Short-term Innovative and Exploratory Research Project

ALPHA FOUNDATION FOR THE IMPROVEMENT OF MINE SAFETY AND HEALTH

The Impact of Contractor Utilization on Health and Safety in Underground Kentucky Coal Mines

Final Technical Report

1.0 – COVER PAGE –

Grant Number: AFSTI14-1

Project Title:	The Impact of Contractor Utilization on Health and Safety.
Organization:	Boston University School of Public Health
Principal Investigator(s):	Leslie I. Boden.
Contact Information:	email - lboden@bu.edu; phone - 617-638-4635
Full Period of Performance:	May 1, 2014 –July 31, 2015

ACKNOWLEDGEMENTS/DISCLAIMERS

This study was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (ALPHA FOUNDATION). The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.

1.0 COVER PAGE
2.0 EXECUTIVE SUMMARY 2
3.0 PROBLEM STATEMENT AND INNOVATION OBJECTIVE 4
Related Research 5
4.0 RESEARCH APPROACH 6
Contractor Indicator 6
Other Data Sources 11
Methods 11
Outcome variables 11
Control variables 12
Statistical Specification 16
5.0 SUMMARY OF ACCOMPLISHMENTS AND INNOVATION HIGHLIGHTS 16
Violations 17
Injury Rates 18
6.0 CONCLUSION & INNOVATION ASSESSMENT 20
7.0 REFERENCES 22
8.0 TECHNICAL APPENDIX 24

2.0 EXECUTIVE SUMMARY

Background:

How a firm chooses to allocate employment has important consequences for the health and safety of workers. Weil (2014) discusses the use of subcontracting arrangements across a number of industries and shows the systematic negative effect these agreements can have on worker outcomes. Underground mining has historically been one of the most dangerous industries in the United States. Coleman et al. (2007) found that between the years 1983 and 2004, about 5700 person years were lost each year due to mine worker injuries.

There are two main types of contracting arrangements prevalent in the coal industry: independent contractors and contract operators. An independent contractor is "any person, partnership, corporation, firm association or other organization that contracts to perform services or construction at a mine" (Barret, Fotta, and Rethi, 1996). On the other hand, a contract operator runs day-to-day activities of the mining operation and is liable for employees but typically leases mine operating rights and equipment from a larger, unaffiliated company and sells all production to that company. Research focused on understanding the role between this type of ownership arrangement and health and safety outcomes has been hampered by the inability to systematically identify which mines have contract operators.

Objective:

The objectives of this study are as follows: (1) to use existing data sources (environmental reclamation and mine safety data) to identify contractor-operated underground coal mines in Kentucky; (2) to determine if the utilization of contract operators has changed over time; and (3) to test if there exist differences in Mine Safety and Health Act violations and higher injury rates for contract-operated mines relative to owner-operator mines, controlling for other explanatory factors.

Methods:

We used MSHA data to identify the operator of these mines and surface reclamation permit data to identify the owner. Disparities between the operator or its controller and the owner or its parent indicated the presence of a contractor operator.[1] We then used negative binomial regression to estimate MSHA compliance violations, significant and substantial violations, injury rates, and traumatic injury rates, controlling for mine and controller characteristics available from MSHA and the Energy Information Administration (EIA). Because of data limitations, we focused on violations and injuries in 1999-2013. Following Morantz (2013), who writes that traumatic injury rates are less likely to be underreported

[1] A controller is the legal owner of the operating entity of a mine.

and therefore more reliable measures of worker risk, we focused our attention on traumatic injuries[2]. Based on our calculations, only 3 percent of contractor-operator mining quarters occurred in mines reporting more than 60 full-time equivalent (FTE) employees, compared with 24 percent of non-contractor-operator quarters. For this reason, we restricted our analysis to mines with no more than 60 FTEs.

Findings:

We were able to identify the contractor status of 88 percent of the active underground coal mine-quarters in Kentucky between 1993 and 2014 by comparing the operator identified in MSHA records with the reclamation permit holder, supplemented with additional information about controllers and subsidiaries. In some cases, information was missing from the permit databases, so we were unable to determine their status. After identifying contractor status, we were able to determine the time trend of contractor-operated underground mines (Figure 2). We found no trend over the past 20 years in the proportion of these mines operated by contractors. However, in the past 5 years, there was an upward trend among small mines, where contractor operation is concentrated.

We did not find significant differences in violations or significant and substantial violations between contractor and non-contractor operated mines (Tables 3 and 4). In the 1999-2013 period, contractor operated mines with 15 or fewer FTEs had a statistically-significant 57 percent higher reported traumatic injury rate than similar mines without contract operators (Table 6). There was no statistically significant difference in the reported traumatic injury rate in mines with more than 15 FTEs but no more than 30. For mines with more than 30 and up to 60 FTEs, contractor-operated mines experienced an injury rate 73 percent of otherwise similar non-contract mines. That is, excess contractor risks only occurred in the smallest mines. These results apply only to underground coal mines in Kentucky. Experience may differ in West Virginia and other states with contractor operated underground coal mines. We also note that differences we found between contractor-operated mines and other mines may not be causal. On the other hand, not finding statistically-significant differences does not imply that differences do not exist. Data quality or sample size may have been inadequate to detect actual differences.

Assessment of Innovation:

This study has employed a new method to determine whether a mine is operated by its owner or by a contractor. This method, linking reclamation permit data to MSHA data, allows researchers to understand the impact of contractor's operating mines on safety, exposure to coal mine dust, productivity, and other outcomes. This novel approach should allow much more accurate identification of contractor-operated mines than methods used in the past. We consider this a

[2] Using Morantz's definition, traumatic injuries include amputations, enucleations, fractures, chips, dislocations, foreign bodies in eyes, cuts and lacerations, punctures, burns/scalds, crushings, and (chemical, electrical, and laser) burns. They also include all fatal injuries.

breakthrough; although its importance will depend on whether research using this method can identify mines that require special attention because their employees may be at additional risk.

Recommendations:

1. Traumatic injury rates for the smallest contractor mines operating with less than 15 FTEs appear substantially elevated. This may suggest the value of increased regulatory scrutiny of those mines. There is some statistically insignificant indication that somewhat larger contract mines may be more dangerous than similar-sized non-contract mines.
2. However, we found no evidence that contractor-operated mines operating with 16 to 60 FTEs are more dangerous than non-contractor-operated mines of the same size. This may suggest that these mines do not need additional regulatory attention. It may be worth repeating this research in West Virginia to see if our results can be reproduced.
3. Determining which mines were contractor-operated was time-consuming and expensive. If MSHA altered its reporting guidelines to require mine operators to report injuries and hours worked by site and contractor-operator status, identification of contractor-operated mines would be simpler, more complete, and more accurate. Additional analysis of safety and health conditions in these mines could be done more easily and quickly.

3.0 PROBLEM STATEMENT AND INNOVATION OBJECTIVE

How a firm chooses to allocate employment has important consequences for the health and safety of workers. Weil (2014) discusses the use of subcontracting arrangements across a number of industries and shows the systematic negative effect these agreements can have on worker outcomes. Evidence from high risk industries such as petrochemical, construction and trucking indicate the negative effects associated with contracting out work result from a desire by companies to avoid liability or regulatory oversight (Rebitzer, 1995; Azari-Rad, Philips, and Thompson-Dawson, 2003; James, Johnstone, Quinlan, and Walters, 2007).

There are two main types of contracting arrangements prevalent in the coal industry: independent contractors and contract operators. An independent contractor is "any person, partnership, corporation, firm association or other organization that contracts to perform services or construction at a mine" (Barret, Fotta, and Rethi, 1996). Subcontracting of this variety provides for gains in specialization to the operator and in terms of economic efficiency more broadly. On the other hand, a contract operator runs day-to-day activities of the mining operation and is liable for employees but typically leases mine operating rights and equipment from a larger, unaffiliated company and sells all production to that company. There is suggestive evidence that contract operators have been used to operate a substantial proportion of underground coal mines, however, because this status is not tracked by any regulatory body, it has been difficult to determine the true prevalence of this ownership arrangement overtime.

Understanding the relationship between contract work and workplace injury and illness is likely an important aspect to consider in any strategy used to improve worker outcomes. The primary barrier to understanding this relationship has been a lack of data on these contracting arrangements.

Related Research

[Mining and Organization]

Underground mining has historically been one of the most dangerous industries in the United States. Coleman et al. (2007) found that between the years 1983 and 2004, about 5700 person years were lost each year due to mine worker injuries. Multiple factors have been connected to mine injuries – including (but not limited to) behavioral concerns (Coleman et al. 2007), profitability (Asfaw et al. 2013), and mine size (Peters and Fotta 1994). Additional concerns can include length of worker shift, years of mine employment, and age.

