The Effectiveness of Chinese Regulations on Occupational Health and Safety: A Case Study on China’s Coal Mine Industry

Jiuchang Wei, Peng Cheng & Lei Zhou


To link to this article: https://doi.org/10.1080/10670564.2016.1186369

Published online: 16 Jun 2016.

Article views: 240

View related articles

View Crossmark data
The Effectiveness of Chinese Regulations on Occupational Health and Safety: A Case Study on China’s Coal Mine Industry

Jiuchang Wei, Peng Cheng and Lei Zhou
University of Science and Technology of China, China

ABSTRACT
To assess the effectiveness of Chinese regulations on occupational health and safety, this study provides an exploratory method by applying multiple interrupted time series (MITS) analysis. Taking coal mine safety in China as a case study, this article analyzes the background of the coal industry, especially during the period 1980–2009, and selects three typical pieces of national legislation specific to mining and work safety as the interventions. The data relevant to coal mine safety and the ‘third variables’ were collected to empirically support the study. The estimated results indicate different effects of these interventions on state-owned enterprise (SOE) mines and township and village enterprise (TVE) or small mines. Specifically, though the mortality rate in SOE mines is on a downward trend, these interventions have had no significant effect on it. However, only the 2002 act significantly reduced the mortality rate per million tons in TVE mines. The effectiveness of the interventions seems to depend on certain conditions, such as technology, administration and socioeconomic environment and type of coal mine.

Introduction
China is the world’s largest coal producer and consumer.1 According to the BP Statistical Review of World Energy (June 2012), in 2011, China produced nearly 2 billion tons oil equivalent of coal, which is larger than the combined total of the next seven largest producers, including the US, India and Australia. Meanwhile, China’s coal consumption has increased at an extremely high rate. China’s coal consumption has never accounted for less than 65% of China’s energy resource supply over the past 50 years. However, the economy and energy demand are still increasing quickly.2

The coal industry has long been regarded as one of the most dangerous industries in China.3 According to the Chinese State Administration of Coal Mine Safety, the average annual number of deaths due to mining accidents ranged from 1,049 to 6,995 between 2000 and 2013, though the number has decreased by half since 2000.4 In total, there were over 31,000 coal mine accidents that occurred

CONTACT
Jiuchang Wei  Weijc@ustc.edu.cn

and 52,000 people died during 2001–2010. In response to this poor safety management performance, the Chinese government has been constantly reforming its coal mining safety regulatory system. A large number of comprehensive national legislations, regulations and administrative agencies directly dealing with mine safety have been enacted and set up, such as the Mineral Resources Law (zhonghua renmin gongheguo kuangchan ziyuan fa) in 1986, the Mining Safety Law (zhonghua renmin gongheguo kuangshan anquan fa) in 1993, the Coal Law (zhonghua renmin gongheguo meitan fa) in 1996, the Work Safety Law (zhonghua renmin guoheguo anquan shengchan fa) in 2002, and the State Administration of Coal Mine Safety (SACMS), in which all staff and funding are independent of local governments and coal mines.

More importantly, however, the main concern this article raises is whether the safety of working in China’s coal mines has improved over the years, which also means whether the coal mine safety regulatory system—these consist of national laws and regulations and administrative agencies—has been effective in the coal mining industry. This consideration provides a prelude to the empirical query, ‘Have these interventions played a significant role in coal mine safety and indeed made the work less hazardous?’ To answer this question, this study attempts to analyze the effectiveness of the safety regulatory system, especially the effectiveness of the national legislation, by applying multiple interrupted time series (MITS) analysis. An examination of the impact of the legislation should shed light on the effectiveness of the coal mine safety regulatory system.

This article is structured as follows: the next section presents a literature review. The following section provides the research design, which includes background, method, third variables and data. The empirical results and discussion are then presented in the next two sections. The conclusions are summarized in the final section.

**Literature Review**

**The Controversy Over the Effectiveness of Coal Mine Safety Regulations**

The effectiveness of safety legislation or regulations in the coal mining industry has been widely discussed by sociologists and scholars. Research on this question has focused on whether these regulations can improve coal mine safety and how to achieve more effective regulations. However, previous studies have not reached a consensus about the efficacy of safety regulations. According to Lewis-Beck and Alford, there are three kinds of participants in the effectiveness of safety regulations debate: radicals, reactionaries and reformers. Radicals and reactionaries both believe that these regulations will not make the mines safer, but their reasons are very different. Radicals consider that safety will cost money, so they defeat safety legislation to avoid these costs. However, reactionaries think these safety legislations and regulations cannot have a significant effect on mine safety because of the failure to change the inherent dangers in the activity of mining coal and the carelessness of the miners. Many studies...
have also agreed with reactionaries’ view on safety legislation and found that coal safety legislation has not made any significant impact on coal mine safety. However, reformers are more optimistic about the effectiveness of legislation. They believe the laws can reduce dangers in the mines; and some studies have also found that safety regulations and inspections have a significant positive influence on coal mine safety.

