

TOTAL FACTOR PRODUCTIVITY GROWTH IN INDIAN HEAVY ENGINEERING GOODS ENTERPRISES : AN APPLICATION OF RADIAL AND NON-RADIAL MALMQUIST PRODUCTIVITY INDICES

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Using Data Envelopment Analysis (DEA) based non-radial and radial measures of technical efficiency the present study evaluates the performance of 25 major public sector heavy engineering goods enterprises over the period of 1990/91 to 2007/08. The empirical findings reveal average technical efficiency in tune to 52.1 percent in the selected public sector heavy engineering goods enterprises. The decomposition of non-radial technical efficiency measure into mix efficiency and local radial measure of technical efficiency reveals that global inefficiency is caused by local technical inefficiency in general and managerial inefficiency in particular. However, mix inefficiency and scale inefficiency are the scant sources of technical inefficiency in the public sector heavy engineering goods enterprises of India.

Keywords: Data Envelopment Analysis, Slack Based Measure, Indian Public Sector

INTRODUCTION

The present study evaluates the total factor productivity (TFP) of 25 major public sector heavy engineering goods enterprises (PSEs) during the period 1990/91 to 2007/08. The relevance of this study stems from the fact that these enterprises are significantly contributing to the employment, exports and value added of Indian manufacturing sector in general and public sector in particular. In recent years, many of public enterprises engaged in the production of heavy engineering goods turned out to be loss making units. The data with Ministry of Heavy Industry and Public Enterprises (MHIP) reveals that out of 32 public sector heavy engineering goods enterprises, 16 are incurring losses and thus, disclose the appalling status of the health of Indian public sector heavy engineering goods industry (Government of India, Ministry of Heavy Engineering and Enterprises. Annual Report, 2008-09). Against this background, it has become imperative to analyze the growth robustness of these public sector heavy engineering enterprises through analyzing the status of productivity growth in these enterprises. The analysis is must to design a suitable revival strategy for sustainable growth of these enterprises.

In India, there has been a considerable research on the TFP growth of Indian manufacturing sector. The survey of existing literature on measuring the TFP growth of Indian manufacturing sector contains the studies which can be categorized broadly in three distinct categories. First category includes those studies which concentrate on measuring TFP growth at highly aggregated level [see, for example, Neogi and Ghosh (1998), Pradhan and Barik (1999), Singh (2000-01), Goldar and Kumari (2003)]. The focus of the second category is on the analysis of TFP growth of single manufacturing industry [see, for example, Beri (1962), Sastry (1966), Mehta (1974), Gupta and Patel (1976), Singh and Singh (1984), Dawar (1990), Sharma and Upadhyay (2003-04), Singh and Agarwal (2006)]. There are relatively few studies in the third category which analyze the inter-

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state variations in TFP growth for a single industry or group [see, for example, Ray (2002), Kumar (2003), Chattopadhyay (2004), Kumar and Arora (2009)]. To the best of our knowledge, there has been no published study that concentrated on the evaluation of TFP growth in public sector heavy engineering goods enterprises of India. The present study is an endeavor in this direction and aims to enrich the existing literature on the TFP growth of Indian manufacturing sector in general and of public sector heavy engineering enterprises in India. The study has been conducted with the twin objectives of analyzing the extent of TFP growth in public sector heavy engineering goods industry of India along with the identification of the sources of TFP growth. To pursue these objectives, the study has been organized in five sections. Including this introductory one, the next Section-2 discusses the methodology applied. Section-3 debates the results of empirical analysis and section-4 concludes the chapter.

METHODOLOGY

The literature spells out two basic approaches to the measurement of total factor productivity growth: (i) the econometric estimation of a production, or cost, or some other function, and (ii) the construction of index numbers using nonparametric methods. In this study, we adopted the latter because it does not require the imposition of a possibly unwarranted functional form on the structure of the production technology as required by the econometric approach. Three different indices are frequently used to evaluate total factor productivity growth: the Fisher, Törnqvist and Malmquist indices. The Malmquist productivity index (MPI) has been selected to analyze the productivity growth in the manufacturing sector of 16 major Indian states. The selection of Malmquist productivity index over that of Törnqvist and Fisher Ideal indices is due to the fact that only the MPI i) allows the decomposition of productivity changes into two mutually exclusive components namely, a) technical efficiency change, and b) technological change; ii) does not require price data, thereby avoids the problems associated with unavailability or distortions of price information; and iii) does not require a pre-specified optimizing criterion such as cost minimization or profit maximization. The main disadvantage of the MPI is the lack of a stochastic specification and thus, making it insensitive to any random shocks or data measurement errors.