In addition to the more 'traditional' factors impacting mine safety, the rapid increase in the number of miners working for contract operations has also been of interest to researchers. Although the Mine Safety Health Administration (MSHA) collects data on contractors in mining (including hours worked, and the number of injuries), it does not collect these data on a mine-specific basis. This presents a hurdle when trying to determine whether contractors are more at risk within individual mines than are controller-employed workers. Several studies have attempted to characterize injury disparities between independent contracted and traditional mine workers. Muzaffar et al. (2013) evaluated data on both independent contract workers (not miners working for contractor-operators) and traditional mine workers between 1998 and 2007 to determine if there were notable differences between the two groups in relation to fatal mining accidents. Their data indicated that the univariate odds of a fatal incident as opposed to a non-fatal incident were 2.8 times higher for contracted workers than operators. They also utilized a multivariate model, which associated other factors with fatality. These included being an independent contract worker, being more than 8 hours into a working day, and having less overall experience in that specific mine. However, this study did not address differences in type of work being done and this could bias results upwards.

A 2011 NIOSH study, led by Pappas and Mark suggested that there were large safety disparities between contractor-operated underground coal mines and non-contractor mines. Examining the period from 1992 to 2009, they calculated the contract operator injury rate per 200,000 hours to be 16.6, as compared to 10.8 for all mines. However, there were two major problems with this comparison. First, their method of identifying contractor-operated mines excluded mines with no injuries, thus biasing upward the calculated injury rate. In addition, the injury rate comparison did not take mine size into account. Contractor-operated mines are generally smaller, and smaller mines tend to have higher injury rates.

Work done by Buessing and Weil in a 2014 working paper suggests that there is "increased risk exposure for contract operations and mines with high contractor utilization". They utilized MSHA data from 2000 to 2010 and modeled factors leading to negative health outcomes, such as geology, unionization, mine size, controller, and history of violations. Their results suggested that there are certain contracting companies that are typically performing riskier work (construction, blasting, etc.). As a result, there are differences in the types of contractors that are hired – some that are higher risk positions, and some that have lower injury rates (engineers, for example). They suggest that there are increased rates of injuries among contractor workers overall, and that it is suggestive that tactics to avoid liability lead to poorer worker health and safety outcomes.

[Innovation Objective]

Research on the safety impacts of contractors' operating underground coal mines has been hampered by the difficulty of identifying which mines are operated by contractors. MSHA's contractor database does not identify where contractors worked or whether the contracting is for a specialized function (for example, trucking or electrical work) or for operating a mine. Previous research has had limited success in overcoming this problem. Our innovation, as described below, is using surface reclamation permit data to identify the owner of the mine and comparing the owner and the operator to determine whether they are the same or part of the same organization (for example, subsidiaries of the same controller). This allows us to identify contractor-operated mines and conduct a statistical analysis that does not suffer from the same biases as discussed above. It provides a method by which other researchers can identify contractor-operated mines, enabling them to conduct research on whether these mines differ in important ways from traditionally operated mines. Our safety research could be done in other states and, in addition, other outcomes, like productivity, could be studied.

4.0 RESEARCH APPROACH

Contractor Indicator

The universe of mines considered for analysis was all active Kentucky underground mines going back to 1983.

To create this dataset the following resources were utilized.

- Mine Safety and Health Administration (MSHA) Data: Quarterly production and employment files along with administrative records on ownership were all sourced from MSHA's Enforcement Data (website: http://ogesdw.dol.gov/views/data_catalogs.php).
- Applicant Violator System (AVS) Data: This database from the Office of Surface Mines (OSM) has information on all the mining permits issued in the US. We were provided with an AVS data extract for all Kentucky permits going back to 1983.[3] Each observation is a permit entry with issue date and expiration

[3] The file is referred to as "KY Permits-05302014.xlsx" in the data creation files and was provided by Charles DeVinney of OSM.

date. The data also contain information on the MSHA IDs covered by the permit, the permit holder, its parent company, the operators and the operator's parent company.[4]

- Surface Mining Information System (SMIS) Data: Available through Kentucky's Division of Mine Permits, the database was used as an alternative source for linking permits to MSHA IDs. Along with providing the relevant permit numbers for a MSHA ID, it also provided information on ownership and mine location. The interface can be accessed through the website (http://minepermits.ky.gov/Pages/SurfaceMiningInformationSystem.aspx).[5]
- Kentucky Mine Mapping Information System Data (KMMIS): A tool provided by Kentucky's Division of Mine Safety, this website provides information on permits issued for an MSHA ID. The information on the website allowed us to fill in missing data on the AVS database (website: http://minemaps.ky.gov/MineSearch.aspx)

Using these databases, we constructed a quarterly panel database of all active underground mines in Kentucky going back to 1983. The database contained owner and operator information as sourced from MSHA and the relevant permit associated with a mine as well as the operator and permit holder associated with that permit from the AVS database. This data structure gave us the ability to simultaneously compare which companies were held responsible for a mine by the two regulatory bodies in a given period of time. We hypothesized that finding discrepancies in this information would allow us to differentiate contract operations from other mining operations.

Our initial build of this database used information on MSHA IDs that existed on both sources to connect observations. Unfortunately, records are much less complete for the period prior to 1990. Given the high percentage of missing information and the unreliability of data from the 1980's, we focused our data entry and auditing on observations from 1990 to the present. As a result, our full sample is 30,191 mine-quarter observations. (See Figure 1 for a description of the sample selection process).

Some mines did not have permit data using our method merging MSHA IDs and time periods. We filled in this missing information by using the KMMIS and SMIS. Specifically, we first did a manual search for MSHA ID's that had no permit information in the AVS. If any permitting information existed, it was entered in a manner similar to the AVS data and subsequently merged with the MSHA data using the MSHA ID. As a quality control measure, this process was independently conducted by two research assistants. Any discrepancy across the two independent entries was pulled for further review and, after comparing the two manual entries with the original source, one of the two was kept.

[4] The AVS data can be accessed on a single observation basis through the AVS website (https://avss.osmre.gov/secure/home.aspx). A user has full access to the database on a query basis if logged in as a guest.
[5] To access this website one has to use IE8 and Java needs to be updated to the latest version.

Some MSHA IDs had permitting information, but the permit dates did not cover all production periods. Each of these problematic observations was reviewed individually and our best judgment about the correct permit information for a given quarter was determined using the KMMIS and SMIS data. At the end of this data entry process, 11% of mines in our database had missing permit information.

There were situations where the controller listed by MSHA was a subsidiary of a larger company. To avoid counting a subsidiary as a contract operator, we gathered the top national coal producer lists from 1994-2012 (all years publicly available online through the Energy Information Administration (EIA). We compared this list to our mine dataset to determine which of those companies that appeared on the EIA's lists also appeared in our dataset. For those companies that were present in both lists, we acquired their subsidiaries' names from the U.S. Security Exchange Commission for all years that information was available. For every subsidiary, we manually checked if they were listed as a controller in the MSHA dataset. This examination allowed us to account for spelling discrepancies between the S.E.C. and our mine dataset. We adjusted our algorithm to recode any mines operated by these subsidiaries as non-contractor operations.

With our completed dataset, we examined the ownership information associated with each mine across the data sources. Using matching algorithms, we calculated the number of mines for which an operator or a controller coincided with a permit holder or its parent company across the two data sources. Mines that were not matched were part of our universe of potential contract operations. Of these, we reclassified as non-contractor those mines for which the operator was controlled by large publicly traded companies.

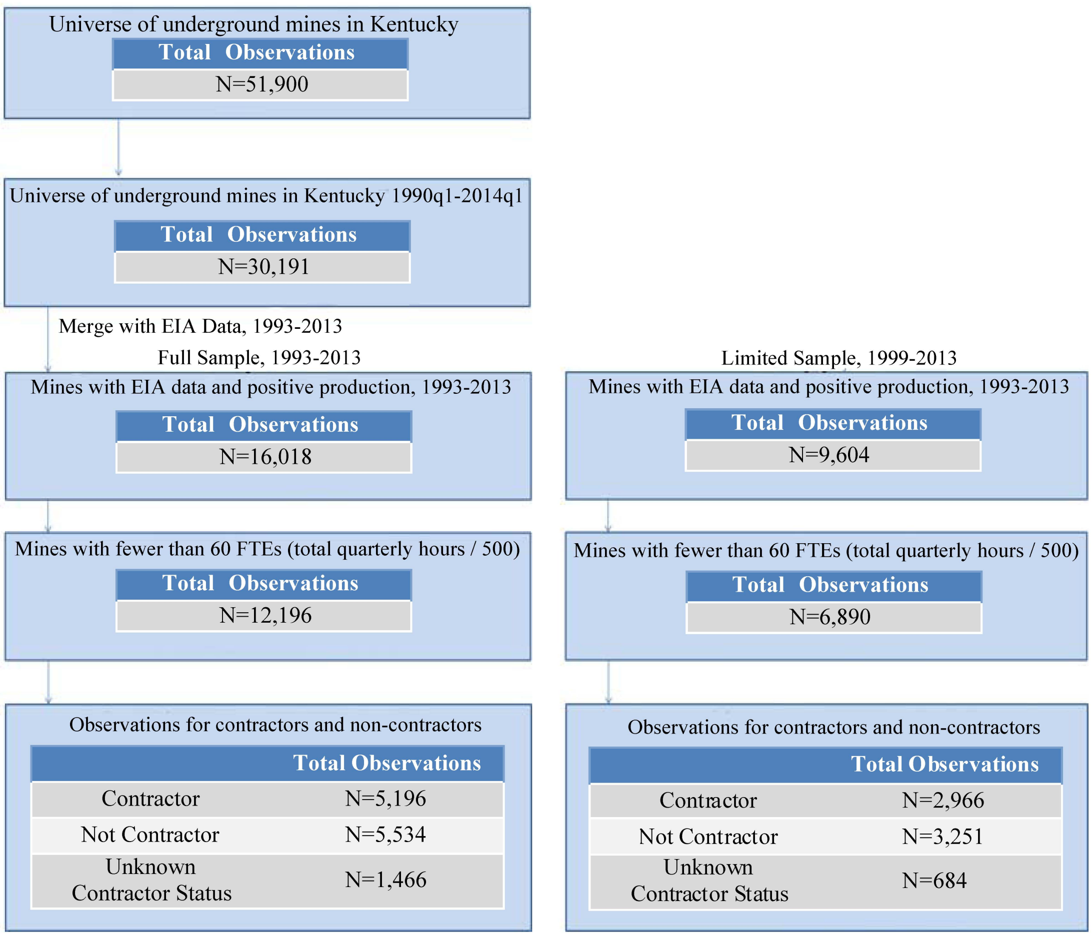
We had a concern about the quality of MSHA data for years prior to 1999. When Morantz (2013) studied the union effect on traumatic injury rates, she found a very small and statistically insignificant effect in the period 1993-1998 but a strong and significant effect from 1999-2010. She noted that this might have reflected a change in the impact of unions over time. However, an alternative explanation is that the MSHA data before 1999 were not as accurately collected which would result in less statistical precision and a less accurate estimate of the union effect. Because of this concern, we have focused our analysis on the period beginning in 1999.[6] We have included in the appendix tables that show the sensitivity of our analysis to the choice of period.