There are two main reasons which may lead to the controversy over the effectiveness of coal mine safety regulations: one is the research methods; the other is the lagging effect. The research method divergences lie not only in constructing the dummy variables but also in the application of industry data. Kniesner and Leeth found a regulatory approach to workplace safety from over 200 dynamic mine safety regressions by using data from the Mine Safety and Health Administration (MSHA). In addition, data from Chinese government statistics also show the regulation system in China has been largely ineffective since 1997 even though this study did not use quantitative methods. However, as mentioned above, with data that are more aggregated than industrial average data, Lewis-Beck and Alford found that the 1941 and 1969 regulations significantly reduced the fatality rate in US coal mining where the 1952 regulation did not increase mine safety.

The other explanation is the lagging effect, which means that safety regulation needs to take time and investment to become effective. For example, to examine the possible timing effects, Bradbury separated the implementation of the regulation into three phases, and the estimates do appear to show that the safety effect of state Occupational Safety and Health Administration (OSHA) enforcement is strongest in the second five years of its implementation. One extension of this time lag explanation has been documented by Shi who stated that safety regulations could work firstly by reducing the most serious accidents and then by gradually improving overall safety performance. The main factors causing these asynchronous effects, according to this study, are cost effectiveness and the time for application of investment, technology and equipment. Overall, it is these two aspects that cause the controversy over the effectiveness of coal mine safety regulations; and the controversy still continues.

**The Dilemma of China’s Coal Mine Safety**

Coal mining is a very risky business and devastating accidents occur in all countries that produce commercial quantities of the mineral. According to the *China Energy Development Report*, Chinese coal consumption was 3.425 billion tons in 2011, which accounted for nearly 70% of primary energy consumption. However, the coal production conditions are so tough and risky that the coal industry had

---


18Andrews-Speed et al., ‘The regulation of China’s township and village coal mines’.

19Lewis-Beck and Alford, ‘Can government regulate safety?’.

20Bradbury, ‘Regulatory federalism and workplace safety’.


22Changming Xiang, ‘China’s coal consumption accounted for nearly 70% of energy consumption, the adjustment of China’s energy structure has become imperative’ [Zhongguo meitan xiaofei zhan nengyuan xiaofei jin qicheng, nengyuan jiegou jidai tiaozheng’], *Chinese Radio Network*, (4 September 2012), available at: [http://money.163.com/12/0904/19/8A62DKH00253BOH.html](http://money.163.com/12/0904/19/8A62DKH00253BOH.html) (accessed 8 March 2016).
been called ‘the industry with the worst health and safety performance in China’ in the last decade of the twentieth century.23 Given the huge production and consumption numbers in China, and the inherent risk of working underground with combustible elements, significant numbers of mine accidents are to be expected in the country. Coal mining accounts for less than 4% of the broadly defined industrial workforce while it causes over 45% of industrial fatalities in China. However, coal mining could be a dilemma for China’s safety regulations. Just as Tu said, ‘On the one hand, coal will be irreplaceable as the primary form of energy driving China’s economic juggernaut …. On the other hand, coal is also fueling a safety (and environmental) crisis …’.24

To improve the safety management performance of China’s coal industry, the Chinese government has been constantly strengthening its coal mining safety regulatory system. A large number of comprehensive national legislations, regulations and administrative agencies have been enacted and set up to deal with mine safety directly or indirectly. However, there have been few studies addressing the effectiveness of coal safety laws or regulations. Many studies about coal mines in China have discussed the occupational health and safety, like occupational disease issues,25 coal dust explosions,26 or safety culture assessment and social impacts,27 etc. In terms of the policy and regulatory effects, lots of studies focus on small-scale coal mines or township28 and township and village enterprise (TVE) mines.29 Moreover, these studies do not involve the aspect of coal mine safety, for which they use qualitative analysis to investigate the economic impact or assess the regulatory framework.30

The protection of workers’ lives and health is an important sign of progress and civilization of a country.31 So, the series of protective laws, regulations, policies and measures are followed by the introduction of coal mine safety. For example, since 1982, the Chinese central government has initiated five pieces of basic law, four pieces of laws and regulations, six pieces of administrative laws and regulations, and three pieces of safety technical standards to improve coal mining safety.32 At the same time, the national average mortality (per million tons) decreased from 7.31 in 1982 to 0.87 in 2009.33 Therefore, the authors should seriously consider, ‘Have these pieces of legislation made coal mining less hazardous?’ and ‘Can government regulate coal mine safety through legislation or regulations?’ So, the main purpose of this study is to fill this research gap by analyzing the impact of laws or regulations on coal mine safety in China, especially in the context of China’s coal industry after Deng Xiaoping’s reform and opening up.

**Research Design**

**Background**

In China, coal production began to accelerate at such a speed that the average annual growth rate was as high as 8.8% between 1950 and 2003. However, the sharp increase in coal production also caused

---

23 Laurence, ‘Safety rules and regulations on mine sites’.
25 Chen et al., ‘Focusing on coal miners’ occupational disease issues’.
30 Page, ‘Blood on the coal’.
31 Ghosh et al., ‘Relationships of working conditions and individual characteristics to occupational injuries’.
a sharper increase in fatalities. Though in the immediate aftermath of 1949 there was a substantial improvement in the record which probably remained broadly respectable, local governments built thousands of new small coal mines without basic safety conditions during the Great Leap Forward period, which in turn created the high fatality rate. In 1959 and 1960, 5,098 and 6,036 workers died due to coal mine accidents, respectively, which became the worst records in China’s history. After the fanaticism of the Great Leap Forward faded away, the Cultural Revolution followed in 1966, and the number of fatalities climbed from around 1,000 in 1965 to more than 4,500 in 1978. The number and rate of fatalities have since fluctuated and still remain exceptionally and unnecessarily high.

