Productivity Growth in Selected Indian Steel Companies 2000 To 2016: A Malmquist Approach

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Abstract

The paper observed that there are twenty six Indian steel companies productivity was deteriorated, whereas only one company evidenced productivity gain much during the study period. On the whole the deteriorating productivity was due to decline in both technical efficiency at (-) 0.30 per cent and technical change at (-) 7 per cent. In other words the negative sign of both efficiency and technology suggested that there was a declining total factor productivity growth.

INTRODUCTION

India was the world's third-largest steel producer in 2017. The growth in the Indian steel sector has been driven by domestic availability of raw materials such as iron ore and cost-effective labour. Consequently, the steel sector has been a major contributor to India's manufacturing output. The Indian steel industry is very modern with state-of-the-art steel mills. It has always strived for continuous modernisation and up-gradation of older plants and higher energy efficiency levels. Indian steel industries are classified into three categories such as major producers, main producers and secondary producers. India's finished steel consumption grew at a compound annual growth rate of 5.69 per cent during 2008-18 to reach 90.68 million tonnes.

REVIEW OF EARLIER STUDIES

Mongia and Sathaye (1998) estimated productivity growth for six energy - intensive industries in India. They also investigated aluminium, cement, fertiliser, glass, paper, iron and steel sectors as well as total manufacturing covering the period 1973-93. The overall conclusion from the growth accounting approach was that the presumably rapid growth of energy demand was unlikely to be significantly moderated by productivity growth.

Dheenadhayalan (2008) assessed the efficiency of the liquidity management of the company. The study used major public sector organization namely Steel Authority of India Limited (SAIL). The present study covers a period of 10 years from 1996-97 to 2005-06 and employed the statistical techniques, namely average, Standard Deviation (SD) Coefficient of Variation (CV) and Compound Annual Growth Rate (CAGR) for analyzing the data. The study concluded that the short - term liquidity of the SAIL was satisfactory from the year 2004-05, further it can be suggested that the liquidity management of SAIL is very good and is satisfactory.

Ketan (2012) studied sufficiency of the business enterprises along with the profitability ratios of 12 public sector undertakings (PSUs) that are under the control of Ministry of Steel. This research gives the results of profitability with reference to the period from 2006-07 to 2010-11. For the purpose of profitability analysis of the various steel industries ratios are selected and calculated through various statistical techniques and tools like mean and ANOVA test.

Saravanakumar and Kim (2012) applied the Malmquist productivity index in order to estimate total factor productivity growth and its components (efficiency change and technological progress) in Indian manufacturing during the pre- and post-reform periods. The results illustrate that the economic reforms have not exerted positive effects on productivity growth in Indian manufacturing.

Singh (2016) applied the MPI approach to measure technical change and productivity growth in 40 Indian sugar companies for the period 2004-05 to 2013-14. Decomposition of TFP growth into technical change and technical efficiency change reveals that the negative growth is only due to technological regress.

Badri NarayanRath (2018) compared the total factor productivity (TFP) growth and its components for both manufacturing- and service-based firms in India for the period 2008 to 2014. Comparing TFP growth at the sub-sectoral level shows that mean TFP growth is highest in the case of IT firms as compared to the chemical, textile and trade industries.

DATA AND METHODOLOGY

DATA

The study is based on the secondary data collected from the electronic data base “PROWESS” compiled by the Centre for Monitoring Indian Economy (CMEI). The data base consists of data on various aspects of Indian manufacturing and is compiled from the annual reports submitted by the firms. The sample consists of 27 Indian steel companies between 2000 and 2016, with a total of 690 observations[1] and the market share of 55 per cent of the total industry sales.

PERIOD OF THE STUDY

The required data was collected for the period 2000-01 to 2016-17; the latest year for which the complete set of data available and thus the study covers a period of 17 years.

METHODOLOGY

MALMQUIST PRODUCTIVITY INDEX

The Data Envelopment Analysis (DEA) is a special mathematical linear programming model and test to assess efficiency and productivity. It allows use of panel data to estimate changes in total factor productivity and breaking it down into two components namely, technological change (TC) and technical efficiency change (TEC). TFP growth measures how much productivity grows or declines over time. When there are more outputs relative to the quantity of given inputs, then TFP has grown or increased. TFP can grow when adopting innovations such as electronics, improved design, or which we call “technological change” (TC). TFP can also grow when the industry uses their existing technology and economic inputs more efficiently; they can produce more while using the same capital, labour and technology, or more generally by increases in “technical efficiency” (TEC). TFP change from one year to the next is

[1] Firms for which unacceptable values were recorded for certain variables, such as negative or zero values for fixed assets, and those for which a continuous time series was unavailable were subsequently excluded from the sample.

therefore comprised of technological change and changes in technical efficiency. The TEC is further decomposed into pure technical efficiency change (PTEC) and scale efficiency change (SEC).

