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Productive performance of Indian mining industry: A stochastic frontier decomposition

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Abstract

This paper has estimated the Total Factor Productivity (TFP) growth of Indian mining Industry for the period 1989-2014 based on a decomposed formulation of stochastic production frontier. Productivity growth and its decomposed components have been compared over the study period. It is found that the annual average TFP growth of mining industry rose up from 3.66 % during 1989-2005 to 8.76 % during 2006-2014. Further, the result of decomposition reflects that the major source of productivity growth has changed from Technological Progress (TP) in initial years to Technical Efficiency Change (TEC) in recent years. In view of this, it could be suggested that mining industry in India requires to focus on investment in innovation and up-gradation of existing technology to further enhance productivity.

Keywords: total factor productivity, mining industry, panel data, stochastic frontier analysis (SFA).

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1. Introduction

Mineral resources are one of the most important natural resources in India which generates enormous value, in spite of being a finite resource. As a sub-sector of the industry, mining and quarrying sector contributes 2.8 percent of the total Gross Domestic Product (GDP), accounting Rs. 283062 crore in the year 2014-15 (RBI, 2016). Mining activities contribute to national income through foreign exchange earnings and employment generation. The existence of long run co-movement between mineral export and economic growth well describes the above-mentioned facts (Sahoo, Sahoo & Sahu, 2014). It is also evident that mining and industry sector play a vital role in improving the standard of living and quality of life of the nearby areas (Samantaraya, Sahoo, Mallick & Bhuyna, 2014). Beside this, mining sector provides the basic raw materials for the industrial sector, which is extracted by following different phases of operations. Reconnaissance is the first and preliminary phase of a regional exploration where survey is conducted for the identification of mineral deposits. Secondly, there is prospecting, which is a detail exploration phase. The last phase is extraction of mineral named as mining. All the phases require huge capital investment as well as adoption of advanced technology, which force to liberalize the mineral sector in India. As a result, the long experienced restriction in Indian mining sector has ended with the formulation of National Mineral Policy (NMP) in 1993. Before the formulation of NMP, major minerals have been kept under exclusive control of public sector. Similarly, Foreign Direct Investment (FDI) is not allowed in mining operation.

Since the beginning of 1990s, mining sector has been moving with an upward trend in terms of mineral production. It could have been achieved due to the liberalized policy which might have stimulated the investment in mining activities or adoption of advanced technology for mining operation. Further, the mining firms could have enhanced the scale of operation due to promotional policy towards mining. All these factors could have affected the overall productive efficiency of mining firms. This paper enquires whether the possibility of the output growth is achieved through improvement in total factor productivity or through large use of inputs for the extraction activities. Further, if the upward trend in output growth is due to productivity change, the question arises that whether it is due to technological progress or technical efficiency change or because of the scale of operation. In order to find out the possible sources of output growth in Indian mining, at first we have estimated the TFP growth of mining industry for the period 1989 to 2014. Further, to identify the sources of productivity growth, it has been decomposed into the above-mentioned components.

2. Historical Overview of Mining Sector in India

India has experienced a noticeable growth in mineral production in terms of both quantity and monetary value. Since independence, fuel minerals hold a major share in the total value of mineral production in India. The composition of total value of mineral during 1951 reflects a share of 65% value by fuel mineral, followed by 24% metallic minerals and 11% jointly by non-metallic and minor minerals. However, the value of mineral composition reflects a declining trend for metallic minerals, which reported at 8 % in the total value of mineral production in 2001. Metallic mineral production has revived with the start of this century and reported at 18 % of total value in 2011. However, in case of non-metallic and minor minerals, although the share in total value of production has declined during 1980s, after that consistently it has shown increasing trend.

Mineral resources not only add value to the national income through domestic industrial sector, but also by export earnings. India is a leading exporter of minerals and ores to 188 countries of the world. The total value of mineral export of India is Rs 1740 crore in 1990-91(RBI, 2011) which rose up to Rs.1, 59,747 crore in 2012-13 (IMY, 2013). The details on value of mineral composition trend are presented in Figure 1.

