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Dummy variable model analysis with law factors on safety production in Chinese coal mine industry

Tan Haixia[a], Wang Hongtu[a,b], Chen Lin[c], Shi Feng[a,] a*

[a]*State and local joint engineering laboratory of methane drainage in complex coal gas seam, Chongqing University, Chongqing, China.*
[b]*State Key Laboratory of Coal Mine Disaster Dynamics and Control, Chongqing University, Chongqing, China.*
[c] *Exploration Institute of Geology and Mineral Resources, Yunnan Bureau of Geology and Mineral Resources, Kunming, China*

Abstract

This paper investigates the security role of "three laws and one regulation" (*PRC Mine Safety Law*, *PRC Coal Law*, *PRC Safety Production Law* and *the Regulation of Reporting and Investigating Production Accident*) on coal mine safety production in China through a dummy variable model analysis. The results show that the security role of "three laws and one regulation" made the death rate reduced by 0.895 persons per million tons coal. The terms of economic penalties and sanctions would be closely consistent with the level of economic development, and the stronger law enforcement, the better its implementation result.

Keywords: coal mine safety production; law factors; dummy variable model; comparative analysis

1. Introduction

Coal mining has historically been confronted with higher accident incidence and severity rates than other industries in China. Many reasons will trigger accidents, and the principal one is insufficient safety input in China. But, a little attention was paid to increase safety input according to technical codes or requirements, generally felt unnecessary or too costly to manufacturers. As a result, corporations can generally realize the safety input problems only when unacceptable accidents happened. Law is the best factor to urge enterprises to enhance investment in safety. Under the severe safety situation of Chinese

* Corresponding author. Tel.: +86-023-65111237; fax: +0-000-000-0000 .
E-mail address: haix@cqu.edu.cn.

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coal mining, the construction of laws on safety production was strengthened continuously over the last two decades, and mine safety was improved gradually.

However, the security role of laws or regulations on coal mine safety production was a debated issue. Some argued that these laws or regulations had a deterrent effect on coal mine occupation accidents [1-2], while other argued that these laws and regulations lead to take up much society costs due to the lack of operability [3-4]. At present, there is no related theoretical study to clarify the above debates. In this paper, these debates will be analyzed and discussed using the dummy variable model of death rate per million tons coal relying on solid empirical findings.

2. "Three laws and one regulation" and methods

2.1. "Three laws and one regulation"

There were many laws or regulations related to coal mine safety production in China. Here, only took these laws or regulations that played central security role in coal mine safety production into account for study, including *PRC Mine Safety Law* (enforced in May 1, 1993), *PRC Coal Law* (enforced in December 1, 1996), *PRC Safety Production Law* (enforced in November 1, 2002) and *the Regulation of Reporting and Investigating Production Accident* (enforced in June 1, 2007).

In general, compared with the similar laws and regulations in different periods, the latter was the amendments and improvements of preceding laws, which manifest a comprehensive effect with inherited effects. Thus, the impacts from other laws should be eliminated when comparing different laws. And dummy variable method is a common method to remove or eliminate the influence of homogeneous factors at different times which is often used to eliminate seasonal factor [5].

2.2. Methods

Dependent variable is influenced by some qualitative variables (such as law, gender etc.) besides some quantitative variables in the regression analysis. In view of above laws and regulations played significant security roles on Chinese coal mine safety production, law factors should be considered in the regression model of coal mine safety production. The setting of dummy variable, indicate by D, is the common method to solve value assignment of qualitative factors. The value of D could be assigned man-made as "0" or "1" according to its dichotomy characteristics, where D=1 means that the qualitative factors possess certain attributes or subjected by some factors (here law factor), while D=0 is the contrary.

3. Influence factors of coal mine safety production and indicators established

3.1. Death rate per million tons coal (Y)

The safety level of coal mine could be well reflected by death rate per million tons coal (Y). The death rate per million tons coal in China from 1990 to 2008 was shown in Fig. 1. Death rate per million tons coal remained at a high level in the 1990's and continued to decline since year 2000 though the increase output of raw coal.