Prior to 1978, although the government had been seriously concerned about coal mine safety and established several regulations and guidelines to improve mine conditions, the regulation systems were generally weak and ineffectual. This is mainly attributed to the characteristics of the times. During the period of the Great Leap Forward, coal mine safety inspection was regarded as an unnecessary obstacle to increased production and was thereby abolished. The frequent political movements, like the ‘Great Leap Forward’ and the ‘Cultural Revolution,’ together with some unrealistic economic policies, resulted in confusing states in the aspects of political, economic, cultural and other fields.

In subsequent years, China entered into Deng Xiaoping’s reform and opening up era. Deng Xiaoping, the Chinese senior leader, implemented a series of reforms in the coal industry and liberalized coal prices. Since then coal production and prices have shifted from centrally planned to market determined prices. At the same time, the rapid development of the economy stimulated the energy demand, especially the demand for coal. So, the TVE mines were overtly encouraged by all levels of government from the early 1980s. When coal production grew steadily, especially the production of TVE mines, the number of fatalities started to show an ascending trend. In this period, however, the extremely hazardous working conditions brought greater attention from the central government, and several legislations and regulations designed to improve coal mining safety were passed. Among these pieces of legislation and regulations, the passage of The Mineral Resources Law of the PRC went into effect on 1 October 1986.

Along with the first passage of the state’s legislation earmarked for the mining industry, many implementing rules and regulations aimed at improving mining safety were successively promulgated. Eight years later, Rules for the Implementation of the Mineral Resources Law was promulgated by State Council. Over the last two decades there has been an explosion in the number of laws, regulations and subordinate administrative measures implemented in China. In 1993 and 1996, two more special laws focusing on the mining industry and safety were promulgated, The Law of the People’s Republic of China on Safety in Mines (Mining Safety Law) and The Coal Law of the People’s Republic of China (Coal Law), respectively. The Mineral Resources Law was revised in 1996 and a package of regulations was issued in 1998. Promulgated on 29 June 2002, The Law of the People’s Republic of China on Work Safety (Work Safety Law) went into effect on 1 November 2002. This law defined the safety regulatory system of the government, indicated that comprehensive regulation of national safety should combine with special regulations by functional departments concerned at all levels of government. In 2004, the State Administration of Work Safety (SAWS) issued the Rules and Procedures on Mining Safety (meitan anquan guicheng) and, by 2005, had issued approximately 100 coal mining-specific announcements, rules and regulations. During these

34Wang, ‘Regulating death at coalmines’.
36Wright, ‘The political economy of coal mine disasters in China’.
37Wang, ‘Regulating death at coalmines’.
40Andrews-Speed et al., ‘The regulation of China’s township and village coal mines’.
two decades some additional related regulations have been introduced. A comparatively integrated, sophisticated and complex legal regime of coal mine safety has been established. The national legislation, administrative regulations, judicial interpretations, departmental rules, local regulations and local rules have all made significant contributions to this regulatory scheme.

In this study, the main purpose is to examine whether the national legislation has had an impact on coal mine safety since 1978. So the first area of work is to scan all the national coal mining-specific legislation and screen out the most representative ones. Here, the Mineral Resources Law of 1986 should be considered firstly because it was the first time in history that China had a systematic set of rules concerning mineral exploration specially.41 Due to the fact that it established broad principles of mining safety that must be adhered to, and was formulated for the purpose of ensuring safety in production in mines, preventing accidents and protecting the personal safety of workers and staff at mines and promoting the development of the mining industry,42 the Mining Safety Law of 1993 is the second selected intervention. The third choice is the Work Safety Law of 2002. The Work Safety Law, for the first time, codified workers’ safety interests as statutory rights and has the stated purpose of ‘enhancing supervision and control over work safety, preventing accidents due to lack of work safety and keeping their occurrence at a lower level, ensuring the safety of people’s lives and property and promoting the development of the economy’.43 These three pieces of national legislation represent the government’s greatest determination to regulate coal mine safety in different historical periods and backgrounds.

**Method**

To evaluate the impact of coal mine safety legislation, this article employed multiple interrupted time series (MITS) analysis.44 Measurement of a variable at more or less equally spaced time intervals produces time series data. Measurements are taken at several time periods yielding a series of scores. The objective is to explain trends and changes in the series, in particular, how an intervention affects the time series. The MITS analysis plays an important role in research on the effects of public policy. A number of areas of intervention policy, e.g. distributive politics,45 laws or regulations,46 would appear to lend themselves to this approach. The research issue is whether the observations in this time series have been affected by the safety legislation (i.e. intervention). MITS analysis seems to be the most convenient method to measure time (general trend) and intervention effect.