This study uses the output-oriented model of DEA-Malmquist to put much weight on the expansion of output quantity out of a given amount of inputs. Therefore, TFP index is a ratio of the weighted aggregate outputs to weighted aggregate inputs, using multiple outputs and inputs. Input and output quantities of industries are sets of data used to construct a piece-wise frontier over the data points. Efficiency measures are then calculated relative to this frontier that represents an efficient technology. The best-practice industry determines the production frontier, that is, those that have the highest level of production given a level of economic inputs. Points that lie below the piece-wise frontier are considered inefficient while points that lie on or above the frontier are efficient. Since many inputs are used, and shared outputs may be produced, the Malmquist approach was developed to combine inputs and outputs and then measure changes.

The Malmquist index measures the total factor productivity change (TFPC), between two data points over time, by calculating the ratio of distances of each data points relative to a common technology.

As per Malmquist Productivity Index (MPI) approach, total factor productivity can increase not only due to technical progress (shifting of frontier) but also due to improvement in technical efficiency (catch-up). This approach has become quite popular because: (i) it does not require price data, therefore suitable when price data are not available or price data are distorted, (ii) it rests on much weaker behavioural assumptions, since it does not assume cost minimizing or revenue maximizing behaviour, (iii) it uses time serious data and provides a decomposition of productivity change into two components – technical change and technical efficiency change. The significance of the decomposition is that it provides information on the source of overall productivity change **(Singh and Agarwal, 2006).**

The measurement of the Malmquist productivity index is based on distance functions. For simplicity, $z^t = (x^t, y^t)$ *and* $z^{t+1} = (x^{t+1}, y^{t+1})$, where x^t is the vector of inputs used in production and y^t is the vector of outputs. Now, for each time period *t=1,…..T,* the output distance function is defined as follows:

$$D^t(z) = \inf\{\theta : y^t/\theta \in P^t(x)\}$$
$$= [\sup\{\theta : y^t \in P^t(x)\}]^{-1} \quad (1)$$

where superscript *t* and D^t denote that technology in period *t* is used as the reference technology. θ is scalar, and its value is the efficiency score for each production activity. It satisfies $0 < \theta \leq 1$ for a non-negative output level, with a value of 1 indicating a point of the frontier, and thus a technically efficient production activity. This output distance function is defined as the reciprocal of the maximal proportional expansion of output vector y^t with the given input vector x^t in relation to the technology at *t.*

The Malmquist productivity index is defined as follows:

$$TFP = M^{t} = \frac{D^{t}\left(z^{t+1}\right)}{D^{t}\left(z^{t}\right)} \qquad (2)$$

This formulation is called the output-oriented Malmquist productivity index in period *t*, $M^{t}(z^{t+1},z)$, where the technology in period t is the reference technology for two differing pairs of outputs and inputs. Alternatively, we can define M^{t+1} where the technology in period $t+1$ is employed as the reference technology.

Consistent with the study of Fare *et al*., (1994), the output-based Malmquist productivity index is defined as the geometric mean of two output-distance functions, in order to avoid selecting an arbitrary benchmark:

$$M\left(z^{t+1},z^{t}\right)=\left[M^{t}.M^{t+1}\right]^{1/2}$$
$$=\left[\left(\frac{D^{t}\left(z^{t+1}\right)}{D^{t}\left(z^{t}\right)}\right)\left(\frac{D^{t+1}\left(z^{t+1}\right)}{D^{t+1}\left(z^{t}\right)}\right)\right]^{1/2} \qquad (3)$$

Equation (3) can be rewritten as:

$$M\left(z^{t+1},z^{t}\right)=\left(\frac{D^{t+1}\left(z^{t+1}\right)}{D^{t}\left(z^{t}\right)}\right)X\left(\frac{D^{t}\left(z^{t+1}\right)}{D^{t+1}\left(z^{t+1}\right)}\right)\left(\frac{D^{t}\left(z^{t}\right)}{D^{t+1}\left(z^{t}\right)}\right)^{1/2} \qquad (3`)$$

where the ratio outside the brackets measures the change in relative efficiency between *t* and *t+1*, and the geometric mean inside the brackets measures the shift in frontier. That is, the Malmquist productivity index can be decomposed into change in efficiency and change in technical progress[2].

