

# The Effect of Unionism on Accidents in U.S. Coal Mining, 1897-1929

William M. Boal

College of Business and Public Administration  
Drake University, Des Moines, IA 50311  
Telephone 515-271-3129  
Email [william.boal@drake.edu](mailto:william.boal@drake.edu)

January 2008

**ABSTRACT:** This study estimates the effect of unionism on accident fatalities in early twentieth-century coal mines by applying count-data methods to two panel datasets—a state-level dataset where unionism is measured by membership, and a mine-level dataset where unionism is measured by contract coverage. Both datasets show frequent fatalities and considerable variation in unionism over time and in any given year. In both datasets, unionism is estimated to have lowered accident fatalities by about 40 percent, and is statistically highly significant, confirming the claim of former union president John Mitchell a century ago. The union effect persists after controlling for state safety regulations, which indicates that the union effect did not operate simply through organized pressure for safety legislation. Instead, the union effect may have operated, as Mitchell suggested, through union miners supporting each other in refusing to work in unsafe places.

**ACKNOWLEDGEMENTS:** This paper has benefited from helpful comments on earlier drafts by Kristen Monaco, Harry Paarsche, John H. Pencavel, David M. Smith, seminar participants at Drake University, Iowa State University, and the University of Nebraska, and two anonymous referees.

# The Effect of Unionism on Accidents in U.S. Coal Mining, 1897-1929

January 2008

**ABSTRACT:** This study estimates the effect of unionism on accident fatalities in early twentieth-century coal mines by applying count-data methods to two panel datasets—a state-level dataset where unionism is measured by membership, and a mine-level dataset where unionism is measured by contract coverage. Both datasets show frequent fatalities and considerable variation in unionism over time and in any given year. In both datasets, unionism is estimated to have lowered accident fatalities by about 40 percent, and is statistically highly significant, confirming the claim of former union president John Mitchell a century ago. The union effect persists after controlling for state safety regulations, which indicates that the union effect did not operate simply through organized pressure for safety legislation. Instead, the union effect may have operated, as Mitchell suggested, through union miners supporting each other in refusing to work in unsafe places.

## 1. Introduction

In the early twentieth century, the coal industry occupied a central role in the United States economy similar to petroleum's role today. Coal was critical for power generation, home heating, chemicals, and transportation. The coal industry employed a large workforce: 860,000 workers—about 2 percent of the U.S. labor force—at its peak in 1923.<sup>1</sup> Moreover, the coal industry attracted public attention in two ways the contemporary petroleum industry does not. First, the coal industry experienced chronic labor conflict manifested in regular national strikes. Second, the industry suffered deadly accidents, including large-scale explosions, with alarming frequency. Many studies have examined either unionism or accidents in early twentieth-century coal mining, but hardly any have considered the two together.<sup>2</sup> The present study fills this gap by estimating the effect of unionism on accident fatalities in coal mining.

In so doing, the present study incidentally generates evidence on competing models of union behavior. Assume occupational safety is costly to employers but desired by workers, and consider the predictions of two leading models of union behavior: the "right-to-manage" (or "labor-demand-curve") model and the "efficient-bargaining" model. Under the "right-to-manage" model, unions and employers contract only on wages, while employers unilaterally set employment and (presumably) other workplace variables. If wages are set above the market wage, the employer can reduce safety, thereby saving costs, and still hire all the workers it needs. So the "right-to-manage" model predicts that unionism will *reduce* safety. By contrast, under the "efficient-bargaining" model, unions and employers contract on all workplace variables, including

employment and (presumably) safety. Under plausible conditions, unions will seek improved safety along with higher wages, so this model predicts that unionism will *increase* safety and reduce accidents.<sup>3</sup>

The present study uses two large panel datasets on coal mining in the early twentieth century at the state level and the mine level. The econometric specifications are simple, but recognize the count structure of accident data. Moreover, unionism is measured with some care. A robust finding emerges: unionism appears to have reduced the frequency of fatal accidents in coal mining by about 40 percent. This robust finding contrasts with the inconclusive findings of the recent scholarly literature, but strongly confirms the claims of John Mitchell, former president of the United Mine Workers, writing a century ago.

The plan of the paper is as follows. The next section reviews the small literature on unionism and occupational safety. The third section describes early twentieth-century coal mining technology and the types of accidents that miners suffered. The fourth section presents estimates of the union effect on accidents using a state-level panel dataset. The fifth section presents estimates of the union effect using a mine-level panel dataset. The last section summarizes and interprets the results.

## **2. Review of literature on unionism and accidents**

Studies of unionism and occupational safety are surprisingly few and disappointingly inconclusive. Weil (1991, 1992) showed that unionism sharply increases the frequency and intensity of inspection by the Occupational Safety and Health

Administration. However, the effect of such inspections on accidents may be limited (Viscusi, 1986; Kniesner and Leeth, 2004). Workplace safety committees, which often include direct participation by unions, also increase the frequency and intensity of inspection in Oregon (Weil, 1999) and reduce the frequency of injuries in the United Kingdom (Reilly, Paci, and Holl, 1995). Unions in the United Kingdom appear to have a positive effect on the probability of any injury occurring at a workplace, but a negative effect on the injury rate when they do occur (Litwin, 2000).

Two recent studies examined the union effect on accidents specifically in coal mining and found opposite results. Appleton and Baker (1984) and several unpublished dissertations cited therein found significantly *positive* effects of unionism on accidents using data from the 1970s. Positive effects are attributed in part to union job-bidding rules that induce too-rapid movement of workers between job assignments. By contrast, Reardon (1996) found *negative* effects using data from the 1980s. In fact Reardon's point estimates were similar in magnitude to those reported in this paper.<sup>4</sup> However, his standard errors were large so 95% confidence intervals include zero. These two studies both use cross-section data, so individual mine effects cannot be controlled for. Of course, mines have rarely changed union status in recent years, so mine effects would be difficult to separate from the union effect even if the authors had access to panel data.

In a pair of studies, Fishback (1986, 1987) estimated the determinants of fatal coal mining accidents using panel data on states in the early twentieth century. The first study focused on the effects of state safety legislation. Fishback included 15 different measures of legislation and enforcement as explanatory variables, with unionism included as a control variable. Perhaps because so many measures were included, his standard errors

were very large. His estimated coefficients of unionism indicated that the union reduced small-scale accidents by less than one percent and *increased* total accidents by about 35%, but the standard errors were so large that conventional confidence intervals of the union effect would include very large positive or negative effects on accident rates.<sup>5</sup> Fishback concluded that union membership did not lower accident rates and that state safety legislation had “at best limited impact.”<sup>6</sup> Fishback’s second (1987) study focused on the effects of changes in liability rules in the early 1900s, which shifted liability for accidents from workers to employers, and on the effects of workers’ compensation programs, which removed liability from workers altogether. Unionism was again included as a control variable. Fishback’s point estimates indicated that changes in liability rules and workers’ compensation tended to increase accidents substantially, a result he attributed to increased moral hazard. However, standard errors were very large, and only workers’ compensation programs with exclusive state insurance funds were statistically significant. The estimated coefficient of unionism indicated that the union reduced total accidents by about 46% (similar to estimates reported below in this paper) but again standard errors were so large that conventional confidence intervals of his estimated union effect would include very large positive or negative effects on accident rates.<sup>7</sup> Thus no clear conclusions on the effect of unionism can be drawn from the Fishback studies.

### **3. Causes of coal mining accidents**

#### **3.1 Coal mining technology**

In the early twentieth century, nearly all coal in the U.S. was mined using underground methods. Access to the coal seam might be a vertical opening or “shaft” or, in mountainous areas, a horizontal opening or “drift”. Most mines extracted coal using the “room-and-pillar” method, whereby narrow fingers (“rooms”) were driven into the coal seam by individual miners or small groups of miners. As parallel rooms were driven forward, coal between the rooms was removed leaving “pillars” of coal to support the rock and coal above (the “roof”). Miners also shored up the roof with timbers and tried to stay alert to signs of shifting or weakening in the roof. As mines were developed, ventilating systems were required to ensure adequate oxygen to the workers at the face and to remove methane gas released from the rock by mining. Large fans at the surface were supplemented by elaborate systems of doors and partitions to direct the air flow past the coal face.

Miners usually removed coal from the coal face by first undercutting it with a pick or a cutting machine. Cutting machines were rarely used in 1900, but by 1929 accounted for 75 percent of bituminous coal output.<sup>8</sup> Then explosives were used to blast (or “shoot”) the coal down. Sometimes coal was blasted down without undercutting, a practice called “shooting off the solid.” The broken coal was then loaded by hand into mine cars mounted on rails and hauled to the surface by horses, mules, or locomotives. Because of difficulties in moving around the mines, absence of communication devices, and poor lighting, workers at the coal face were difficult to supervise. As a result, they were usually paid on piece—either per car or per ton of coal loaded. In many cases they were permitted to stop work and leave the mine when they pleased (Goodrich, 1925; Brophy, 1964).

Strip mining was practiced on a limited scale in the early twentieth century. As late as 1929, only 3.8% of bituminous coal mined in the U.S. was produced by strip mines. In a few smaller producing states—Indiana, Kansas, Missouri, Montana, and North Dakota—strip mining contributed more than 30 percent of total output, but in large producing states, strip mining was minimal. For example, in West Virginia, strip mining contributed only 0.1% of total output as late as 1929.<sup>9</sup>

### 3.2 Direct causes of accidents

Underground coal mining was and still is an extremely hazardous occupation. As shown in table 1, roughly 4 workers in 1000 lost their lives each year in the early twentieth century.<sup>10</sup> By far the most common cause of fatal and nonfatal accidents was falls of roof material, usually at the coal face. The second most common cause was haulage—workers were run over or crushed against the sides of mine passages by mine cars or locomotives. Though these two kinds of accidents were together responsible for about 70 percent of deaths and injuries in coal mining, they usually killed or maimed just one or two miners at a time and received little attention in the popular press. More dramatic but less frequent accidents were explosions of coal dust or of methane gas released from the earth by mining. This kind of accident often killed dozens or even hundreds of miners simultaneously and received great attention in the press. Other mine hazards included electricity used to power locomotives, and explosives used to shoot down the coal.

Accident rates may have been influenced by mining technology. For example, the introduction of machine mining may have contributed both to roof falls and

explosions. The movement of machines around the mine could sometimes dislodge timbers supporting the roof and the noise of machines may have concealed from miners the warning sounds of weakening roof. Machines unquestionably increased coal dust and may have released methane gas more rapidly than pick mining, which would have increased the risk of explosions. “Shooting off the solid” was widely viewed as dangerous because it required more explosives than traditional mining, and because it generated more coal dust. Strip mining, by contrast, was thought to be safer than underground mining.<sup>11</sup>

By all accounts, prevention of accidents required constant vigilance on the part of miners. Brophy (1964, p. 41) notes miners’ interdependence in maintaining a safe working environment.

### 3.3 Role of the union in preventing accidents

The United Mine Workers of America (UMWA), formed in 1890, was the only effective union of coal miners during the early twentieth century. The UMWA achieved its first major success in 1897 when it won wage increases for miners in Illinois, Indiana, Ohio, and western Pennsylvania. The following year it won the eight-hour day for these same miners. Thereafter it attempted to organize the rest of the industry, achieving substantial success with federal government support during World War I. This success was reversed during the 1920s as coal prices fell and the union held firm on wages, until the union was almost destroyed. However, the union recovered rapidly and organized most of the industry with the tacit support of the federal government in 1933.

While UMWA representatives often claimed that unionism reduced coal mining accidents,<sup>12</sup> formal union contracts made surprisingly little reference to safety. Typical contract language specified only that the mine operator was required to supply sufficient timbers to support the roof and that the miner was required to use them. Moreover, the contract language constrained the behavior of miners more than operators. For example, the 1904 contract with the operators of the Kanawha District contained the following clause.

15. The scale of prices agreed to for mining shall include the work required to mine, shoot and load the coal, and properly timber the working places in the mines, and the Operator shall be required to furnish the necessary props and timber to properly timber all working places. If any miner shall fail to properly timber and care for his working place, and such failure shall entail falls of slate, rock and the like, or if, by improper or reckless shooting of the coal in room or entry, the mine props or other timbers shall be disturbed, or unnecessary falls result, the miner whose fault is the occasion of such damage shall repair the damage without compensation, and if such miner fails to repair such damage, it shall be considered a dischargeable offense, and he may be dealt with at the discretion of the Superintendent.<sup>13</sup>

While there is little evidence of unionism's effect on accidents in contract language, there is clear evidence in the accident statistics, according to John Mitchell (1908), former president of the UMWA from 1898 to 1907. Using government data for 1907, Mitchell noted that the number of coal miners killed per thousand employed was

about twice as high in “partially organized” states as in “thoroughly organized states,” and nearly four times as high in “unorganized” states as in “thoroughly organized states.” Mitchell’s numbers are plotted in figure 1 against estimates of the percent of coal miners who were paid-up members of the UMWA from Boal (2006). Coal operators sometimes responded that union mines were safer because they worked less—fewer days per year because of higher costs and fewer hours per day because of union contracts.<sup>14</sup> If so, then fatality rates per 1000 workers might not be comparable across states. One can crudely adjust for differences in hours and days worked by dividing accident fatalities by output instead of by employment. Figure 1 therefore also plots accident fatalities per million tons of coal. As Mitchell himself noted, this alternative measure yields the same conclusion.