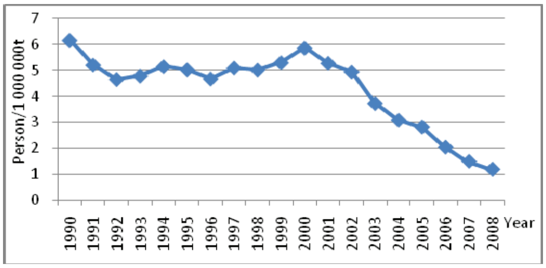

Fig.1 Death rate per million tons coal in China from1990 to 2008

3.2. Indicators established

The death rate per million tons coal can reflect the safety level of coal mine well. The reduction of death rate not only originates from poor safety technology and safety management, also other hidden root causes including social, economic, and basic investment in coal mining, such as various prevention and control factors [6], and deployment and usage of new technology [7], etc. When establishing the model of death rate per million tons coal, the factors mentioned above should all be considered. Finally, variations across periods within coal mining industry in terms of how effects of adoption of laws or regulations provided additional facilitation of above factors for safety production. Usually, the safety state of coal mining industry can be better represented by comparative indexes.

3.2.1. Mechanized level of mining (X_1)

The production conditions of equipment were usually regarded as an important factor in the intrinsic safety in safety engineering. Mechanized mining can directly reduce exposure time and number of workers under hazardous conditions, which then improve work efficiency and reduce occupation accidents. Mechanized level of mining was 63.69% in 1990, and was 90.82% in 2008, rising by 42.6% during 1990-2008.

3.2.2. Number of coal mining professional personnel in whole employed persons (X_2)

Enhanced the level of safety technology is a process that results from the efforts and activities of a group or of an organizational system.

$$X_2 = \frac{Number\ of\ coal\ \min e\ engineer\ personnel}{Number\ of\ coal\ \min e\ staff\ and\ wor\ker s} \times 100\% \qquad (1)$$

The number of coal mining professional personnel in whole employed persons was 2.49% in 1990, and 7.99% in 2008, a more than 3-fold increase.

3.2.3. Per capita GDP (X_3)

There was a strong correlation between per capita GDP measuring the level of economic development and safety production [8-9]. The total amount indexes should be represented on inflation-adjusted basis. Per capita GDP was RMB 1644 yuan in 1990, and RMB 4517.57 yuan in 2008 with constant 1990 RMB, a more than 174.8% increase in real terms during 1990-2008.

3.2.4. All-personnel labor efficiency of coal face workers (X_4)

$$X_4 = \frac{Raw\ coal\ ourput / a}{Attendance\ in\ all\ personnel \times working\ day / a} \qquad (2)$$

All-personnel labor efficiency of coal face workers was 1.217 (t/work efficiency) in 1990, and 5.709 (t/work efficiency) in 2008, more than 4-fold increase over 1990-2008.

3.2.5. Total investment per ton coal in capital construction (X_5)

Adequate investment in capital construction during the initial phases was the key to produce an essential safe system.

$$X_5 = \frac{Investment\ in\ coal\ \mathrm{min}e\ capital\ construction}{Raw\ coal\ output} \tag{3}$$

The data of investment in coal mine capital construction was deflated by price indices for investment in fixed assets. Used 1991 constant RMB, total investment per ton coal in capital construction was 19.019 (yuan/t) in 1990, and 42.542 (yuan/t) in 2008, rose by 123.7% during 1990-2008.

3.2.6. Dummy variables on "three laws and one regulation"

"Three laws and one regulation" played an important role in reducing the death rate per million tons coal.

D_1—PRC Mine Safety Law; *D_2—PRC Coal La w*; *D_3—PRC Safety Production Law*;

D_4—the Regulation of Reporting and Investigating Production Accident

3.3. Index data

According to the above formula each index, as well as CHINA COAL INDUSTRY YEARBOOK (the data sources of Y, X_1, X_4 and X_5), CHINA TECHNOLOGY STATISTICAL YEARBOOK (the data sources of X_2) and CHINA STATISTICAL YEARBOOK in 2009 (the data sources of X_3), Table 1 showed that the calculated data of all indicators from 1990 to 2008.