The Malmquist productivity index (MPI), as proposed by Caves, Christensen and Diewert (1982) is defined using distance functions, which allow one to describe multi-input, multi-output production technology without involving explicit price data and behavioural assumptions (such as cost minimization or profit maximization). One may define input distance functions and output distance functions. An input distance function characterizes the production technology by looking at a minimal proportional contraction of the input vector, given an output vector. An output distance function considers a maximal proportional expansion of the output vector, given an input vector. For purposes of this paper, we utilize the output-oriented distance functions to calculate MPI since the manufacturing firms are more likely try to increase their outputs given their use of inputs, rather than try to decrease inputs given their outputs.

The Radial Malmquist Productivity Index

Before we define the distance function we first define the technology. Consider a sample of K states using $x^t \in R_+^M$ inputs in the production of $y^t \in R_+^M$ outputs in time period $t, t=1, \dots, T$. The graph of the production technology in period t is the set of all the feasible input-output vectors

$$GR^t = \{(y^t, x^t), x^t \text{ can produce } y^t\}, t=1, \dots, T$$

where technology is assumed to have the standards properties, such as convexity and strong disposability, described in Fare *et al.* (1994).

A multiple-input, multiple-output production technology can be represented by the *production possibility set* which is defined in terms of GR^t as

$$P^t(x^t) = \{y^t : (y^t, x^t) \in GR^t\}, \quad t=1, \dots, T$$

A functional representation of the technology is provided by Shephard's (1970) *output distance function*

$$D_o^t(x^t, y^t) = \min_{\theta} \left\{ \theta : \frac{y^t}{\theta} \in P^t(x^t) \mid \theta > 0 \right\}, \quad t=1, \dots, T$$

The distance function is less than, or equal to one if and only if the output y belongs to the output set. The manufacturing sector of the state is considered technically efficient if the distance function equals one and the values less than one indicate inefficiency.

The TFP change, measured by the MPI, between periods t and $t+1$, can be defined using the period t technology as

$$M_o^t(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}$$

Similarly, the MPI using period $t+1$ technology may be defined as:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \sqrt{\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}}$$

In order to avoid choosing the MPI of an arbitrary period Färe *et al.* (1994) specified the Malmquist productivity change index as the geometric mean of both the above equations.

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \sqrt{\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}}$$

Färe *et al.* (1994) further states that the MPI formula in equation (2.2.6) can be equivalently rewritten as:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \sqrt{\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}}$$

The first ratio on the right hand side of above equation measures the changes in technical efficiency between period t and $t+1$ as a 'catching-up to the frontier' effect. The second term measures the change in production technology (i.e., technical change) usually referred as a shift in production frontier.

$$EC = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)};$$

$$TC = \sqrt{\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}}$$

In order to calculate the Malmquist productivity index for state k' between t and $t+1$ for a constant returns-to-scale (CRS) technology, the four different distance functions that make up the index, that is, $D_o^{t+1}(x^{k',t+1}, y^{k',t+1})$, $D_o^{t+1}(x^{k',t+1}, y^{k',t+1})$, $D_o^t(x^{k',t+1}, y^{k',t+1})$, and $D_o^{t+1}(x^{k',t}, y^{k',t})$ are required to be calculated using linear programming approach. For calculating output distance functions for the manufacturing sector of state k' , four different linear programming problems can be stated as:

$$\begin{aligned}
 & D_o^{t+j}(x^{k',t+j}, y^{k',t+j})^{-1} = \max \theta^{k'} \\
 & \text{subject to} \\
 & \theta^{k'} y_m^{k',t+j} \leq \sum_{k=1}^K z^{k,t+i} y_m^{k,t+i}, \quad m = 1, \dots, M; \\
 & \sum_{k=1}^K z^{k,t+i} x_n^{k,t+i} \leq x_n^{k',t+j}, \quad n = 1, \dots, N; \\
 & z^{k,t+i} \geq 0, \quad k = 1, \dots, K.
 \end{aligned}$$

where

$(i,j)=(0,0)$ for solving for $(D_o^t(x^{k',t}, y^{k',t})^{-1})$;

