American National Standard for Sanitation – Nonsewered Waste-Disposal Systems – Minimum Requirements. Not until 2003 did MSHA remove the formal application requirement and its associated paperwork burden. Without changing the substantive standards, MSHA simply made public the criteria required for approval. *See* Standards for Sanitary Toilets in Coal Mines, 68 Fed. Reg. 37082-87 (June 23, 2003) (amending 30 C.F.R. §§ 71.500, 75.1712-6), *available at* http://www.epa.gov/EPA-IMPACT/2003/June/Day-23/i15813.htm. *See also* EUGENE BARDACH & ROBERT A. KAGAN, GOING BY THE BOOK: THE PROBLEM OF REGULATORY UNREASONABLENESS (1982) (arguing that strategy of demanding inflexible, uniform adherence to inefficient regulations is ultimately counterproductive in promoting desired regulatory ends).

61 On May 20, 2006, five miners died in the wake of an explosion at Darby Mine in Harlan County, Kentucky. *See* Fact Sheet 95-8, *supra* note 3.

62 On August 6, 2007, the collapse of Crandall Canyon Mine in Emery County, Utah, caused the deaths of six miners (and, subsequently, of three rescue workers). See Fact Sheet 95-8, *supra* note 3; MSHA, GENWAL RESOURCES INC[.] CRANDALL CANYON MINE[,] MINE ID: 4201715, *available at* http://www.msha.gov/Genwal/CrandallCanyonupdates.asp (last visited July 17, 2008) (noting that on Friday, August 17th, at 8 a.m. EDT, "[t]hree rescue workers are confirmed dead" and "all rescue efforts have been suspended.").

the distribution of multi-fatality mining disasters. If such major accidents are random events – perhaps triggered by a confluence of human error and unpredictable environmental conditions – then it would be unfair to hold MSHA responsible for failing to deter them, and unwise for MSHA to devote any special resources or programs to preventing them (at least beyond the level already being expended). On the other hand, if empirical analysis revealed major mine disasters to be statistically predictable, then it is possible that MSHA could do more to anticipate and deter them from occurring.[63] In this manner, statistical modeling could help MSHA forecast which arenas for potential regulatory refinements are the most likely to result in concrete improvements.

In short, the wealth of microdata available on U.S. mines presents policymakers with a unique opportunity to peer inside the "black box" of regulation. Careful analysis of historical data could not only shed light on the potency of today's regulations and enforcement techniques, but could also help MSHA identify the most promising areas for future experimentation.

IV. THE THEORY AND PRACTICE OF TARGETED REGULATION

Besides analyzing historical data in the manner described above, MSHA could put its vast data repository to an even more important and innovative use. By developing algorithms to identify high-risk mines – algorithms which could be updated in "real time" as new mine-level information was amassed each quarter – officials could proactively seek to prevent major mining accidents before they occur. In short, MSHA could design a statistically-based strategy of "targeted" enforcement to augment (and, ideally, synergistically enhance) its current inspection activity. In the remainder of this Article, I will briefly sketch the theory behind regulatory targeting, highlight other governmental settings in which it has been applied, and describe how MSHA might use this approach to enhance safety and health in U.S. mines.

A. *Theoretical Background*

Theories of targeted regulation usually rest on most, if not all, of four assumptions.[64] First, regulatory agencies are resource-constrained, and there-

---

[63] In twenty-five of thirty-nine disasters from five countries (including 19 from the United States), Braithwaite concludes that serious violations "either caused the disaster, were among the causes, or made the disaster worse than it would have been without the violations." BRAITHWAITE, *supra* note 36, at 75-76. For purposes of this analysis, a mining "disaster" is defined as an incident in which five or more persons lose their lives. *Id.* at 15. Based in part on this evidence, Braithwaite argues that "if there were 100 percent compliance with coal mine laws, the majority of miners who die in coal mines would be saved." *Id.* at 75.

[64] The term "targeted enforcement" is historically evolving; to date, there is no universally accepted definition. Indeed, many of the theoretical articles described or cited here as models of targeted enforcement do not contain the word "targeting" or "targeted." I use the term here simply as a convenient shorthand, to describe the regulatory approach that is the subject of this Article, and the reader should bear in mind that other authors' usage of the term may differ from mine.

fore, it is impractical for them to continuously monitor all of the entities within their statutory purview. Second, once a given standard is set,[65] the agency's paramount goal is to minimize total production of the social ill that the standard is designed to deter (or alternatively, to maximize industry-wide compliance with the regulatory standard, which may be the best available proxy).[66] Third, not all regulated entities are the same.[67] Since different firms' costs of compliance and other characteristics (e.g., internal culture, rate of discounting, risk aversion, etc.) differ, they are likely to respond differently to the same set of policy stimuli. Finally, the interaction between agency bureaucrats and inspected entities typically extends over a lengthy (if not indefinite) time horizon, with multiple opportunities for the inspector to evaluate each firm's compliance,

---

65 As Viscusi and Zeckhauser note, there is an important policy tradeoff between the stringency of standard-setting and the likelihood of noncompliance. The higher the standard, the higher the fraction of firms that will choose not to comply. Therefore, at some point increasing the stringency of a standard is likely to actually *lower* overall compliance with a given regulation. Although this insight highlights the importance of setting standards at the "right" level at the outset, it does not negate the imperative to maximize the level of compliance achieved for any given standard and level of enforcement expenditure. *See* W. Kip Viscusi & Richard J. Zeckhauser, *Optimal Standards with Incomplete Enforcement*, 27 PUB. POL'Y 438 (1979).