Our analysis was further limited to include only mines with fewer than 60 FTEs (full time equivalent workers). Only 3 percent of mine-quarters that we identified as contractor-operated had more than 60 FTEs in a calendar quarter. To make proper statistical comparisons, it would be inappropriate to include larger mines in the non-contractor sample because there are very few comparable mines in the contractor sample. The sample was then split by contractor status. There were 5,196 mine-quarters in the years 1993-2013 that were contractor-operated, 5,534 not contractor-operated (472), and 1,466

[6] We know that inspector hours reported prior to 1997 in the MSHA data (and used in our violations analyses) are unreliable and this reporting issue could also affect other MSHA measures.

that lacked adequate ownership information to determine contractor status. For the 1999-2013 period, these numbers were 2,966, 3,251, and 684 respectively.

Figure 1. Sample Selection and Distribution of Observations



Unlike the contractors in the MSHA database, which include any contracting operation with work related to mining, this measure only looks at mine operators. It indicates which of these mines are owner-operated and which mines are contractor operated. Because the method proposed in this report is not a direct measure of contract operations, but a proxy using other information, we conducted the following set of robustness checks to validate our measure:

1) As a check on our process for determining contractor-operated mines, we sent a list of mines in our sample that we flagged as contract mines in the first quarter of 2014 to MSHA and the Kentucky EEC for verification.[7] Both agencies were sent a list of 20 mines that we believed were contract mines and 5 that we

[7] In the first quarter of 2014, our database has 123 unique underground mines, 44 of which are identified as potential contract operations.

thought were not contract operations but were uncertain about our classification. Each agency was asked to determine whether these mines were in their opinion contract operations. Of the 20 believed contract operations sent to MSHA, our MSHA contacts believed that 15 were contract mines and that we also correctly identified 4 of the 5 we thought were not contract operations. The Kentucky EEC provided feedback on how well the data we provided them matched the permit information they had on file. There were a few discrepancies in terms of who the permit listed as the operator on file, but these discrepancies did not appear to change the classification of contractor status for the submitted sample. Based on the discrepancies between our data and the MSHA and Kentucky EEC data, we refined our matching method by doing additional research on subsidiaries of larger companies and manual review. For the mines for which we were able to ascertain contractor status, we compared mines we know to be contract operations to mines we identified as potential contractor operations. Of these, we correctly identified 85-90 percent. This is important because non-differential misclassification of mines' status will bias the estimated impact of contracting on injury rates.

2) We examined average production and employment by whether a mine was identified as a potential contract mine or not. Mines identified as contract operations were on average smaller both in terms of production and employment size. This is consistent with reports that have described contract mines as generally smaller than non-contractor-operated mines.
3) Additionally, an examination of court records and proceedings provided us information on the names of known contract operations earlier in our sample period. Although a small subsample of 4 mines, these mines were all picked up by our algorithm as probable contract operations.
4) Following our initial algorithm and each of the checks above, there remained a large number of mines for which we were unable to identify the contractor status due to incomplete ownership information. To further investigate these cases, we added two quality check steps to our identification of contractors. First, we checked ownership information for matching names that were not flagged as such because the word ordering was different across name variables. For example, "James Booth et al" and "Booth James" would not originally be caught by a direct check of matching names. Searching for this type of switch allowed us to identify some mines as contractor that were previously unidentifiable, as well as to correct some mines that were erroneously flagged as non-contractor operations. Second, for those mines that still lacked sufficient information for us to identify their contractor status, we examined historical patterns in the ownership information we did have. For cases where operators and controller-operators were consistently linked to a single permittee and parent company, we interpolated the missing ownership information based on these name patterns and used the inferred ownership data to fill in the missing contractor status where possible.

Although none of the above methods are perfect, they all seem to suggest our algorithm is picking up the type of operations we were hoping it would. As a result, we are reasonably satisfied with the ability of our algorithm to detect contract operations.

Other Data Sources

MSHA Data: MSHA provides all its historical data in tables available through the Department of Labor's (DOL's) Enforcement Database.[8] Information was gathered from the following MSHA datasets: MSHA accidents, MSHA violations, MSHA controller history, MSHA inspections, MSHA operator history, and MSHA quarterly employment.[9] Data were available going back to the 1980's, however, a number of reporting changes make certain variables less reliable in earlier years. For instance, MSHA assessment data prior to 1995 is incomplete.[10] MSHA also notes inspector hours prior to 1997 were not always consistently recorded. These reporting issues may impact the validity of our estimates in the earlier years of our dataset.

EIA Form 7A Data: The EIA conducts a yearly survey (EIA Form-7A) to gather information on mine characteristics for operations that produced 10,000 or more short tons of coal and/or employed workers for 5,000 hours or more in a year. The authors obtained variables gathered in the survey such as union status, seam height, method of mining used in each working section, and number of beds, which are important covariates for any statistical analysis of factors affecting injury rates and productivity. Although some of the variables can be accessed publicly through the EIA, we obtained the restricted ones through a data access agreement with the EIA for use in this project.

Methods

Outcome variables

Violations: Although not a direct measure of worker injury outcomes, a mine operator with a substantial number of violations is likely exposing their workers to undue risk. Thus, we first consider if a relationship exists between contractor status and the number of violations an operator receives. Number of violations alone may not capture mine operators that are particularly egregious. As a result, we also look at the count of significant and substantial violations as an indicator of whether an operator was exposing their workers to increased risk.[11]

Injury Rates: We focus on two safety outcomes: total number of injuries and the number of traumatic injuries.[12] When considering reported injuries as an outcome, the issue of underreporting needs to be addressed. There are a number of

[8] Available at <http://ogesdw.dol.gov/views/data_summary.php>

[9] The actual table names are: msha_accident, msha_assessd_violation, msha_controller_history, msha_inspection, msha_operator_history, msha_qtrly_oprtr_emplymnt.

[10] Morantz (2011), at p. 705.

[11] A significant and substantial violation is defined by MSHA as: "(1) The underlying violation of a mandatory standard; (2) The existence of a discrete safety hazard contributed to by the violation; (3) A reasonable likelihood that the hazard contributed to will result in an injury; and (4) A reasonable likelihood that the injury in question will be of a reasonably serious nature." (see http://www.msha.gov/SOLICITOR/faqs.htm)

[12] Fatalities are the least likely of the measures to be misreported but are rare occurrences. As a result, there is usually not enough statistical power to link company characteristics to fatality rates. Since this study focuses only on a subsample of mines this issue is particularly salient and thus fatalities as a separate category were not included as a main outcome of interest.

reasons a mine may choose to not report injuries, including lowering workers compensation premiums which are (imperfectly) experience rated, and potentially decreasing the probability of inspection. Because some of these motivations are correlated with reasons to contract out work, using reported injuries as a dependent variable could yield biased estimates. As a result, along with reporting results for all injuries, we provide results on our preferred measure – traumatic injuries. The definition for a traumatic injury is provided in Morantz (2013).[13] Traumatic injuries avoid some of the issues of reporting bias because they are injuries that are more obviously associated with working in a mine and less easily concealed. Traumatic injuries are more prevalent than fatalities, but less likely to suffer from biases than are reported total injuries.[14] About 40% of reported injuries are traumatic.

