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Contribution of Safety to Mining Economic Growth in China

Tan Haixia, Wang Hongtu, Yuan Zhigang, Liu Jingcheng, Chen Lin, Haladou Abdou
State and local joint engineering laboratory of methane drainage in complex coal gas seam, Chongqing University, Chongqing 400030,China;
Key Lab for Exploitation of China Southwestern Resources & Environmental Disaster Control Engineering, Ministry of Education, Chongqing University, Chongqing 400030, China,
Geology and Mineral Resources Exploration Academy of Yunnan Geology and Mineral Resources Bureau, Kunming 650051, China;
School of Economics and Business administration, Chongqing University, Chongqing 400030, China
E-mail: haix@cqu.edu.cn;

Abstract: Safety input is a safeguarding force to mining, as well as one of main reasons for the increased growth rates of Total Factor Productivity (TFP). To figure out the contribution of the safety input to mining economic growth, a new production safety index system with six principal items describing China mining safety was constructed. The study found that China mining production safety level was improved continuously from 0.462 in 1991 to 7.687 in 2007, a more than 16-fold increase. Using co-integration theory and dynamic construction model, a mining economic growth model was established based on the new production safety index system. The empirical results prove that labor input and capital input are still major factors to promote mining economic growth, and the production safety not only contributed the short-term GDP growth of mining industry but also helped present 7% of contribution rate to the long-term elasticity coefficient.

Keywords: mining; production safety index; economic growth model; contribution rate of safety input to economy growth

1. Introduction

Mining has historically been one of the highest accident incidence and severity rates of any China industry because of its hazardous working situation or condition. There are many reasons to trigger accidents, and the insufficient safety resource is the principle one in Chinese industries. Safety input, which is, generally regarded as sunk cost without or unworthy output. A little attention was paid to increase safety input following technical codes or requirements as a result of the penetrability between safety input and production input, the safety funded up-front and its' benefit hysteresis. So, making clear how safety investment contributes to mining economic growth in becoming an accurate cognition of safety input and its effect.

There have been studies that contribution rate of safety investment to economic growth (CRS) can be mathematically designed by input-output approach, superposition method and product-function method [1-3]. In their studies, CRS was defined as the share of safety output in total output value, and safety output was generally divided into derogation part and increment part. The increment part has been included in GDP, but derogation part was too difficult to estimate and was found in theory not in the productivity statistics.

In the passing studies, safety output derived from three aspects safety input including level of safety technology, safety capital input and safety labor input. Where, safety capital input involved safety allowance from government, expenditure in labor protection and occupational disease; safety labor input involved the number of safety technologists and safety managers. In fact, it was difficult to differentiate safety input from production input [4]. National Mining Association thought, 30 years proven, that coal mine accidents had been significantly reduced by deployment and usage of new technology.

As is mentioned above, their approaches led to the unsatisfied and undervalued the contribution of safety input. However, the experiences of CRS become an important factor for the successful flowing process.

2. Methods

Capital input and labor input, in addition to safety, are the driving force to economic growth of mining. However, because of safety's fuzzy, indeterminate and relative nature, the contribution of safety to economic growth differs from that of other production factors. Safety production environment can make for tremendous rise of Total Factor Productivity, thus the economic growth is accelerated. For example, safety and productivity were improved in the mechanized system

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than the conventional system [5]. So safety value is not a pure investment-output, studying safety contribution should lay great emphasis on systems analyst rather than independent of the overall economy.

Contribution rate is defined as a share of some or other portion growth in gross growth in economics. All contribution rates owe something to the legacy of general concept. CRS should be defined as a share of safety value growth in total economic growth.