Take the Mineral Resources Law of 1986, for example. To assess the effect of this intervention, the authors estimated the following simple interrupted time series equation:

\[
Y_t = b_0 + b_1X_{1t} + b_2X_{2t} + b_3X_{3t} + e_t
\]

where \(Y_t\) represents annual observations on coal mining fatalities; \(X_{1t}\) is a counter for years, from 1 to \(N\), of the number of observations; \(X_{2t}\) is a dummy variable scored as 0 for observations before 1987, and 1 for 1987 and after; \(X_{3t}\) is a counter of years, scored as 0 for observations before 1987, and 1, 2, 3, … for 1987 and after; \(b_0, b_1, b_2, b_3\) are parameters to be estimated; and \(e_t\) is an error term.

---

The parameters $b_0$ and $b_1$ indicate the level and slope of the time series prior to implementation of the 1986 legislation, respectively. And $b_2$ and $b_3$ represent the short- and long-run impacts of the 1986 legislation.

Now, a straightforward extension of the preceding logic will develop the MITS analysis to introduce the other two interventions represented by the following regression equation:

$$ Y_t = b_0 + b_1 X_{1t} + b_2 X_{2t} + b_3 X_{3t} + b_4 X_{4t} + b_5 X_{5t} + b_6 X_{6t} + b_7 X_{7t} + e_t $$

(2)

where $Y_t$, $X_{1t}$, $X_{2t}$, $X_{3t}$, $X_{4t}$, $X_{5t}$, $X_{6t}$, and $X_{7t}$ are defined as with Equation (1); $X_{4t}$ is a dummy variable scored as 0 for observations before 1994, and 1 for 1994 and after; $X_{5t}$ is a counter of years, scored as 0 for observations before 1994, and 1, 2, 3, … for 1994 and after; $X_{6t}$ is a dummy variable scored as 0 for observations before 2003, and 1 for 2003 and after; and $X_{7t}$ is a counter of years, scored as 0 for observations before 2003, and 1, 2, 3, … for 2003 and after. Hence, $b_4$ and $b_5$ capture the short- and long-run impacts of the 1993 legislation, $b_6$ and $b_7$ those of the 2002 legislation. Then, through estimation of this model, this article was able to bring to light the probable effects of the three pieces of legislation on coal mine safety.

### Third Variables

Besides national legislation, are there any other variables which may influence coal mine safety? Previous studies indicated that economic factors, geological characteristics, mining technique, mine size, unionization, safety culture, miner's characteristics, etc., might be expected to influence coal mine safety. Among these ‘third variables,’ this article managed to select four which are correlated with the MITS results, and which may result in the frequent occurrence of fatalities in Chinese coal mines. This article employed the indicator ‘average annual price of raw coal’ to represent the coal price ($E_t$). Whether technological advances in coal mining may reduce mine safety or not has still not reached a consensus. For example, Wieck has argued that it may increase the amount of explosive gas, coal dust, electricity, fire hazards and total work time, thus reducing mine safety. There is some evidence, however, that technology can make mining less risky. Regarding the measure of technology variable, the authors employed the indicator ‘fully mechanized mining rate’, which is represented by $T_t$. Many smaller mines make their appearance during boom periods, only to disappear when demand slackens. The debate about the impact of small-scale mines on mine safety is also grouped into two categories: less or more safe, just

---


49Wright, ‘Competition and complementarity township and village mines and the state sector in China’s coal industry.’


51Andrews and Christenson, ‘Some economic factors affecting safety in underground bituminous coal mines.’
like that of mining technology. Here, the extent of small-scale mining operations, \( S_t \), is represented by the percentage of their annual production in total. There are two general categories of mining: underground mining and surface mining. Generally speaking, there is a common belief that underground mining is more dangerous than surface mining.\(^{52}\) To check this possibility, this article introduced the variable \( U_t \) which represents the percentage of underground mine production in total, as a control.

Equation (2) uncovered short- and long-run effects for national legislation on coal mine safety (see \( b_3, b_5 \) and \( b_7 \)). Here this article has cast doubt on these results, speculating that they are caused by the ‘third variables’, \( E_t, T_t, S_t \) and \( U_t \). Below, this article enters these variables into the MITS model indicated by the Equation (2) findings, in order to investigate this prospect.

\[
Y_t = \beta_0 + \beta_1 X_{1t} + \beta_3 X_{3t} + \beta_5 X_{5t} + \beta_7 X_{7t} + \alpha E_t + \beta T_t + \gamma S_t + \delta U_t + e_t
\]

(3)

Where \( E_t, T_t, S_t \) and \( U_t \) represent annual observations on coal price, mining technology, small mine size and type of mining, respectively. \( \alpha, \beta, \gamma, \delta \) are parameters to be estimated; others are defined as with Equation (2).