Mitchell’s figures are quite surprising in view of the scant attention given to safety by union contracts and the inconclusive results found by recent scholars. Questions naturally arise. Mitchell’s figures represent only fifteen states in a single year—does the negative relationship hold for other states and years? Was the union perhaps more successful at organizing states with less dangerous mines? Put differently, does the negative relationship still hold after controlling for differences across states other than unionism? If so, how can the union effect be explained, absent contract language on mine safety? Mitchell himself suggested two explanations. First, he claimed that union workers tended to support each other in refusing to work in unsafe places. (Goodrich (1925 pp. 86-89) supports this claim, citing the work of union mine committees in enforcing safe conditions.) Second, Mitchell claimed that union workers through their organization were better able to secure safety legislation from their state

governments and to ensure its enforcement.<sup>15</sup> The remainder of this paper seeks to verify Mitchell's figures and claims using much more data and modern econometric techniques.

#### **4. State-level evidence on the effect of unionism on accidents**

##### 4.1 Data

One way to verify Mitchell's claims is to expand the number of states and years of data, refine the measure of unionism, and include controls. This section reports estimates of econometric models of coal-mine accident fatalities using panel data for 25 states over the period 1902 to 1929 as a function of union membership and a variety of controls.

Coal-mining accident fatalities by year and state were reported by the U.S. Bureau of Mines, although data are missing for a few states in the first few years of the sample. (Data on nonfatal injuries were not reported at all, except in 1911.) Employment, average number of days worked, and the fraction of coal mined by machines were all reported by state and year (except in 1909) by the U.S. Geological Survey. These data were reported on a consistent basis for the 24 largest bituminous coal-producing states and for the anthracite fields of eastern Pennsylvania, which are included here as a separate "state."<sup>16</sup> The Geological Survey also reported the fraction of coal produced by strip mining beginning in 1914; the number of employees working eight-hour days, nine-hour days, and ten-hour days beginning in 1903; and the fraction of coal output "shot off the solid" beginning in 1911.<sup>17</sup> Estimates of the fraction of mine employees who were paid up members of the United Mine Workers, by state, were taken

from Boal (2006, table 3). A measure of state mine safety regulation suggested by Fishback (2006, p. 292) is also included. This variable is simply the number of important safety regulations in effect, from a list of 13 important regulations compiled by Fishback (1986, page 284, table 2).

Descriptive statistics of the state panel dataset, which includes 394 observations, are reported in table 2. In this sample, the average number of accident fatalities was about 102 and the average fraction unionized was about 41%. Days worked were less for coal miners than for other workers during this period, as noted by Fishback (1992) and others. The average number of safety regulations in effect—proposed by Fishback (2006) as an index of state efforts to regulate mine safety—ranged from zero to 10, with an average of about 5. These averages do not reveal trends. Machine mining, strip mining, and the fraction of employees working an eight-hour day rose sharply over the sample period, while the fraction of coal “shot off the solid” fell slightly. Safety regulation increased in most states, though not at a constant pace. Unionism rose until about 1919, and fell sharply in the 1920s.

## 4.2 Estimates

I estimated models of accident fatalities as a function of unionism and other variables, with fixed state effects to account for unobserved differences in accident risk across states. Ordinary least squares is widely recognized as an unsatisfactory method for estimating accident models because the fitted values can often be negative and because the variance of the error term is typically positively related to the conditional

mean. Count data regression models for panel data, pioneered by Hausman, Hall, and Griliches (1984) and surveyed by Cameron and Trivedi (1998), offer a better method.

The simplest model for count data is the Poisson distribution. However, the Poisson assumes that the conditional mean of the dependent variable (here, accident fatalities) equals its conditional variance. Formal tests described by Cameron and Trivedi (1998, pp. 77-78) showed that these coal accident data suffer from *overdispersion* (variance greater than mean). Following common practice, I turned to the negative binomial distribution. In particular, I used the variant of the negative binomial that Cameron and Trivedi (1998) call “NB1,” under which the probability of  $y_{it}$  fatal accidents in a given state (i) and year (t) is given by

$$f(y_{it}|x_{it}) = \frac{\Gamma(\lambda_{it} + y_{it})}{\Gamma(\lambda_{it}) \Gamma(y_{it})} \left(\frac{\delta}{1+\delta}\right)^{\lambda_{it}} (1+\delta)^{-y_{it}}$$

where  $\Gamma(\cdot)$  is the gamma function,  $\lambda_{it} = \exp(x_{it}' \beta)$ ,  $x_{it}$  is a vector of regressors, and  $\beta$  is a vector of unknown coefficients. The NB1 distribution’s conditional mean is  $\lambda_{it}/\delta$  and its conditional variance is  $\lambda_{it}(1+\delta)/\delta^2$ . Thus the ratio of variance to mean is  $(1+\delta)/\delta$ , which is greater than one for all positive  $\delta$ .<sup>18</sup> The parameters  $\delta$  and  $\beta$  are estimated simultaneously by maximum likelihood, but only the  $\beta$  parameters are of economic interest.

Because the conditional mean is an exponential function, each element of  $\beta$  may be interpreted as the approximate percent change in mean accidents caused by a one-unit increase in the corresponding element of  $x_{it}$ . If any of the variables in  $x_{it}$  are entered in logarithmic form, the corresponding element of  $\beta$  is the elasticity of mean accidents with respect to that variable. Here, employment and average days of operation were so

entered for ease of interpretation—if their coefficients are one, then accidents are proportional to industry size and days of operation. Since employment and days are thus controlled for, the other coefficients may be interpreted as *ceteris paribus* effects on mean accident *rates* (accidents per worker or accidents per worker-day).

Column (1) of table 3 displays coefficient estimates of a simple NB1 model of coal mining accident fatalities with state fixed effects, year fixed effects, and four regressors, including unionism.<sup>19</sup> Displayed in parentheses are heteroskedastic-consistent standard errors. The elasticity of accident fatalities with respect to workers is about one, as expected. The elasticity with respect to average days of operation is slightly less than one, suggesting that mines were more hazardous when worked less frequently, but the difference is not statistically significant. The effect of machine mining is positive but not statistically significant.

Unionism, by contrast, has a clear negative effect on accidents. Raising the fraction unionized from zero to one lowers accident fatalities by about 33 percent in logarithmic terms. The t-statistic for unionism is greater than 3.2, for a p-value of about one-tenth of one percent.

Column (2) adds another regressor: the number of safety regulations, which also has a clear negative effect on accidents. The t-statistic is about 2.8, for a p-value of less than one percent. The estimated value of the coefficient is about one-fifth the size of the coefficient of unionism. This suggests that increasing the number of regulations by five lowers accident fatalities by about the same amount as increasing the fraction unionized from zero to one. Note also that the estimated coefficient of unionism falls only slightly when the number of safety regulations is included. This suggests that Mitchell's second

explanation for the negative union effect on accidents—that the union secured safety legislation—was less important than his first explanation—that union workers supported each other in refusing to work in unsafe places.

Column (3) adds regressors controlling for laws increasing employer liability, and establishing Workers Compensation.<sup>20</sup> Fishback (1987) and Fishback and Kantor (2000) have suggested that these laws may have created moral hazard problems, tending to increase the number of accidents. The estimated coefficients are indeed positive, but not significant. Also added is a regressor for unionism in the Lewis era. John L Lewis became acting president of the UMWA in 1919 and president in February 1920. This regressor is therefore defined as the fraction of workers who are members of the UMWA for year 1919 or later, and as zero for earlier years. Thus the coefficient of this variable measures the *change* in unionism's effect on safety in the Lewis era. The estimated coefficient is positive, suggesting that the UMWA was less effective in reducing accidents after Lewis became its leader.<sup>21</sup> However, the estimated coefficient is of only borderline significance: the hypothesis of no change in union effectiveness is rejected at ten percent significance but not at five percent significance.

Columns (4) through (6) add more regressors controlling for strip mining, the length of the workday, and “shooting off the solid.” Data on these variables are not available for all years, so the sample size falls sharply. None of the additional estimated coefficients are statistically significant and some have unexpected signs. Inclusion of these regressors does not reduce the estimated effect of unionism—indeed the estimated coefficient increases in magnitude. The coefficient of the number of safety regulations hardly changes.

To further investigate the robustness of the union effect, I split the dataset into two subperiods with roughly equal numbers of observations: 1903-1911 and 1913-1929. Table 4 displays coefficient estimates by subperiod of the same specifications shown in columns (1), (2), and (3) of table 3. (Other specifications could not be estimated for both subperiods because of insufficient data or insufficient variation in the data for a particular subperiod.) Although standard errors increase substantially because of the reduced sample sizes, the estimated coefficient of unionism it increases slightly in magnitude and remains significant (at ten percent in the earlier period and at one percent in the later period). Again, the estimated coefficient of unionism falls only slightly when the number of safety regulations is included. The estimated coefficient of the number of safety regulations is hardly changed from the previous table, though its standard error is larger.

Similar results were produced by alternative specifications and estimation methods. For example, the year dummies were replaced by a time trend. Both year-dummy and time-trend specifications were re-estimated by Poisson maximum likelihood, which is consistent (though not efficient) if the true distribution is NB1. Both year-dummy and time-trend specifications were re-estimated by nonlinear least squares, which is also consistent (though not efficient) if the true distribution is Poisson or NB1. These alternative specifications and estimation methods produced little change in the estimated coefficients of unionism and the number of safety regulations, or in their statistical significance (see appendix B).

The estimated effect of unionism may be biased if unionism was not truly exogenous. If the union tended to organize the most dangerous mines, then the above estimates of the union effect are biased toward zero, and the true union effect was even

stronger than that reported here. But any such bias is probably small because state fixed effects are included in every specification. Moreover, other studies suggest that the main determinants of unionism in coal during this period were not accident rates but rather local and national political conditions and coal prices.<sup>22</sup> So it would appear that Mitchell's claim of a negative effect of unionism on accidents holds up very well in state-level data, even after including other states and years and after controlling for observed and unobserved differences across states. Moreover, the estimated effect of unionism is hardly disturbed after controlling for safety legislation, so Mitchell's first explanation—that union workers tended to support each other in refusing to work in unsafe places—seems more plausible than his second explanation—that unions were better able to secure safety legislation.

## **5. Mine-level evidence on the effect of unionism on accidents**

### 5.1 Data

A second way to verify Mitchell's claims is to investigate unionism and safety at the mine level. This section reports estimates of econometric models of coal-mine accident fatalities using a panel dataset of individual coal mines in West Virginia. The mine-level data complement the state-level data in several ways. First, the measure of unionism is slightly different. In the state-level data, unionism was measured quantitatively by the fraction of workers who were paid-up members of the union, a continuous variable, but in the mine-level data unionism is measured qualitatively by whether the mine was operated under union contract. Second, by including a separate

regressor for state-level unionism, Mitchell's explanations can be investigated further. If accidents were reduced because union workers tended to support each other in refusing to work in unsafe places, the union effect should be captured by the mine-level union variable. By contrast, if accidents were reduced because the union promoted safety legislation and its enforcement, the union effect should be captured by the state-level union variable.

West Virginia's unique history as a union battleground provides an ideal setting for measuring the effect of unionism at the mine level. In most states, the union status of mines changed infrequently and more or less simultaneously, so union effects are difficult to estimate precisely using mine-level data. By contrast, different fields in West Virginia changed union status at different times (see Boal 1992, 1994). Many mines in this sample changed union status twice over the sample period. Some changed union status four times. Thus any union effects should be easier to measure.

Data at the mine level on the numbers of accident fatalities, workers employed, days of operation, and on the fraction of coal mined by machine were reported by the West Virginia Department of Mines for the years 1897 and 1899 through 1928. Complete data at the mine level were not reported before 1897, after 1928, or for the year 1898. These limitations yield a maximum of 31 years of data for each mine. Unfortunately, data on length of the workday, strip mining, and "shooting off the solid" were never reported by the Department of Mines.

Information on the union status of individual mines is not available in any single source. I pieced together information from a variety of sources, including articles in trade journals, union publications, newspapers, and miscellaneous other sources (see data

appendix.) Union status is defined here as whether the mine was operating under contract with the United Mine Workers of America. Needless to say, union status could not be ascertained for every mine in every year. Nevertheless, I was able to ascertain the union status of 533 mines for an average of about fourteen years each. (The union status of fifteen of these mines was observed for all 31 years.) Observations on mines under union contract for only part of the year were omitted from estimation. For estimation purposes, unionism is represented by a dichotomous variable equal to one for unionized mines and zero for nonunion mines. To investigate whether unionism operated at the state level as well as the mine level, statewide unionism was introduced in some specifications reported below. Statewide unionism, measured as the fraction of coal mined under union contract, was taken from Boal (1994) and is available for every year.