66 Whether or not regulatory agencies should seek to maximize societal efficiency by explicitly taking into account the costs of compliance borne by regulated entities – and inducing the industry as a whole to bear these costs in the most cost-efficient way – remains controversial. In general, requiring that regulatory policy meet this additional test significantly complicates models of targeted regulation. *See, e.g.*, Jon D. Harford, *Measurement Error and State-Dependent Control Enforcement*, 21 J. ENVTL. ECON. & MGMT. 67, 77 (1991) (noting that state-dependent enforcement models, of the sort described in the paper, violate the cost-minimizing principle since firms with identical abatement costs are treated differently); Jon D. Harford & Winston Harrington, *A Reconsideration of Enforcement Leverage When Penalties Are Restricted*, 45 J. PUB. ECON. 391, 395 (1991) (concluding, in a similar vein, that "state-dependent enforcement remains a second-best strategy in a world in which standards are set in a separate decision from the monitoring strategy").

67 Although listed here as a general feature of "targeting" models, the third assumption (that firms are heterogeneous with respect to their costs of compliance and other characteristics) is not universal. A well-developed class of game-theoretic models, although sharing the other assumptions listed above and implying that regulatory agencies should "target" firms based on past behavior, nevertheless assumes that firms have homogenous cost functions. *See* Lana Friesen, *Targeting Enforcement to Improve Compliance with Environmental Regulations*, 46 J. ENVTL. ECON. & MGMT. 72, 74 (2003) (proposes similar targeting scheme to that proposed by Harrington, but assuming that firms are moved randomly into target group); Joseph Greenberg, *Avoiding Tax Avoidance: A (Repeated) Game-Theoretic Approach*, 32 J. ECON. THEORY 1, 9 (1984) (describing optimal auditing scheme to detect tax avoidance, which subsequent theorists adapt to context of environmental regulation); William Harrington, *Enforcement Leverage When Penalties Are Restricted*, 37 J. PUB. ECON. 29, 34-35 (1988) (applying logic of Greenberg's model to enforcement of environmental regulations); Clifford S. Russell, *Game Models for Structuring Monitoring and Enforcement Systems*, 4 NAT. RES. MODELING 143, 159 (1990) (proposing similar targeting strategy as Harrington); Harford & Harrington, *supra* note 66, at 392 (1991) (noting that since model causes otherwise identical firms to emit different levels of a pollutant, it does not minimize abatement costs for a given total pollution reduction); Harford, *supra* note 66, at 77 (1991) (making similar observation).

and multiple opportunities for the firm to choose a future course of action in light of past experience and new information.

In light of these assumptions, the essence of targeted enforcement is the agency's capacity and willingness to "tailor" its enforcement strategy – the probability of inspection, the size of penalties, and so forth – to regulated entities' past inspection history and/or other observable characteristics. In other words, as one scholar has put it, "[t]argeting is the practice of inspecting firms most likely to violate a regulation,"[68] as opposed to a one-size-fits-all strategy in which inspection probabilities, penalties, etc., are all applied uniformly across the entire regulated industry. Although differing widely in their methodological assumptions, targeting models imply that for any given budget constraint, an optimally designed targeting strategy maximizes the industry-wide rate of compliance.[69] At the outset, the agency's goal is to divide regulated entities into different types based on each one's relative likelihood of compliance.[70] Then by subjecting the "high-risk" firms to a more stringent enforcement regime than the "low-risk" types, the agency can strive to equalize the marginal rates of non-compliance across different firm types.[71] By targeting firms in this manner, the

---

68 Eric Helland, *The Enforcement of Pollution Control Laws: Inspections, Violations, and Self-Reporting*, 80 REV. ECON. & STAT. 141, 141 (1998).

69 *Id.* at 141. For class of models relying on game-theoretic structure and assuming identical firms' abatement cost functions, see sources cited *supra* note 67. There are other models resting on various alternative assumptions but sharing this key implication. *See, e.g.*, Helland, *supra* note 68, at 152 (1998) (proposing model in which targeting produces more cooperation in form of self-reporting); Anthony Heyes & Neil Rickman, *Regulatory Dealing – Revisiting the Harrington Paradox*, 72 J. PUB. ECON. 361, 363 (1999) (arguing that model that incorporates "horizontal" regulatory dealing, in which agency and firm interact in multiple domains, is consistent with a targeting model that maximizes net regulatory effectiveness); John Livernois & C. J. McKenna, *Truth or Consequences: Enforcing Pollution Standards with Self-Reporting*, 71 J. PUB. ECON. 415, 437 (1999) (similarly proposes that when prior models are extended to include self-reporting requirement, it's not surprising that compliance rates are so high despite low penalties); A. Mitchell Polinsky & Daniel L. Rubinfeld, *A Model of Optimal Fines for Repeat Offenders*, 46 J. PUB. ECON. 291, 292 (1991) (model suggesting that under certain assumptions, repeat criminal offenders should be punished more severely if they have higher "offense propensities"). Importantly, however, targeting models do *not* necessarily minimize the total abatement cost for a given reduction in pollution or other externalities. *See* Harford & Harrington, *supra* note 66, at 394-95; Harford, *supra* note 66, at 77.