**Data**

As mentioned above, the authors chose three major pieces of national legislation, namely the *Mineral Resources Law* of 1986, the *Mining Safety Law* of 1993 and the *Work Safety Law* of 2002, to examine the effectiveness of government safety legislation in coal mining. In this study, this article focused on the effectiveness of regulations after Deng Xiaoping’s reform and opening up, so the data from 1980 to 2009 are extracted. Figure 1 exhibits the scatter of mortality rate per million tons of raw coal production from 1980 to 2009. The three vertical dotted lines represent the three pieces of national legislation enacted in 1986, 1993 and 2002, respectively. Figure 1 shows that the general trend of the mortality rate per million tons since 1980 is declining though there are several fluctuations during this period. Figures 2 and 3 show the scatters of mortality rate per million tons of raw coal production in SOE mines and TVE/small mines from 1980 to 2009, respectively. Both these rates since 1980 are declining though there are several fluctuations during this period according to the figures. The figures indicate that there are very major differences in those rates. The mortality rate in TVE/small mines is larger than for SOE mines. Figure 4 shows the trends of indicators \( E_t, T_t, S_t \) and \( U_t \) from 1980 to 2009, and that both the percentage

---

of small-scale mines’ annual production in total ($S_t$) and the percentage of underground mine production in total ($U_t$) have some small fluctuations while the average annual price of raw coal ($E_t$) and fully mechanized mining rate ($T_t$) have a marked increase during this period.

The data in this study mainly comprise two parts: first, given the very major differences in mortality rate in SOE mines and TVE/small mines, this article selected $Y_{1t}$: ‘mortality rate per million tons of raw coal production in SOE mines’ and $Y_{2t}$: ‘mortality rate per million tons of raw coal production in TVE/small mines’ as independent variables to reflect the impacts of national legislation, sourced from the *China Coal Industry Statistics Compendium (1949–2009)* [Zhongguo meitan gongye tongji ziliao huibian (1949–2009)], which was edited by China Coal Industry Association organizations. The official

---

data, which are considered as relatively reliable, had to be used in this book, and the main statistical indicators, comprehensively and systematically reflect various periods since the founding of the coal industry development and changes. The annual data were listed in a sequence and the raw data were obtained from the coal mine accidents inquiry system of the China State Administration of Coal Mine Safety. The advantages of choosing these indicators lie in the facts that they: (1) focus attention on the most serious type of injury directly; and (2) are the most relevant for miners to inform them of whether their chances of being killed on the job are increasing or decreasing along with the changes in coal production. Second, this article selected ‘average annual price of raw coal’ ($E_t$), ‘fully mechanized mining rate’ ($T_t$), ‘percentage of small-scale mines’ annual production in total’ ($S_t$), ‘percentage of underground mine production in total’ ($U_t$) as the ‘third variables’. The data on ‘average annual price of raw coal’ were obtained from China Coal Industry Statistics Compendium (1949–2009) [Zhongguo meitan gongye tongji ziliao huibian (1949–2009)] (before 2004) and China Statistical Yearbook (after 2004). Other variables ($T_t$, $S_t$, $U_t$) were obtained from the China Coal Industry Statistics Compendium (1949–2009) [Zhongguo meitan gongye tongji ziliao huibian (1949–2009)].

**Results**

This article used the Multiple Linear Regression method to estimate Equation (2) in SPSS 16.0. Table 1 shows the estimated results of mortality rate in SOE mines. The number of observations (1980–2009) is 30, the efficient of multiple determination $R^2$ (adjusted) is 0.975 and the Durbin–Watson statistic is 2.387. The parameter estimation shows that only the long-run impact of the Mining Safety Law of 1993 is statistically significant at the 0.05 level ($t$-ratios of $b_5$ exceed $|2|$). However, the short-run changes of the Mining Safety Law of 1993 and the Work Safety Law of 2002 are statistically insignificant at the 0.05 level (none of the $t$-ratios of $b_4$, $b_6$ exceed $|2|$); while the short-run effect of the Mineral Resources Law of 1986 is statistically significant ($t$-ratio of $b_2$ is $-2.189$). Second, this article also estimated Equation (3). The efficient of multiple determination $R^2$ (adjusted) is 0.973 and the Durbin–Watson statistic is 2.266. The results show that the four ‘third variables’ ($E_t$, $T_t$, $S_t$ and $U_t$) have a non-significant effect on the coal mine mortality rate in SOE mines ($t$-ratios are 0.402, 0.181, 0.732 and $-1.960$, respectively).

Table 2 shows the estimated results of mortality rate in TVE/small mines. In the first part, the number of observations (1980–2009) is 30, the efficient of multiple determination $R^2$ (adjusted) is 0.937 and
the Durbin–Watson statistic is 1.641. The long-run impact of the Mining Safety Law of 1993 and the Work Safety Law of 2002 are statistically significant at the 0.05 level (t-ratios are 5.422 and –6.378). The short-run impact of the Work Safety Law of 2002 is statistically significant. The estimation of Equation (3) is shown in the second part, the efficient of multiple determination \( R^2 \) (adjusted) is 0.940 and the Durbin–Watson statistic is 1.259. The variations in small-scale mining operations (S) appear significantly important (t-ratio is –4.723).