Table 1. Calculated data of all indictors from 1990 to 2008

Indicator	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Y (person/1000 000t)	6.16	5.21	4.65	4.78	5.16	5.03	4.67	5.10	5.02	5.30
X_1 (%)	63.69	68.69	72.26	71.02	66.36	71.96	71.58	73.27	73.63	73.41
X_2 (%)	2.488	2.435	2.341	2.375	2.349	2.369	4.416	4.943	4.886	5.266
X_3 (1990=100)(yuan)	1644	1757.66	1902.28	2189.69	2641.93	3005.04	3196.94	3244.76	3216.10	3175.15
X_4 (t/work efficiency)	1.217	1.259	1.330	1.398	1.590	1.780	1.923	2.079	2.180	2.258
X_5 (1991=100) (yuan/t)	19.019	22.916	22.227	21.022	18.593	20.933	20.719	25.079	15.452	10.421
D_1	0	0	0	0.667	1	1	1	1	1	1
D_2	0	0	0	0	0	0	0.083	1	1	1
D_3	0	0	0	0	0	0	0	0	0	0
D_4	0	0	0	0	0	0	0	0	0	0
Indicator	2000	2001	2002	2003	2004	2005	2006	2007	2008	–
Y (person/1000 000t)	5.86	5.28	4.94	3.72	3.08	2.81	2.04	1.49	1.18	–
X_1 (%)	74.43	75.43	77.78	81.47	82.72	80.10	85.50	88.20	90.82	–
X_2 (%)	5.900	6.211	7.101	6.906	5.582	6.357	6.471	7.347	7.991	–
X_3 (1990=100)(yuan)	3239.01	3305.97	3324.28	3411.65	3649.21	3786.09	3923.51	4212.26	4517.57	–
X_4 (t/work efficiency)	2.526	2.780	3.118	3.343	3.764	4.109	4.334	4.570	5.709	–
X_5 (1991=100) (yuan/t)	7.405	8.508	8.316	12.255	13.028	25.615	28.981	31.760	42.542	–
D_1	1	1	1	1	1	1	1	1	1	–
D_2	1	1	1	1	1	1	1	1	1	–
D_3	0	0	0.167	1	1	1	1	1	1	–
D_4	0	0	0	0	0	0	0	0.583	1	–

Note: As *PRC Mine Safety Law* was enforced from May 1, 1993, in 1993, D_1 played a role only 8 months, so the value of D_1 was assigned to "0.67 (i.e. 8/12)" in 1993, "0" before and "1" from 1994 to 2008. Similarly, the value of D_2, D_3 and D_4 can be assigned.

4. Empirical analysis

4.1. Regression model of death rate per million tons coal without law dummy variables

4.1.1. Model

Through the results of correlation fitting (XY line graph), the regression model can be expressed as follows

$$Y_t = C + \alpha_1 \frac{1}{1+X_{1t}^2} + \alpha_2 \frac{1}{1+X_{2t}^3} + \alpha_3 \frac{1}{1+X_{3t}^2} + \alpha_4 \frac{1}{1+X_{4t}^2} + \alpha_5 \frac{1}{X_{5t}} + \mu_t \quad (4)$$

Where Y_t is death rate per million tons coal in period *t* (person/1 000 000 t); X_{1t} is mechanized level of mining in period *t* (%); X_{2t} is number of coal mining professional personnel in whole employed persons in period *t* (%); X_{3t} is per capita GDP in period *t* (yuan); X_{4t} is all-personnel labor efficiency of coal face workers in period *t* (t/work efficiency); X_{5t} is total investment per ton coal in capital construction in period *t* (yuan/t). μ_t is a random error in period *t*, and *t* = 1990, 1991, ⋯, 2008. C_I is constant, C_I and the coefficients $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5$ are parameters to be estimated.

4.1.2. Model estimation

The solution of regression of data from 1990 to 2008 based on Eq. (4) can be obtained with Eviews 5.0.

$$Y_t = -2.139 + 24519.37 \frac{1}{1+X_{1t}^2} - 13.959 \frac{1}{1+X_{2t}^3} - 5704890 \frac{1}{1+X_{3t}^2} + 10.155 \frac{1}{1+x_{4t}^2} + 21.167 \frac{1}{X_{5t}} \quad (5)$$

t-value	-2.601	3.688	-2.287	-2.645	3.118	7.300
P	0.022	0.003	0.040	0.020	0.008	0.000

As seen from the t-value of Eq. (5), the values of all explaining variables entered distinctly into the model. Eq. (5) with some goodness-of-fit measures, obviously, *R-squared* was equal to 0.964, *adjusted R-squared* 0.949, *S.E. of regression* 0.330, *F-statistic* 68.660, and *D. W.* 2.851.