70 For an example of a model that relaxes this assumption – assuming, instead, that the regulator does not known individual firms' compliance costs – *see* Mark Raymond, *Enforcement Leverage When Penalties are Restricted: A Reconstruction Under Asymmetric Information*, 73 J. PUB. ECON. 289 (1999).

71 *See* Devon Garvie & Andrew Keeler, *Incomplete Enforcement with Endogenous Regulatory Choice*, 55 J. PUB. ECON. 141, 158 (1994) (targeting model in which firms with higher abatement costs – who are the least likely to comply with regulations – received a larger fraction of regulatory resources and face higher penalties than firms with lower abatement costs); Nicola Persico & Petra Todd, *Using Hit Rate Tests for Racial Bias in Law Enforcement: Vehicle Searches in Wichita* 3-4 (Nat'l Bureau of Econ. Research, Working Paper No. 10947, 2004) (in racial profiling model of vehicle searches, efficient targeting in absence of biased preferences implies that "hit

agency can achieve the highest possible rate of compliance for any given level of expenditure.

A key feature of targeting models that deserves special attention is the importance of information. Without credible information about the past behavior (or other pertinent characteristics) of inspected firms, targeting would be a fruitless endeavor. The more extensive and high-quality the data available to a regulatory agency, the more accurately it can differentiate among firms, and therefore the greater the potential efficacy of targeted enforcement methods.

B. *Prior Applications to U.S. Regulated Economy*

The application of targeted enforcement techniques by state and federal regulatory agencies is far from unprecedented. On the contrary, a diverse array of public agencies have embraced targeting principles in recent decades and used them to help prioritize the deployment of regulatory resources.

Perhaps the most well-known example of targeted enforcement among U.S. municipalities is the COMPSTAT (computerized statistics) philosophy of targeted law enforcement developed by New York City Chief of Police William Bratton in 1994, and subsequently replicated in a number of other U.S. metropolitan areas. One of the hallmarks of the COMPSTAT approach is the analysis of detailed, real-time data on crime trends at the precinct, patrol borough, and city-wide levels. By analyzing such data at frequent intervals, the agency's top management can rapidly identify crime "hot spots" as they emerge, and deploy enforcement resources towards those regions that pose the greatest relative crime risk.[72] Although not without its skeptics,[73] COMPSTAT has been widely credited with significantly reducing crime rates in many of the cities in which it has been applied.[74]

Targeted enforcement principles have also become well established among a number of federal regulatory agencies. The Environmental Protection Agency, for example, has recently implemented a comprehensive effort to "target [its] efforts to areas of greatest need," including analysis of compli-

---

rates" for finding contraband goods should be equalized across all observable categories of drivers).

72 *See, e.g.* James J. Willis et al., *Compstat in Practice: an In-Depth Analysis of Three Cities*, POLICE FOUNDATION (2003), *available at* http://www.policefoundation.org/pdf/compstatinpractice.pdf; Philadelphia Police Dep't: CompStat Process, http://www.ppdonline.org/hq_compstat.php (last visited Mar. 2, 2008); Encyclopedia Britannica Online, Police: Compstat, http://www.britannica.com/eb/article-260923/police (click on "The history of policing in the West" hyperlink under "Table of Contents" sidebar; click on "Compstat" hyperlink) (last visited Mar. 2, 2008).

73 *See, e.g.*, Steven D. Levitt, *Understanding Why Crime Fell in the 1990s: Four Factors that Explain the Decline and Six that Do Not*, 18 J. ECON. PERSPECTIVES 163, 172-73 (2004) (arguing that the impact of policing strategies on national crime rates during the 1990s was probably "minor").

74 *See* Encyclopedia Britannica Online, *supra* note 72.

ance/enforcement history and pollutant emissions of regulated entities, analysis of sector-based trends, and risk-based predictions of the relative environment effects of different regulated facilities.[75] A 1995 empirical study of U.S. air pollution regulation confirmed that EPA enforcement patterns in this area were broadly consistent with a targeting model of enforcement, in which enforcement of integrated steel firms was influenced by plant-level characteristics and behavior.[76] The fact that federal programs have been criticized in recent years for *not* allocating inspection resources based on quantitative risk assessments suggests that targeted enforcement may be becoming the presumptive norm among those agencies for which such methods are technologically feasible.[77]

All three of the primary regulatory agencies within the U.S. Department of Labor – OSHA, MSHA, and the Employment Standards Administration (ESA) – have pursued targeted-enforcement initiatives in recent years. For example, ESA's Wage and Hour Division, which enforces the federal minimum wage and overtime laws, is currently engaged in an ongoing effort (begun in

---

75 U.S. ENVTL. PROT. AGENCY, OFFICE OF ENFORCEMENT AND COMPLIANCE ASSURANCE (2201A), PROTECTING YOUR HEALTH & THE ENVIRONMENT THROUGH INNOVATIVE APPROACHES TO COMPLIANCE: HIGHLIGHTS FROM THE PAST 5 YEARS 20 (1999). The publication reads, in pertinent part, as follows:

> Effective compliance . . . [is] also dependent on effective targeting of the most significant public health and environmental risks. Because of this and a recognition that government resources are finite, EPA has worked since the reorganization to improve our ability to target our efforts to areas of greatest need.
>
> EPA has enhanced these targeted approaches by using a broad array of environmental quality information, demographics, and information on the results of our compliance monitoring activities. We target our enforcement and compliance assistance efforts taking into account:
>
> • sector-based environmental problems or compliance patterns;
>
> • statute-specific compliance problems; and
>
> • an analysis of compliance/enforcement history and pollutant releases
>
> New methods of examining these data incorporate risk considerations, which predict the relative effects of facilities, or groups of facilities, on the human population.
>
> When targeting is effective and violations are identified, the process of bringing the violators back into compliance can result in significant impacts on human health and the environment.

76 Wayne B. Gray & Mary E. Deily, *Compliance and Enforcement: Air Pollution Regulation in the U.S. Steel Industry*, 31 J. ENVTL. ECON. & MGMT. 96, 110 (1996).

77 *See* Benjamin M. Simon et al., *Allocating Scarce Resources for Endangered Species Recovery*, 14 J. POL'Y ANALYSIS & MGMT. 415, 423, 430 (1995) (criticizing Fish and Wildlife Service for not using Priority Ranking System – designed to quantify relative risks faced by particular species – as basis for budgetary allocations); Henry H. Willis, *Guiding Resource Allocations Based on Terrorism Risk* § 3 (RAND Center for Terrorism Risk Management Policy, Working Paper No. WR-371-CTRMP) (March 2006), *available at* http://www.rand.org/pubs/working_papers/WR371 (critiquing the Department of Homeland Security's Urban Area Security Initiative for not allocating funds in proportion to relative levels of terrorism risk faced by different metropolitan areas).

2005) to target its limited inspection resources more effectively.[78] A primary focus on the project has been to "develop[] a methodology for determining low-wage industries with the highest potential for violations, and analyze[] the relationship between violation and complaint rates in order to strengthen targeted enforcement activities."[79] Using statistical evaluations and audits by external contractors, the agency sought to identify those groups of establishments affecting low-wage workers most likely to violate wage and hour laws. By 2007, empirical analysis conducted at the agency's behest by Boston University and an independent consulting firm revealed that among fast-food establishments, franchisees generally had worse safety records than their company-owned counterparts, indicating that fast-food franchisees should become a primary focus of WHD enforcement activity.[80]

Among the most mature and extensive targeting programs within the Department of Labor is OSHA's Site-Specific Targeting (SST) program, whose goal is to "direct enforcement resources to those workplaces where the highest rate of injuries and illness have occurred."[81] Beginning in 1999, the program has relied on establishment-level survey data of large employers in historically high-injury industries. Based on its injury rate in prior years, each firm is assigned to a primary, secondary, or tertiary inspection list. Once the lists are compiled, federal OSHA inspectors nationwide use these lists to prioritize programmed inspections among non-construction workplaces. Only after inspecting all sites on the primary list may an OSHA area office proceed to the secondary list, and only after completing the secondary list may inspectors move on to the tertiary list.[82] Besides the SST program, OSHA also uses national and local "emphasis" programs to target specific hazards and industries deemed to pose the greatest risks.[83] Although the latter programs only encompass states under OSHA's regulatory purview, states that conduct their own enforcement

---

78 *See* U.S. Dep't of Labor, DOL Annual Report, Fiscal Year 2005 Performance and Accountability Report: Outcome Goal 2.1 – Increase Compliance with Worker Protection Laws, http://www.dol.gov/_sec/media/reports/annual2005/SG2.htm#1 (last visited Mar. 3, 2008) ("WHD continues to evaluate performance measures in low wage industries, focusing on developing models for common compliance strategies across low-wage industries.").

79 *See* U.S. DEPARTMENT OF LABOR ANNUAL REPORT (2006) PERFORMANCE AND ACCOUNTABILITY REPORT – STRATEGIC GOAL 2: A SECURE WORKFORCE, PERFORMANCE GOAL 06-2.1A (ESA), *available at* http://www.dol.gov/_sec/media/reports/annual2006/SG2.htm (last visited Mar. 3, 2008).

80 See U.S. DEPARTMENT OF LABOR ANNUAL REPORT (2007) PERFORMANCE AND ACCOUNTABILITY REPORT – STRATEGIC GOAL 3: SAFE AND SECURE WORKPLACES, Performance Goal 07-3C (ESA), 130-133, *available at* http://www.dol.gov/_sec/media/reports/annual2007/SG3.htm (last visited Mar. 3, 2008).

81 *See* OSHA Directive 07-03 (CPS 02) – Site-Specific Targeting 2007, § IX (A), *available at* http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=3549 (last visited Mar. 3, 2008).

82 *See id.*, at Part XII.