**Discussion**

The downward trend of the mortality rate per million tons of raw coal production indicates that the risk of fatal injury from mining one million tons of raw coal is less than almost one-tenth what it was

| Table 1. The estimated results of mortality rate in SOE mines. |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Model                          | Beta            | t               | Sig.            | 95% confidence interval for B |
| Equation (2)                   |                 |                 |                 | Lower bound | Upper bound     |
| \( b_{i0} \)                   | 5.413           | 29.343          | 0.000           | 5.030      | 5.795           |
| \( b_{i1} \)                   | –0.294          | –7.135          | 0.000           | –0.380     | –0.209          |
| \( b_{i2} \)                   | –0.519          | –2.189          | 0.04            | –1.010     | –0.027          |
| \( b_{i3} \)                   | 0.097           | 1.665           | 0.110           | –0.024     | 0.218           |
| \( b_{i4} \)                   | 0.128           | 0.587           | 0.563           | –0.323     | 0.579           |
| \( b_{i5} \)                   | 0.151           | 3.022           | 0.006           | 0.047      | 0.255           |
| \( b_{i6} \)                   | 0.061           | 0.266           | 0.793           | –0.412     | 0.534           |
| \( b_{i7} \)                   | –0.093          | –1.857          | 0.077           | –0.196     | 0.011           |
| Equation (3)                   |                 |                 |                 | Lower bound | Upper bound     |
| \( b_{i0} \)                   | 5.912           | 2.869           | 0.009           | 1.641      | 10.200          |
| \( b_{i1} \)                   | –0.216          | –2.945          | 0.007           | –0.368     | –0.064          |
| \( b_{i2} \)                   | 0.167           | 2.590           | 0.017           | 0.033      | 0.301           |
| \( b_{i3} \)                   | 0.048           | 0.520           | 0.609           | –0.144     | 0.240           |
| \( b_{i4} \)                   | –0.050          | 0.382           | 0.706           | –0.024     | 0.035           |
| \( b_{i5} \)                   | 0.005           | 0.382           | 0.706           | –0.024     | 0.035           |
| \( E_t \)                      | –0.055          | –2.051          | 0.050           | –0.111     | 0.001           |
| \( S_t \)                      | 0.016           | 0.731           | 0.473           | –0.029     | 0.061           |

| Table 2. The estimated results of mortality rate in TVE/small mines. |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Model                          | Beta            | t               | Sig.            | 95% confidence interval for B |
| Equation (2)                   |                 |                 |                 | Lower bound | Upper bound     |
| \( b_{i0} \)                   | 6.734           | 35.513          | 0.000           | 6.318      | 7.151           |
| \( b_{i1} \)                   | –0.505          | –11.239         | 0.000           | –0.598     | –0.412          |
| \( b_{i2} \)                   | –0.469          | –1.818          | 0.083           | –1.005     | 0.066           |
| \( b_{i3} \)                   | 0.372           | 5.851           | 0.000           | 0.240      | 0.504           |
| \( b_{i4} \)                   | –0.512          | –2.163          | 0.042           | –1.003     | –0.021          |
| \( b_{i5} \)                   | 0.188           | 3.450           | 0.002           | 0.075      | 0.301           |
| \( b_{i6} \)                   | –0.781          | –3.145          | 0.005           | –1.297     | –0.266          |
| \( b_{i7} \)                   | –0.177          | –3.246          | 0.004           | –0.289     | –0.064          |
| Equation (3)                   |                 |                 |                 | Lower bound | Upper bound     |
| \( b_{i0} \)                   | 22.615          | 9.930           | 0.000           | 17.904     | 27.326          |
| \( b_{i1} \)                   | 0.354           | 2.593           | 0.016           | 0.072      | 0.636           |
| \( b_{i2} \)                   | –0.584          | –3.150          | 0.004           | –0.968     | –0.200          |
| \( b_{i3} \)                   | –0.035          | –0.186          | 0.854           | –0.420     | 0.351           |
| \( b_{i4} \)                   | –0.966          | –3.942          | 0.001           | –1.473     | –0.459          |
| \( E_{i3} \)                   | 0.022           | 0.745           | 0.464           | –0.038     | 0.081           |
| \( S_t \)                      | –0.258          | –3.109          | 0.000           | –0.362     | –0.154          |
30 years ago. How much did the national legislation regarding mine safety contribute to this significant reduction in mortality rate in SOE mines and TVE/small mines, respectively?

Firstly, these three pieces of national legislation have a long-run influence. For SOE mines, the observations plotted in Figure 2 show that at the beginning of the 1980s, the annual mortality rate started to exhibit a downward trend (regard \( b_{15} \)). While the Mineral Resources Law of 1986 and the Work Safety Law of 2002 seem to have no significant impact on mortality rate in SOE mines because none of the \( t \)-ratios of \( b_{15} \) or \( b_{17} \) exceed \[2\], the mortality rate during 1986–1992 and 2002–2009 still steadily moved downward, as indicated in Figure 2. Although the Mining Safety Law was enacted in 1993, the annual mortality rate after that is anomalous, which shows fluctuation between 1.0 and 2.0. The MITS analysis also shows that this Act did not increase mine safety (regard \( b_{15} = 0.151 \)), which is statistically significant (\( t \)-ratio is 3.022). For TVE/small mines, as indicated in Figure 3, the mortality rate has undergone two phases: fluctuations (1980–2002) and the rapid decline (2002–2009). The \( t \)-ratio of \( b_{13} \) is –1.922, where the \( t \)-ratios of \( b_{15} \) and \( b_{17} \) are 5.422 and –6.378. Although the impacts of the Mining Safety Law of 1993 and the Work Safety Law of 2002 are statistically significant, only the Work Safety Law of 2002 (\( b_{17} = –1.149 \)) appears to have improved mine safety while the Mining Safety Law of 1993 (\( b_{15} = 0.977 \)) did not.