Control variables

A mine has many characteristics that could affect injury and violation rates beyond the fact that it is run by a contract operator. For instance, mines with very low seam heights are typically more dangerous, if all other factors that determine the likelihood of increased injury are equivalent between two mines.[15] Also, larger mines will tend to have more injuries and violations because more individuals are potentially exposed at any given time. It is important to control for all these factors to avoid attributing a relationship between contractor status and the outcomes of interest that can be explained by other features of the mine. The MSHA and EIA data provide a number of key mine characteristics, summarized in Table 1. These characteristics are controlled for in all the specifications.

[13] The injuries included in this measure are: bites and stings, amputations, enucleations, fractures and chips, cuts and lacerations, punctures, burns/scalds, including chemical, electrical and laser burns. See Morantz (2013) for a full description on the justification for the use of these particular injury descriptions.
[14] See Table 2 for prevalence figures of traumatic injuries relative to total injuries.
[15] [CITE – I have this somewhere, will hunt down.]

Table 1: Description of Variables.

Variable	Definition	Source
Contractor indicator	Indicator for mine's status as a contract operation	MSHA, AVS, SMIS, KMMIS
Mine size	Full time equivalents (FTEs), or 500 employee hours per quarter	MSHA
Mine size categories	Category 1: 0 -15 FTEs; Category 2: 15 - 30 FTEs; Category 3: 30 - 60 FTEs	
Log of controller size	Natural log of controller size, with controller size measured in units of 100 FTEs	MSHA
Mine age	Age of mine in years since the first operator began work at the mine (top censored at 43)	MSHA
Productivity	Coal production (in millions of tons per 200,000 employee hours)	MSHA
District indicators	Indicators for whether a mine is located in a particular MSHA district (used to determine if the mine is in Kentucky)	MSHA
Subunit indicators	Indicators for whether a mine has a particular subunit (underground, surface, office, etc.)	MSHA
Quarter/year indicators	Indicators for whether an observation is in a particular year or quarter	MSHA
Inspection days	Number of MSHA inspection days (defined as five inspection hours) in a quarter	MSHA
Union indicator	Indicator for whether a mine is unionized	EIA
Number of coal beds	Number of coal beds at a particular mine	EIA - Confidential
Mean coal bed thickness	Average thickness, in inches, of the coal bed at a particular mine	EIA - Confidential
Recoverable reserves	Estimated tonnage of recoverable coal reserves (in 100,000 tons)	EIA - Confidential
Traumatic injury	Amputations, enucleations, fractures, chips, dislocations, foreign bodies in eyes, cuts and lacerations, punctures, burns/scalds, crushings, burns (chemical, electrical, and laser), and fatal injuries.	
Mining method percentages	Percent of underground operation that uses a particular mining method (conventional, continuous, longwall, shortwall, and other). The sum of the five proportions will add to 1 for each individual mine-quarter.	EIA - Confidential

Figure 2 indicates that our measure was relatively flat until 2006, seemed to begin a decline until 2011 but has been increasing in recent years. It also illustrates why looking at small mines is a more relevant sample.

Figure 2. Proportion of Underground Coal Mines Operated by Contractors

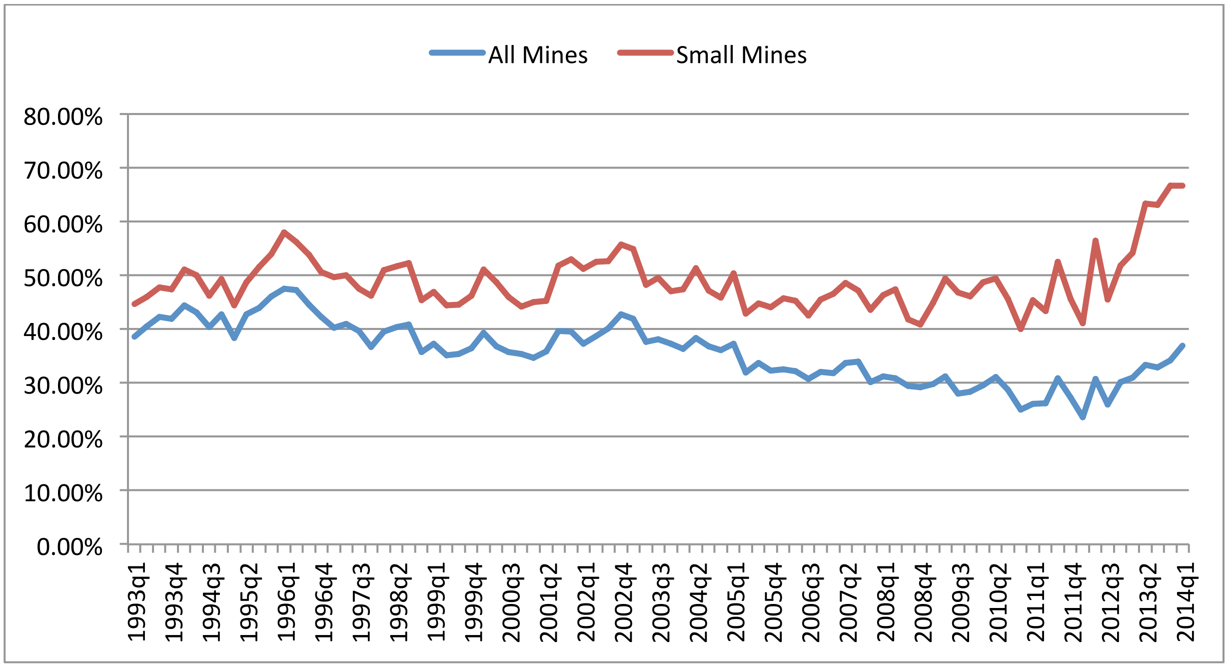


Table 2 provides statistics describing our final sample and highlighting the difference in characteristics of mines identified as contractor-operated from those that are not contractor-operated. The table only provides information for mines with fewer than 60 FTEs (full time equivalent workers). As noted above, this is because there are very few mines identified as contract operations with more than 60 full FTEs. Even with this limitation, contract operations tend to be smaller both in terms of employment and production. They also appear to receive more citations per inspector hour and more significant and substantial violations than other small mines. This difference in poor violation records has been linked to poor outcomes for miners.[16] However, these factors do not immediately reveal a difference in measurable injury outcomes as evidenced in Table 2. Indeed, contractor mines' injury rates appear to be lower than those of mines not operated by contractors. These initial summary results do not yet control for differences across the two groups. As discussed above, to make an unbiased comparison of the differences in injury rates across these two groups, we need to conduct a multivariate regression analysis which controls for other factors that influence the likelihood of violation or injury for a mine.

[16] Smith, Ellen, "Investigation Finds $70 million in Unpaid Fines Leaves Deadly and Crippling Legacies," Mine Safety and Health News, November 12, 2014, available at < http://www.minesafety.com/wp-content/uploads/2014/11/Civil_Penalties_Special_Report_20141.pdf>.

Table 2. Study Sample Statistics.

	Mine-Quarters	
	Contractor	No contractor
Injuries per 200,000k hours		
Total (all injuries)	8.251	10.395
Traumatic injuries	3.440	4.256
Basic operational characteristics		
Coal Productivity (millions of tons per 200,000 hours)	0.578	0.632
Mine age (years)	5.931	7.224
FTEs	20.35	31.13
Fewer than 15 FTEs	39.49%	20.82%
15 to 29.9 FTEs	39.05%	25.68%
30 to 60 FTEs	21.46%	53.49%
Employees	21.08	27.99
Fewer than 14 Employees	35.02%	20.01%
14-27.9 Employees	41.33%	30.33%
28-549.9 Employees	22.27%	46.26%
50+ Employees	1.38%	3.40%
Violations per inspection day		
Total	0.981	0.887
Significant and substantial	0.381	0.332
EIA mine characteristics		
Union	0.00%	1.57%
Recoverable reserves (100,000s of tons)	7.810	18.728
Number of coal beds at the mine site	1.001	1.015
Mean bed thickness (inches)	38.462	45.502
Type of underground mine		
Continuous	76.49%	90.36%
Conventional	17.09%	4.83%
Longwall	0.14%	0.00%
Shortwall	0.61%	0.59%
Sample size (mine-quarters)	2,981	3,264

Sample includes active KY Underground Coal Mine-Quarters from 1999-2013 with less than 60 FTEs and whose contractor status has been identified

A Full Time Equivalent (FTE) is defined as 500 employee hours worked.

Total injuries include all injuries associated with accidents in the underground subunit of mines in the sample

Traumatic injuries are defined by the characteristics of the injury and include amputations, enucleations, fractures, chips, dislocations, foreign bodies in eyes, cuts and lacerations, punctures, burns/scalds, crushings, burns (chemical, electrical, and laser), and fatalities.

Statistical Specification

The outcome variables of interest are not normally distributed. They are count data (1, 2, 3, 4, 5, etc.) and tend to be clustered at lower values such as 0 and 1. For this kind of data, linear regression is not suitable. The appropriate statistical approach is a negative binomial specification, which we use. Details of the statistical specification are presented in the Appendix.