83 *See id.*, at Part IX (A).

under Section 18 of the Occupational Safety and Health Act of 1970[84] ("state plan" states) have also developed innovative and highly detailed methods of targeting high-risk workplaces using workers compensation data and other site-specific information on past compliance and injuries.[85]

Although MSHA has not implemented formal agency-wide targeting programs like those used by its sister agency, for decades it has implicitly recognized the value of singling out those mines likely to pose the greatest hazards for special regulatory scrutiny. For example, two of the six criteria used to calculate penalties through the regular assessment process are "the operator's history of previous violations" and "the demonstrated good faith of the operator in attempting to achieve rapid compliance after notification of a violation."[86] In effect, then, mines whose poor prior inspection history and/or apparent lack of good faith suggest a high likelihood of future violations are penalized more heavily than their lower-risk counterparts. In amending Section 110 of the Mine Act, the MINER Act of 2006 further enhanced MSHA's ability to target non-compliant mines. Under a new provision, any operator who "willfully" violates a regulation (or refuses to comply with certain orders) may be fined up to $250,000 and/or jailed for up to one year, and repeat violators may be fined up to $500,000 and jailed for up to five years.[87] Through its state grant program, MSHA has also helped to fund special emphasis programs intended to target mines and categories of mine workers deemed to be at the greatest risk of injuries.[88]

As these illustrative examples suggest, the concept of regulatory targeting is anything but novel. Rather, what distinguishes the last several decades from earlier periods is the increasing sophistication with which public agencies have brought these principles to bear on real-world problems. Instead of relying on rudimentary "rules of thumb" to identify high-risk groups, public agencies

---

84 *See* 29 U.S.C. § 667 (2000) (OSHA "opt-out" provision).

85 OSHA, U.S. DEP'T OF LABOR, OSHSA REPORT ENFORCEMENT: TARGETING HIGH-RISK WORKSITES (2001), *available at* http://www.osha.gov/dcsp/osp/oshspa/2001_report/enforcement.html.

86 *See* MSHA, U.S. Dep't of Labor,: Categories of Civil Penalties, http://www.msha.gov/PROGRAMS/ASSESS5.HTM (summarizing provisions of 30 CFR 100).

87 MINER Act of 2006, Pub. L. No. 109-236, § 8 (a)(1)(B) (2006).

88 Authorized by the Coal Act, the program provides approved states with the funds required to provide specialized health and safety training to resident miners. *See* U.S. DEPT. OF LABOR, U.S. LABOR DEPARTMENT'S MSHA ISSUES INCREASED FUNDING FOR STATE HEALTH AND SAFETY TRAINING GRANTS (2008), *available at* http://www.msha.gov/MEDIA/PRESS/2008/NR080310.asp. For an example of an individual state grant program, *see, e.g.*, MSHA STATE GRANT PROGRAM – COMMONWEALTH OF MASSACHUSETTS PROGRAM SUMMARY, *available at* http://www.msha.gov/TRAINING/STATES/MASTATE.asp (describing special emphasis program that targets mining operations with higher accident experiences and mines with histories of uncorrected mine safety and health violations for consultative health and safety site inspections, and also emphasizes training of contract mine workers due to their disproportionately high fatality rates).

have increasingly relied upon computer-aided statistical modeling techniques to generate nuanced predictions of the relative risks posed by individual regulated entities. In so doing, they have been aided immeasurably by technological advances that facilitate the collection, storage and analysis of detailed data on different characteristics of the regulated economy.

V. HOW REGULATORS COULD USE INSPECTION AND SAFETY DATA TO TARGET HIGH-RISK MINES

As argued above, a necessary component of targeted regulation is the capacity for an agency to meaningfully distinguish among regulated firms. The more accurate and extensive the data available to inspectors, the greater their potential ability to forecast the level of risk posed by different establishments, and therefore the more fruitful targeting-based enforcement techniques are likely to be. Given the singularly rich and extensive historical data available to MSHA, mining safety regulation seems like a particularly promising arena in which to apply to targeted enforcement techniques.

Nevertheless, the mere availability of high-quality data does not ensure that computer-based targeting will be a practical or effective alternative in any given regulatory environment. To serve as an effective enforcement tool, a targeting strategy must satisfy two additional criteria: it must rely on a sound statistical methodology, and its implementation must be both politically and economically feasible. Therefore, in this final section, I suggest how MSHA might develop a targeted enforcement strategy that meets these additional criteria.

A. *Designing a Targeting Protocol: Methodological Challenges*

At a minimum, a targeting protocol must employ statistical methodologies to generate credible predictions about which mines pose the gravest risks in future periods, based on the analysis of available historical data. To be of practical value to MSHA inspectors, moreover, a protocol ideally should: (1) enable analysts, when confronted with empirical uncertainties about cause and effect, to directly and readily calculate the probability of each hypothesis upon which the targeting model relies; (2) allow MSHA, when appropriate, to fully utilize pre-existing knowledge and expert opinion about mining safety; (3) make it easy to update the targeting model in a statistically principled manner as new data are acquired, without requiring MSHA to analyze the entire dataset anew; and (4) anticipate the possibility that the criteria most useful for targeting purposes (for technological or other reasons) may shift over time.