Cobb-Douglas production function was a theoretical approach to evaluate variety contribution rate for depicting the relation between output and input of capital and labor. It was widely used for examining the effect share of part in entirety. In this paper, a mining's multifactor C-D production function model was established based on growth model of Barro (2000) which was expanded from C-D production function.

$$\ln Y^T = \ln A + \alpha \ln K + \beta \ln L + \gamma \ln S \qquad (1)$$

We assumed that technological progress was Hicks-neutral, A was the Solow residual or TFP growth rate; Y_t, K_t, L_t and S_t denoted output of mining, mining capital input, number of mining labor, and level of mining safety, respectively; and the coefficients α β and γ denoted respectively the capital elasticity, labor elasticity and safety elasticity of production to be estimated, and γ was the observation CRS.

3. Index and Data Sources

3.1. Output of Mining

In all informed researches, data processing without considering inflation and time, which had not comparability on statistical significance [6]. Nominal mining total output value was deflated by mining PPI indices, used constant 1991 RMB.

3.2. Capital Stock and Capital Services of Mining

Using perpetual inventory approach, total value of mining fixed assets at current year was equal to that the sum of net fixed assets at preceding year and investment in fixed assets at current year deducted depreciation of fixed assets at current year.

Chow [7] considered that fixed assets had not practically inflation from 1952 to 1978 in China, price regulation was unnecessary as calculating accumulation of fixed assets. Afterward, it was deducted 30% liquid capital by Li Zilai (2001) [8]. We adopted Li's estimation result. And in the light of about annual 7.4% proportion of mining investment in construction and innovation in total investment of whole country since 1978, so net value of mining fixed assets was 7.4% proportion of mining fixed assets stock in that of whole country. The data of mining investment in capital construction and innovation was used as that of mining investment in fixed assets, deflated with price indices of investment in fixed assets.

Depreciation rates of fixed assets were discrepancy. Considering Chinese economic with a faster increase since 1990s, depreciation rate should also be raised step by step. It was supposed that depreciation rate of fixed assets was a linear function.

$$Y = 0.05 + 0.00326X \qquad (2)$$

Where Y and X denote depreciation rate and time (year).

3.3. Labor Services of Mining

Due to short of the quality index of the labor members, we cannot help but adopt the number of labor members. With extracted and transported by hand substituted gradually by machines, mining employed persons decreased significantly, from 905 ten thousand in 1991 to 535 ten thousand in 2007.

3.4. Safety Indexes of Mining

Enterprises' safety state can be better represented by comparative index. Accidents may develop from a sequence of deficiencies not only involving poor safety technology and safety management, also other hidden root causes including insufficient investment in infrastructure, poor comprehensive management system, and ill mine production environment, that can be represented by accident causation theory [9]. Besides, mine environment protection [10] and technology development capability [11]. The mining safety index system was composed of six principal items based on index's availability and comparability (Figure 1.).

The data of nominal output of mining, capital services and labor services of mining, X_1 and X_5 were all published by CHINA STATISTICAL YEARBOOK, the data of X_2 and X_6 by CHINA TECHNOLOGY STATISTICAL YEARBOOK, the data of X_3 by CHINA LABOUR STATISTICAL YEARBOOK, the data of X_4 by CHINA COAL INDUSTRY YEARBOOK.

Weight distribution is necessary for calculating the aggregative indicator of level of mining safety production environment, level of mining technology development capability and mining production safety index. Principal Component Analysis (PCA) was a good statistical analysis technique. Its strength lies in that the calculated aggregative indicators not only still retain the major information of original variable, also can cut down subjectivity and arbitrariness.