In a previous empirical work, **Fare *et al*., (1994**) utilized non-parametric linear-programming techniques. As can be seen in (3`), we must solve four different linear programming problems: $D^{t}(z^{t})$, $D^{t}(z^{t+1})$, $D^{t+1}(z^{t})$, *and* $D^{t+1}(z^{t+1})$. Calculating the Malmquist index relative to the variable returns to scale technology. $D_{j}^{t}\left(z^{t}\right)$ for each industry, $j \in k = 1,.....,K$, one of the four different linear programming problems, can be stated as[3]:

$$\left[D_{j}^{t}\left(z_{j}^{t}\right)^{-1} = \max_{\theta,w}\theta_{j}\right] \qquad (4)$$

subject to $\theta_{j} y_{m,j}^{t} \leq \sum_{k=1}^{K} w_{k}^{t} y_{m,k}^{t}$ $\qquad m = 1,\ldots, M \qquad$ (4a)

$$\sum_{k=1}^{K} w_{k}^{t} x_{n,j}^{t} \leq x_{n,j}^{t} \qquad n = 1,\ldots,N \qquad (4b)$$

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[2] See **Fare *et al*., (1994)** for a graphical explanation.

[3] **Ray and Desli (1997)** emphasized the importance of variable-returns-to-scale (*VRS*) in using a reference technology. In some cases, however, the *VRS* method has an infeasible solution **(Ray and Desli, 1997, p.1037).** In response to **Ray and Desli (1997), Fare *et al*., (1997)** commented that constant-returns-to-scale captures long-run results, whereas the *VRS* is appropriate for the short-run. Since our study analyzes the long-run productivity trend for 2000 to 2016, we use the method of **Fare *et al*., (1994).**

$w_k^t \geq 0 \; k = 1,\ldots,K$ (4c)

where $n = 1,\ldots,N$ are inputs, $m = 1,\ldots,M$ are outputs, and w_k^t is an intensity variable indicating the production intensity of a particular activity. (Here, each industry is an activity). These intensity variables are used as weights in taking convex combinations of the observed outputs and inputs in both (4a) and (4b). From Equation 4, the reciprocal of the output distance function can be used to find the maximum of θ, which gives the maximal proportional expansion of output given constraints (4a)–(4).

For the other distance functions, the computation of $D^{t+1}(z^{t+1})$ is exactly the same as (4), where $t + 1$ is substituted for t. Two other distance functions require information from two periods, $D^t(z^{t+1})$ can be computed by replacing $y_{m,j}^t$ and $x_{n,j}^t$ in (4a) and (4b) with $y_{m,j}^{t+1}$ and $x_{n,j}^{t+1}$, respectively, and $D^{t+1}(z^t)$ is the same as $D^t(z^{t+1})$, where the t and $t + 1$ superscripts are exchanged[4].

The output-oriented Malmquist indices of productivity change are computed using the data envelope approach discussed below. We used the computer software DEAP **(Coelli, 1996)** to calculate these indices.

The following tables presented estimated mean values are geometric mean of Malmquist indices viz; total factor productivity changes (TFPCH), decomposed into technical efficiency change (EFFCH) and technological change (TECHCH). TECHCH is further decomposed into pure technical efficiency change (PECH) and scale efficiency change (SECH). The companies are arranged in descending order of their Malmquist productivity indices (TFPC). The value of TFPC higher than unity reveals productivity growth and lower than one indicates decline in productivity. Percentage change in productivity is given by (TFPC-1) x 100. The same rule applies to other indices presented in the table.

The total factor productivity change can be decomposed as,

TFP change = Technical efficiency change (catching up effect)
x Technical change (frontier effect)

Further technical efficiency change decomposed as,

Technical efficiency change = Scale efficiency change x Pure efficiency change

RESULTS AND DISCUSSION

ESTIMATES OF COMPANY MEANS OF TOTAL FACTOR PRODUCTIVITY GROWTH DURING THE STUDY PERIOD

Table 1 presents the estimation of Malmquist Productivity Index (MPI) for companies of Indian steel industry. The given MPI were the geometric mean of the twenty seven companies for the study period (2000-2016). The industry as a whole witnessed the deteriorated change in the productivity growth during the study period and this declining pattern was mainly contributed by the both technical efficiency (-0.30 per cent) and technical change (-7 per cent).