The branch of empirical methodologies ideally suited for the above task is known as Bayesian statistics (or Bayesian econometrics).[89] Unlike classical

---

[89] This branch of statistical methodology is named after Thomas Bayes (1702-1761), an English minister and mathematician who "was the first to use probability inductively and who established a mathematical basis for probability inference." *Thomas Bayes*, ENCYCLOPEDIA

or "frequentist" approaches, Bayesian methodologies meet all of the requirements mentioned above. First, Bayesian approaches enable one to calculate directly the probability of hypotheses whose empirical validity is uncertain, a task for which the classical framework is not as well suited.[90] Second, Bayesian methodologies permit policymakers to build prior knowledge and expertise directly into the modeling framework, which is otherwise difficult to achieve.[91] Third, the Bayesian approach is inherently dynamic, in the sense that models can be continuously updated as new information is accrued, without requiring the analyst to periodically "re-run" the entire model.[92] Finally, Bayesian models can readily account for potential "regime changes" by including time-varying coefficients.[93] Bayesian "time series" methods are particularly well suited to the type of forecasting that regulatory targeting requires, since they are designed to handle situations like that confronting MSHA officials, in which researchers must use historical data on individual agents' past behavior to predict future behavior.[94]

Given their significant practical advantages, Bayesian statistical methods have become well established across a wide range of fields in recent years.[95] Practical applications of such methods of have helped to further such diverse practical endeavors as the identification of medical drug interactions,[96] gene profiling,[97] the conduct of clinical and evaluation of health care outcomes,[98]

BRITANNICA ONLINE (2008), *available at* http://www.britannica.com/EBchecked/topic/56807/Thomas-Bayes.

90 *See, e.g.*, JAMES O. BERGER, STATISTICAL DECISION THEORY AND BAYESIAN ANALYSIS 119-20 (2006) (describing Bayesian approaches' superior capacity to make direct probability statements about uncertainty).

91 *See, e.g.*, *id.* at 118-119 (arguing that Bayesian approaches more readily allow researcher to take advantage of significant prior information when it is available); TONY LANCASTER, AN INTRODUCTION TO MODERN BAYESIAN ECONOMETRICS 5-6 (2004) (describing way in which prior beliefs about probability are interpreted in context of Bayes' theorem).

92 *See* MIKE WEST & JEFF HARRISON, BAYESIAN FORECASTING AND DYNAMIC MODELS 23-25 (1997) (describing way in which information is progressively updated in dynamic Bayesian models); *see also* LANCASTER, *supra* note 91, at 6 (providing example of how application of Bayes' theorem may cause a researcher to change his or her prior belief about the relative likelihoods of two competing models).

93 *See* WEST & HARRISON, *supra* note 92, at 24 (noting that indexing of θ_t by t in dynamic models implies that parameters may change over time, for example, when "influential factors affecting the time series process" are themselves unstable).

94 *See id.* at 28-31 (historical overview of application of Bayesian methodologies to dynamic forecasting).

95 *See* Jeff Strnad, *Should Legal Empiricists Go Bayesian?*, 9 AM. L. & ECON. REV. 195, 195 (2007).

96 *See, e.g.*, William DuMouchel, *Bayesian Data Mining in Large Frequency Tables, with an Application to the FDA Spontaneous Reporting System*, 53 AM. STATISTICIAN 177 (1999).

97 *See, e.g.*, Sampsa Hautaniemi et al., *A Novel Strategy for Microarray Quality Control Using Bayesian Networks*, 19 BIOINFORMATICS 2031 (2003).

food-safety testing,[99] exchange-rate forecasting,[100] spam filtering[101] and options pricing.[102]

MSHA itself has, in fact, already recognized the potential value of Bayesian techniques in targeting high-risk mines. In the early 1980s, an MSHA official with statistical expertise used Bayesian quality control methods to generate "control charts" identifying individual mines with anomalously high patterns of injuries.[103] However, the success of the initiative was hampered by a number of practical constraints, such as significant time lags between the occurrence and reporting of accidents, difficulties in integrating mine-level inspection records into MSHA's injury database, and the awkwardness of translating the algorithms upon which the control charts relied into flexible computer applications. Consequently, this pioneering effort was ultimately abandoned.[104]

In the last decade, however, many of these technological barriers have eased significantly. Not only has the MINER Act greatly enhanced MSHA's ability to collect real-time injury data,[105] but the database upon which the agency now relies enables one to examine the inspection and injury history of each U.S.

---

98 *See, e.g.*, D.J SPIEGELHALTER & MYLES K. ABRAMS, BAYESIAN APPROACHES TO CLINICAL TRIALS AND HEALTH CARE EVALUATION (2004).

99 *See, e.g.*, M.A.J.S. VAN BOEKEL ET AL., BAYESIAN STATISTICS AND QUALITY MODELING IN THE AGRO-FOOD PRODUCTION CHAIN (2004).

100 *See, e.g.*, Jonathan H. Wright, *Bayesian Model Averaging and Exchange Rate Forecasts* (FRB International Finance, Discussion Paper No. 779, September 2003), *available at* http://ssrn.com/abstract=457345.

101 *See, e.g.*, M. Sahami, et. al., *A Bayesian Approach to Filtering Junk Email.*, *AAAI Workshop on Learning for Text Categorization* (AAI Technical Rep., WS-98-05, 1998), *available at* ftp://ftp.research.microsoft.com/pub/ejh/junkfilter.pdf.