Unlike the state-level dataset, the mine-level dataset is only a sample. Moreover it is not a random sample but rather reflects availability of data on union status. Figure 2 compares sample and total data for West Virginia over the period 1897 through 1928.<sup>23</sup> Panel (a) shows that only about one-third of West Virginia mines are included in the sample, but panels (b) and (c) show that the sample mines produced about half of West Virginia's coal output and employed about half of its coal workers. Thus the sample mines are a little larger than average and panel (d) shows that the sample mines accounted for at least half of the accident fatalities reported in West Virginia coal.<sup>24</sup> In other respects, the sample seems representative of the entire state, despite its nonrandom character. Panel (e) shows that the fraction of coal mined by machine in the sample closely matches that in West Virginia as a whole. Panel (f) shows that trends in unionism roughly matched trends in West Virginia as a whole.

Descriptive statistics of the mine-level dataset, which includes 7486 observations, are reported in table 5. The mean number of accident fatalities is less than one but the dataset includes some awful disasters, the worst taking the lives of 197 workers.<sup>25</sup> The number of workers employed varies from 1 to 1340, with a mean of 148 workers. The number of days of operation varies from 1 to 365, with a mean of 205 days. Machine mining was gradually adopted by the West Virginia coal industry during the sample period. In this sample, the fraction of coal mined by machine varies from zero to one with a sample mean of about two-thirds. This mean is higher than the mean for the state-level dataset because the mine-level dataset contains more observations toward the end of the period and because machine mining was more common in West Virginia than the rest of the U.S. even in the same years. About 30 percent of the observations were unionized. In fact, most mines in the dataset were unionized for part of the sample period, but no mines were unionized for the entire period, and some mines—particularly in the extreme south of the state—remained nonunion for the entire period.

## 5.2 Estimates

I estimated negative binomial models of accident fatalities on this mine-level dataset using the same specifications I used for the state-level dataset. However, I was forced to omit regressors for the length of the workday, strip mining, and “shooting off the solid” for lack of data.<sup>26</sup>

Column (1) of table 6 displays coefficient estimates of a simple NB1 model of coal-mining accident fatalities with mine fixed effects.<sup>27</sup> Mine effects control for differences in geological conditions and thus for any tendency of the union to organize

the most or least dangerous mines. A time trend was included instead of year effects because some regressors vary over time but not across mines. Displayed in parentheses are heteroskedastic-consistent standard errors. Accident fatalities are much less than proportional to employment at the mine level. Accident fatalities are negatively related to days worked. This may reflect reverse causality at the mine level—mines suffering disasters usually shut down temporarily for repairs.<sup>28</sup> Hardly any time trend is indicated. The effect of machine mining is negative and just barely statistically significant at 5 percent.

Unionism again has a clear negative effect on accident fatalities. Moving from nonunion to union operation lowers accident fatalities by about 40 percent in logarithmic terms, an estimate remarkably similar to the state-level estimate reported above. The t-statistic is greater than 8.

Column (2) adds another regressor: the number of safety regulations, which also has a clear negative effect on accidents. The t-statistic is greater than three, for a p-value of less than one percent. Just as in the state-level regressions, the estimated value of the coefficient is about one-fifth the size of the coefficient of unionism, so converting a mine from nonunion to union operation lowers accident fatalities by about the same amount as increasing the number of regulations by five. Again the estimated coefficient of unionism falls only slightly and remains strongly significant when the number of safety regulations is included. This casts more doubt on Mitchell's second explanation for the union effect on accidents—that the union secured safety legislation.

Column (3) adds a dummy variable for West Virginia's law establishing Workers Compensation in 1912 (West Virginia did not pass a law increasing employer liability). The estimated coefficient is positive, as in the state-level data, but not significant.

Column (4) adds a dummy variable for World War I (1917 and 1918), a dummy variable for the Lewis era (1919 and thereafter), and an interaction between the Lewis-era dummy and the union dummy. The coefficients of the first two are not significant, but the coefficient of the interaction variable is significantly *negative*, in contrast to the corresponding state-level estimate. Its negative sign indicates that the UMWA in West Virginia was considerably *more* effective in reducing accidents after Lewis became its leader. The estimated union coefficient before the Lewis era is now only about -0.2, but in the Lewis era the estimated effects of unionism sum to about -0.5.

Column (5) adds a regressor for the fraction unionized statewide, using estimates reported in Boal (1994).<sup>29</sup> This regressor is introduced to provide an alternative measure of the union's ability to secure safety legislation and ensure its enforcement at the state level. The estimated coefficient is very small, and an order of magnitude smaller than its standard error. Moreover, introducing this variable has no effect on the estimated coefficients of unionism, the number of safety regulations, and the union dummy during the Lewis era. This casts still more doubt on Mitchell's second explanation for the union effect on accidents—that the union secured safety legislation.<sup>30</sup>

In summary, the NB1 estimates in table 6 offer clear evidence of a negative union effect on accident fatalities at the mine level, similar in magnitude to the union effect found in the state-level dataset. So Mitchell's claim of a negative effect of unionism on accidents holds up very well even in mine-level data to which he could not have had

access. There is no evidence of an effect of statewide unionism and there is again a separate effect of state safety regulations, so Mitchell's first explanation—that union workers tended to support each other in refusing to work in unsafe places—again seems more plausible than his second explanation—that unions were better able to secure safety legislation.

## **6. Summary and interpretation of results**

Mitchell's claim that unionism decreased accidents in coal mining was based on simple averages computed from only one year of data, but his claim holds up remarkably well with larger datasets and more sophisticated statistical methods. Panel datasets at the state and mine levels confirm that unionism lowered accident fatalities in coal mines by somewhere between 20 and 60 percent, even after controlling for state safety regulations, changes in employer liability, Workers' Compensation, and allegedly dangerous mining techniques like machine mining or "shooting off the solid." The effect of unionism on fatalities was equivalent to about five state safety regulations. Nevertheless, the union effect on accident fatalities appears to have operated separately from state safety regulation, which casts doubt on Mitchell's second explanation for the union effect—that unions were better able to secure safety regulation. Mitchell's first explanation—that union workers tended to support each other in refusing to work in unsafe places—seems more likely.

The negative effect of unionism on accidents lends support to the "efficient-bargaining" model of union behavior, at least regarding safety. Although safety issues

were hardly mentioned in formal union contracts, the mine-level results suggest that unionized miners may have “bargained” informally for—and received—more safety. By contrast, a positive effect of unionism on accidents would have favored the “right-to-manage” model.

The magnitude of the union effect can be calculated in terms of lost lives. In 1915, near the midpoint of both samples, 2269 miners were killed on the job in the United States. Using  $-0.4$  as the coefficient of unionism, state-by-state calculations show that if the entire industry had been unionized only 1758 miners would have been killed, while if the entire industry been nonunion 2622 miners would have been killed, a difference of 864 lives for that year. The estimated union effect is much larger in absolute terms, but similar in relative terms to the apparent effect of the Coal Mine Safety and Health Act, passed in 1969. In the five years from 1965 to 1969, 1228 coal miners were killed in the United States, whereas in the five years from 1973 to 1977, only 700 miners were killed, a decline of 43 percent.<sup>31</sup>

Alternatively, the magnitude of the union effect can be calculated in terms of miners’ willingness-to-pay for safety. Applying the  $-0.4$  coefficient of unionism to the fatality rate of 4.3 deaths per thousand miners reported in table 1 implies that unionism saved about 1.7 lives per thousand miners per year. Estimates of the value of a statistical life using modern data are typically about 200 times median full-time annual earnings.<sup>32</sup> Simple multiplication implies that miners would have been willing to pay 0.34 times their annual earnings for the reduction in accident fatalities induced by the miners’ union. Put differently, the union effect on accident fatalities alone (ignoring non-fatal injuries) would have been equivalent to a 34 percent increase in miners’ wages.<sup>33</sup> By comparison,

estimates of the explicit effect of unionism on coal miners' wages vary widely, but most estimates are well below 34 percent.<sup>34</sup> All these calculations lend some support the unionists' claims that "if other reasons were lacking, the labor union has fully justified its existence by the fact that to it can be traced the saving of life and health."<sup>35</sup>

## References

- Appleton, William C., and Joe G. Baker, "The Effect of Unionization on Safety in Bituminous Deep Mines," *Journal of Labor Research*, Vol. 5, No. 2 (Spring 1984), pp. 139-148.
- Bloch, Louis, *Labor Agreements in Coal Mines*, New York: Russell Sage Foundation, 1931.
- Boal, William M., "The Unionization of West Virginia Coal, 1900-1935: a Chronology," Ohio State Univ. Dept. of Economics Working Paper 92-4, April 1992.
- Boal, William M., "Estimates of Unionism in West Virginia Coal, 1900-1935," *Labor History*, Vol. 35, No. 3 (Summer 1994) pp. 429-441.
- Boal, William M., "New Estimates of Paid-Up Membership in the United Mine Workers, 1902-1929, by State and Province," *Labor History*, Vol. 47, No. 4 (November 2006), pp. 537-46.
- Boal, William M., and John H. Pencavel, "The Effect of Labor Unions on Employment, Wages, and Days of Operation: Coal Mining in West Virginia," *Quarterly Journal of Economics*, Vol. 109, No. 1 (February 1994) pp. 267-298.
- Brophy, John, *A Miner's Life*, Madison: University of Wisconsin Press, 1964.
- Buffum, David, "Workmen's Compensation: Passage and Impact." Ph.D. dissertation, University of Pennsylvania.
- Cameron, A. Colin, and Pravin Trivedi, *Regression Analysis of Count Data*, Econometric Society Monograph No. 30, Cambridge: Cambridge University Press, 1998.

Census Bureau, *Statistical Abstract of the United States 2004-05*, Washington: GPO, 2005.

*Coal Age*, New York, various issues.

Drury, Doris, *The Accident Records in Coal Mines of the United States: a Study of the Literature with Comparisons of the Records in Other Coal-Producing Countries*, Bloomington, Indiana: Department of Economics, Indiana University, 1964.

Emmet, Boris, "Labor Relations in the Fairmont, West Virginia Bituminous Coal Field," *Bureau of Labor Statistics Bulletin*, No. 361, Washington, DC: GPO, 1924

Fishback, Price V., "Workplace Safety in the Progressive Era: Fatal Accidents in Bituminous Coal Mining, 1912-1923," *Explorations in Economic History*, Vol. 23, No. 3 (July 1986) pp. 269-298.

Fishback, Price V., "Liability Rules and Accident Prevention in the Workplace: Empirical Evidence from the Early Twentieth Century," *Journal of Legal Studies*, Vol. 16., No. 2 (June 1987) pp. 305-328.

Fishback, Price V., *Soft Coal, Hard Choices: the Economic Welfare of Bituminous Coal Miners, 1890-1930*, Oxford: Oxford University Press, 1992.

Fishback, Price V., and Shawn Everett Kantor, *A Prelude to the Welfare State: the Origins of Workers' Compensation*, Chicago: University of Chicago Press, 2000.

Fuess, Scott M., Jr., and Mark A. Loewenstein, "Further Analysis of the Theory of Regulation: The Case of the 1969 Coal Mine Health and Safety Act," *Economic Inquiry*, Vol. 28, No. 2 (April 1990), pp. 354-389.

Goodrich, Carter, *The Miner's Freedom: A Study of the Working Life in a Changing Industry*, Boston: Marshall Jones, 1925.

Graebner, William, *Coal-Mining Safety in the Progressive Period: the Political Economy of Reform*, Lexington: University of Kentucky Press, 1976.

Hausman, Jerry, Bronwyn H. Hall, and Zvi Griliches, "Econometric Models for Count Data with an Application to the Patents-R&D Relationship," *Econometrica*, Vol. 52, No. 4 (July 1984), pp. 909-938.

Hume, Britt, *Death and the Mines: Rebellion and Murder in the United Mine Workers*, New York: Grossman, 1971.

Kniesner, Thomas J., and John D. Leeth, "Data Mining Mining Data: MSHA Enforcement Efforts, Underground Coal Mine Safety, and New Health Policy Implications," *Journal of Risk and Uncertainty*, Vol. 29, No. 2 (September 2004), pp. 83-111.

Lewis, H. Gregg, *Unionism and Relative Wages in the United States*, Chicago: University of Chicago Press, 1963.

Lewis-Beck, Michael S., and John R. Alford, "Can Government Regulate Safety? The Coal Mine Example," *American Political Science Review*, Vol. 74, No. 3 (September 1980), pp. 745-756.

Litwin, Adam Seth, "Trade Unions and Industrial Injury in Great Britain," Centre for Economic Performance Working Paper No. CEPDP0468, London School of Economics, August 2000.

Mitchell, John, "Conservation in the Coal Industry," *American Mining Congress Proceedings*, Vol. 11 (1908), 185-195.

Reardon, Jack, "The Effect of the United Mine Workers of America on the Probability of Severe Injury in Underground Coal Mines," *Journal of Labor Research*, Vol. 17, No. 2 (Spring 1996), pp. 239-252.