$(i,j)=(1,1)$ for solving for $(D_o^{t+1}(x^{k',t+1}, y^{k',t+1})^{-1})$;

$(i,j)=(0,1)$ for solving for $(D_o^t(x^{k',t+1}, y^{k',t+1})^{-1})$ and

$(i,j)=(1,0)$ for solving for $(D_o^{t+1}(x^{k',t}, y^{k',t})^{-1})$

In the above linear programming problems, $z^{k,t}$ is an intensity variable indicating the intensity at which a particular state is employed in constructing the frontier of the technology set. The technology specified here is non-parametric but assumes constant returns-to-scale and strong disposability of inputs and outputs.

The Non-radial and Slacks-based MPI

The radial approaches suffer from neglect of the adjustments in the input(s) or output(s) slacks while accounting for the performance of a given decision making unit. However, these slacks do effect the performance of a DMU under evaluation. In an effort to overcome this problem, several authors, e.g., Zhu (1996, 2001), Tone (2001, 2002) and Chen (2003) have developed non-radial measures of efficiency and super efficiency. We develop here the non-radial, slacks-based MI as follows:

$$[SBM - 0]$$

$$\delta^s((x_0, y_0)^t) = \min_{\psi, \lambda} 1 / \left(1 + \frac{1}{m} \sum_{i=1}^m \psi_i \right)$$

subject to

$$x_0^t \geq X^s \lambda$$

$$(1 + \psi_i) y_{i0}^t = \sum_{j=1}^n y_{ij}^s \lambda_j \quad (i = 1, \dots, q)$$

$$L \leq e\lambda \leq U$$

$$\lambda \geq 0, \psi \geq 0.$$

$$[SuperSBM - 0]$$

$$\delta^s((x_0, y_0)^t) = \min_{\psi, \lambda} 1 / \left(1 - \frac{1}{q} \sum_{i=1}^q \psi_i \right)$$

subject to

$$x_0^t \geq X^s \lambda$$

$$(1 - \psi_i) y_{i0}^t = \sum_{j=1}^n y_{ij}^s \lambda_j \quad (i = 1, \dots, q)$$

$$L \leq e\lambda \leq U$$

$$\lambda \geq 0, \psi \geq 0.$$

From above it can be seen that the output-oriented models take all output slacks (shortfalls) into account but not input slacks (excesses). Thus, the non-radial and slacks-based MI evaluates the four elements of $MI : \delta^1((x_0, y_0)^1), \delta^2((x_0, y_0)^2), \delta^1((x_0, y_0)^2)$ and $\delta^2((x_0, y_0)^1)$ by the means of

$[SBM - I]$ and $[SuperSBM - I]$ programs.

However, the above discussed models viz., radial and non-radial SBM models either consider input(s) slacks or output(s) slacks but they do not consider mutually these slacks. To overcome this problem, we shall now discuss radial and non-oriented approaches to compute MI. The models under this category deal with the input(s) as well as output(s) slacks correspondingly. The $[SBM]$ and $[SuperSBM]$ models used for obtaining the productivity scores of Public Sector Enterprises engaged in the production of heavy engineering goods are presented by the following fractional programs:

[SBM]

$$\delta^s((x_0, y_0)^t) = \min_{\phi, \psi, \lambda} \left(1 - \frac{1}{m} \sum_{i=1}^m \phi_i \right) / \left(1 + \frac{1}{q} \sum_{i=1}^q \psi_i \right)$$

subject to

$$(1 - \phi_i)x_{i0}^t = \sum_{j=1}^n \lambda_j x_{ij}^s (i = 1, \dots, m)$$

$$(1 + \psi_i)y_{i0}^t = \sum_{j=1}^n \lambda_j y_{ij}^s (i = 1, \dots, q)$$

$$L \leq e\lambda \leq U$$

$$\lambda \geq 0, \phi \geq 0, \psi \geq 0.$$

[SuperSBM]