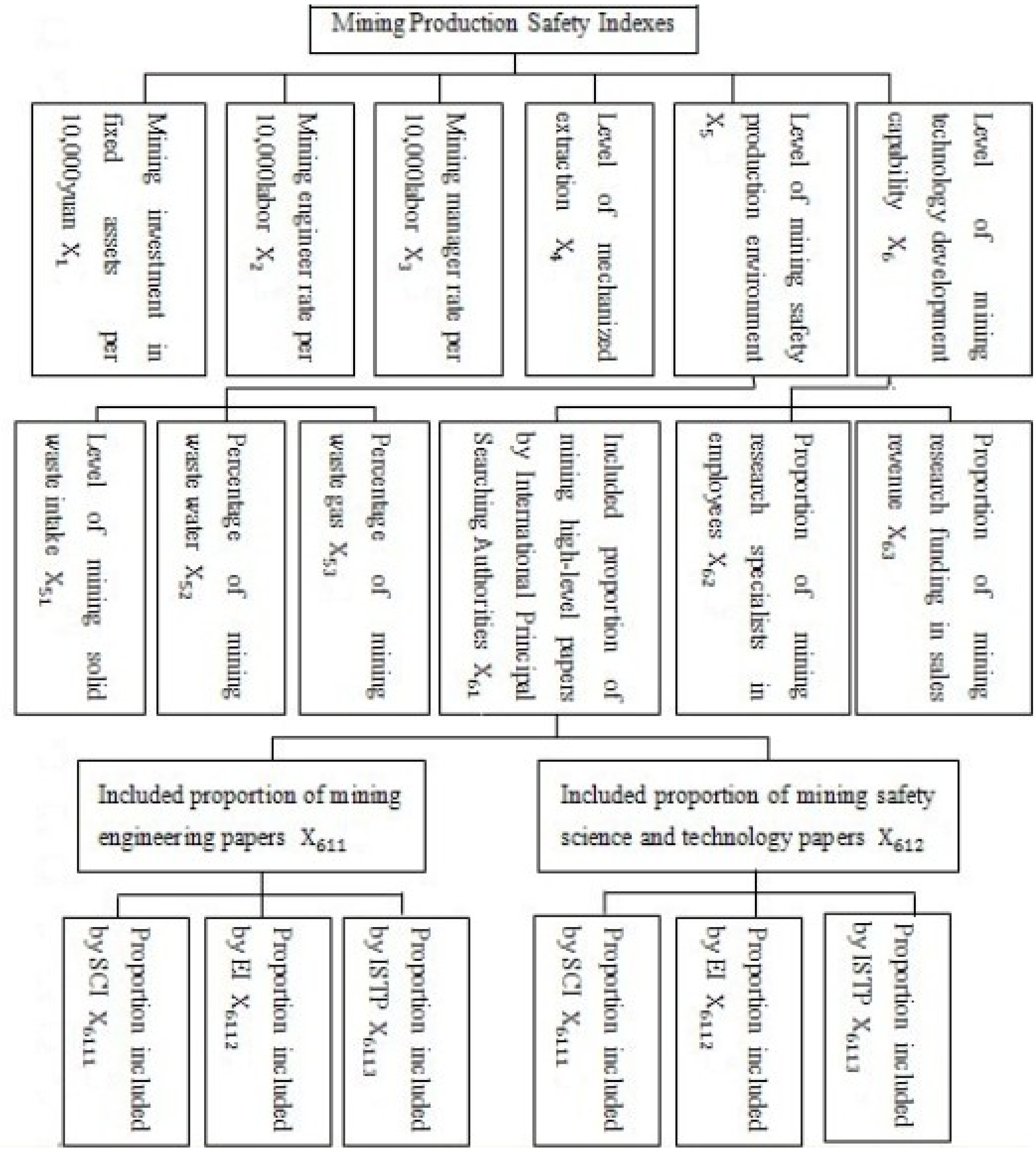

Figure 1. Index system of mining production safety.

When the index system finished, used the relative comparative method, the initial data were converted into index value. The score of No. i in No. j index was

$$v_{ij} = \frac{X_{ij} - X_{\min(j)}}{X_{\max(j)} - X_{\min(j)}} \times 10 \qquad (3)$$

Where, X_{ij} was the initial data of the No. i in No. j index, and $X_{max(j)}$ and $X_{min(j)}$ were the maximum and minimum within the sample interval of No. j index. The composite index can be acquired:

$$Composite\,index = V_1 \times W_1 + V_2 \times W_2 + \cdots + V_P \times W_P \qquad (4)$$

Where, W_i was the matched weight number of corresponding principal component.