Rather than presenting the regression coefficients, we use the Incidence Rate Ratio (IRR) for ease of exposition. The IRR for the injury regression is the ratio of the injury rate to a baseline rate related to a one unit increase in an independent variable. These are presented n Tables 3-6. In these tables, the reference group is non-union, non-contractor-operated mines using the continuous mining method. Each IRR indicates the ratio of the rate in contractor-operated mines to non-contractor-operated mines in the same size class. An IRR below 1.0 indicates a rate less than a non-contractor-operated mine, while a rate more than 1.0 indicates a rate greater than a non-contractor mine. For example, in Table 3, the first row IRR compares contractor-operated mines with 15 or fewer FTEs to mines that were otherwise the same but were not contractor-operated. In Table 3, the IRR for this row is 0.958, indicating a violation rate very close to a non-contractor mine of the same size.

5.0 SUMMARY OF ACCOMPLISHMENTS AND INNOVATION HIGHLIGHTS

One of the goals of this project was to demonstrate an improved method of determining whether an underground coal mine was contractor-operated, using publicly-available MSHA data and publicly-available data on reclamation permits. We were able to make this determination for almost 90 percent of the active underground mine-quarters in Kentucky for the period 1993-2014. This is the major innovation of this study.

Another aim was to determine whether there have been any trends in the proportion of underground coal mines in Kentucky that were contractor-operated. According to Table 2, contractor-operated mines make up a little more than 50 percent of the active mine-quarters in our sample. As shown in Figure 2, it appears that the percent of contract-operated mines has remained steady over the past 20 years, but when broken down by mine size, it appears that contract-operated mines have been increasing as a percent of small mines in recent years.

To address the final aim of this grant, we determine how contract-operated mines affect health and safety outcomes for workers. In line with the above-described specifications, Table 3 through Table 6 present results for our final sample over the time period for which we have complete data. Due to the various reporting issues with MSHA data in the 1990's that we referenced earlier, we estimated specifications focusing on the years from1999 to 2013. To see the sensitivity of our results to looking at earlier and later periods, we re-estimated injury rates and violations using each year from 1998 through 2001 as break points and looking at both before and after these break points. These results are included as appendix tables. There was minimal variation in the results across all these different cuts of the data.

The data presentations also designate the statistical significance of the outcome, marked by a number of asterisks. A single asterisk (*) denotes a statistical significance level of 10 percent, a double asterisk (**) denotes a statistical significance level of 5 percent, and a triple asterisk (***) denotes a statistical significance level of 1 percent. Outcomes with no asterisks indicate the results are statistically insignificant. It should be noted that this does not indicate that a difference does not exist; rather it means that we were unable to detect a difference that meets stringent scientific standards.

Violations

The first outcome of interest is the total number of violations a mine received in a quarter. The IRR in Table 3 indicates contractor-operated mines are associated with a 5 to 19 percent reduction of violations from 1999 to 2013. This result is significant for the larger mine size categories (categories 2 and 3).

Table 3: Contractor Impacts: All Violations. 1999-2013

Mine Size	IRR (standard error)
Contractor, Size Category 1 ($0 < FTEs \leq 15$)	0.958 (0.139)
Contractor, Size Category 2 ($15 < FTEs \leq 30$)	0.857** (0.067)
Contractor, Size Category 3 ($30 < FTEs \leq 60$)	0.817** (0.071)

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Coefficients are incidence rate ratios, indicating the ratio of the violation rate to the violation rate for non-contractor-operated mines.

Standard errors take into account that violation rates in the same mine are likely to be correlated (clustered at the mine level). They are shown in parentheses

Mine and controller size are measured in Full Time Equivalents (FTEs), where each FTE is 500 employee hours.

Sample includes KY Underground Coal Mine-Quarters from 1999-2013 with less than 60 FTEs and whose contractor status has been identified

Violations are recorded for mines during MSHA inspections when inspectors find any violations of health or safety standards.

The all-violations outcome is a broad measure and includes everything from minor violations to closures. It is less informative in understanding the severity of danger to which a miner is exposed. To try to determine which mines have particularly important violations, the significant and substantial violations, as defined by MSHA, are also used as an outcome. Table 4 reports the results of the significant and substantial violations for the preferred specifications. Generally speaking, there are only minor differences from the all violations results, and some of the contractor coefficients have slightly greater statistical significance.

Table 4: Contractor Impacts: Significant and Substantial Violations. 1999-2013

Contractor, Size Category 1 ($0 < FTEs \leq 15$)	0.911 (0.162)
Contractor, Size Category 2 ($15 < FTEs \leq 30$)	0.839* (0.082)
Contractor, Size Category 3 ($30 < FTEs \leq 60$)	0.733*** (0.075)

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Coefficients are incidence rate ratios, indicating the ratio of the significant and substantial violation rate for contractor-operated mines to the rate for non-contractor-operated mines.

Standard errors are clustered at the mine level and shown in parentheses

Mine and controller size are measured in Full Time Equivalents (FTEs), where each FTE is 500 employee hours.

Sample includes KY Underground Coal Mine-Quarters from 1999-2013 with less than 60 FTEs and whose contractor status has been identified

Significant and substantial violations are violations for which the inspector, based upon the particular facts surrounding the violation, believes there exists a reasonable likelihood the hazard contributed to will result in an injury or illness of a reasonably serious nature.

Injury Rates

The violation results are inconclusive at best, and although interesting from a regulatory standpoint, only provide information on worker exposure to unsafe conditions, not actual outcomes. To understand how contract operators directly affect health and safety outcomes, we first look at total reported injuries. Table 5 provides the results of the relationship between a mine having a contract operator and the likelihood of a reported injury. Looking at the period 1999 to 2013, our analysis suggests that the contractor effect varies by mine size, with lower injury rates in the larger contract-operated mines and higher injury rate in smaller contract-operated mines (although these results are not statistically significant).

Table 5: Contractor Impacts: All Injuries. 1999-2013

Contractor, Size Category 1 ($0 < FTEs \leq 15$)	1.136 (0.188)
Contractor, Size Category 2 ($15 < FTEs \leq 30$)	0.905 (0.114)
Contractor, Size Category 3 ($30 < FTEs \leq 60$)	0.694*** (0.087)

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Coefficients are incidence rate ratios, indicating the ratio of the injury rate to rate for contractor-operated mines to the rate for non-contractor-operated mines.

Standard errors are clustered at the mine level and shown in parentheses

Mine and controller size are measured in Full Time Equivalents (FTEs), where each FTE is 500 employee hours.

Sample includes KY Underground Coal Mine-Quarters from 1997-2013 with less than 60 FTEs and whose contractor status has been identified .

Total injuries include all injuries underground subunit of mines in the sample

Table 6 shows the same set of specifications as in Table 5 but focuses on traumatic injuries as the outcome variable. That is, of small mines, contract mines have an increased probability of injury of 57% compared with non-contract mines. Injury risks are also higher in the second size category but are not significantly different across operator type, whereas larger mines with contract operators appear to lower the probability of traumatic injury compared to non-contractor operations (27%).

Table 6: Contractor Impacts: Traumatic Injuries. 1999-2013

Contractor, Size Category 1 ($0 < FTEs \leq 15$)	1.569* (0.365)
Contractor, Size Category 2 ($15 < FTEs \leq 30$)	1.184 (0.171)
Contractor, Size Category 3 ($30 < FTEs \leq 60$)	0.730** (0.098)

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Coefficients are incidence rate ratios, indicating the ratio of the traumatic injury rate to the base case rate for contractor-operated mines to the rate for non-contractor-operated mines.

Standard errors are clustered at the mine level and shown in parentheses

Mine and controller size are measured in Full Time Equivalents (FTEs), where each FTE is 500 employee hours.

Sample includes KY Underground Coal Mine-Quarters from 1999-2013 with less than 60 FTEs and whose contractor status has been identified

Traumatic injuries are defined by the characteristics of the injury and include amputations, enucleations, fractures, chips, dislocations, foreign bodies in eyes, cuts and lacerations, punctures, burns/scalds, crushings, burns (chemical, electrical, and laser), and fatalities.

Along with these findings, we have created a dataset integrating MSHA production, employment, and injury data, operator and controller data from reclamation permit data files, and our contract-operator measure for each mine, in every quarter from 1993 to 2014. We have provided this dataset, along with all the other publicly available measures used in our analysis as a tool for researchers to use in better understanding and identifying the relationship between ownership structures and other measures of interest.

We have just recently completed our analysis and, to date, we have not made public presentations or published any papers. We plan to finish writing and submit an academic paper to the American Journal of Industrial Hygiene during the next 2-3 months.

6.0 CONCLUSION & INNOVATION ASSESSMENT

Using existing data sources, we were able to determine which Kentucky underground mines were likely run by contract-operators and which were likely not. Much of this was done using automated techniques, but there were a number of quality control checks that required manual review. So although our method can be applied more broadly, it in time intensive and necessitates a certain level of data quality.