Reilly, Barry, Paci, Pierella, and Holl, Peter, "Unions, Safety Committees and Workplace Injuries," *British Journal of Industrial Relations*, Vol. 33, No. 2 (June 1995), pp. 275-288.

*United Mine Workers Journal*, Indianapolis and Washington, various issues.

United Mine Workers, *Proceedings of the Convention*, Indianapolis, various issues.

United States Department of Commerce, *Historical Statistics of the United States: Colonial Times to 1970*, 1975.

United States Geological Survey, *Mineral Resources of the United States*, Washington: Government Printing Office (various issues) [after 1923 published by United States Bureau of Mines].

United States Coal Commission, *Report, Part III: Bituminous Coal--Detailed Labor and Engineering Studies*, Washington, D.C.: Government Printing Office, 1925.

Viscusi, W. Kip, "The Impact of Occupational Safety and Health Regulation, 1973-1983," *Rand Journal of Economics*, Vol. 17, No. 4 (Winter 1986), pp. 567-580.

Viscusi, W. Kip, "The value of a statistical life: a critical review of market estimates throughout the world," *Journal of Risk and Uncertainty*, Vol. 27, No. 1 (August 2003), pp. 5-76.

Weil, David, "Enforcing OSHA: The Role of Labor Unions," *Industrial Relations*, Vol. 30, No. 1 (Winter 1991), pp. 20-36.

Weil, David, "Building Safety: The Role of Construction Unions in the Enforcement of OSHA," *Journal of Labor Research*, Vol. 13, No. 1 (Winter 1992), pp. 121-130.

West Virginia Department of Mines, *Annual Report*, Charleston, various issues.

## Appendix A: data sources

### A.1 State-level dataset

*Percent union:* This variable is given in Boal (2006, table 3). Boal estimates union membership by state using the international union's per-capita tax receipts, and then divides membership by total employment as reported in *Mineral Resources of the United States*. Estimates are available annually for 1902-1911, biennially for 1913-1923, and in 1926 and 1929. Pennsylvania anthracite is recorded as a separate observation.

*Accident fatalities:* Data on fatalities were taken from the following U.S. Bureau of Mines publications.

- Albert H. Fay, "Coal Mine Fatalities in the United States, 1870-1914," Bulletin 115, GPO 1916.
- Albert H. Fay, "Coal Mine Fatalities in the United States, 1919," Bulletin 196, GPO 1920.
- William W. Adams, "Coal Mine Fatalities in the United States, 1923," Bulletin 241, GPO 1924.
- William W. Adams, "Coal Mine Fatalities in the United States, 1926," Bulletin 283, GPO 1927.
- William W. Adams, "Coal Mine Fatalities in the United States, 1929," Bulletin 341, GPO 1931.

*Laws:* The number of safety regulations was computed from Fishback (1986, p. 284, table 2). Fishback does not report laws for North Dakota. Dummy variables for Workers Compensation Laws were constructed from Fishback and Kantor (2000, p. 103 table 4.3).

Dummy variables for employer liability laws were constructed from Fishback and Kantor (2000, pp. 251-254).

*Other state-level data:* Data on employment, average days of operation, machine mining, strip mining, fraction of the workforce on an eight-hour day, and “shooting off the solid” were taken from the annual publication *Mineral Resources of the United States* published by the U.S. Geological Survey through 1923, and by the U.S. Bureau of Mines thereafter. Pennsylvania anthracite is reported separately. “Shooting off the solid,” is not reported before 1911, but apparently it was universally practiced in Pennsylvania anthracite (U.S. Geological Survey, 1910, part II, p. 10). For all years before 1911, I therefore assumed a value of one for Pennsylvania anthracite and “missing” for all other states. “Strip mining” is not reported before 1914. In that year, small amounts of strip-mined coal were produced in Indiana, Kansas, Missouri, Oklahoma, and Pennsylvania anthracite. For all years before 1914, I therefore assumed a value of “missing” for these states and zero of all other states.

## A.2 Mine-level dataset

*Union status:* The union status of 533 mines was determined for as many years as possible by collecting references to West Virginia mines in the following sources.

- Bituminous Operators' Special Committee (1923), "The United Mine Workers in West Virginia," submitted to the U.S. Coal Commission, September 10, 1923.
- *Black Diamond* , Chicago, various issues.
- *Coal Age* , New York, various issues.
- *Coal Trade Bulletin* , Pittsburgh, various issues.

- Corbin, David Alan (1981), *Life, Work, and Rebellion in the Coal Fields: The Southern West Virginia Miners, 1880-1922*, Urbana: University of Illinois Press.
- Emmet, Boris (1924), "Labor Relations in the Fairmont, West Virginia Bituminous Coal Field," Bureau of Labor Statistics Bulletin No. 361, July 1924.
- Freeburg, Victor O. (1925), "The Fairmont Coal Strike," *Law and Labor*, June 1925, Vol.7, No.6, pp.151-158.
- Lane, Winthrop D. (1921), *Civil War in West Virginia: A Story of Conflict in the Coal Mines*, New York: B.W. Huebsch.
- Lee, Howard B. (1969), *Bloodletting in Appalachia*, Morgantown: West Virginia University.
- Lunt, Richard D. (1979), *Law and Order vs. the Miners: West Virginia, 1907-1933*, Hamden: Archon Books.
- Mooney, Fred (1967), *Struggle in the Coal Fields: The Autobiography of Fred Mooney*, (J.W. Hess, ed.), Morgantown: West Virginia University.
- *The New York Times*, New York, various issues.
- Robertson, Thomas J. and Ronald L. Lewis (1993), "Conflict at Coal River Collieries: The UMWA vs. the Brotherhood of Locomotive Engineers," *West Virginia History*, Vol. 52, pp.73-90.
- Ross, Phil (1994), "The Scotts Run Coalfield from the Great War to the Great Depression: A Study in Overdevelopment," *West Virginia History*, Vol. 53, pp. 21-42.
- Tams, W.P. (1963), *The Smokeless Coal Fields of West Virginia*, Morgantown: West Virginia University.

- *United Mine Workers Journal*, Indianapolis and Washington: various issues.
- United Mine Workers of America, *Proceedings of the Convention*, various issues.
- United States Senate Committee on Education and Labor, 67th Congress, First Session, Hearings pursuant to S. Res. 80 "...to investigate the recent acts of violence in the coal fields of West Virginia...", Washington, 1921.
- United States Senate Committee on Interstate Commerce, 70th Congress, First Session, Hearings pursuant to S. Res. 105 "...to investigate conditions in the coal fields of Pennsylvania, West Virginia, and Ohio," Washington, 1928.
- United States Senate Subcommittee of the Committee on Mines and Mining, 72nd Congress, First Session, Hearings on S. 2935 "...a bill...to create a Bituminous Coal Commission...", Washington, 1932.
- West Virginia State Federation of Labor, *Proceedings of the Convention and Official Year Book*, various issues.

*Other data:* Data on employment, days of operation, machine mining, accident fatalities, and nonfatal injuries were taken from the *Annual Report* of the West Virginia Department of Mines. These data are reported on a fiscal year basis (ending June 30) through 1924, and on a calendar year basis thereafter. Accident fatalities and nonfatal injuries for the last six months of 1924 are included in 1925. I first developed this panel using data available for the early 1920s. Later, I collected data for earlier and later years as available. Hence attrition occurred both backward and forward in time. The dataset and a list of mines included are available from the author by request.

## Appendix B: alternative estimates

### B.1 Alternative state-level estimates

Table B1 shows NB1 maximum likelihood estimates of specifications similar to those in table 3, but with a time trend replacing the year dummies. Again, heteroskedastic-consistent standard errors are given in parentheses. The estimated coefficient of the time trend is negative but not significantly different from zero. The other estimated coefficients are roughly similar to those in table 3. Tests of the null hypothesis of the time trend against the alternative hypothesis of year dummies are not very decisive.

Table B2 shows Poisson maximum likelihood estimates with year dummies. Poisson estimates are consistent (though not efficient) if the true distribution is NB1. Table B3 shows Poisson maximum likelihood estimates with year dummies replaced by a time trend. Again, heteroskedastic-consistent standard errors are given in parentheses. Again the estimated coefficients are roughly similar to those in table 3. However, tests for overdispersion suggested by Cameron & Trivedi (1998, p.78, eq. 3.40) strongly reject the Poisson model in favor of the NB1.

Table B4 shows nonlinear least squares estimates of the function

$$y_{it} = \lambda_{it} + \varepsilon_{it} = \exp(x_{it}' \beta) + \varepsilon_{it} ,$$

where  $y_{it}$  is the number of fatalities in state  $i$  at time  $t$ , and  $\varepsilon_{it}$  is a random error term, with year dummies. Nonlinear least squares estimates are consistent (though not efficient) if the true distribution is Poisson or NB1, but they are not efficient because the error term  $\varepsilon_{it}$  is heteroskedastic. Table B5 shows nonlinear least squares estimates with

year dummies replaced by a time trend. Again, heteroskedastic-consistent standard errors are given in parentheses. Again the estimated coefficients are roughly similar to those in table 3.

Table B6 shows nonlinear two-stage least squares estimates of the same function

$$y_{it} = \lambda_{it} + \varepsilon_{it} = \exp(x_{it}' \beta) + \varepsilon_{it} ,$$

with unionism treated as endogenous. The instruments are two variables suggested by Fishback and Kantor: the number of state laws protecting unionism, and the imputed fraction unionized in manufacturing industries (see "Worker Compensation Project Data-first data set," at <http://www.u.arizona.edu/~fishback/wcdata.xls>). Unfortunately, neither instrument is closely correlated with unionism in coal: the correlation of state laws and coal unionism is 0.138, and the correlation of imputed unionism in manufacturing and coal unionism is 0.123. The estimates shown in table B6 should be viewed bearing in mind the poor quality of the instruments. The estimated coefficient of unionism is similar to those produced by other estimation methods for the simple specification shown in column (1), but the estimated coefficient is quite different for specifications (2) through (6). Little can be inferred from the nonlinear two-stage least squares estimates, however, because the standard errors are huge.

## B.2 Alternative mine-level estimates

Table B7 shows Poisson maximum likelihood estimates of the effect of unionism on accident fatalities in West Virginia coal mines. The point estimates of the coefficients are roughly similar to the NB1 estimates presented in table 6, but the standard errors are three to five times larger.

Table B8 shows NB1 estimates of the effect of unionism on nonfatal injuries. Data on nonfatal injuries are often considered suspect because the definition of a reportable injury may have varied. Moreover, the union may have influenced the reporting of injuries (most likely increasing it). In fact, there is evidence that the definition of a reportable injury was gradually broadened in West Virginia after 1924. From 1897 to 1924, the average ratio of total nonfatal injuries to accident fatalities was 2.1, with a maximum of 3.6 in 1915. The ratio rose to 3.9 in 1925, to 5.0 in 1926, to 5.8 in 1927, and so forth, reaching a maximum of 40.8 in 1936.<sup>36</sup> I therefore excluded data on nonfatal injuries after 1924. This exclusion and other missing values reduced the number of usable observations from 7486 to 5779.<sup>37</sup>

In any case, the estimated coefficient of unionism on nonfatal injuries is small and insignificant. If the union did influence the reporting of injuries, then this coefficient represents the net union effect on both true injuries and reporting, so it is difficult to interpret. The estimated coefficient of the number of safety regulations, however, is negative and slightly larger in absolute value than the corresponding estimated coefficient for fatalities, and is again easily significant at conventional levels. The estimated coefficient of the interaction between the Lewis-era dummy and the union dummy is also negative and significant indicating that the UMWA in West Virginia was more effective in reducing injuries after Lewis became its leader. The coefficient of statewide unionism is large, but its standard error is even larger.

## Endnotes

---

<sup>1</sup> Coal employment: U. S. Bureau of Mines, *Mineral Resources of the United States*, 1929, Part II, pp. 694-695. U.S. labor force: U.S. Department of Commerce, *Historical Statistics of the United States*, Vol. 1, page 126, series D-1.

<sup>2</sup> Graebner's (1976) historical study is an important exception, but it contains no data analysis.

<sup>3</sup> Moreover, the positive effect of unionism on safety might be magnified if inframarginal workers value safety more than marginal workers, or if safety is a workplace public good (Freeman and Medoff, 1984, pp. 8-10).

<sup>4</sup> Reardon (1996) estimated logit models predicting whether a mine experienced a severe injury. The coefficients of the union dummy were -0.443 and -0.311, depending on the specification (table 2, p. 244). The frequency of injury in the sample was only about 1.5 percent in his sample of 392 mines (table 1, p. 244) so the percent effect of unionism on the accident rate is well-approximated by Reardon's estimated union coefficient.

<sup>5</sup> See Fishback (1986) table 1, p. 272 and table 3, p. 286. Other possible reasons for the large standard errors are Fishback's complicated simultaneous-equations estimation framework, the short time span of his panel, and his imputation of the union variable in many observations.

<sup>6</sup> Fishback (1986) p. 293.