$$\delta^s((x_0, y_0)^t) = \min_{\phi, \psi, \lambda} \left(1 + \frac{1}{m} \sum_{i=1}^m \phi_i \right) / \left(1 - \frac{1}{q} \sum_{i=1}^q \psi_i \right)$$

subject to

$$(1 + \phi_i)x_{i0}^t = \sum_{j=1}^n \lambda_j x_{ij}^s (i = 1, \dots, m)$$

$$(1 - \psi_i)y_{i0}^t = \sum_{j=1}^n \lambda_j y_{ij}^s (i = 1, \dots, q)$$

$$L \leq e\lambda \leq U$$

$$\lambda \geq 0, \phi \geq 0, \psi \geq 0.$$

The above discussed fractional programs can be transformed into LPs. The above discussed model under the exclusive scheme evaluates the four components of MI : $\delta^1((x_0, y_0)^1)$, $\delta^2((x_0, y_0)^2)$, $\delta^1((x_0, y_0)^2)$ and $\delta^2((x_0, y_0)^1)$ using [SBM], and, in case if the corresponding LP is found infeasible, we then apply [SuperSBM].

For this non-oriented model, [SuperSBM] is always feasible and has a finite minimum in any returns to scale (RTS) environment, but under some mild conditions, i.e., for each output $i (= 1, \dots, q)$ at least two DMUs must have positive values. This can be seen from the constraint in (5.9).

DATABASE AND CONSTRUCTION OF INPUT-OUTPUT VARIABLES

The empirical analysis has been confined to the period 1990/91 to 2007/08 and the required data has been culled out from the various issues of Public Enterprises Survey, Ministry of Heavy Industries and Public Enterprises. One output (i.e., Gross Value Added) and two inputs (i.e., Gross Fixed Capital stock and Number of Employees) have been used to obtain the efficiency scores for public sector heavy engineering goods industry of India. The total number of employees has been utilized as the proxy of the variable for the labour input. To generate a series of third input gross fixed capital (GFC) stock, we followed the popular perpetual inventory method. This requires a gross investment series, an asset price deflator, a depreciation rate, and a benchmark capital stock.

EMPIRICAL RESULTS

The measures of productivity growth in Indian Public Sector Enterprises (PSEs) have been obtained using three different DEA models. These three models have been classified under two category radial and non-radial. The radial models do not consider the improvement in input-output slacks while calculating the Malmquist productivity index. However, the additive models such as slack based models (SBM) and super slack based (Super SBM) models take care of slack adjustments while reporting the productivity indices. If the value of TFP index using the additive model is greater (less) than the radial measure of productivity then the given decision making unit (DMU) represents an improvement (deterioration) in the input-output slack adjustment process and vice-versa.

Table 1 provides the Malmquist TFP summary for 25 heavy engineering PSEs operating over the period 1991 to 2008. Given the radial measure of Malmquist productivity index, an average annual growth of TFP has been observed to the tune of 1.9 percent per annum. Thus, the average annual growth of TFP in these PSEs is near about 2 percent per annum. The level of productivity growth in these PSEs varies from the minimum of -10.6 percent for Hindustan Cables Ltd. (F18) to the maximum of 18.9 percent for Richardson and Cruddas (1972) Ltd. (F24). Thus there exists a huge variation in the productivity performance of heavy engineering PSEs under evaluation.

The comparison of Radial Malmquist productivity index with the Additive models (i.e., Super-SBM) represents that there exists diminutive difference between the Radial measures and Non-Radial measures of TFP growth. The TFP index falls just by 0.1 percent. The relative difference of radial and SBM based non-radial measure of TFP is to the tune of 0.1 percent. Further approximately the same difference has been observed in between the TFP growth rate reported using the Non-Radial models of SBM and Super-SBM. The reduction in TFP growth while applying SBM model depicts that if we consider the slack adjustments as the performance indicator than the average annual growth of productivity in heavy engineering PSEs has been observed to the tune of 1.8 percent per annum. Hence, such a little difference between the Radial and Non-Radial measure of productivity represents that the output slacks are freely disposable in heavy engineering PSEs and thus not much information is distorted from the application of radial model of TFP growth. To search the source of TFP growth, the Malmquist productivity index has been decomposed into the indices of efficiency change and technological progress. The decomposition of radial Malmquist index represents that the technical progress at the rate of 8.5 percent per annum is the major contributor of TFP growth in these PSEs. In all the 25 PSEs, the technical change index is above unity which depicts that the rate of technical progress is substantial in heavy engineering PSEs and also observed to be the driving force of TFP change.