102 *See, e.g.*, Theofanis Darsinos & S.E. Satchell, *Bayesian Forecasting of Options Prices: A Natural Framework for Pooling Historical and Implied Volatility Information* (Cambridge Working Papers in Econ. No. 0116, 2001).

103 *See* JON KOGUT, MSHA, COMPUTER PROGRAMS FOR STATISTICAL GRAPHICS IN SAFETY ANALYSIS 10-14 (1982) (describing dynamic control charts, which monitor processes' statistical variations), available from National Mine Health and Safety Academy Library, Beaver, W.Va. 25813; JON KOGUT, AN EMPIRICAL BAYES METHODOLOGY FOR ACCIDENT RISK ESTIMATION AND INCIDENCE RATE COMPARISON (1981), HSAC Report No. 11MC, available from MSHA Health and Safety Analysis Center, P.O. Box 25367, Denver, Colo. 80225; JON KOGUT, EMPIRICAL BAYES ESTIMATION FOR POISSON PROCESSES WITH SKEWED EXPOSURES (1981), *in* PROCEEDINGS OF THE AMERICAN STATISTICAL ASSOCIATION, SOC. STAT. SECTION, 346-49.

104 Telephone Interview with George Fesak, Director of MSHA's Program Evaluation & Info. Res. Office (Oct. 19, 2007); Telephone Interview with Jonathan Kogut, former Mathematical Statistician, MSHA's Program Evaluation & Info. Res. Office (Oct. 24, 2007).

105 *See* Mine Improvement and New Emergency Response Act of 2006 (MINER Act), P.L. 109-236, 2006 S. 2803 § 5(a) (amending section 103(j) of the Federal Mine Safety and Health Act of 1977 to require that mine operators report within fifteen minutes deaths as well as injuries or entrapments that may reasonably cause deaths).

mine in an integrated fashion.[106] Meanwhile, given recent advancement in computing technology, the translation of Bayesian models into user-friendly, automated computer programs has become much more tractable.[107] In short – perhaps for the first time in MSHA's history – it is now both methodologically and technologically feasible for the agency to develop a statistically based protocol for targeting additional investigative resources toward high-risk mines.

B. *Implementing a Targeting Protocol: Practical Challenges*

In order to test the efficacy of any given protocol, the most practical (and methodologically sound) approach would be initially to pilot the protocol among a select number of "pilot" districts. Only after comparing outcomes in the pilot districts to outcomes in other non-pilot districts, and confirming that the program is both tractable and demonstrably efficacious, would it be appropriate to consider nationwide implementation.

Yet implementing a pilot program, even in a few districts, would be costly. Therefore, the threshold practical challenge would be obtaining the resources required to target those mines identified as high-risk. At its current funding level, MSHA has struggled even to complete all of the mandated annual inspections required under the Act, and therefore asking MSHA to do "more with less" is unlikely to be a practical solution.[108] Three potential models of generating earmarked funds merit consideration.

First, MSHA could seek Congressional authorization to slightly relax the MINE Act's requirement that all surface and underground mines nationwide be inspected twice and four times a year, respectively. For example, Congress might require a minimum of only three annual inspections of underground mines, and/or one inspection of surface mines, to take place in the pilot districts for the duration of the program. By freeing up a small proportion of the time that would otherwise be devoted to comprehensive inspections, Congress could create sufficient regulatory "slack" to enable the program to proceed. In practice, it could be difficult to garner sufficient support from industry stakeholders (especially the United Mine Workers) for this option to gain political traction.

---

[106] For a discussion of MSHA's continuing improvement of its data-processing capacity, see MSHA, U.S. DEP'T OF LABOR, CONGRESSIONAL BUDGET JUSTIFICATION (FY 2009) 47-48, *available at* http://www.dol.gov/dol/budget/2009/PDF/CBJ-2009-V2-09.pdf.

[107] LANCASTER, *supra* note 91, at xiv (noting that "[i]n 1989 the computer methods described here were scarcely known; in 1995 they would have been difficult for a beginner to apply; today, application of these computer-intensive methods is little (if any) more difficult than application of the methods traditionally used in applied econometrics").

[108] In November of 2007, the Department of Labor issued a report criticizing MSHA's failure to carry out the required inspections. *See* OFFICE OF INSPECTOR GENERAL, U.S. DEP'T OF LABOR, OFFICE OF AUDIT, MINE SAFETY HEALTH ADMINISTRATION: UNDERGROUND COAL MINE INSPECTION MANDATE NOT FULFILLED DUE TO RESOURCE LIMITATIONS AND LACK OF MANAGEMENT EMPHASIS (2007), *available at* http://www.oig.dol.gov/public/reports/oa/2008/05-08-001-06-001.pdf.

A second approach might be for MSHA to develop partnerships with individual states that are willing to test innovative methods to enhance mine safety within their borders. Since MSHA already funds a number of innovative state programs, there would be ample precedent for such a state-federal collaboration.[109] Those states that are already expending state funds on mine-safety programs might be willing to allocate a portion of these funds to a pilot targeting program. Making such collaboration effective would necessitate extensive and timely information sharing between state and federal officials, which would require, in turn, considerable startup costs. In the long run, however, such a collaborative model holds considerable appeal.

