Safety Science 50 (2012) 1472–1479

Contents lists available at SciVerse ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Empirical analysis on contribution share of safety investment to economic growth: A case study of Chinese mining industry

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ARTICLE INFO

Article history:
Received 22 July 2011
Received in revised form 14 January 2012
Accepted 21 January 2012
Available online 13 March 2012

Keywords:
Mining industry
Production safety indexes
Economic growth model
Contribution share of safety input to economy growth

ABSTRACT

Insufficient investment in safety is one of the most important reasons which lead to frequent accidents in Chinese mining industry. Safety input has long been regarded as a ‘sunk cost’, lacking output, and little attention from mining companies was focused on increasing safety input according to technical codes or technical requirements due to the narrow understanding on safety input. So, the empirical analysis on the contribution share of safety investment to economic growth is very important. In this paper, a new set of production safety indexes including six 1-level indexes for describing the safety level of mining production in China was constructed on the basis of Granger causality test. Meanwhile, a mining economic growth model was constructed on the basis of the new production safety indexes with co-integration theory and dynamic modeling system. The empirical results show that the production safety factor in the short term indeed drives the GDP growth in the mining industry although labor and capital input remain the major factors impacting mining economic growth, and its long term contribution share is 7.7%. Principal Component Analysis (PCA) of production safety indexes, shows that the safety level of mining production increased more than 21-fold during 1991–2009, and the investment in mining technology development capability, mining safety production environment and mechanized level of mining should be the direction to focus for improving the safety level of mining production.

1. Background and problem statement

Work-related injuries are unwelcome byproducts of economic activity. On average, there is a higher rate of occupational deaths in the mining industry than most other industries in China due to the hazardous nature of the work conditions. Insufficient safety input is the principal one in Chinese mining industries among various factors that could trigger accidents. Safety input is generally felt unnecessary or too costly to manufacturers and has long been regarded as a ‘sunk cost’, lacking output. Little attention from mining companies was focused on increasing safety input according to technical codes or technical requirements, which results from safety input penetrated into the production input, and investment in safety was in advance of its benefit. Generally, only when accidents happened, would a corporation recognize safety input problems. It is therefore intended that estimating contribution share of safety investment to economic growth (CSS) will be very important to understand the safety input and its role correctly.

There have been studies that CSS can be mathematically designed by input–output approach, superposition method and product-function method (Luo, 2004; Lui and Shi, 2006; Mou and Wang, 2006). In these studies, CSS 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, including increase in value of GDP or decrease in work efficiency loss, improvement in the value of safety condition and safety credit and others, was too difficult to estimate, which exists only in theory but not in the productivity statistics. However, they cannot avoid using GDP. Their formula for common calculating CSS was presented as follows:

$$E_S = \frac{Y_S}{Y} \times 100\% = \frac{Y_D + Y_I}{Y} \times 100\% \quad (1)$$

where E_S refers to CSS; Y_S, Y, Y_D and Y_I denoted safety output, GDP, derogative output, and increment output, respectively. According to the above definition of CSS, an accurate formula should be presented as follows because of the lack of Y_D in Y:

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doi:10.1016/j.ssci.2012.01.012

$$E_S = \frac{Y_D + Y_I}{Y + Y_D} \tag{2}$$

The denominator of Eq. (1) is smaller than that of Eq. (2), so the E_S value of Eq. (1) is enlarged.

Actually, the adopted formula was presented as follows in all existing literatures:

$$E_S = \frac{Y_I}{Y} \tag{3}$$

A positive number (Y_D) was subtracted both in numerator and in denominator of Eq. (2). Therefore, the value of E_S in Eq. (3) was reduced compared with that of Eq. (2).