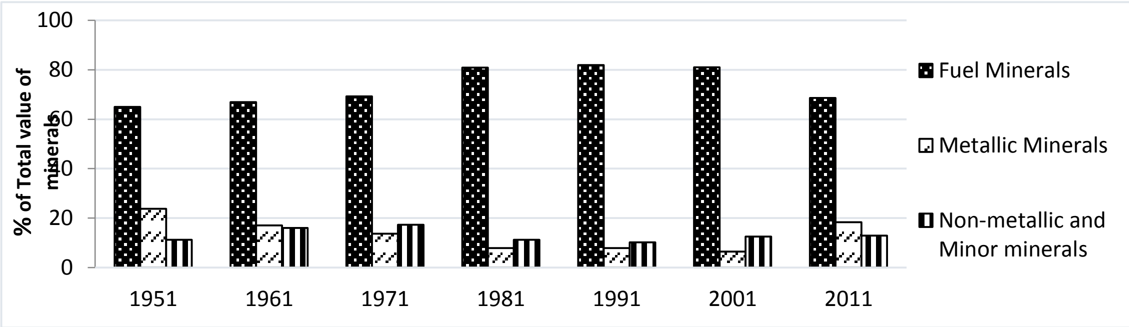

Figure 1. Composition of mineral production in India.
Source: Indian Mineral Industry at a Glance 2011-12, Indian Bureau of Mines Nagpur

The perusal of Figure 1 reflects that increasing trend in the value share of fuel minerals has declined after 2001. However, metallic, non-metallic and minor minerals, which constantly reflect a declining trend over the period, have improved in value share during 2001 and 2011.

Mineral sector of Indian economy is a major destination for employment generation. As per the latest data, the average daily employment in Indian mining sector is estimated at 533243 persons in 2011-12 (IBM, 2011-12). The major sub-sector specific employment has been presented in Figure 2.

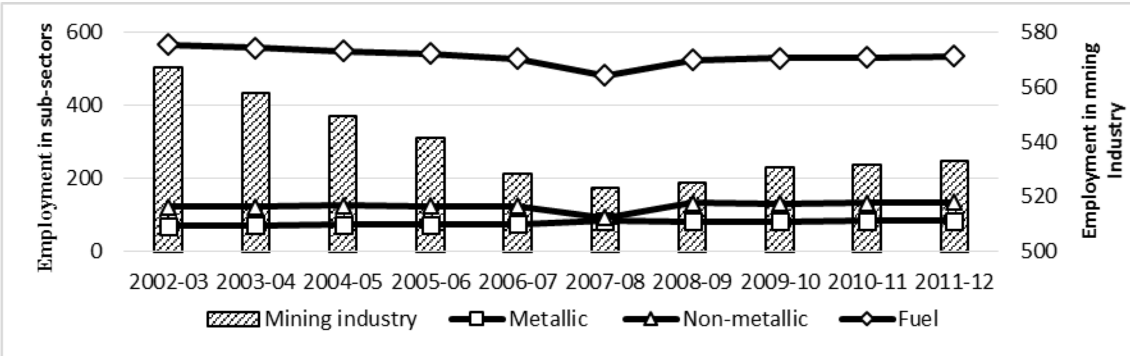

Figure 2. Average daily employment in mining and its sub-sectors (in '000)
Source: Indian Mineral Industry at a Glance 2011-12, Indian Bureau of Mines Nagpur

The above discussion on mining sector reflects the relative importance of the sector being an important source of employment, output and export earnings for the Indian economy. Besides, the strong forward linkage of mining sector with the other sectors of the economy suggests for the investigation of productivity growth. In the next section, we have discussed some previous literature relating to productivity estimation of mining and industry sector at micro level.

3. Literature Review

The available literature on productivity growth in mining are mostly belongs to the partial measure. Labor productivity has been a major concern in available study on productivity in mining. Existing literature reveals the specific focus on productive performance measurement for particular mining rather than the mining industry. It is also observed that studies in context to productivity in Indian mining sector are very few in numbers.

Labor productivity is well evident of achieving output growth in the context of various mining. Role of labor productivity in achieving output growth and comparative advantage in mineral production has been reflected in context to many mineral abundant countries (Darmstadter, 1999; Tilton & Landsberg, 1997; Aydin & Tilton, 2000; Garcia et al., 2001; Tilton, 2001). The labor productivity relating to copper industry in United States reveals that technological innovation is important for mineral endowed country to get comparative advantage in Production (Aydin & Tilton, 2000). Similarly, labor productivity growth is found to be largely driven by technological change in Chile (Garcia et al., 2001). However, quality of mineral deposit and operational factors are found to be equally important in addition to technological factors and innovations to enhance labor productivity in context to copper mining in Chile and Peru (Jara et al., 2010). In productivity literature, studies have attempted to investigate drivers of productivity growth in relation to mineral resource. Technological factors, operational structure and social determinants of productivity are reflected in the literature (Darmstadter, 1999; Naples, 1998). Kulshreshtha & Parikh (2002) decomposed total factor productivity growth of coal mining in India and found evidence of technical advances in surface mining and efficiency improvement in underground mines as contributing factor of TFP growth. However, output growth in case of Australian mining industry is evident of being input driven rather than productivity (Asafu-Adjaye & Mahadevan, 2003). In a recent study, multi-factor productivity growth for mining has been estimated by constructing a composite index, namely depletion yield index which considers factors such as resource depletion and investment for capacity building in mining with output growth (Topp et al., 2008). A comparative analysis of productivity growth in mining sector of United States and Canada has been undertaken to observe both single factor productivity as well as the multi-factor productivity (Bradley and Sharpe, 2009). The productivity growth for Australian mining sector has been estimated in a decomposition formulation, which provides information on the sources of productivity growth in mining sector (Syed et al., 2013).