The negative coefficient value of $1/(1+X_{3t}^2)$ made out that death rate per million tons coal had risen with the increasing of per capita GDP. This result confirmed the study "When a low level of economic development, the death number of occupation accidents on the upswing" [8-9].

The regression results of Eq. (5) on the assumption that the relationship between death rate per million tons coal and key influence indicators on safety production has no significant impact by other factors. However, with economic rapid development and township and private coal mines in large numbers, the legal system of safety production was tightened up by government, so the characteristic of death rate per million tons coal may also be for a change.

4.2. Regression model of death rate per million tons coal with law dummy variables

4.2.1. Model

A dummy variable model involving laws can understand better the effects of laws on coal mine safety production. Dummy variable model had two forms, differential intercept model and differential slope coefficient model. A differential intercept dummy variable—the hypotheses of no slope change due to law factors based on Eq. (4) can be expressed as follows

$$Y_t = C + \alpha_1 \frac{1}{1+X_{1t}^2} + \alpha_2 \frac{1}{1+X_{2t}^3} + \alpha_3 \frac{1}{1+X_{3t}^2} + \alpha_4 \frac{1}{1+X_{4t}^2} + \alpha_5 \frac{1}{X_{5t}} + \beta_1 D_{1t} + \beta_2 D_{2t} + \beta_3 D_{3t} + \beta_4 D_{4t} + \mu_t \quad (6)$$

Where, the definition of *Y* and X_i were synonymous with Eq. (4), and D_i was defined as follows

D_1—*PRC Mine Safety Law;* D_2—*PRC Coal Law;* D_3—*PRC Safety Production Law;*

D_4—*the Regulation of Reporting and Investigating Production Accident*

And μ_t was a random error, C_2 was constant, C_2 and the coefficients $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \beta_1, \beta_2, \beta_3, \beta_4$ were parameters to be estimated, and t = 1990, 1991, ⋯, 2008.

4.2.2. Model estimation

Accordingly, the direction and magnitude of the change in death rate per million tons coal that may result from each introduced law or regulation was estimated used Eviews 5.0. More specifically, how different the effects of these laws or regulations were determined. The regression solution of Eq. (6) is

$$Y_t = -0.914 + 20529.21\frac{1}{1+X_{1t}^2} - 2.604\frac{1}{1+X_{2t}^3} - 1318854\frac{1}{1+X_{3t}^2} + 4.531\frac{1}{1+X_{4t}^2} + 13.767\frac{1}{X_{5t}}$$

t-value -0.641 2.025 -0.366 -0.159 0.872 3.176

P 0.537 0.074 0.723 0.877 0.406 0.011

$$+0.089D_{1t} + 0.580D_{2t} - 0.866D_{3t} - 0.697D_{4t} \qquad (7)$$

0.066 1.324 -1.493 -1.724

0.949 0.218 0.170 0.119

Comparing the regression result of Eq. (7) with that of Eq. (5), obviously, eq. (7) was better, and its *R-squared* was equal to 0.980, *adjusted R-squared* 0.961, *S.E. of regression* 0.290, *F-statistic* 50.136, and *D. W.* 2.331. A negative and significant coefficient of D_i suggested that the law had a positive influence on the change in death rate; "negative" meant that death rate decrease will become larger (stronger deterrence effect). A positive and significant coefficient suggested that the law had a negative influence on the change in death rate; "positive" meant that death rate decrease will become smaller (weaker deterrence effect).

4.3. Comparative analysis empirical results and security roles of "Three Laws and One Regulation"

By comparing residual tests and model stability tests of Eq.(5) with that of Eq.(7), it can be quite helpful to illustrate whether the introduction of dummy variables improves the model goodness of fit. Table 2 showed the comparison of the results of hypothesis testing of Eq. (5) without involved law dummy variables and Eq. (7) with involved law dummy variable.