Secondly, the three pieces of national legislation also have short-run impacts (1986–1987, 1992–1993, 2002–2003). For SOE mines, only \( b_{12} \) is statistically significant (\( t \)-ratio is –2.189), while \( b_{14} \) and \( b_{16} \) are not. This means that only the Mineral Resources Law of 1986 has a short-run impact on mortality rate in SOE mines. For TVE/small mines, only \( b_{16} \) is statistically significant (\( t \)-ratio is –2.189) while \( b_{12} \) and \( b_{14} \) are not. So the Work Safety Law of 2002 brings a significant short-run influence on mortality rate in TVE/small mines.

From the model regression, the \( R^2 \) (adjusted) of 0.975 (in SOE mines) and 0.937 (in TVE/small mines) demonstrate that the combination of national legislation variables accounts for the declining trend in mortality rate very well. However, the independent variables in Equation (2) are integer variables naturally ordered by years, not ‘real’ legislative action. So this article still needs to examine the context and content of these laws to find some suggestive associations.

The significant short-run effect of the Mineral Resources Law of 1986 on reducing the mining risk in SOE mines may be due to its ‘birth order’.\(^5^4\) The Mineral Resources Law of 1986 was the first national legislation introduced into the lawless situation after Deng Xiaoping’s reform and opening up. At the national level, the rules for mining safety were suddenly changed from none to some. Around these years, Regulations on Mine Safety, Regulations on Mine Safety Supervision and many other regulations were enacted to increase mine safety. The Mineral Resources Law of 1986 indicated the legal regime of mineral resources management established initially,\(^5^5\) which mean the exploration, utilization and protection of mineral resources moved into the legal orbit. However, this law seems to have had no short- or long-run effect on mine safety in TVE/small mines. The economic background during this period could have played a factor. In order to meet the economic demand and improve coal output, the Chinese government adopted an ‘in all possible places, use all possible forms’ policy to encourage the coal industry with the opening of the economy in 1979. As a result, township and village coal mines with TVE or individual investment began forming in large numbers. There were 10,000 township and village coal mines in China by 1980, while the number rose to 100,000 by 1991, as indicated in The Compiling Committee of China Coal Industry Yearbook of 1992. Although these TVE/small mines have long proved to be economically important,\(^5^6\) there is an obvious need to address many negative aspects arising from small-scale mines; the high casualty rate is a serious one.\(^5^7\) The explosive growth of small-scale mines may have led to the high level and fluctuating mortality rate in TVE/small mines during 1980–1991.

\(^5^4\) Lewis-Beck and Alford, ‘Can government regulate safety?’


\(^5^7\) Gavin Hilson and Oliver Maponga, ‘How has a shortage of census and geological information impeded the regularization of artisanal and small-scale mining?’, Natural Resources Forum 28, (2004), pp. 22–23.
Though the *Mining Safety Law* of 1993 was the first legislation named ‘safety law’ on labor safety, it failed to have an effect on the coal mine safety situation, especially in the 1990s. The improvement of coal mine safety in SOE mines seems to have ceased, or at best slowed, while the mortality rate in TVE/small mines has an anomalous rise in the late 1990s. So this article needs to focus on the background of those years. In 1993, the Chinese government made a significant move on the coal industry. They decided to release coal price controls gradually and reform the state-owned enterprise operation system. Many state-owned small mines were privatized and subcontracted to individuals. The remaining large-scale state-owned coal mines were reorganized into modern companies. The coal marketing environment was changed, and coal companies have become market-driven. As a result, both SOE mines and TVE/small mines paid more attention to the demands of marketing, thus cutting off the safety input which was usually regarded as an operational cost. On the one hand, low investments in safety became a chronic issue for China's coal mining industry. On the other hand, the rapid price increase made coal mining such a profitable business that some mines were encouraged to overproduce to pursue high profits and increased the chance of fatal accidents. This phenomenon may be the main reason why the *Mining Safety Law* of 1993 failed to have the desired effect on coal mine safety.

As for the *Work Safety Law* of 2002, this is the basic law of work safety in various industries in China and represents a further improvement of the legislative regime of coal mine safety. The Act established a basic management system of work safety, but also provided a legal basis for the industry to implement safety management. Following the introduction of the Act, *Permit Regulations on Work Safety* in 2004, *Special Provisions on the Prevention of Coal Mine Accidents* in 2005, *Provisions on Accident Reporting and Investigation of Work Safety* in 2007, and many regulations have been promulgated. Public attention and outrage culminated in the passage of laws and regulations to prevent the recurrence of unwanted events. During 1992–2002, the National People’s Congress, State Council and relevant departments promulgated six laws and five pieces of regulation in response to the rising number of accidents. The legal regime of coal mine safety has been basically built, which undoubtedly helped to make significant contributions to coal mine safety and has been an area of focus in recent years in China. Though the *Work Safety Law* of 2002 has had no significant short- and long-run impact on mortality rate in SOE mines, the mortality rates were mostly on a downward trend during 2002–2009; and this Act really had a significant effect on mortality rate in TVE/small mines. The downward drift of the mortality rate should be attributed to the central government’s regulation. The *Work Safety Law* of 2002 and a series of laws and regulations created before 2002 have also had some influence, such as the *Coal Law* in 1996, the *Criminal Law Amendment of the People’s Republic of China* in 1999, *Regulations for Supervision on Coal Mine Safety* in 2000, *Regulations for Coal Mine Safety* in 2001, etc., all of which have proved that the government was paying attention to, and acting on, coal mine safety. Besides, an administrative agency—SAWS—was established by the State Council in 2001 and is responsible for all industrial health and safety policy and enforcement in China. The agency ‘separated policy-making and enforcement from mining production’ and is a ‘revolutionary move in China’.