<sup>7</sup> See Fishback (1987) table 2, p. 323, and sample mean accident rates given on page 322. Buffum (1992) also estimated regressions for fatal accidents using the same state-level panel data as Fishback. However, Buffum used strike data as a proxy for unionism. Buffum acknowledged that strikes could be positively or negatively related to unionism, so one cannot infer from his study whether unionism had a positive or negative effect on accidents.

<sup>8</sup> U.S. Geological Survey (1929), *Mineral Resources of the United States*, part 2, page 750, table 46.

<sup>9</sup> U.S. Geological Survey (1929), *Mineral Resources of the United States*, part 2, page 750, table 46.

<sup>10</sup> The accident rate today is roughly one-tenth what it was in the early twentieth century. See U.S. Department of Labor, Mine Safety and Health Administration, "Coal Fatalities for 1900 through 2001," <http://www.msha.gov/centurystats/coalstats.htm>, accessed January 23, 2003.

<sup>11</sup> Drury (1964), pp. 75-85. U.S. Geological Survey, *Mineral Resources of the United States*, 1913, part 2, pp. 765-766. Succeeding volumes of *Mineral Resources* also warned of the dangers of "shooting off the solid."

<sup>12</sup> "Government Statistics Show Life Depends on Unionism," *United Mine Workers Journal*, Vol. 25, No. 29 (November 26, 1914), p. 4. "Miners Pay Fearful Price in West Virginia," *United Mine Workers Journal*, Vol. 38, No. 10 (May 15, 1927), pp. 8-9. "Union Guards Life and Property; Fewer Deaths in Organized Mines," *United Mine Workers Journal*, Vol. 38, No. 22 (November 15, 1927), p. 5. By contrast, in the 1960s

---

the International Union's Safety Department consisted of one man (Hume, 1971, pp. 156-157, 161; Finley, 1972, p. 232).

<sup>13</sup> "Articles of Agreement made and entered into this 31<sup>st</sup> day of March, 1904, by and between the Operators of the Kanawha District of West Virginia and the United Mine Workers of America, governing the operation of the mines in said District for the two years ending March 31<sup>st</sup>, 1906," page 6, section 15. Similar language appeared in other contracts, such as those for District 12 (Illinois), reported in Bloch (1931, pp. 363-413).

<sup>14</sup> "Union Mines Are Safe," *Coal Age*, Vol. 26, No. 13 (September 25, 1924), p. 425.

<sup>15</sup> Mitchell (1908, pp. 189-190). All mine safety regulation occurred at the state level during this period. The federal government did not inspect coal mines until 1941 and was not given enforcement powers until 1953 (Drury, 1964, p. 47).

<sup>16</sup> The following coal-producing states are omitted: California, Georgia, Idaho, Nevada, North Carolina, Oregon, and South Dakota. In total, these states accounted for less than one-tenth of one percent of U.S. coal employment, output, and fatalities.

<sup>17</sup> I assume that any state producing zero output from strip mining in 1914 also produced zero output in prior years.

<sup>18</sup> See Hausman, Hall, and Griliches (1984) pp. 921-922, and Cameron and Trivedi (1998) pp. 73-74.

<sup>19</sup> Likelihood-ratio tests show that state fixed effects are collectively significant.

Hausman tests reject random-effects in favor of fixed effects.

<sup>20</sup> These dummy variables equal zero through the year the law was passed, and equal one thereafter.

<sup>21</sup> Whether the change in unionism's effect was due to Lewis himself, or due to other factors such as declining coal prices and declining unionism, is difficult to say with these data.

<sup>22</sup> See Boal (1992) and Boal and Pencavel (1994, pp. 271-298). An attempt was made to estimate the accident equation by nonlinear two-stage least squares, but the poor quality of available instruments led to huge standard errors. See appendix B.

<sup>23</sup> State-level data for panels (a) through (e) are taken from *Annual Reports* of the West Virginia Department of Mines. State-level data on unionism, shown in panel (f), are from Boal (1994).

<sup>24</sup> The sample was determined by the availability of information on union status. If information sources were more likely to report on large mines, then one might expect the sample mines to be larger than average.

<sup>25</sup> Explosion in Monongah No. 8 mine, in Marion County, 1908.

<sup>26</sup> A peculiar feature of the Department of Mines data is that accident data for 1897-1924 reflect fiscal years ending June 30, accident data for 1926-1928 reflect calendar years ending December 31, and accident data for 1925 reflect an 18-month period from July 1, 1924 to December 31, 1925. To accommodate the 1925 data, I introduced a dummy variable for 1925 and constrained its coefficient to equal  $\ln(18/12) = 0.405465$ .

<sup>27</sup> Likelihood-ratio tests show that mine fixed effects are collectively significant.

Hausman tests reject random-effects in favor of fixed effects.

<sup>28</sup> When mine fixed effects are omitted, the coefficients of workers and days are close to one, as in the state-level data.

---

<sup>29</sup> Boal's (1994) study, though limited to West Virginia, supplies estimates for every year, unlike the estimates used in the state-level dataset described above.

<sup>30</sup> Roughly similar estimates for fatalities were produced by Poisson maximum likelihood, except that the standard errors were three to five times larger. By contrast NB1 estimates for nonfatal injuries were somewhat different: the union effect was small and insignificant, although the effect of safety regulations was similar to its effect on fatalities. However, the estimates for nonfatal injuries are more difficult to interpret because of apparent changes in reporting. See appendix B.

<sup>31</sup> Figures from Mine Safety and Health Administration, table 5 at <http://www.msha.gov/STATS/PART50/WQ/1931/wq31c105.htm> accessed November 17, 2005. Studies of the Act that control for technology, coal demand, and so forth, yield roughly similar estimates (Lewis-Beck and Alford (1980), and Fuess and Loewenstein (1990)). However, Kniesner and Leeth (2004) argue that the decline in accidents should not necessarily be attributed to the Act.

<sup>32</sup> A survey of recent studies finds that the median estimate of the value of a statistical life is about \$7 million in 2000 dollars (Viscusi and Aldy, 2003, p. 18). Meanwhile, median weekly earnings of all full-time workers in the U.S. were \$576 in 2000 (U.S. Census, 2005, p. 411, table 623) which imply median annual earnings of about \$30,000 for a 52-week year.

<sup>33</sup> The figure of 34 percent is an underestimate if the income elasticity of the value of a statistical life is less than one, because coal miners earned much less than today's workers. Viscusi and Aldy (2003, p. 37) believe the income elasticity is between 0.5 and 0.6.

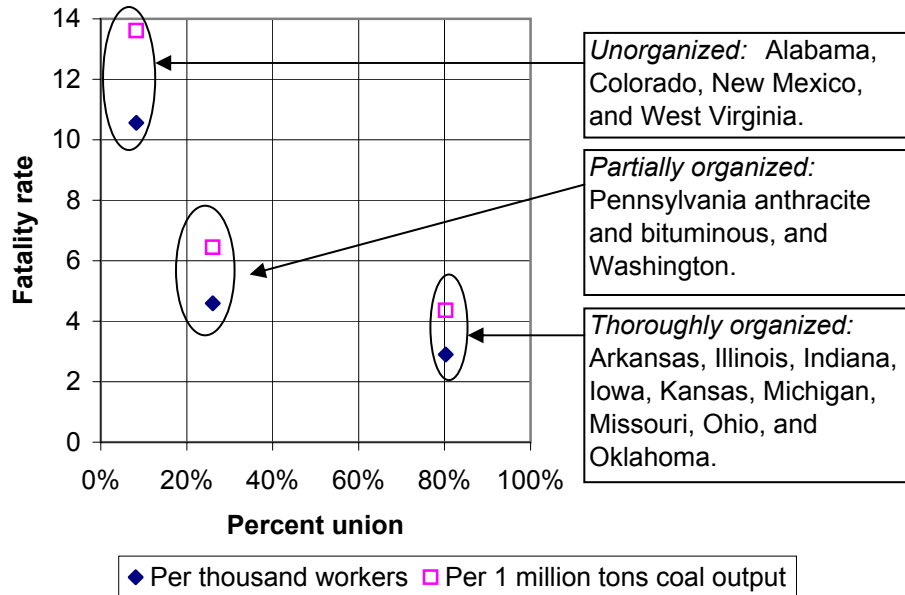
<sup>34</sup> Union relative wage effects above 34 percent are reported by Lewis (1963, page 77, table 9). Union relative wage effects well below 34 percent are reported by Boal and Pencavel (1994, pp. 283-285, tables III and IV), Emmet (1924, p. 86), and Fishback (1992, p. 95, table 6-8).

<sup>35</sup> "Government Statistics Show Life Depends on Unionism," *United Mine Workers Journal*, Vol. 25, No. 29 (November 26, 1914), p. 4.

<sup>36</sup> The 1933 *Annual Report* of the West Virginia Department of Mines noted the increase in nonfatal injuries and blamed it on "more complete reports" received (p. 12). In that year, the ratio of nonfatal injuries to fatalities reached 31.5.

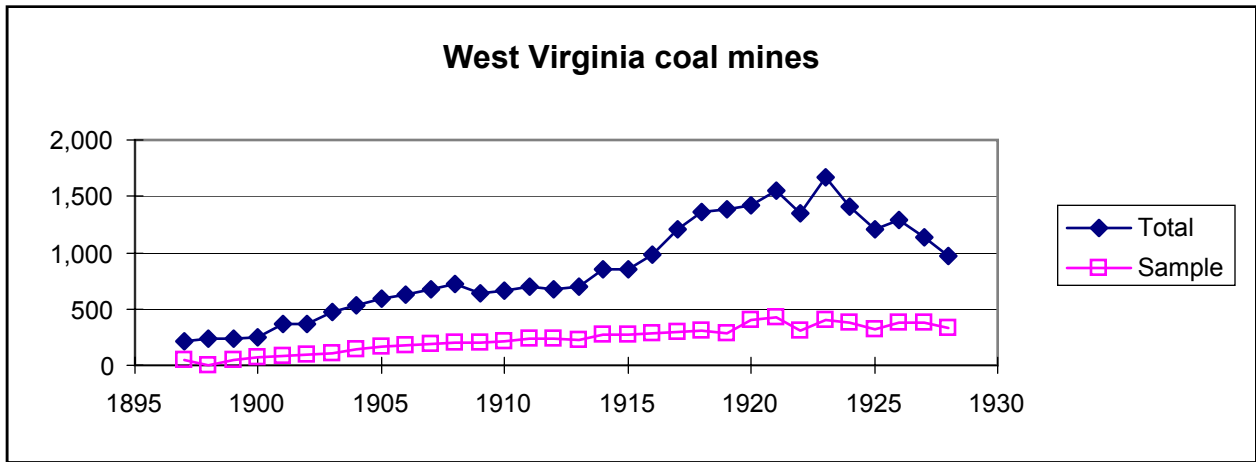
<sup>37</sup> If the data after 1924 are included, the estimated coefficient of statewide unionism in the regressions reported below becomes implausibly large—about 2.3 with a t-statistic of about 3. This is because the sharp rise in reported nonfatal injuries in West Virginia in the late 1920s coincided with a sharp decline in unionism. See figure 2 panel (f).