Third, MSHA could seek an additional appropriation with which to conduct a pilot program. Congress has periodically granted MSHA such special appropriations for a variety of purposes, sometimes as part of much larger bills, and therefore seeking a Congressional earmark would be one possibility.[110] Alternatively, the National Institute of Occupational Safety and Health (NIOSH), the federal agency whose mandate is to conduct research and make recommendations for the prevention of work-related injury and illness,[111] might finance a pilot program to enable the agency to determine the effectiveness of targeted-regulation techniques.[112]

Importantly, the first of these three alternatives (relaxing the minimum inspection requirements in pilot districts) poses a risk that the other two do not. If the targeting effort were unsuccessful, it conceivably could lead to a *decline* in safety and health in pilot districts, since some mines would be inspected less frequently than before. In contrast, because the second and third approaches would not require MSHA to curtail its current enforcement activities, they should not pose any such risks. In other words, even in the worst case scenario – in which the targeting algorithm was completely ineffective – the second and third approaches would enable MSHA to ensure that pilot and non-pilot districts alike were protected by the same minimum "floor" of regulatory scrutiny.

---

109 U.S. DEP'T OF LABOR, MSHA STATE GRANT PARTICIPANTS, *available at* http://www.msha.gov/TRAINING/STATES/STATES.asp.

110 In June of 2006, for example, Congress appropriated to MSHA, as part of the Emergency Supplemental Appropriations Act for Defense, the Global War on Terror, and Hurricane Recovery, "$25,600,000 for the enforcement of mine safety law with respect to coal mines, including the training and equipping of inspectors," provided that MSHA make quarterly progress reports and use the money by September 30, 2007. P.L. 109-234, 2006 HR 4939 § 7008 (2006).

111 *See* NIOSH, CENTER FOR DISEASE CONTROL & PREVENTION, ABOUT NIOSH, *available at* http://www.cdc.gov/niosh/about.html.

112 Because mining remains a dangerous occupation, NIOSH regularly funds research projects regarding mining safety and health. *See* NIOSH, CENTER FOR DISEASE CONTROL & PREVENTION, OFFICE OF EXTRAMURAL PROGRAMS: PROGRAM REPORT FISCAL YEAR 2005 (DRAFT) 5, *available at* http://www.cdc.gov/niosh/oep/pdfs/Annual-Report-2005.pdf (last visited Sept. 28, 2008) (discussing various "[a]reas of focus" in mining research, which include "assessment of safety interventions," "reduction of injuries from materials handling," and "hearing loss prevention").

After funds were secured for a targeting program, the salient practical question would then become how to put them to use. Once a mine has been identified as high-risk by a targeting protocol, precisely what exact form(s) of intervention should state or federal inspectors apply in an effort to reduce its level of potential hazards? Since mining conditions vary widely across and within regions,[113] it probably would not be prudent to apply an identical intervention strategy to each and every targeted mine. Given the critical importance of such programmatic design questions, before implementing any pilot program, MSHA (or its state-level collaborators) would be wise to consult with a wide variety of stakeholders and mining experts within each pilot district, in order to formulate a technique (or set of techniques) that was best suited to the conditions characterizing that particular region.

VI. CONCLUSION

The goal of this Article has been to suggest several ways in which empirical analysis could enhance safety-and-health enforcement in U.S. mining. From a regulatory perspective, what makes the industry unique is not simply the fact that the Mining Safety and Health Administration has a much larger per-capita budget at its disposal than its sister agency, the Occupational Safety and Health Administration, which oversees the remainder of the U.S. economy. Additionally, what sets mining apart is the incredibly rich array of fine-grained, publicly available data on the history of each and every U.S. mine. Remarkably, mining is the *only* U.S. industry for which complete information is available not only on inspections, but also on fatalities, accidents, injuries, employment, production, and ownership.

The implications of this fact, I suggest, are profound. First of all, by analyzing historical data, MSHA could learn much about the relationship between compliance and safety, the marginal deterrence effect of MSHA inspections, and the phenomenology of major mining disasters – all of which could shed new light on the agency's current regulatory practices. Second, in light of recent methodological and technological advances, mine safety and health enforcement would be an ideal context in which to apply advanced regulatory targeting techniques. By designing a statistical algorithm to compare levels of risk across individual mines, and channeling special resources towards those mines that are predicted to pose the highest risk, inspectors could adopt a more proactive stance in helping to avert future mining disasters.

Since the above proposals have been sketched only in broad strokes, many detailed questions of programmatic design remain. Yet given the leveling off in mining fatality rates since the 1990s – and the recent spike in highly-

---

[113] For an interactive presentation of all fifty states' mining industries, including data on production, employment, and consumption, see NATIONAL MINING ASSOCIATION, STATE MINING STATISTICS, *available at* http://www.nma.org/statistics/state_statistics.asp (select the year of interest and the desired state from the map).

publicized mining disasters – this is a particularly opportune time to act. Bringing empirical analysis to bear on the task of reducing mining fatalities could help save additional lives, and among all of the Department of Labor's constituent agencies, MSHA is ideally positioned to pioneer and test such regulatory innovations.