After reviewing the previous studies, it is observed that most of the studies in context to Indian mining sector are based on partial measure of productivity and focus on specific minerals. It encourages us to undertake a comprehensive study on Indian mining, based on total factor productivity in a decomposition formulation.

4. Analytical Framework

The productive efficiency is analyzed through using the Stochastic Frontier Analysis (SFA) procedure. In a SFA, the production function reflects the optimum feasible output level for a production unit with the use of various combinations of inputs in addition to the available technology. Efficiency and technological progress are treated as basic components of productivity. The frontier approach of measuring productivity has an advantage of measuring productivity growth by decomposing it into different components, which is explained in details under the section productivity decomposition. Aigner, Lovell & Schmidt (1977) as well as Meeusen & van den Broeck (1977) proposed the time-varying stochastic production frontier in a translog framework, which is as given below.

$$\ln y_{it} = \alpha_0 + \sum_j \alpha_j \ln x_{jit} + \alpha_t t + \frac{1}{2}\sum_j \sum_l \beta_{jl}\, ln\, x_{jit}\, ln\, x_{lit} + \frac{1}{2}\beta_{tt} t^2 + \sum_j t\beta_{tj}\, ln\, x_{jit} + v_{it} - u_{it} \quad \dots\dots (1)$$

The above production function consists of two error terms. Firstly, the stochastic error which has been capture through v_{it} consists of production losses due to unforeseen factors beyond the control of a production unit. Whereas u_{it} is an inefficiency error which is firm specific and non-negative in nature. Further, both the error terms are distributed independently and identically. The production function adopted for this study can be written as

$$\ln Y_{it} = \alpha_0 + \alpha_l ln\, L_{it} + \alpha_k ln\, K_{it} + \alpha_e ln\, E_{it} + \frac{1}{2}\beta_{ll}(\ln L_{it})^2 + \frac{1}{2}\beta_{kk}(\ln K_{it})^2 + \frac{1}{2}\beta_{ee}(\ln E_{it})^2 + \beta_{lk}(\ln L_{it})(\ln K_{it}) + \beta_{ke}(\ln K_{it})(\ln E_{it}) + \beta_{le}(\ln L_{it})(\ln E_{it}) + \beta_{tl}(\ln L_{it})t + \beta_{tk}(\ln K_{it})t + \beta_{te}(\ln E_{it})t + \alpha_t t + \frac{1}{2}\beta_{tt}t^2 + (v_{it} - u_{it}) \quad \dots\dots (2)$$

In the above equation Y_{it} is the observed output level for i^{th} firm at t^{th} period. The labour (L), capital (K) and energy (E) are three inputs used by mining firms for mineral extraction. In the specified model, inefficiency error follows a positive truncation of normal distribution $N^{+}(\mu, \sigma_u^2)$. The inefficiency error can be written as a product of exponential function of time (Battese & Coelli, 1992; Greene, 1997)

$$u_{it} = \eta_t u_i = u_i[exp\{-\eta(t-T)\}] \quad \dots\dots (3)$$

where, t=1, 2.....,T and i=1, 2,....,N

Technical efficiency (TE) is a ratio of observed output level of a firm to the maximum feasible level as estimated by the frontier model. So the technical efficiency of i^{th} firm in t^{th} period can be estimated as

$$\mathrm{TE}_{it} = \exp\left(-u_{it}\right) \quad \dots\dots (4)$$

The above equation can be used to estimate technical efficiency change (TEC), which is nothing but the change in TE. In a similar fashion, technological progress (TP) can be obtained from the estimated production function by taking partial differentiation of the function with respect to time.

$$TP_{it} = \frac{\partial\, ln\,(y_{it})}{\partial t} = \alpha_t + \beta_{tl}(\ln L_{it}) + \beta_{tk}(\ln K_{it}) + \beta_{te}(\ln E_{it}) + \beta_{tt}t \quad \dots\dots (5)$$