If there is a necessary for calculating multi-stage composite indexes, we should step calculate following above measure and calculate first lower index.

The safety index system can give insight as to what kind of potential problems in mining safety input. The mining production safety index was 0.462 in 1991, and 7.687 in 2007, a more than 16-fold increase (Table 1.). It rose rapidly since 1996, and keeping a steady and upper state since into the 2100's but 2003. The benefit of increased the level of mining product safety index can be formulated from existing mine data on occupational deaths. The mine occupational incidents had more than 145 thousand deaths during 1991-2007. As shown in Figure 2., there is a prominent reverse correlation ship between the level of production safety index and the death number of mining occupational accidents. The severity of mining occupational accidents death was bettered owing to the heightened role of production safety index.

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Table 1. China mining production safety index from 1991 to 2007

Year	Safety index	Year	Safety index	Year	Safety index
1991	0.462	1997	4.664	2003	2.217
1992	0.530	1998	4.356	2004	7.403
1993	1.138	1999	5.924	2005	7.576
1994	1.243	2000	8.346	2006	6.913
1995	1.477	2001	7.575	2007	7.687
1996	4.813	2002	7.411		

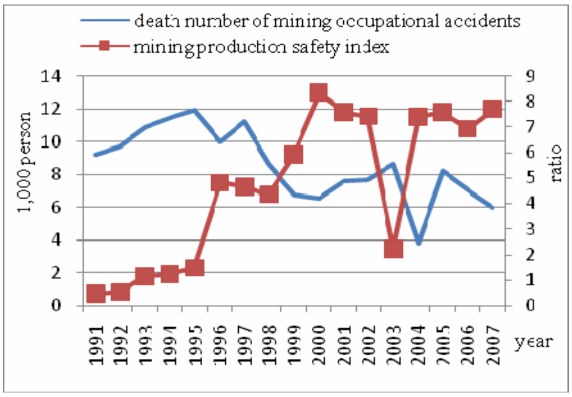

Figure 2. Death number of mine occupational accidents and mining production safety indexes during 1991-2007.

4. Empirical

Given that Eq. (1) was at the long-term equilibrium state, using the dynamic modeling method, mining economic growth model can be expressed with actual output.

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln S_t + E_t^T \quad (5)$$

Before beginning to estimate the unobserved long-term trend Y_T, the parameter α, β and γ must first be estimated. A second-order Autoregressive Distributed Lag (ADL) model the period 1991-2007 was constructed based on Eq. (5), and gained the long-term trend E_t^T :

$$\ln Y^* = -1.3104 + 0.321 \ln K^* + 0.8470 \ln L^* + 0.0698 \ln S^* \quad (6)$$

$$E_t^T = \ln Y_t - 0.32 \ln K_t - 0.85 \ln L_t - 0.07 \ln S_t + 1.31 \quad (7)$$

In the long-term equilibrium, the standardized capital elasticity, labor elasticity and safety elasticity of production respectively were equal to 0.26, 0.68 and 0.06. The bigger labor elasticity of production was mainly because of quite a number of China small-and medium-sized mines extracted and transported still by hand.