Table 2. Comparison of the results of hypothesis testing of eq.(5) and eq.(7)

Hypothesis-testing	Null Hypothesis	Eq. (5)		Eq. (7)	
		Test Results (P-value)	Conclusion	Test Results (P-value)	Conclusion
Serial Correlation LM Test	Without serial correlated	F=4.3390(0.0593)	With serial correlated	F=0.7709(0.4055)	Without serial correlated
ARCH LM Test	Without Heteroscedasticity	F=7.4496(0.0148)	With Heteroscedasticity	F=0.0137(0.9082)	Without Heteroscedasticity
Histogram-Normality Test	Normal distribution	$Chi^2(2)$=0.7239(0.6963)	Normal distribution	$Chi^2(2)$=1.4526(0.4837)	Normal distribution
Ramsey RESET Test	Regression correct	F=3.8957(0.0719)	Regression incorrect	F=1.1549(0.3686)	Regression correct

As seen from Table 2, obviously, Eq. (7) without serial correlated, without heteroscedasticity, and following normal distribution and regression configured correct.

From the sign and values of β_i, the direction and magnitude of the effects of law factors can be determined from Eq. (7):

Without taking into account the impact of “three laws and one regulation” condition, death rate per million tons coal is average reduced by: C_2 = -0.914 (person); Under enforced *PRC Mine Safety Law* condition, death rate per million tons coal is average reduced by: $C_2 + \beta_1$ = -0.914 + 0.089)= -0.825 (person); Under enforced *PRC Coal Law* condition, death rate per million tons coal is average reduced by: $C_2 + \beta_2$=-0.914 + 0.580= -0.334 (person); Under enforced *PRC Safety Production Law* condition, death rate per million tons coal is average reduced by: $C_2 + \beta_3$ = -0.914 + (-0.866)= -1.780 (person); Under enforced *the Regulation of Reporting and Investigating Production Accident* condition, death rate per million tons coal is average reduced by: $C_2 + \beta_4$ = -0.914 + (-0.697)= -1.611 (person).

Under other conditions unchanged, with the quantitative variables for each additional one unit, the enforcement of “three laws and one regulation” make death rate per million tons coal average reduce by 0.895 person ($\beta_1 + \beta_2 + \beta_3 + \beta_4$ = 0.089 + 0.580 –0.866 – 0.697).

Now, given

$$20529.21\frac{1}{1+X_{1t}^2} - 2.604\frac{1}{1+X_{2t}^3} - 1318854\frac{1}{1+X_{3t}^2} + 4.531\frac{1}{1+X_{4t}^2} + 13.767\frac{1}{X_{5t}} = Q \quad (8)$$

So, the relationship of each of “three laws and one regulation” acted on death rate per million tons coal can be shown by Figure 2.

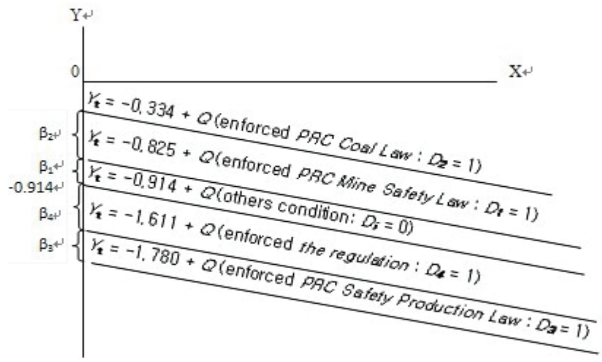

Fig.2 Relationship of each of “three laws and one regulation” acted on death rate per million tons coal

5. Conclusions

(1) The results of multiple regression model show that mechanized level of mining and total investment per ton coal in capital construction have a positive effect on coal mine safety production, and per capita GDP a negative effect. This means that any change in death rate reduced will depend on these variables, as well including number of coal mining professional personnel in whole employed persons and all-personnel labor efficiency of coal face workers.

(2) The implementation of “three laws and one regulation” on average makes the death rate per million tons coal reduced by 0.895 person; “*PRC Mine Safety Law*” and “*PRC Coal Law*” make coal mine death rate increased instead of decreased, and the ratio of security role of “*PRC Safety Production Law*” and "*the Regulation of Reporting and Investigating Production Accident*” on coal mine death rate-reducing is about 5:4.

(3) Our theoretical and subsequent empirical work indicates that the laws and regulations on coal mine safety production play an important role in deterrent death from coal mine occupation accidents. And the more detail penalty rules of law, the stronger operability in the implementation process; the terms of economic penalties and sanctions is closely consistent with the level of economic development, and the greater punishment, the better its implementation. The conclusion of analysis developed could be used to help policy makers to tailor more effectively laws and regulations to particular coal mine conditions.

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