**Figure 1: Fatality rates in coal mining, 1907, in Mitchell's "unorganized," "partially organized," and "thoroughly organized" states**

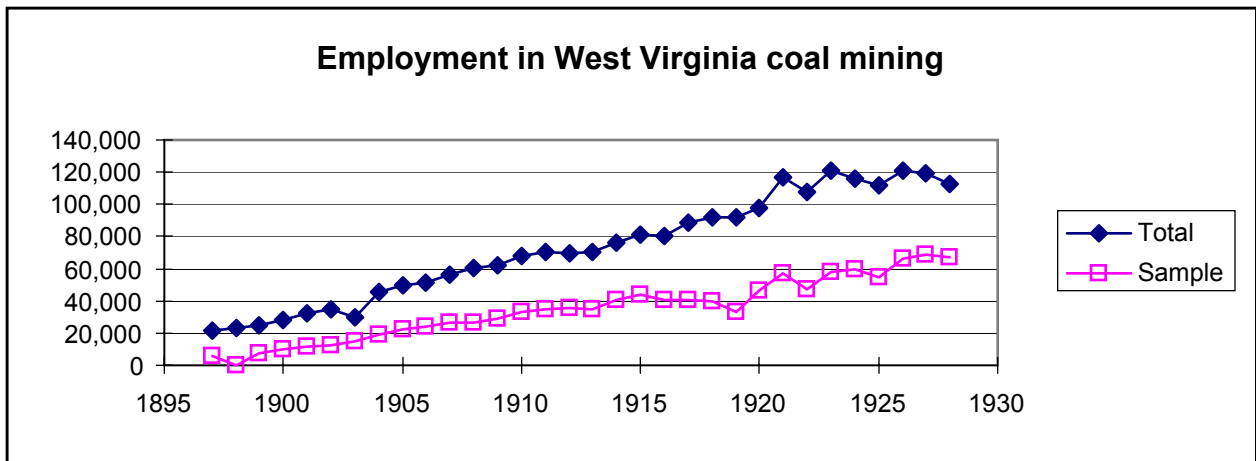


**Figure 2: Comparison of total and sample data for West Virginia coal mines**

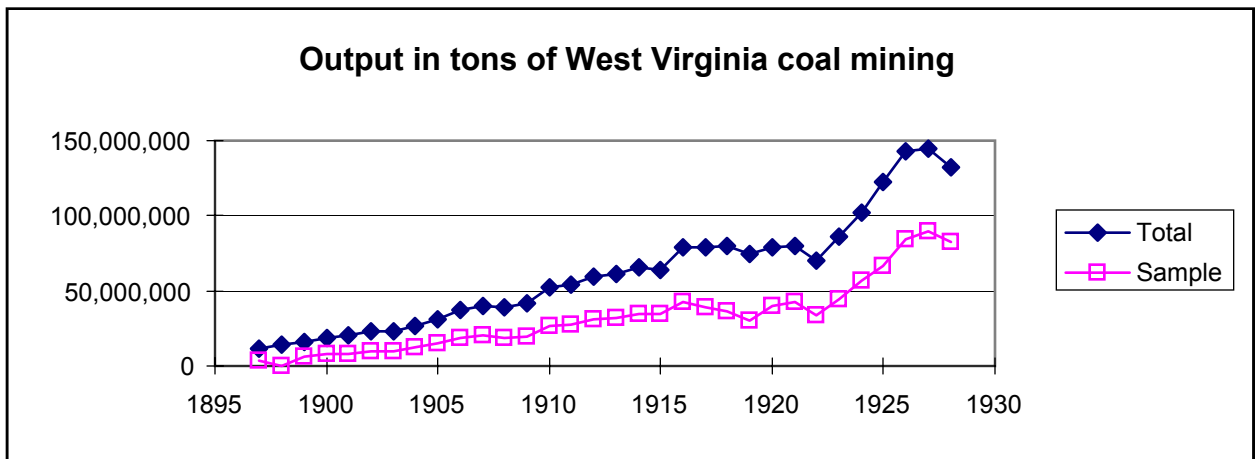
(a)



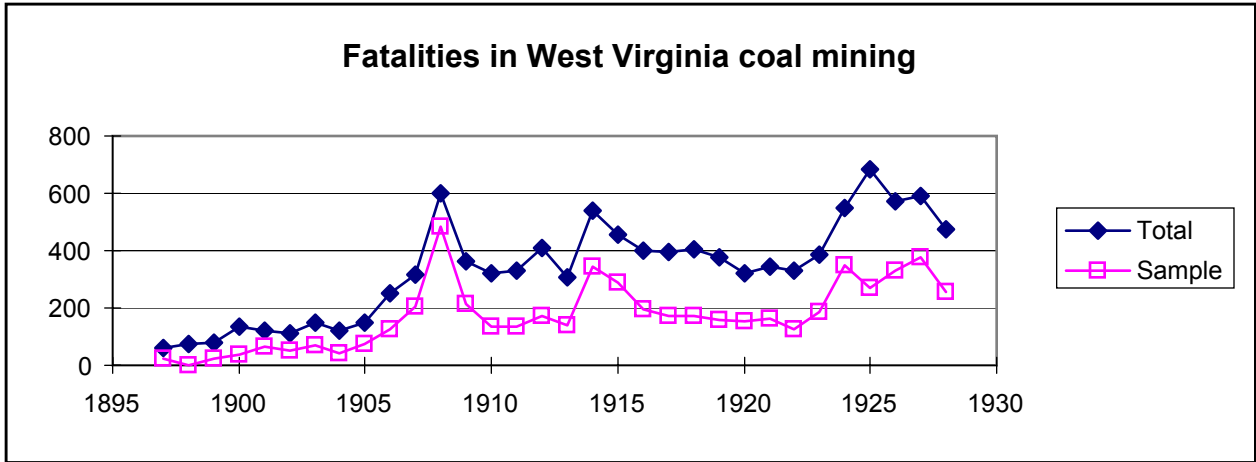
(b)



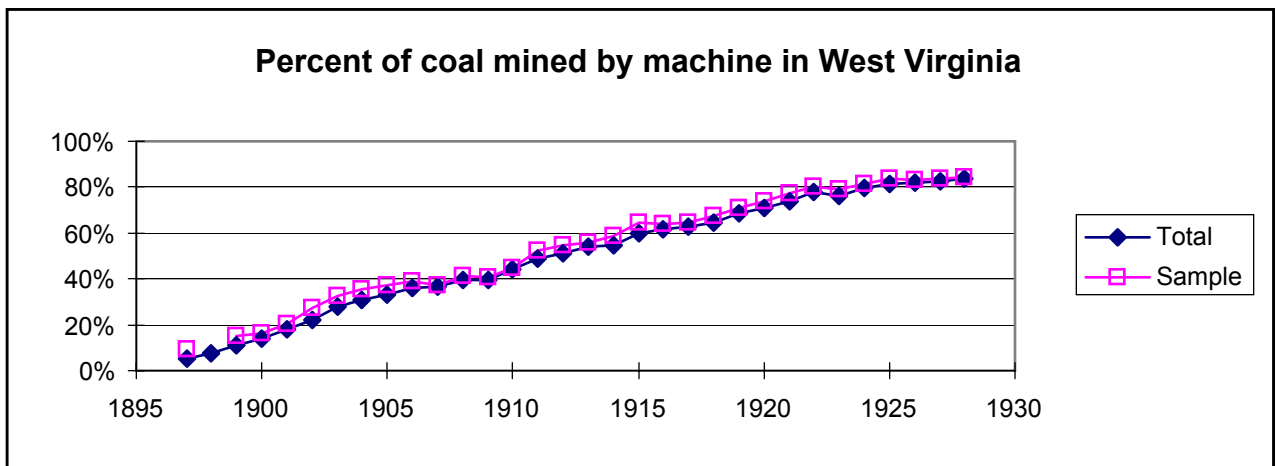
(c)



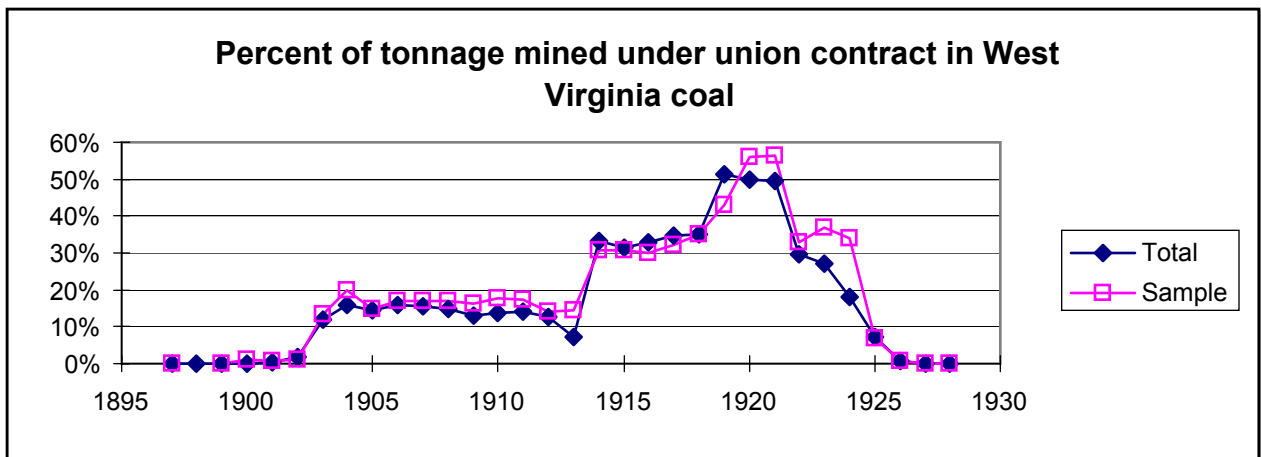
(d)



(e)



(f)



**Table 1:  
Causes of accidents in U.S. coal mining**

**(a) Fatalities in bituminous coal, 1912-1923**

	Number	Percentage of total	Per 1000 employed per year
Falls of roof and coal	9125	50.0%	2.15
Mine cars and locomotives	3313	18.2%	0.78
Explosions of gas and coal dust	2228	12.2%	0.53
Electricity	770	4.2%	0.18
Explosives	685	3.8%	0.16
Other underground	657	3.6%	0.16
Shaft fatalities	360	2.0%	0.08
Surface fatalities	1105	6.1%	0.26
<b>TOTAL</b>	<b>18243</b>	<b>100.0%</b>	<b>4.30</b>

Source: U.S. Coal Commission (1925), vol. 3, p. 1658.

**(b) Nonfatal injuries in all coal mining, 1911**

	Number	Percentage of total	Per 1000 employed
Falls of roof and coal	2860	42.6%	3.96
Mine cars and locomotives	1992	29.6%	2.76
Explosions of gas and coal dust	208	3.1%	0.29
Electricity	34	0.5%	0.05
Explosives	281	4.2%	0.39
Other	1344	20.0%	1.86
<b>TOTAL</b>	<b>6719</b>	<b>100.0%</b>	<b>9.30</b>

Source: Bureau of Mines Bulletin 115, p. 99, table 64.

**Table 2:**  
**Descriptive statistics of state-level panel data, 1902-1929 [a]**

Variable	Number of obs	Mean	Standard Deviation	Minimum	Maximum
Fatalities	394	101.7	160.0	0	799
Fraction of workers who are members of the UMWA	394	0.415	0.335	0	1.027
Total number of workers	394	29814	45816	534	194981
Log total number of workers	394	9.397	1.325	6.280	12.181
Average number of days worked	394	209.3	37.7	97	321
Log average number of days worked	394	5.327	0.190	4.575	5.771
Fraction of output mined by machine	394	0.314	0.272	0	0.994
Number of important mine-safety regulations [b]	383	5.149	2.539	0	10
Law increasing employer liability (dummy variable)	394	0.485	0.500	0	1
Workers Compensation law (dummy variable)	394	0.398	0.490	0	1
Fraction union during Lewis era [c]	394	0.131	0.275	0	1.027
Fraction of output strip-mined	344	0.024	0.072	0	0.493
Fraction of workers on 8-hour day	374	0.707	0.376	0	1
Fraction of workers on 9-hour day	374	0.097	0.205	0	1
Fraction of workers on 10-hour day	374	0.145	0.263	0	0.988
Fraction of output "shot off the solid"	237	0.335	0.285	0.005	1

[a] Years included in panel: 1902, 1904, 1905, 1906, 1907, 1908, 1910, 1911, 1913, 1915, 1917, 1919, 1921, 1923, 1926, and 1929.

States included in panel: Alabama, Arkansas, Colorado, Iowa, Illinois, Indiana, Kansas, Kentucky, Maryland, Michigan, Missouri, Montana, North Dakota, New Mexico, Ohio, Oklahoma, Pennsylvania bituminous, Pennsylvania anthracite, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, and Wyoming.

[b] Regulations are from the following list of 13 suggested by Fishback (1986, 2006):

- Mine must be sprinkled or rock-dusted to prevent explosions.
- Fireboss must examine mine for gas daily in gaseous mines.
- Mine management must provide adequate timbers to prop up roof.
- Underground electric wires must be insulated.
- Miners must not ride on coal cars underground.
- Permissible explosives must be used.
- State inspectors must pass a qualifying exam.
- Inspectors can close a mine immediately for some violations.
- Inspectors can make arrests for safety violations.
- Mine foremen must be licensed by a state board.
- All miners must be licensed by a state board.
- Foremen must ensure that all men have training.
- Foremen must make a minimum number of visits to the workplace each dat.

[c] Fraction of workers who are members of the UMWA times a dummy variable for year 1919 or la

Sources: UMWA membership from Boal (2006), table 3.

Safety regulations from Fishback (1986) pp. 284-285, table 2.

Employer liability and Workers' Compensation laws from Fishback and Kantor (2000, pp. 252-254)

All other data from U.S. Geological Survey.

**Table 3:**  
**NB1 ML estimates of coal mining fatalities for state-level data, 1902-1929**

Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Fraction of workers who are members of the UMWA	-0.335 (0.103)	-0.317 (0.109)	-0.395 (0.119)	-0.590 (0.163)	-0.610 (0.173)	-0.767 (0.212)
Log total number of workers	0.918 (0.096)	0.948 (0.098)	0.950 (0.115)	0.957 (0.114)	0.911 (0.107)	0.932 (0.150)
Log average number of days worked	0.794 (0.088)	0.796 (0.092)	0.835 (0.091)	0.774 (0.153)	0.878 (0.180)	0.957 (0.187)
Fraction of output mined by machine	0.140 (0.214)	0.279 (0.219)	0.297 (0.209)	0.282 (0.246)	0.102 (0.254)	0.777 (0.425)
Number of important mine safety regulations		-0.054 (0.020)	-0.051 (0.020)	-0.054 (0.023)	-0.049 (0.019)	-0.057 (0.034)
Law increasing employer liability (dummy variable)			0.059 (0.121)	0.106 (0.126)	0.090 (0.142)	0.155 (0.144)
Workers' Compensation law (dummy variable)			0.027 (0.144)	0.073 (0.151)	0.104 (0.161)	0.073 (0.148)
Fraction union during Lewis era [a]			0.226 (0.118)	0.229 (0.132)	0.302 (0.174)	0.336 (0.187)
Fraction of output strip-mined				0.151 (0.653)	-0.013 (0.641)	0.228 (0.676)
Fraction of workers on 8-hour day					-0.166 (0.157)	0.043 (0.116)
Fraction of workers on 9-hour day					-0.334 (0.237)	0.076 (0.243)
Fraction of workers on 10-hour day					-0.267 (0.234)	-0.002 (0.209)
Fraction of output "shot off the solid"						0.820 (0.592)
Number of states	25	24	24	24	24	24
Number of (state x year) observations	394	383	383	333	318	210
Log-likelihood function	-1673.1	-1640.5	-1638.9	-1429.5	-1349.5	-879.6

[a] Fraction of workers who are members of the UMWA times a dummy variable for year 1919 or later.