Upon tested, all variables in real terms were I(1) and had Cointegration relationship among variables. A second-order ADL model was established based on Eq. (5), and the long-term equilibrium was included into the model for having a negative moderating effect on change rate of output [12].

$$g(Y)_t = -0.016 g(Y)_{t-1} - 0.647 g(Y)_{t-2} + 5.390 g(K)_t$$

t-vlue	-0.201	-8.300	5.390
P	0.853	0.004	0.013

$$-1.717 g(K)_{t-1} - 2.366 g(K)_{t-2} - 1.333 g(L)_t$$

-1.231	-2.615	-4.059
0.306	0.079	0.027

$$-0.971 g(L)_{t-1} + 3.597 g(L)_{t-2} + 0.143 g(S)_t$$

-3.655	12.518	4.780
0.035	0.001	0.017

$$-2.005 ECM_{t-1} - 0.081 \quad (8)$$

-5.206	-1.171
0.014	0.326

R^2=0.991, adjusted R^2=0.959, S.E.=0.043, F=31.499, D. W.=2.903

Where, g(·) s denoted first nature log then difference, the previous period's $g(Y)$, $g(Y)_{t-1}$, was called predetermined or lagged variables, and $g(Y)_{t-2}$ the second-order lagged variable of $g(Y)$, were $g(K)_{t-1}$, $g(K)_{t-2}$, and $g(L)_{t-1}$, $g(L)_{t-2}$ so. And the equilibrium (error) correction term was

$$ECM_t = \ln Y_t - 0.32 \ln K_t - 0.85 \ln L_t - 0.07 \ln S_t + 1.31 \quad (9)$$

The explaining factors of Eq. (8) in the economic growth volatility process were resolved into long-term component and short-term component. The negative feedback of explaining variable ECM_{t-1} gave expression to the long-term law of China mining economic growth. Growth rate of mining total output value had considerable inertia $g(Y)_{t-1}$ and $g(Y)_{t-2}$. It was also influenced by change rate of capital inputs and labor inputs and their inertias $g(K)_t$, $g(K)_{t-1}$, $g(K)_{t-2}$, $g(L)_t$, $g(L)_{t-1}$ and $g(L)_{t-2}$, besides change rate of safety inputs $g(S)_t$. All these influences were in the short-term.

The value of change rate of safety $g(S)_t$ entered distinctly into the model and was positive. It was shown that safety factor accelerated surely the mining economic growth in short-term and answered to our anticipation, that is, the higher of mining production safety level, the more advantaged to accelerate economic growth.

The accommodation coefficient of Eq. (8) in medium-and long-term equilibrium equal to -2.005, which meant a minus 2.005 feedback correction effect of long-run equilibrium relationship working for mining total output value growth. The comparative bigger effect meant that system can rapidly finish correcting when long-run equilibrium has a deviation.

Furthermore, the bigger elasticity coefficients of capital change rate and labor change rate and that of their inertia indicated that capital contribution and labor contribution were still main factors to accelerate mining economic growth in the short run.

Hypothesis testing results of Eq. (8) (Table 2) showed that Eq. (8) has a higher closeness of fit to real empirical data, and formulated a better performing of change regularity of China mining economic growth.

Table 2. Hypothesis testing results of Eq. (8)

Hypothesis-testing	Null hypothesis	Test results (P-value)	Conclusion
Serial Correlation LM Test	Without serial correlated	F=0.9724 (0.5827)	Without serial correlated
ARCH LM Test	Without Heteroscedasticity	F=1.9655(0.1885)	Without Heteroscedasticity
Histogram-Normality Test	Normal distribution	$Chi^2(2)$=0.5851(0.7464)	Normal distribution
Ramsey RESET Test	Regression correct	F=0.8708(0.6039)	Regression correct

5. Conclusions

The level of China mining production safety has been continuously improved, the safety relative value index is 0.462 in 1991, which rises to 7.687 in 2007. It is huge increase in 1996 thanks to safety situation and policy.

The positive safety elasticity of production in the short run and safety factor included materially mining economic growth model indicate that safety promotes mining total output value growth not only in the short-run but also in the long-run with 7% of pulling value. In addition, the bigger capital elasticity and labor elasticity of production and their inertia elasticity show that capital inputs and labor inputs are still the major factors to promote China mining economic growth.

Contribution rate of safety to mining economic growth analysis can aid for mines and administrative authority in making decisions for improving the system.

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