Just as the estimated results show, the ‘third variables’ may influence coal mine safety in SOE mines and TVE/small mines. For SOE mines, the coal price and underground mine production do not appear important whereas coal mining technology does contribute significantly to an explanation of mine

---

59 Homer, ‘Coal mine safety regulation in China and the USA’.
62 State Administration of Coal Mine Safety (SACMS).
safety. From this result, one previous conclusion that technology advances can make coal mining less risky has been proved.\textsuperscript{64} for the negative relationship between coal mining technology and mortality rate per million tons. Figure 2 shows that the fully mechanized mining rate basically rose steadily from 1980 to 1992 and remained stable during 1993–2002, but increased substantially after that. Thus, there is reason to believe that the mortality rate in SOE mines has some relationship with the upward trend of coal mining technology. Because the mortality rate per million tons was selected as the dependent variable in this study, which is not only related with the fatalities in coal mining but also dependent on coal production, the more developed the coal mining technology, the higher the coal production, which also means the lower the mortality rate per million tons. For TVE/small mines, the authors do not take the coal mining technology and underground mine production into consideration, because the data for these two independent variables exist only for the SOEs. The small-scale mining operations have a significant effect on mine safety in TVE mines. It really makes sense that the higher proportion of small-scale mines will increase the chance of fatal accidents in TVE/small mines.

Conclusions

China’s coal mining safety record has improved since 1980. This study is an exploratory attempt to use statistical methods to examine the factors behind the improvement in coal mine safety. By applying the MITS analysis method, this article has analyzed the promulgated background of coal mining laws and regulations, and selected three typical pieces of national legislation as the interventions in both the SOE mines and TVE/small mines. Besides, the coal mine safety data from 1980 to 2009 were collected to empirically support the study. Meanwhile, this article also analyzed the influence of ‘third variables’ on coal mine safety. The estimated results indicate that the answer to the empirical question—have these interventions played a significant role in coal mine safety management and indeed made the work less hazardous?—will be different depending on many factors, such as technology, administration and socioeconomic environment, type of coal mine and structural reforms of the sector. Coal mine safety exhibited major differences of mortality rate in SOE mines and TVE/small mines. So this article may draw conclusions by looking at different types of coal mine and time frames. That may be one of the reasons why previous studies have not reached a consensus about the effectiveness of safety regulations in China’s coal mine industry.

The examination of the impact of these pieces of legislation should shed light on the effectiveness of the coal mine safety legal regime, as well as the government regulatory system. First, promulgation of the laws and regulations should analyze and combine with the specific context of the time, and cannot go against the era trend. Second, the legal regime and regulatory system should be comprehensive but also targeted; meanwhile the enforcement should be enhanced. Third, the implementation of safety laws and regulations should achieve sustainability even though they do not show effectiveness at the beginning.

This article may have several implications for China’s mine safety regulation. First, the Chinese government must focus on adequate mine capacity in order to ensure safe working conditions. The estimated results empirically support the view that more developed the coal mining technology will lead to higher the coal production and a lower mortality rate. Due to the low productivity of China’s coal industry, more advanced technology and investment would have a dramatic impact on mine safety and is necessary for China’s coal-mining industry to meet the growing demand for the resource. Second, large numbers of TVE/small mines have also influenced the nature of China’s coal mine industry. The Chinese government also recognizes the high risk and less input in safety in TVE/small mines, and they now try to reinforce the supervision over and management of work safety in TVE/small mines. Closing those mines that cannot meet the required safety standard, and forcing the up-to-standard ones to

keep their eyes on safety input by regularly checking on them, may be helpful to reduce the incidence of accidents. At the same time, the government and mine companies also need to tighten the supply of labor which might have been a factor leading to better safety provisions. Carrying out staff education and training on this topic regularly will be necessary. Third, though the SOE mines have always been considered as having a higher safety record than TVE/small mines, especially in modern coal mines, several disasters have still astonishingly occurred. These SOE mines should pay more attention to production organization and safety management, and review all aspects of their business operations to avoid accidents, including organizational structure, management models, information handling and personnel management.

Acknowledgements

The authors acknowledge the financial support from the National Natural Science Foundation of China (71522013, 71373250 and 71490735), the Major/Innovative Program of Development Foundation of Hefei Center for Physical Science and Technology (2014FXCX004), and the Youth Innovation Promotion Association CAS.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Jiuchang Wei, Ph.D., is a professor of risk management at the University of Science and Technology of China. He is working on subjects related to risk communication and disaster management.

Peng Cheng is a Ph.D. student at the University of Science and Technology of China. His research interests are situated in the fields of disaster management and occupational safety.

Lei Zhou is a joint postdoctoral researcher at the University of Science and Technology of China, and Huishang Bank. His research focuses on occupational safety and health.