State fixed effects and year fixed effects included in all equations.  
Heteroskedasticity-robust standard errors in parentheses.

**Table 4:**  
**NB1 ML estimates of coal mining fatalities for state-level data by subperiod, 1902-11 and 1913-29**

Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Subperiod	1903-11	1903-11	1903-11	1913-29	1913-29	1913-29
Fraction of workers who are members of the UMWA	-0.553 (0.251)	-0.502 (0.260)	-0.465 (0.264)	-0.521 (0.179)	-0.504 (0.178)	-0.630 (0.211)
Log total number of workers	0.840 (0.304)	0.732 (0.334)	0.008 (0.129)	0.895 (0.139)	0.944 (0.130)	0.897 (0.142)
Log average number of days worked	0.812 (0.151)	0.809 (0.173)	0.446 (0.194)	0.887 (0.142)	0.868 (0.144)	0.961 (0.163)
Fraction of output mined by machine	0.611 (0.480)	1.248 (0.873)	1.307 (0.844)	0.237 (0.371)	0.375 (0.368)	0.561 (0.364)
Number of important mine safety regulations		-0.089 (0.088)	-0.104 (0.080)		-0.039 (0.033)	-0.042 (0.032)
Law increasing employer liability (dummy variable)			-0.204 (0.258)			0.284481 0.153663
Workers' Compensation law (dummy variable)			-0.155 (0.310)			0.166 (0.159)
Fraction union during Lewis era [a]						0.233 (0.177)
Number of states	25	24	24	25	24	24
Number of (state x year) observations	194	191	191	200	192	192
Log-likelihood function	-829.4	-819.4	-823.5	-819.7	-799.1	-796.4

[a] Fraction of workers who are members of the UMWA times a dummy variable for year 1919 or later.

State fixed effects and year fixed effects included in all equations.  
Heteroskedasticity-robust standard errors in parentheses.

For the 1903-1911 subperiod, there were insufficient data or insufficient variation in the data to estimate the effects of strip mining, employer liability, Workers' Compensation laws, and "shooting off the solid."  
For the 1913-1929 subperiod, these effects were not significant at conventional levels.

**Table 5:**  
**Descriptive statistics of mine-level panel data, 1897-1928**

	Number of obs	Mean	Standard Deviation	Minimum	Maximum
Fatalities	7486	0.740	4.774	0	197
Mine under union operation (dummy variable)	7486	0.304	0.460	0	1
Statewide tonnage under union contract (fraction)	7486	0.216	0.164	0.000	0.513
Total number of workers	7486	148.4	111.7	1	1340
Log total number of workers	7486	4.709	0.825	0	7.200
Number of days worked	7486	205.3	65.8	1	365
Log number of days worked	7486	5.243	0.477	0	5.900
Fraction of output mined by machine	7486	0.638	0.390	0	1
Number of important mine-safety regulations [b]	7486	5.659	1.680	3	7
Workers Compensation law (dummy variable)	7486	0.705	0.456	0	1

Note: Year 1898 not included for lack of data.

Sources: Union dummy based on author's compilations (see data appendix).

Statewide unionism from Boal (1994, table 2, pp. 438-439).

Fatalities, workers, days, and fraction of output mined by machine from West Virginia Department of Mines, *Annual Report*.

[b] Regulations are from the following list of 13 suggested by Fishback (1986, 2006):

- Mine must be sprinkled or rock-dusted to prevent explosions.
- Fireboss must examine mine for gas daily in gaseous mines.
- Mine management must provide adequate timbers to prop up roof.
- Underground electric wire must be insulated.
- Miners must not ride on coal cars underground.
- Permissible explosives must be used.
- State inspectors must pass a qualifying exam.
- Inspectors can close a mine immediately for some violations.
- Inspectors can make arrests for safety violations.
- Mine foremen must be licensed by a state board.
- All miners must be licensed by a state board.
- Foremen must ensure that all men have training.
- Foremen must make a minimum number of visits to the workplace each dat.

**Table 6:**  
**NB1 ML estimates of coal mining fatalities for West Virginia mine-level data,**  
**1897-1928**

Regressor	(1)	(2)	(3)	(4)	(5)
Mine under union operation (dummy variable)	-0.423 (0.050)	-0.367 (0.070)	-0.387 (0.070)	-0.204 (0.102)	-0.205 (0.102)
Log total number of workers	0.182 (0.033)	0.181 (0.055)	0.186 (0.056)	0.200 (0.056)	0.200 (0.056)
Log number of days worked	-0.141 (0.032)	-0.108 (0.042)	-0.106 (0.042)	-0.132 (0.042)	-0.132 (0.042)
Annual time trend	-0.0001 (0.003)	0.015 (0.006)	0.011 (0.007)	0.022 (0.008)	0.022 (0.009)
Fraction of output mined by machine	-0.114 (0.058)	-0.105 (0.102)	-0.111 (0.102)	-0.110 (0.102)	-0.111 (0.102)
Number of important mine safety regulations		-0.080 (0.026)	-0.088 (0.025)	-0.094 (0.033)	-0.096 (0.035)
Workers' Compensation law			0.118 (0.074)	0.028 (0.076)	0.023 (0.079)
World War I dummy variable [a]				0.165 (0.108)	0.166 (0.108)
Postwar (Lewis era) dummy variable [b]				-0.077 (0.121)	-0.076 (0.122)
Union dummy during Lewis era [c]				-0.291 (0.138)	-0.294 (0.141)
Statewide tonnage under union contract (fraction)					0.023 (0.170)
Number of mines	533	533	533	533	533
Number of (mine x year) observations	7486	7486	7486	7486	7486
Log-likelihood function	-5948.2	-5943.6	-5942.4	-5930.7	-5930.6

[a] Equals one for 1917 and 1918, and equals zero otherwise.

[b] Equals zero through 1918, and equals one thereafter.

[c] Equals zero through 1918, and equals union dummy variable thereafter.

Mine fixed effects included in all equations.

Heteroskedasticity-robust standard errors in parentheses.

**Table B1:**  
**NB1 ML estimates of coal mining fatalities for state-level data, 1902-1929**  
**with year dummies replaced by time trend.**

Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Fraction of workers who are members of the UMWA	-0.429 (0.088)	-0.313 (0.099)	-0.356 (0.108)	-0.480 (0.143)	-0.477 (0.151)	-0.578 (0.189)
Log total number of workers	1.004 (0.085)	1.022 (0.085)	1.026 (0.099)	1.068 (0.099)	1.021 (0.101)	0.948 (0.121)
Log average number of days worked	0.831 (0.093)	0.864 (0.095)	0.917 (0.104)	0.930 (0.155)	0.999 (0.183)	1.076 (0.157)
Annual time trend	-0.009 (0.002)	-0.002 (0.003)	-0.003 (0.004)	-0.004 (0.005)	-0.002 (0.006)	-0.011 (0.007)
Fraction of output mined by machine	0.008 (0.216)	0.247 (0.213)	0.297 (0.195)	0.235 (0.232)	0.046 (0.242)	0.670 (0.405)
Number of important mine safety regulations		-0.056 (0.016)	-0.053 (0.016)	-0.057 (0.018)	-0.056 (0.016)	-0.048 (0.026)
Law increasing employer liability (dummy variable)			0.014 (0.119)	0.034 (0.124)	0.055 (0.154)	0.129 (0.141)
Workers' Compensation law (dummy variable)			-0.030 (0.120)	-0.014 (0.125)	0.047 (0.152)	0.098 (0.148)
Fraction union during Lewis era [a]			0.128 (0.076)	0.130 (0.086)	0.155 (0.103)	0.238 (0.100)
Fraction of output strip-mined				0.443 (0.638)	0.194 (0.657)	0.273 (0.694)
Fraction of workers on 8-hour day					-0.197 (0.161)	-0.030 (0.104)
Fraction of workers on 9-hour day					-0.376 (0.248)	0.008 (0.261)
Fraction of workers on 10-hour day					-0.161 (0.233)	0.037 (0.195)
Fraction of output "shot off the solid"						0.509 (0.424)
Number of states	25	24	24	24	24	24
Number of (state x year) observations	394	383	383	333	318	210
Log-likelihood function	-1684.8	-1650.2	-1649.3	-1441.1	-1361.8	-881.2
Likelihood ratio test of time trend against year effects - test statistic	23.54	19.32	20.72	23.16	24.6	3.13
Degrees of freedom	15	14	14	14	14	11
P-value	0.073	0.153	0.109	0.058	0.039	0.989

[a] Fraction of workers who are members of the UMWA times a dummy variable for year 1919 or later.

State fixed effects included in all equations.  
Heteroskedasticity-robust standard errors in parentheses.

**Table B2:**  
**Poisson ML estimates of coal mining fatalities for state-level data, 1902-1929**

Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Fraction of workers who are members of the UMWA	-0.421 (0.147)	-0.381 (0.151)	-0.458 (0.166)	-0.673 (0.209)	-0.830 (0.221)	-0.992 (0.271)
Log total number of workers	1.006 (0.140)	1.022 (0.140)	1.089 (0.176)	1.177 (0.177)	1.044 (0.148)	1.052 (0.198)
Log average number of days worked	0.838 (0.112)	0.851 (0.114)	0.909 (0.119)	0.803 (0.185)	0.940 (0.216)	0.988 (0.226)
Fraction of output mined by machine	0.003 (0.295)	0.288 (0.303)	0.372 (0.293)	0.274 (0.339)	-0.034 (0.308)	0.918 (0.535)
Number of important mine safety regulations		-0.083 (0.028)	-0.082 (0.030)	-0.089 (0.033)	-0.065 (0.023)	-0.056 (0.040)
Law increasing employer liability (dummy variable)			-0.047 (0.146)	-0.005 (0.155)	0.007 (0.162)	0.146 (0.171)
Workers' Compensation law (dummy variable)			-0.076 (0.174)	-0.038 (0.187)	0.030 (0.191)	0.084 (0.190)
Fraction union during Lewis era [a]			0.233 (0.161)	0.220 (0.179)	0.425 (0.241)	0.468 (0.257)
Fraction of output strip-mined				0.807 (0.993)	0.380 (0.895)	0.871 (0.944)
Fraction of workers on 8-hour day					-0.140 (0.190)	0.081 (0.153)
Fraction of workers on 9-hour day					-0.376 (0.268)	0.148 (0.277)
Fraction of workers on 10-hour day					-0.410 (0.269)	0.019 (0.280)
Fraction of output "shot off the solid"						1.230 (0.761)
Number of states	25	24	24	24	24	24
Number of (state x year) observations	394	383	383	333	318	210
Log-likelihood function	-2959.2	-2832.4	-2816.5	-2524.0	-2232.4	-1402.7
T-test against NB1 overdispersion [b]	3.685	4.227	4.326	4.342	4.413	3.766
P-value, one-sided test	0.00011	0.00001	0.00001	0.00001	0.00001	0.00008

[a] Fraction of workers who are members of the UMWA times a dummy variable for year 1919 or later.

[b] See Cameron & Trivedi (1998) p.78 eq. (3.40).

State fixed effects and year fixed effects included in all equations.  
Heteroskedasticity-robust standard errors in parentheses.