Discussing the results in the context of the literature on health and safety, Morantz (2013) showed that unions did not affect the frequency of all reported injuries, but they did affect the frequency of reported traumatic injuries, suggesting that non-traumatic injury rates are more likely to be unreported, especially in non-union mines. Following Morantz, we also consider traumatic injury rates to be more reliable because they are more likely to be reported. In our data, over the 1993-1997 period, we found, like Morantz, that unionization appears to have virtually no impact on both all injuries and on traumatic injuries. However, in the period 1999-2013, we estimated a strong union impact on traumatic injury rates. (These results are in the appendix.) We hypothesize that the results in the earlier period are caused by poor reporting of both traumatic and non-traumatic injuries by non-union mines in the earlier period. If we use a union IRR significantly less than 1 as an indicator of a more accurate estimate the set of specifications that appear less prone to these biases are the traumatic injury outcomes for the later period (see Table 6). As a result, these are our preferred specifications. From these estimates, we infer that the smallest contract mines are more dangerous than the smallest non-contract mines. There is some statistically insignificant indication that the 15-29.9 FTE contract mines may be more dangerous than similar-sized non-contract mines, but 30-60 FTE contract mines appear to be as safe as or safer than similar-sized non-contract mines.

The results in this analysis cannot be interpreted as causal. There are a number of explanations that could explain the variation in findings across our specifications. For instance, selection bias may be driving the relationship between potential contract operations and injury risk. Smaller mines are often more dangerous, and their production volumes tend to be lower. We control for mine size and productivity. However, these factors can still influence the results through an indirect channel. The type of non-contract operators running mines with these characteristics may be different on average than companies running larger operations. Willingness to operate a small mine in and of itself may indicate weaker management in general and safety management in specific. On the other hand, not finding statistically-significant differences does not imply that differences do not exist. Data quality or sample size may have been inadequate to detect actual differences. Thus, no statistically significant difference between contract operators and non-contract operators of a mine with less than 60 FTE only implies that we were unable to detect a difference that meets stringent scientific standards, not that contract operators are as safe as non-contract operators.

Initially, we believed the number of violations would proxy for poor behavior, in practice this may not be the case. If certain mine operator types are differentially receiving violations, then the null result we find may be a reflection of that. However, this explanation seems unlikely to us.

Although our initial results don't suggest a strong relationship between contract operations and worker outcomes on average, we do believe this type of measure can useful to researchers. This study has provided a methodology that can determine with reasonable acuity, mine operations that are contract operations. The general methods we used to determine contract operators can be applied to other states with underground coal mining activity. It is possible that with a larger sample of mines and differences across state laws, that a causal effect could be estimated more accurately.

More importantly, Figure 2, which plots our contract measure over time, indicates that contract operators are quite prevalent and have been growing recently. Although our methodology is replicable, a better method of reporting and tracking organizational information at a mine-level would prove extremely helpful to researchers and regulators. Organizational choices and the impact they have on worker injury outcomes are important metrics for policy decisions and regulatory targeting.

Future studies of contractor-operated mines in other states could increase our understanding of the health and safety implications of this organizational form. West Virginia would be a good candidate, given the relatively large number of underground coal mines in the state. Also, even though we attempted to minimize reporting bias by focusing on traumatic injuries, studies have shown that underreporting occurs even for traumatic injuries (Davis, et al. 2014, Tak, et al. 2014). If contractors report a smaller proportion of their injuries than do non-contractor-operated mines, studies like this one would underestimate the risk of contractor-operated mines. Therefore, studies of reporting in these mines could provide a better understanding of their health and safety risks. If further study indicated that there were excess risks in these mines, the next step could be to attempt to specify the causes of these risks so prevention efforts could be targeted.

7.0 REFERENCES

Azari-Rad, H., P. Philips, and W. Thompson-Dawson (2003): “Subcontracting and injury rates in construction,” The Industrial Relations Research Association Proceedings 2003, pp. 241–248.

Barret, E. A., B. Fotta, and L. L. Rethi (1996): “Independent Contractor Trends in the United States Mining Industry,” Proceedings of Minesafe International 1996, Australia, 357–362.

Buessing, M., and D. Weil (2013): “Impact of Contracting on Occupational Injuries and Fatalities in Underground Coal Mining,” Working Paper, pp. 1–32.

Coleman, P., and J. Kerkering (2007): “Measuring Mining Safety with Injury Statistics: Lost Workdays as Indicators of Risk,” Journal of Safety Research, 38(5), 523-533.

Davis LK, Grattan KM, Tak S, Bullock LF, Ozonoff A, Boden LI. 2014. Use of multiple data sources for surveillance of work-related amputations in Massachusetts, comparison with official estimates and implications for national surveillance. Am J Ind Med.

James, P., R. Johnstone, M. Quinlan, and D. Walters (2007): “Regulating Supply Chains to Improve Health and Safety,” Industrial Law Journal, 36(2), 163–187.

Morantz, A. (2013): “Coal Mine Safety: Do Unions Make a Difference?,” Industrial and Labor Relations Review, 66(1), 88–116.

Muzaffar, S., K. Cummings, G. Hobbs, P. Allison, and K. Kreiss (2013): “Factors Associated with Fatal Mining Injuries among Contractors and Operators,” Journal of Occupational Environmental Medicine, 55(11), 1337-1344.

Nyden, P. (1993a): “Coal Contracts: Shifting Mining Danger, Responsibility,”

. (1993b): “Massey Contracting Made Controversy,”

. (1993c): “Mining Contractors Owe Millions in Fees, Fines, Wages,”

. (1993d): “Small Mines Shunt Safety Concerns for Large Profits,”

Pappas, D., C. Mark (2011): “A Deeper Look at Contractor Injuries in Underground Coal Mines,” Mining Engineering 2011, 63(11), 73-79.

Peters, R., and B. Fottar (1994): “Statistical Profile of Accidents at Small Underground Coal Mines” Proceedings of Bureau of Mines Technology Transfer Seminar: Improving Safety at Small Underground Mines 1994. Bureau of Mines SP, 18-94.

Rebitzer, J. B. (1995): “Job Safety and Contract Workers in the Petrochemical Industry,” Industrial Relations, 34(1), 40–57.

Tak S, Grattan K, Boden LI, Ozonoff A, Davis L. 2014. Impact of differential injury reporting on the estimation of the total number of work-related amputations. Am J Ind Med 56.

Weil, D. (2014): The Fissured Workplace: Why Work Became So Bad for So Many and What Can Be Done to Improve It. Harvard University Press, Cambridge, MA.

8.0 TECHNICAL APPENDIX

:

This Appendix shows all the coefficients on the statistical analysis. The 1999-2013 column shows the coefficients of the results that are in Tables 3 through 6 in the report. The Appendix is also designed to provide researchers with a sensitivity analysis of break points for the violation and injury regressions. We can see that the results are not sensitive to the break points.

In the Appendix tables:

Coefficients are incidence rate ratios, indicating the ratio of the injury rate to the base case for an increase of one unit of the independent variable.

Standard errors are clustered at the mine level and shown in parentheses

Mine and controller size are measured in Full Time Equivalents (FTEs), where each FTE is 500 employee hours.

Sample includes Kentucky Underground Coal Mine-Quarters from 1997-2013 with less than 60 FTEs and whose contractor status has been identified

Total injuries include all injuries underground subunit of mines in the sample

Traumatic injuries are defined by the characteristics of the injury and include amputations, enucleations, fractures, chips, dislocations, foreign bodies in eyes, cuts and lacerations, punctures, burns/scalds, crushings, burns (chemical, electrical, and laser), and fatalities.

Violations are recorded for mines during MSHA inspections when inspectors find any violations of health or safety standards.

Significant and substantial violations are violations for which the inspector, based upon the particular facts surrounding the violation, believes there exists a reasonable likelihood the hazard contributed to will result in an injury or illness of a reasonably serious nature.

Productivity is measured as millions of tons of coal produced per 200,000 employee hours

Inspection days are defined as total on site inspection hours divided by five.

Union status is determined using EIA public fields mine data.

All regressions include dummy variables for surface operations at the mine site, district fixed effects, and quarter-year fixed effects.