Out of twenty seven companies, only one company achieved productivity improvement while twenty eight companies had recorded productivity deterioration

[4] See **Coelli (1996), p.27** for more details.

during the study period. The positive productivity growth was found in Vardhman Industries Limited at 1.70 per cent and it contributed only by efficiency change of 11.80 per cent whereas the technology regressed at (-) 9 per cent.

Table 1
Sources of Total Factor Productivity Change in Selected Indian Steel Companies during 2000 to 2016

Companies	TFPCH	EFFCH	TECHCH	PECH	SECH
Avon Ispat & Power Ltd.	0.947	1.023	0.926	1.044	0.980
Beekay Steel Inds. Ltd.	0.872	0.971	0.898	0.998	0.973
Bhushan Steel Ltd.	0.917	0.939	0.976	0.972	0.966
Gontermann-Peipers (India) Ltd.	0.916	0.984	0.931	0.964	1.021
India Steel Works Ltd.	0.904	0.975	0.927	1.005	0.971
J S W Steel Ltd.	0.940	0.973	0.967	1.008	0.965
Mahindra Steel Service Centre Ltd.	0.878	0.936	0.938	0.971	0.965
Modern Steels Ltd.	0.941	1.040	0.905	1.050	0.990
Mukand Ltd.	0.961	1.037	0.927	0.973	1.066
National General Inds. Ltd.	0.875	0.949	0.922	1.000	0.949
Panchmahal Steel Ltd.	0.920	1.017	0.905	1.015	1.001
Pennar Industries Ltd.	0.968	0.991	0.976	1.008	0.983
Prakash Industries Ltd.	0.934	0.992	0.941	0.974	1.018
Rashtriya Ispat Nigam Ltd.	0.961	1.035	0.928	0.910	1.137
Rathi Bars Ltd.	0.899	1.010	0.890	1.000	1.010
Rathi Steel & Power Ltd.	0.868	0.929	0.935	0.962	0.965
Real Strips Ltd.	0.886	0.969	0.914	1.009	0.960
Shah Alloys Ltd.	0.829	0.912	0.909	0.948	0.962
Sharda Ispat Ltd.	0.962	1.037	0.927	1.040	0.997
Shivalik Bimetal Controls Ltd.	0.923	1.028	0.898	1.036	0.992
Shri Bajrang Alloys Ltd.	0.969	1.000	0.969	1.000	1.000
Steel Authority Of India Ltd.	0.963	1.072	0.898	0.975	1.099
Steelco Gujarat Ltd.	0.952	0.987	0.965	0.987	1.000
Sunflag Iron & Steel Co. Ltd.	0.980	1.039	0.943	1.011	1.027
Tata Steel Ltd.	1.017	1.118	0.910	1.000	1.118
Tulsyan N E C Ltd.	0.884	0.969	0.913	0.994	0.975
Vardhman Industries Ltd.	0.986	1.003	0.983	1.000	1.003
Steel Industry Mean	**0.927**	**0.997**	**0.930**	**0.994**	**1.002**
Steel Industry Mean Percentage (%)	**-7.30**	**-0.30**	**-7.00**	**-0.60**	**0.20**
Source: CMIE: Centre for Monitoring Indian Economy PROWESS database. Note: All Malmquist index averages are geometric means.					

There were twenty six companies witnessed productivity deterioration during the period in the Indian steel industry. In case of Shah Alloys Limited, it was observed that maximum productivity was worsen at (-) 17.10 per cent due to the poor result of both efficiency change at (-) 8.80 per cent and (-) 9.10 per cent in technological change. There were no companies who improved both technical efficiency and technical change in the selected Indian steel companies and surprised to see the result that no companies had improved (or positive) the technology in the study period. The result suggested that, there were no companies utilised the technology more efficiently during the study period.

The change in the efficiency result was due to changes in both pure and scale efficiency. The technical efficiency improved in 12 out of 27 companies but the result found that negative value of (-) 0.30 per cent in the industry average. In case of pure efficiency change, it was more than unity in ten companies and the similar pattern has emerged in scale efficiency change. There were two companies reported constant return to scale in the Indian steel companies.

CONCLUSION

The study concluded that twenty six companies productivity was deteriorated, whereas only one company evidenced productivity gain much during the study period. On the whole the deteriorating productivity was due to decline in both technical efficiency at (-) 0.30 per cent and technical change at (-) 7 per cent. In other words the negative sign of both efficiency and technology suggested that there was a declining total factor productivity growth.

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