**Table B3:**  
**Poisson ML estimates of coal mining fatalities for state-level data, 1902-1929**  
**with year dummies replaced by time trend.**

Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Fraction of workers who are members of the UMWA	-0.516 (0.121)	-0.333 (0.139)	-0.394 (0.149)	-0.562 (0.181)	-0.610 (0.182)	-0.706 (0.213)
Log total number of workers	1.095 (0.127)	1.093 (0.123)	1.151 (0.144)	1.273 (0.147)	1.197 (0.145)	1.085 (0.161)
Log average number of days worked	0.879 (0.111)	0.936 (0.116)	1.015 (0.138)	1.033 (0.201)	1.096 (0.226)	1.138 (0.204)
Annual time trend	-0.0091 (0.003)	-0.0001 (0.004)	-0.004 (0.005)	-0.005 (0.006)	-0.003 (0.684)	-0.014 (0.008)
Fraction of output mined by machine	-0.159 (0.308)	0.249 (0.306)	0.363 (0.278)	0.227 (0.340)	-0.106 (0.309)	0.743 (0.526)
Number of important mine safety regulations		-0.075 (0.022)	-0.074 (0.023)	-0.082 (0.025)	-0.068 (0.019)	-0.051 (0.029)
Law increasing employer liability (dummy variable)			-0.088 (0.152)	-0.071 (0.157)	-0.035 (0.183)	0.139 (0.166)
Workers' Compensation law (dummy variable)			-0.093 (0.148)	-0.070 (0.153)	-0.020 (0.181)	0.108 (0.168)
Fraction union during Lewis era [a]			0.146 (0.102)	0.148 (0.118)	0.199 (0.137)	0.285 (0.135)
Fraction of output strip-mined				1.148 (0.949)	0.707 (0.918)	0.878 (0.965)
Fraction of workers on 8-hour day					-0.227 (0.185)	0.0001 (0.126)
Fraction of workers on 9-hour day					-0.398 (0.300)	0.098 (0.297)
Fraction of workers on 10-hour day					-0.262 (0.279)	0.154 (0.274)
Fraction of output "shot off the solid"						0.713 (0.566)
Number of states	25	24	24	24	24	24
Number of (state x year) observations	394	383	383	333	318	210
Log-likelihood function	-3069.3	-2934.4	-2920.41	-2648.9	-2363.1	-1425.7
T-test against NB1 overdispersion [b]	3.825	4.134	4.245	4.286	4.221	3.568
P-value, one-sided test	0.00007	0.00002	0.00001	0.00001	0.00001	0.00018
Likelihood ratio test of time trend against year effects - test statistic	220.22	203.98	207.76	249.8	261.32	46.02
Degrees of freedom	15	14	14	14	14	11
P-value	0.000000	0.000000	0.000000	0.000000	0.000000	0.000003

[a] Fraction of workers who are members of the UMWA times a dummy variable for year 1919 or later.

[b] See Cameron & Trivedi (1998) p.78 eq. (3.40).

State fixed effects included in all equations.  
Heteroskedasticity-robust standard errors in parentheses.

**Table B4:**  
**NLS estimates of coal mining fatalities for state-level data, 1902-1929**

Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Fraction of workers who are members of the UMWA	-0.327 (0.122)	-0.257 (0.126)	-0.324 (0.142)	-0.912 (0.219)	-1.318 (0.308)	-0.641 (0.227)
Log total number of workers	1.098 (0.131)	1.117 (0.133)	1.228 (0.193)	1.182 (0.176)	1.185 (0.169)	1.013 (0.156)
Log average number of days worked	0.886 (0.113)	0.924 (0.119)	0.987 (0.124)	0.753 (0.180)	0.853 (0.191)	0.770 (0.169)
Fraction of output mined by machine	-0.442 (0.380)	-0.220 (0.399)	-0.125 (0.352)	0.144 (0.398)	-0.325 (0.397)	0.233 (0.587)
Number of important mine safety regulations		-0.048 (0.032)	-0.051 (0.031)	-0.057 (0.032)	-0.040 (0.027)	-0.059 (0.038)
Law increasing employer liability (dummy variable)			-0.088 (0.176)	0.021 (0.149)	-0.105 (0.184)	0.178 (0.145)
Workers' Compensation law (dummy variable)			-0.092 (0.218)	-0.059 (0.210)	-0.084 (0.206)	0.016 (0.184)
Fraction union during Lewis era [a]			0.162 (0.129)	0.388 (0.165)	0.831 (0.294)	0.196 (0.231)
Fraction of output strip-mined				0.700 (1.285)	0.773 (1.226)	0.148 (0.140)
Fraction of workers on 8-hour day					0.160 (0.141)	0.148 (0.140)
Fraction of workers on 9-hour day					-0.166 (0.244)	0.076 (0.235)
Fraction of workers on 10-hour day					-0.503 (0.309)	0.157 (0.274)
Fraction of output "shot off the solid"						0.218 (1.046)
Number of states	25	24	24	24	24	24
Number of (state x year) observations	394	383	383	333	318	210

[a] Fraction of workers who are members of the UMWA times a dummy variable for year 1919 or later.

State fixed effects and year fixed effects included in all equations.  
Heteroskedasticity-robust standard errors in parentheses.

**Table B5:**  
**NLS estimates of coal mining fatalities for state-level data, 1902-1929,**  
**with year dummies replaced by time trend.**

Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Fraction of workers who are members of the UMWA	-0.440 (0.119)	-0.270 (0.138)	-0.294 (0.151)	-0.653 (0.207)	-0.712 (0.249)	-0.487 (0.167)
Log total number of workers	1.239 (0.159)	1.181 (0.148)	1.193 (0.201)	1.314 (0.233)	1.283 (0.240)	0.933 (0.132)
Log average number of days worked	0.851 (0.117)	0.918 (0.126)	0.948 (0.150)	0.946 (0.219)	1.023 (0.280)	0.882 (0.165)
Annual time trend	-0.010 (0.004)	-0.006 (0.004)	-0.007 (0.005)	-0.007 (0.006)	-0.006 (0.007)	-0.006 (0.007)
Fraction of output mined by machine	-0.684 (0.454)	-0.273 (0.442)	-0.214 (0.347)	-0.353 (0.507)	-0.690 (0.530)	0.174 (0.540)
Number of important mine safety regulations		-0.045 (0.020)	-0.044 (0.021)	-0.054 (0.024)	-0.053 (0.026)	-0.025 (0.026)
Law increasing employer liability (dummy variable)			-0.020 (0.206)	0.014 (0.198)	-0.007 (0.264)	0.243 (0.146)
Workers' Compensation law (dummy variable)			-0.027 (0.195)	-0.024 (0.197)	-0.040 (0.263)	0.161 (0.175)
Fraction union during Lewis era [a]			0.060 (0.100)	0.121 (0.110)	0.176 (0.173)	0.079 (0.112)
Fraction of output strip-mined				2.111 (1.350)	2.093 (1.448)	-0.274 (1.321)
Fraction of workers on 8-hour day					-0.078 (0.151)	0.064 (0.088)
Fraction of workers on 9-hour day					-0.156 (0.285)	0.060 (0.233)
Fraction of workers on 10-hour day					-0.272 (0.413)	0.230 (0.229)
Fraction of output "shot off the solid"						-0.079 (0.539)
Number of states	25	24	24	24	24	24
Number of (state x year) observations	394	383	383	333	318	210

[a] Fraction of workers who are members of the UMWA times a dummy variable for year 1919 or later.

State fixed effects included in all equations.  
Heteroskedasticity-robust standard errors in parentheses.

**Table B6:**  
**N2SLS estimates of coal mining fatalities for state-level data, 1902-1929**  
**with year dummies replaced by time trend.**

Regressor	(1)	(2)	(3)	(4)	(5)	(6)
Fraction of workers who are members of the UMWA	-0.430 (0.251)	-0.031 (0.291)	1.073 (0.782)	1.698 (1.287)	3.192 (2.584)	-15.872 (55.233)
Log total number of workers	1.084 (0.137)	1.065 (0.136)	0.989 (0.208)	1.053 (0.221)	0.977 (0.259)	4.583 (13.972)
Log average number of days worked	0.897 (0.113)	0.986 (0.121)	0.707 (0.203)	1.008 (0.293)	1.194 (0.441)	1.179 (3.082)
Annual time trend	-0.010 (0.004)	-0.001 (0.004)	0.016 (0.011)	0.017 (0.015)	0.043 (0.034)	-0.357 (1.514)
Fraction of output mined by machine	-0.114 (0.360)	0.456 (0.388)	0.942 (0.581)	0.825 (0.670)	0.787 (1.015)	3.739 (23.745)
Number of important mine safety regulations		-0.086 (0.023)	-0.124 (0.037)	-0.119 (0.036)	-0.138 (0.055)	0.318 (1.326)
Law increasing employer liability (dummy variable)			-0.181 (0.181)	-0.134 (0.194)	0.009 (0.236)	-0.680 (4.017)
Workers' Compensation law (dummy variable)			-0.256 (0.193)	-0.310 (0.240)	-0.242 (0.285)	0.360 (0.537)
Fraction union during Lewis era [a]			-0.694 (0.460)	-0.595 (0.499)	-0.732 (0.760)	4.109 (16.106)
Fraction of output strip-mined				4.625 (2.345)	5.343 (3.444)	-15.416 (57.041)
Fraction of workers on 8-hour day					-0.564 (0.369)	0.464 (1.283)
Fraction of workers on 9-hour day					-0.498 (0.422)	1.635 (6.374)
Fraction of workers on 10-hour day					0.020 (0.446)	-0.703 (5.064)
Fraction of output "shot off the solid"						1.281 (5.127)
Number of states	25	24	24	24	24	24
Number of (state x year) observations	394	383	383	333	318	210

[a] Fraction of workers who are members of the UMWA times a dummy variable for year 1919 or later.

State fixed effects included in all equations.  
Heteroskedasticity-robust standard errors in parentheses.

**Table B7:**  
**Poisson ML estimates of coal mining fatalities for West Virginia mine-level data,**  
**1897-1928**

Regressor	(1)	(2)	(3)	(4)	(5)
Mine under union operation (dummy variable)	-0.300 (0.317)	-0.176 (0.369)	-0.161 (0.325)	0.440 (0.400)	0.386 (0.379)
Log total number of workers	0.355 (0.273)	0.306 (0.256)	0.305 (0.256)	0.292 (0.253)	0.295 (0.254)
Log number of days worked	0.398 (0.222)	0.420 (0.223)	0.420 (0.222)	0.266 (0.227)	0.307 (0.230)
Annual time trend	-0.020 (0.012)	0.018 (0.022)	0.020 (0.016)	0.019 (0.014)	0.032 (0.016)
Fraction of output mined by machine	-0.006 (0.266)	0.004 (0.259)	0.008 (0.257)	0.008 (0.259)	-0.016 (0.262)
Number of important mine safety regulations		-0.197 (0.120)	-0.194 (0.133)	-0.045 (0.124)	-0.084 (0.134)
Workers' Compensation law			-0.062 (0.283)	-0.222 (0.273)	-0.351 (0.246)
World War I dummy variable [a]				-0.549 (0.272)	-0.549 (0.272)
Postwar (Lewis era) dummy variable [b]				-0.254 (0.225)	-0.228 (0.226)
Union dummy during Lewis era [c]				-1.222 (0.439)	-1.309 (0.458)
Statewide tonnage under union contract (fraction)					0.679 (0.304)
Number of mines	533	533	533	533	533
Number of (mine x year) observations	7486	7486	7486	7486	7486
Log-likelihood function	4339.7	4387.1	4387.7	4524.3	4536.8

[a] Equals one for 1917 and 1918, and equals zero otherwise.

[b] Equals zero through 1918, and equals one thereafter.

[c] Equals zero through 1918, and equals union dummy variable thereafter.

Mine fixed effects included in all equations.

Heteroskedasticity-robust standard errors in parentheses.

**Table B8:**  
**NB1 ML estimates of coal mining nonfatal accidents for West Virginia**  
**mine-level data, 1897-1928**

Regressor	(1)	(2)	(3)	(4)	(5)
Mine under union operation (dummy variable)	-0.054 (0.074)	0.008 (0.074)	-0.006 (0.072)	0.185 (0.098)	0.176 (0.101)
Log total number of workers	0.225 (0.044)	0.219 (0.043)	0.226 (0.043)	0.227 (0.045)	0.228 (0.045)
Log number of days worked	-0.205 (0.037)	-0.129 (0.038)	-0.129 (0.038)	-0.225 (0.041)	-0.228 (0.040)
Annual time trend	0.010 (0.005)	0.054 (0.008)	0.045 (0.009)	0.072 (0.011)	0.073 (0.011)
Fraction of output mined by machine	0.082 (0.099)	0.087 (0.097)	0.086 (0.097)	0.038 (0.097)	0.035 (0.097)
Number of important mine safety regulations		-0.192 (0.027)	-0.191 (0.026)	-0.085 (0.028)	-0.089 (0.029)
Workers' Compensation law			0.159 (0.077)	-0.044 (0.078)	-0.065 (0.072)
World War I dummy variable [a]				-0.390 (0.082)	-0.394 (0.083)
Postwar (Lewis era) dummy variable [b]				-0.639 (0.113)	-0.646 (0.115)
Union dummy during Lewis era [c]				-0.307 (0.123)	-0.309 (0.122)
Statewide tonnage under union contract (fraction)					0.175 (0.222)
Number of mines	517	517	517	517	517
Number of (mine x year) observations	5779	5779	5779	5779	5779
Log-likelihood function	-6747.1	-6714.9	-6711.8	-6661.6	-6661.2

[a] Equals one for 1917 and 1918, and equals zero otherwise.

[b] Equals zero through 1918, and equals one thereafter.

[c] Equals zero through 1918, and equals union dummy variable thereafter.

Mine fixed effects included in all equations.

Heteroskedasticity-robust standard errors in parentheses.