Table A1. Negative Binomial Regressions: All Violations

	All Years	Cutoff = 1999		Cutoff = 2000		Cutoff = 2001	
	1997-2013	1997-1998	1999-2013	1997-1999	2000-2013	1997-2000	2001-2013
Contractor * Size Category 1 (0 < FTEs ≤ 15)	0.974 (0.130)	1.023 (0.288)	0.958 (0.139)	0.960 (0.220)	0.968 (0.146)	0.846 (0.170)	1.017 (0.160)
Contractor * Size Category 2 (15 < FTEs ≤ 30)	0.860** (0.062)	0.864 (0.136)	0.857** (0.067)	0.907 (0.117)	0.840** (0.067)	0.907 (0.105)	0.836** (0.069)
Contractor * Size Category 3 (30 < FTEs ≤ 60)	0.826** (0.063)	0.859 (0.109)	0.817** (0.071)	0.890 (0.102)	0.803** (0.075)	0.864 (0.088)	0.822** (0.081)
Union	1.026 (0.132)	0.902 (0.166)	1.097 (0.184)	0.902 (0.156)	1.115 (0.200)	0.881 (0.156)	1.190 (0.218)
Size Category 2 (15 < FTEs ≤ 30)	0.427*** (0.038)	0.401*** (0.076)	0.431*** (0.041)	0.356*** (0.054)	0.449*** (0.045)	0.335*** (0.047)	0.472*** (0.049)
Size Category 3 (30 < FTEs ≤ 60)	0.251*** (0.022)	0.199*** (0.036)	0.262*** (0.024)	0.188*** (0.027)	0.273*** (0.026)	0.188*** (0.026)	0.281*** (0.028)
Log of Controller Size	0.844*** (0.018)	0.863*** (0.042)	0.841*** (0.020)	0.870*** (0.033)	0.838*** (0.021)	0.863*** (0.030)	0.839*** (0.022)
Mine Age (years)	1.000 (0.003)	1.001 (0.007)	1.000 (0.003)	0.999 (0.006)	1.000 (0.003)	0.998 (0.005)	1.001 (0.004)
Productivity (million tons/200,000 employee hours)	1.027*** (0.006)	1.003 (0.010)	1.030*** (0.006)	1.004 (0.009)	1.032*** (0.006)	1.014 (0.011)	1.030*** (0.007)
Number of coal beds	0.717*** (0.090)	0.181*** (0.044)	0.731** (0.090)	0.187*** (0.036)	0.744*** (0.080)	0.183*** (0.030)	0.755*** (0.078)
Mean coal bed thickness	0.997** (0.001)	1.003 (0.002)	0.996** (0.001)	1.000 (0.002)	0.997** (0.002)	1.000 (0.002)	0.996** (0.002)
Recoverable reserves	1.000 (0.001)	1.001** (0.000)	0.999 (0.000)	1.001*** (0.000)	0.999*** (0.000)	1.001*** (0.000)	0.998*** (0.000)
Conventional %	1.000 (0.001)	1.002** (0.001)	1.000 (0.001)	1.001 (0.001)	1.000 (0.001)	1.001 (0.001)	1.000 (0.001)
Longwall %	0.994*** (0.001)	0.993*** (0.002)	0.995*** (0.001)	0.993*** (0.002)	0.995*** (0.001)	0.995*** (0.002)	0.995*** (0.001)
Shortwall %	1.000 (0.003)	1.006 (0.006)	0.996** (0.002)	1.005 (0.005)	0.996** (0.002)	1.005 (0.005)	0.996** (0.002)
Inspection days	1.055*** (0.002)	1.079*** (0.006)	1.053*** (0.002)	1.077*** (0.005)	1.052*** (0.002)	1.072*** (0.004)	1.052*** (0.003)
Subunit dummies	Y	Y	Y	Y	Y	Y	Y
District fixed effects	Y	Y	Y	Y	Y	Y	Y
Quarter/Year Fixed Effects	Y	Y	Y	Y	Y	Y	Y
Observations (mine-quarters)	7,458	1,274	6,184	1,840	5,618	2,354	5,104
Contractor mine-quarters	3,571	626	2,945	884	2,687	1,128	2,443

Table A-2. Negative Binomial Regressions: Serious and Substantial Violations

	All Years	Cutoff = 1999		Cutoff = 2000		Cutoff = 2001	
	1997-2013	1997-1998	1999-2013	1997-1999	2000-2013	1997-2000	2001-2013
Contractor * Size Category 1 (0 < FTEs ≤ 15)	1.002 (0.163)	1.609* (0.410)	0.911 (0.162)	1.416 (0.302)	0.909 (0.167)	1.082 (0.228)	0.958 (0.185)
Contractor * Size Category 2 (15 < FTEs ≤ 30)	0.863 (0.078)	1.002 (0.182)	0.839* (0.082)	1.074 (0.164)	0.803** (0.080)	1.034 (0.145)	0.796** (0.082)
Contractor * Size Category 3 (30 < FTEs ≤ 60)	0.754*** (0.068)	0.856 (0.120)	0.733*** (0.075)	0.951 (0.130)	0.696*** (0.074)	0.862 (0.105)	0.720*** (0.081)
Union	1.010 (0.157)	0.868 (0.175)	1.101 (0.232)	0.828 (0.161)	1.152 (0.244)	0.808 (0.162)	1.292 (0.287)
Size Category 2 (15 < FTEs ≤ 30)	0.419*** (0.046)	0.506*** (0.113)	0.406*** (0.048)	0.402*** (0.067)	0.427*** (0.053)	0.344*** (0.055)	0.452*** (0.059)
Size Category 3 (30 < FTEs ≤ 60)	0.260*** (0.028)	0.249*** (0.056)	0.265*** (0.030)	0.218*** (0.038)	0.276*** (0.032)	0.207*** (0.035)	0.284*** (0.035)
Log of Controller Size	0.822*** (0.022)	0.875*** (0.040)	0.814*** (0.025)	0.874*** (0.034)	0.808*** (0.025)	0.862*** (0.032)	0.809*** (0.026)
Mine Age (years)	1.001 (0.004)	1.002 (0.008)	1.000 (0.004)	1.001 (0.007)	1.001 (0.004)	1.000 (0.007)	1.001 (0.004)
Productivity (million tons/200,000 employee hours)	1.014* (0.007)	0.989 (0.014)	1.018** (0.008)	0.993 (0.013)	1.019** (0.008)	1.002 (0.015)	1.018** (0.008)
Number of coal beds	0.721** (0.113)	0.157 (0.295)	0.737** (0.110)	0.169 (0.285)	0.737** (0.107)	0.162 (0.246)	0.745** (0.106)
Mean coal bed thickness	0.994*** (0.002)	0.999 (0.003)	0.994*** (0.002)	0.996 (0.003)	0.995** (0.002)	0.996 (0.003)	0.994*** (0.002)
Recoverable reserves	1.000 (0.001)	1.002*** (0.001)	0.999* (0.000)	1.002*** (0.001)	0.998*** (0.001)	1.002*** (0.001)	0.998*** (0.001)
Conventional %	1.000 (0.001)	1.002* (0.001)	0.999 (0.001)	1.001 (0.001)	1.000 (0.001)	1.002 (0.001)	0.999 (0.001)
Longwall %	0.994*** (0.002)	0.995** (0.002)	0.992*** (0.001)	0.995*** (0.002)	0.992*** (0.001)	0.996** (0.002)	0.992*** (0.001)
Shortwall %	1.003 (0.006)	1.011 (0.009)	0.996 (0.003)	1.010 (0.008)	0.996 (0.003)	1.010 (0.009)	0.996 (0.003)
Inspection days	1.062*** (0.003)	1.091*** (0.008)	1.060*** (0.003)	1.089*** (0.006)	1.059*** (0.003)	1.081*** (0.006)	1.059*** (0.003)
Observations (mine-quarters)	7,458	1,274	6,184	1,840	5,618	2,354	5,104
Contractor mine-quarters	3,571	626	2,945	884	2,687	1,128	2,443