The stochastic production function for the maximum feasible output level produced by i^{th} firm in t^{th} period as stated in equation (1) can be written without any specification of production function as

$$y_{it} = f(x_{it}, \beta, t)\, exp(v_{it})\, exp(-u_{it}) \quad \dots\dots (6)$$

The derivative of logarithmic of equation (6) with respect to time can be written as

$$\dot{y}_{it} = \frac{d \ln f(x_{it})}{dt} + \sum_j \varepsilon_{jt} \frac{dx_{jt}}{dt} - \frac{du}{dt} \quad \dots\dots (7)$$

$$= TP + \sum \varepsilon_j \dot{x}_j - \frac{du}{dt} \quad \dots\dots (8)$$

Total factor productivity is the unexplained part of output growth, which can be achieved by deducting the input growth from output growth. So the TFP growth can be written as

$$T\dot{F}P = \dot{y} - \sum_j P_j\, \dot{x}_j \quad \dots\dots (9)$$

Following Kumbhakar and Lovell (2000), total factor productivity growth can be written in a decomposed form where the components of TFP growth are technological progress, Scale efficiency change, allocative efficiency change and technical efficiency change. It is presented in equation (10) respectively.

$$T\dot{F}P = TP + (RTS - 1)\sum_j \lambda_j \dot{x}_j + \sum (\lambda_j - P_j)\, \dot{x}_j - \frac{du}{dt} \quad \dots\dots (10)$$

4.1 Data and Variable

The study is based on the secondary sources of data on Indian mining firm for the period 1988-2014, extracted from Prowess database of Centre for Monitoring Indian Economy (CMIE). The final data sheet consists of the data on output and inputs of 128 mining firms operated during the study period with total observation of 2180. The output (Y) is measured by deflating total value of output reported by mining firms. Similarly, input such as labour (L), capital (K) and energy (E) are deflated labour days, gross fixed asset using Perpetual Inventory Method (PIM) and deflated power and fuel expenditure of mining firms respectively.

5. Result and Discussion

In this study, we have estimated the trend of TFP growth, technical efficiency change, technological progress and scale component for Indian mining industry for the period 1989-2014. Time varying stochastic frontier technique is adopted for the estimation of productivity growth. Productivity estimation requires validation of modelling the inefficiency effect and technological change for reliable result. Alternative models have been tested to validate the functional form and inefficiency effect. Finally, trans-log production function with inefficiency term following a half normal distribution is found to be suitable for the present study. The estimated result has been presented in Table 1.

Table 1. Estimated coefficient of panel frontier model

Variable	Dependent Variable: ln Output		Variable	Dependent Variable: ln Output	
	Coefficient	t-statistic		Coefficient	t-statistic
C	1.664***	3.59	t	0.060***	4.93
ln L	0.200*	1.76	t^2	-0.040	-0.91
ln E	0.470***	4.41	(lnL)t	0.001	0.88
ln K	0.503***	3.93	(lnE)t	-0.008***	-5.14
$(\ln L)^2$	0.089***	3.09	(lnK)t	0.001	0.87
$(\ln E)^2$	0.045*	1.68	σ^2	2.924***	6.19
$(\ln K)^2$	-0.203***	-8.81	γ	0.969***	83.3
lnL*lnE	-0.185***	-8.18	μ	0.000	
lnL*lnK	0.084***	4.23	η	-0.029***	-7.90
lnE*lnK	0.102***	5.53	**Log-likelihood**	-761.14	

****, ** and *** represents significant at 10 %, 5% and 1% level respectively***

The results of Table 1 reveals that the coefficient of (lnL)t and (lnK)t are positive but insignificant. However, the coefficient of (lnE)t is negative and significant at 1 % level which suggests that technological progress in Indian mining industry is energy saving. Following Berndt (1990), the energy saving bias, as obtained from our estimation, could be defined as proportional use of energy, which is less than average proportional use of all inputs over the period of time. In other words, the mining industry seems to be following energy conservation practices in their operation. It has been found that the average technical efficiency of Indian mining firms is at 0.77 percent level. However, the efficiency levels of firms are changing over time. In the following section, we have presented the result of total factor productivity growth and its decomposition into different components. The total factor productivity growth for Indian mining industry has been obtained through adding the decomposed components that has been obtained through using the decomposition formula given in equation (10). As a result, TFP growth is the summation of technological progress, technical efficiency change and scale efficiency change. Since the price information is not available, allocative efficiency change has not been considered during the estimation of productivity growth. Further, the total factor productivity growth is annual average of these components for the sample firms for the selected periods. The details have been presented in Table 2.