Therefore, this method in which safety output was split from GDP for calculating the value of safety was not accurate. The definition of CSS not only led to a one-sided safety output, but also limited the selection of safety input indexes. Safety output derived mainly from three aspects of safety input including level of safety technology, safety capital input and safety labor input in the past studies (Luo, 2004; Lui and Shi, 2006; Mou and Wang, 2006; Tong and Ding, 2008). Here, technology level of safety was gained by national experts who worded out the percentage how much the level of safety technology took in the contribution share of scientific and technological progress over the whole country; capital input involved safety allowance from government, expenditure on labor protection and occupational disease; and labor input included the number of safety technologists and safety managers. They failed to take into account investment in production, organizational factors, work climate, etc. Accidents were only ascribed to specialty safety factors, and had nothing to do with production input (such as mechanized level of mining, and production management) on the basis of this safety input idea. However, we cannot draw a conclusion that those enterprises who invest abundantly in the above-mentioned professional safety factors and poorly in production will have a high safety level, while those enterprises who invest poorly in professional safety factors and abundantly in production will have a low safety level. In fact, it was difficult to differentiate safety input from production input (Chen, 2002). When backed up by abundant production input, safety input has been somewhat more effective and safety and productivity were improved in the mechanized system more so than the conventional system (Sari et al., 2004; John, 1992). Safety level can be improved with the technology development in production field. The National Mining Association (State Administration of Work Safety, 2005) found that coal mine accidents had been significantly reduced by deployment and use of new technology according to proven practice for 30 years. The maximum safety level of a company can be determined by its organizational management system as current manufacturing strategies have been progressing toward collaborative manufacturing partnerships. Statistics show that over 80% of accidents resulted from unsatisfactory management (Denis and Camille, 2003; Yu, 2007).

As is mentioned above, the definition and research methods on CSS have some defects in past studies. However, the experiences in CSS have formed the foundation for the following successful studies.

Thus, it is necessary to break down the narrow understanding on safety input, and understand the nature of accident and the influence factors of safety in order to resolve the shortfall of safety input problem. In this paper, a case study of the Chinese mining industry addresses a new set of production safety indexes that was constructed on the basis of the Granger causality test. A mining economic growth model was established on the basis of the new production safety indexes through adopting co-integration theory and dynamic construction model. The study provides a theoretical reference for understanding the safety input and the effect of safety input.

2. Definition and calculation method of CSS

Contribution share is defined as a share of some or other portion growth in total growth in economics. All contribution shares owe something to the legacy of general concept. CSS should be defined as a share of safety value growth in total economic growth, and is a relative index, and its magnitude depends upon the relation between safety value increment speed and economic increment speed.

Cobb–Douglas production function was a theoretical approach to evaluate variety contribution share of Total Factor Productivity (TFP), which was bettered many times by Solow, 1957 and Barro and Saka-Imartin (2000) et al after being first pioneered by Cobb and Douglas, 1928. In 1957, Solow and Denison estimated the contribution of technological progress to economic growth with an econometric model, which contribution was the remainder after deducting the contributions of capital and labor.

All the factors that influence economic growth ex labor and capital constitute the so-called general technological progress, and it is the result of technological innovation and management and system innovation. Furthermore, the innovations in the safety field are integrated into all aspects of general technological progress. Here, technical innovations are embodied in a number of improvements in areas, including production technology and safety technology, the utility, integrality, and security of the products, and safety quality of workers; and system and management innovation including the improvements in areas of production management and safety management, production safety laws and regulations and systems, and the safety education and the level of training. Therefore, CSS is an important part of the total contribution of general technological progress, and can be considered as a remainder part after the contributions of technological progress is deduced.

Owing to safety's ambiguity, uncertainty and relativity, safety benefit is not a pure result of input, namely, it cannot be examined without consideration of the overall economic growth, but on the contrary, it focuses on systems analysis methods (Yu and Jiang, 2007). Solow Residual Value Method is suitable for the calculation of contribution of TFP which permeates through the whole rather than an isolated part. The investment of the researched component can be described through a comprehensive index on the basis of an establishment of an integrated economic time series model. Solow Residual Value Model has been confirmed to be a good method and widely used for measuring the contribution of TFP in economics.

In this paper, a mining's multifactor C–D production function model was established on the basis of growth model of Barro and Saka-Imartin (2000) that was expanded from C–D production function.

$$Y^T = AK^{\alpha}L^{\beta}S^{\gamma} \tag{4}$$

$$\text{Or} \ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln S_t \tag{5}$$

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

3. Indexes and data sources

In all informed researches, data processed without considering inflation and time factor, this is not comparable in statistical significance. Measurement of the level of economic gross index