Table A-3. Negative Binomial Regressions: Total Injuries

	All years	Cutoff = 1997		Cutoff = 1998		Cutoff = 1999		Cutoff = 2000		Cutoff = 2001	
	1993-2013	1993-1996	1997-2013	1993-1997	1998-2013	1993-1998	1999-2013	1993-1999	2000-2013	1993-2000	2001-2013
Contractor * Size Category 1 (0 < FTEs ≤ 15)	0.866 (0.118)	0.685* (0.151)	0.988 (0.152)	0.674* (0.138)	1.055 (0.170)	0.647** (0.127)	1.136 (0.188)	0.660** (0.126)	1.184 (0.192)	0.673** (0.124)	1.210 (0.201)
Contractor * Size Category 2 (15 < FTEs ≤ 30)	0.845* (0.075)	0.830 (0.112)	0.867 (0.101)	0.833 (0.105)	0.867 (0.104)	0.814* (0.097)	0.905 (0.114)	0.842 (0.095)	0.869 (0.117)	0.847 (0.092)	0.856 (0.120)
Contractor * Size Category 3 (30 < FTEs ≤ 60)	0.814** (0.069)	0.933 (0.111)	0.738*** (0.080)	0.945 (0.111)	0.713*** (0.081)	0.928 (0.100)	0.694*** (0.087)	0.928 (0.095)	0.680*** (0.088)	0.922 (0.094)	0.641*** (0.088)
Union	1.159 (0.159)	1.246 (0.290)	0.986 (0.206)	1.315* (0.215)	0.690 (0.180)	1.302* (0.191)	0.559 (0.203)	1.284* (0.186)	0.595 (0.212)	1.259 (0.182)	0.643 (0.245)
Size Category 2 (15 < FTEs ≤ 30)	0.956 (0.109)	0.930 (0.189)	0.982 (0.123)	0.879 (0.160)	1.040 (0.130)	0.874 (0.147)	1.054 (0.140)	0.873 (0.136)	1.106 (0.156)	0.887 (0.132)	1.122 (0.163)
Size Category 3 (30 < FTEs ≤ 60)	0.966 (0.111)	0.890 (0.188)	1.028 (0.126)	0.823 (0.156)	1.105 (0.136)	0.823 (0.142)	1.141 (0.149)	0.815 (0.130)	1.222 (0.168)	0.852 (0.130)	1.215 (0.177)
Log of Controller Size	0.987 (0.018)	0.988 (0.036)	0.984 (0.019)	0.988 (0.033)	0.985 (0.020)	0.994 (0.030)	0.982 (0.022)	1.000 (0.028)	0.971 (0.022)	0.997 (0.027)	0.972 (0.023)
Mine Age (years)	1.002 (0.003)	1.003 (0.006)	1.001 (0.004)	1.003 (0.006)	1.000 (0.004)	1.001 (0.006)	1.001 (0.004)	1.000 (0.006)	1.001 (0.004)	1.000 (0.005)	1.001 (0.004)
Productivity (million tons/200,000 employee hours)	1.011 (0.007)	1.026** (0.011)	1.005 (0.009)	1.017* (0.010)	1.010 (0.010)	1.012 (0.009)	1.014 (0.011)	1.011 (0.008)	1.017 (0.012)	1.010 (0.008)	1.020 (0.012)
Number of coal beds	0.737 (0.188)	0.380** (0.145)	0.856 (0.219)	0.317*** (0.119)	0.941 (0.215)	0.399** (0.148)	0.921 (0.207)	0.395*** (0.143)	0.899 (0.206)	0.394** (0.144)	0.881 (0.205)
Mean coal bed thickness	0.999 (0.002)	0.998 (0.003)	0.999 (0.002)	0.998 (0.002)	0.998 (0.002)	0.997 (0.002)	1.000 (0.002)	0.997 (0.002)	1.001 (0.002)	0.997 (0.002)	1.002 (0.002)
Recoverable reserves	1.001*** (0.000)	1.002** (0.001)	1.001*** (0.000)	1.002*** (0.001)	1.001** (0.000)	1.002*** (0.000)	1.001** (0.000)	1.001*** (0.000)	1.001* (0.001)	1.002*** (0.000)	1.001 (0.001)
Conventional %	0.999* (0.001)	1.000 (0.001)	0.998** (0.001)	1.000 (0.001)	0.998** (0.001)	0.999 (0.001)	0.997*** (0.001)	1.000 (0.001)	0.996*** (0.001)	1.000 (0.001)	0.996*** (0.001)
Longwall %	1.003 (0.006)	1.020*** (0.005)	0.991* (0.005)	1.018*** (0.005)	0.991* (0.005)	1.008 (0.006)	0.860*** (0.009)	1.008 (0.006)	0.866*** (0.009)	1.008 (0.006)	0.859*** (0.009)
Shortwall %	0.994** (0.002)	0.996 (0.003)	0.992** (0.003)	0.995** (0.003)	0.994** (0.003)	0.994** (0.003)	0.998 (0.002)	0.993** (0.003)	0.998 (0.002)	0.993** (0.003)	0.998 (0.002)
Observations (mine-quarters)	10,618	3,160	7,458	3,820	6,798	4,434	6,184	5,000	5,618	5,514	5,104
Contractor mine-quarters	5,138	1,567	3,571	1,886	3,252	2,193	2,945	2,451	2,687	2,695	2,443

Table A-4. Negative Binomial Regressions: Traumatic Injuries

	All Years	Cutoff = 1997		Cutoff = 1998		Cutoff = 1999		Cutoff = 2000		Cutoff = 2001	
	1993-2013	1993-1996	1997-2013	1993-1997	1998-2013	1993-1998	1999-2013	1993-1999	2000-2013	1993-2000	2001-2013
Contractor * Size Category 1 (0 < FTEs ≤ 15)	1.141 (0.200)	0.850 (0.242)	1.359 (0.283)	0.855 (0.225)	1.437* (0.315)	0.804 (0.202)	1.569* (0.365)	0.855 (0.207)	1.572* (0.368)	0.928 (0.213)	1.505* (0.368)
Contractor * Size Category 2 (15 < FTEs ≤ 30)	1.013 (0.105)	0.947 (0.159)	1.089 (0.142)	0.958 (0.147)	1.091 (0.150)	0.895 (0.128)	1.184 (0.171)	0.936 (0.128)	1.158 (0.177)	0.930 (0.123)	1.172 (0.184)
Contractor * Size Category 3 (30 < FTEs ≤ 60)	0.802** (0.076)	0.868 (0.124)	0.776** (0.093)	0.890 (0.120)	0.749** (0.096)	0.880 (0.110)	0.730** (0.098)	0.880 (0.107)	0.725** (0.105)	0.876 (0.102)	0.685** (0.114)
Union	0.845 (0.144)	0.966 (0.260)	0.679 (0.166)	0.995 (0.209)	0.493*** (0.129)	1.062 (0.183)	0.244*** (0.075)	1.037 (0.173)	0.233*** (0.084)	1.008 (0.167)	0.232*** (0.099)
Size Category 2 (15 < FTEs ≤ 30)	0.982 (0.148)	0.825 (0.224)	1.075 (0.180)	0.828 (0.202)	1.119 (0.196)	0.869 (0.195)	1.100 (0.207)	0.898 (0.187)	1.107 (0.224)	0.941 (0.188)	1.076 (0.222)
Size Category 3 (30 < FTEs ≤ 60)	1.087 (0.171)	0.847 (0.243)	1.253 (0.212)	0.839 (0.216)	1.318 (0.235)	0.888 (0.209)	1.310 (0.248)	0.910 (0.200)	1.342 (0.266)	0.984 (0.209)	1.263 (0.261)
Log of Controller Size	1.027 (0.023)	1.033 (0.045)	1.034 (0.025)	1.030 (0.041)	1.035 (0.026)	1.023 (0.037)	1.046* (0.027)	1.021 (0.036)	1.042 (0.027)	1.014 (0.034)	1.047* (0.029)
Mine Age (years)	0.998 (0.004)	1.002 (0.007)	0.996 (0.005)	1.001 (0.006)	0.995 (0.005)	0.998 (0.006)	0.996 (0.004)	0.999 (0.006)	0.995 (0.004)	0.999 (0.006)	0.994 (0.004)
Productivity (million tons/200,000 employee hours)	1.017** (0.008)	1.035*** (0.014)	1.007 (0.010)	1.025** (0.013)	1.011 (0.011)	1.024** (0.011)	1.008 (0.012)	1.023** (0.011)	1.011 (0.013)	1.019* (0.011)	1.017 (0.013)
Number of coal beds	0.587** (0.159)	0.371 (0.403)	0.680 (0.183)	0.299 (0.318)	0.737 (0.205)	0.277 (0.291)	0.816 (0.245)	0.276 (0.290)	0.799 (0.253)	0.276 (0.291)	0.759 (0.246)
Mean coal bed thickness	1.000 (0.002)	1.003 (0.003)	0.998 (0.002)	1.002 (0.003)	0.998 (0.002)	1.001 (0.003)	0.999 (0.002)	1.001 (0.003)	0.999 (0.002)	1.001 (0.003)	1.000 (0.002)
Recoverable reserves	1.002*** (0.000)	1.003*** (0.001)	1.002*** (0.000)	1.003*** (0.001)	1.002*** (0.000)	1.002*** (0.001)	1.002*** (0.001)	1.002*** (0.001)	1.002*** (0.001)	1.002*** (0.001)	1.002*** (0.001)
Conventional %	0.999 (0.001)	1.000 (0.001)	0.998 (0.001)	1.000 (0.001)	0.998 (0.001)	0.999 (0.001)	0.998 (0.001)	1.000 (0.001)	0.997* (0.001)	0.999 (0.001)	0.997* (0.001)
Longwall %	0.765*** (0.013)	0.741*** (0.013)	0.859*** (0.006)	0.765*** (0.013)	0.859*** (0.006)	0.753*** (0.013)	0.807*** (0.008)	0.724*** (0.012)	0.871*** (0.009)	0.774*** (0.013)	0.862*** (0.009)
Shortwall %	0.996* (0.002)	0.999 (0.003)	0.992** (0.003)	0.996 (0.003)	0.996* (0.002)	0.996 (0.003)	0.998 (0.002)	0.995 (0.003)	0.999 (0.002)	0.995* (0.003)	0.999 (0.002)
Observations (mine-quarters)	10,618	3,160	7,458	3,820	6,798	4,434	6,184	5,000	5,618	5,514	5,104
Contractor mine-quarters	5,138	1,567	3,571	1,886	3,252	2,193	2,945	2,451	2,687	2,695	2,443

9.0 ACKNOWLEGEMENTS/DISCLAIMERS

We gratefully acknowledge funding from the Alpha Foundation for the Improvement of Mine Safety and Health, grant AFSTI14-1. We received excellent research assistance from Kathryn S. Tomsho, Andrew Busey, and Gregory MacAtee. The findings and conclusions are those of the authors and do not necessarily represent the views of the Alpha Foundation for the Improvement of Mine Safety and Health. Mention of any company name, product or software does not constitute endorsement by the Foundation.