In the study period, the average scale component is estimated to be -0.13, which clarify that mining industry has not achieved productivity growth through scale efficiency change. It is also observed that technological progress has been a dominating factor since the initial year of the study period. However, the technological progress of the mining industry starts declining from 2003onwards. The average technological progress is estimated to be 3.05 % for the period 1989-2014. On the other hand, TFP growth due to technical efficiency change has shifted from 0.14 % in 1989 to 11.44 % in 2014. Moreover, technical efficiency change figures reflect a steady growth after 2004. It is observed that TFP has grown at an annual rate of 5.62 % during 1989-2014. Interestingly, TFP growth of mining industry has increased steadily after the year 2006. It is possibly due to the liberalized policy adopted by Indian Government towards FDI in mining sector, which came to exist since 2006.

Table 2. Decomposition of annual average TFP growth for Indian mining industry

Year	SC (%)	TP (%)	TEC (%)	TFP (%)
1989	-0.01	2.82	0.14	2.94
1992	-0.37	2.85	0.23	2.72
1995	-0.16	3.08	0.40	3.32
1998	-0.14	3.09	0.68	3.63
2001	-0.05	3.25	1.16	4.42
2004	-0.16	3.21	1.97	5.02
2007	-0.41	3.05	3.31	5.95
2010	-0.24	2.98	5.66	8.46
2013	0.04	2.96	9.59	12.60
2014	0.20	2.97	11.44	14.62

Note: Author's Estimation

Although the above decomposition reflects the share of each factor to TFP growth, still it is necessary to observe the relative strength of each component as a contributor to TFP growth over the period of analysis. Figure 3 reflects the strength of each factor over time.

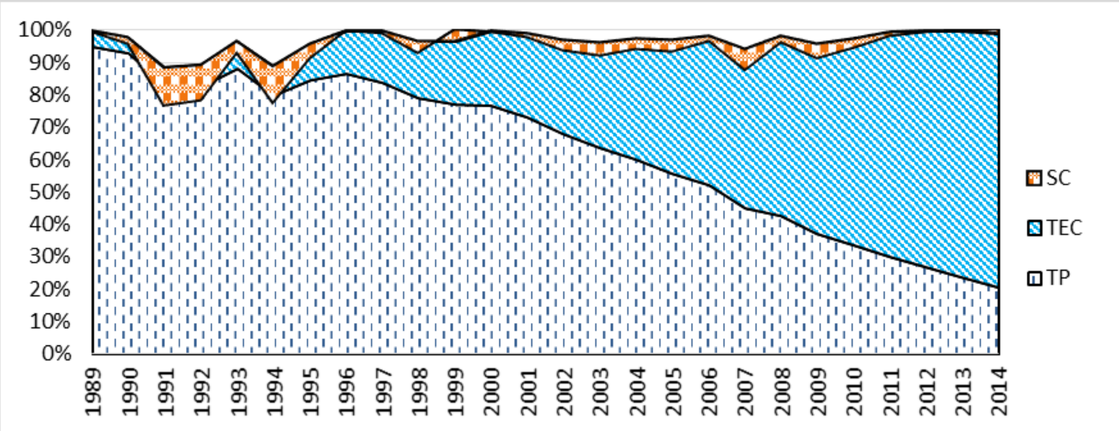

Figure 3. Share of decomposed components in TFP growth over study period

It can be observed that during the initial years, more than 95% of TFP growth is driven by TP, whereas rest 5% share are due to TEC and SC. During the first five years of observation, share of TEC is very nominal in TFP growth. However, the increasing share of TEC in TFP growth reflects the possible impact of National Mineral Policy on technical efficiency improvement of mining industry after 1993. At the same time, it is also observed that share of TP in TFP growth has started declining. As a result, TEC has outperformed in the later phase in terms of contribution to TFP growth of mining sector. In the end year of study, TEC has accounted more than 75% of share in TFP growth as compared to 20 % share of TP. The above discussion reveals that productivity growth in Indian mining sector has moved from TP driven in initial years to TEC driven in recent years.

6. Conclusion

In context to Indian mining industry, the productivity growth has been reflected through the present study. It is found that mining industry is following an energy saving production process and

TFP growth is largely driven by technological progress and technical efficiency change. Moreover, contribution of technical efficiency change is more as compared to technological progress in the recent years, which is found to be reverse in the initial period of the study. The TFP growth is found to be moving faster due to rapid growth in technical efficiency change since 2005. Further, productivity estimates through decomposition of TFP growth has important policy implications for mining sector based on the trend of each components. Declining technological progress suggests for the opportunity of the mining industry to enhance productivity by adopting technological innovations and up-gradation of existing technology. However, the policy makers should look into the ongoing scale of operation issues in mining sector so that any policy decision in this regard will be helpful to achieve scale benefit in productivity of mining firms.

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