Table - 1: Malmquist Summary of Public Sector Heavy Engineering Enterprises of India

Firms	Radial			Non-Radial					
	CRS Radial			SBM			Super Super-SBM		
	EffiCh	TechCh	Malm	EffiCh	TechCh	Malm	EffiCh	TechCh	Malm
F1	1.000	1.088	1.088	1.000	1.087	1.087	1.033	1.034	1.068
F2	1.012	1.094	1.108	1.016	1.123	1.141	1.028	1.102	1.133
F3	0.931	1.086	1.010	0.925	1.082	1.000	0.925	1.080	0.998
F4	0.838	1.069	0.896	0.835	1.082	0.904	0.835	1.082	0.904
F5	0.941	1.091	1.027	0.951	1.074	1.021	0.951	1.074	1.021
F6	0.952	1.103	1.050	0.951	1.081	1.028	0.951	1.081	1.028
F7	1.005	1.085	1.091	1.002	1.081	1.083	1.002	1.081	1.083
F8	0.854	1.068	0.913	0.850	1.071	0.911	0.850	1.071	0.911
F9	0.882	1.080	0.953	0.869	1.072	0.932	0.869	1.072	0.931
F10	0.901	1.065	0.960	0.892	1.079	0.963	0.892	1.079	0.963
F11	0.998	1.103	1.101	0.994	1.167	1.159	0.994	1.151	1.144
F12	0.925	1.103	1.020	0.913	1.116	1.018	0.909	1.118	1.016
F13	0.999	1.101	1.100	1.001	1.098	1.098	1.001	1.098	1.099
F14	0.982	1.082	1.063	0.978	1.083	1.060	0.978	1.083	1.060
F15	0.961	1.079	1.037	0.975	1.063	1.037	0.975	1.055	1.029
F16	0.969	1.073	1.040	0.971	1.070	1.039	0.971	1.070	1.039
F17	1.004	1.083	1.087	0.997	1.085	1.082	0.997	1.084	1.081
F18	0.805	1.109	0.894	0.813	1.098	0.893	0.813	1.098	0.893
F19	0.864	1.084	0.936	0.859	1.079	0.927	0.852	1.083	0.923
F20	0.878	1.094	0.961	0.869	1.090	0.948	0.869	1.090	0.948
F21	0.846	1.077	0.912	0.827	1.076	0.890	0.825	1.078	0.890
F22	0.966	1.084	1.046	0.960	1.083	1.040	0.960	1.083	1.040
F23	0.984	1.077	1.060	0.985	1.082	1.066	0.985	1.083	1.066
F24	1.083	1.098	1.189	1.080	1.086	1.173	1.080	1.086	1.173
F25	0.949	1.059	1.005	0.957	1.075	1.029	0.957	1.075	1.029
Average	0.939	1.085	1.019	0.936	1.087	1.018	0.937	1.083	1.016

Source: Authors' Calculations

The potential TFP growth in the heavy engineering PSEs has been restricted by the negative growth of efficiency component at the rate of 6.1 percent per annum. Such a negative growth of productivity efficiency seems to be the outcome of inability of the firms to catch up the technology frontier i.e., the PSEs are unable to catch-up the shift in technology (or frontier) over the given period of time. Further out of 25 PSEs, only 5 PSEs have recorded a positive growth of efficiency. These five PSEs are Bharat Bhari Udhog Nigam Ltd. (F1), Bharat Heavy Electricals Ltd. (F2), and Heavy Engineering Corporation Ltd. (F7), Electronics Corporation of Indian Ltd. (F17), and Richardson and Cruddas (1972) Ltd. (F24). The efficiency growth ranges between the minimum of -19.5 percent for Hindustan Cables Ltd. (F18) to the maximum of 8.3 percent per annum for Richardson and Cruddas (1972) Ltd. (F24). Here also the difference between the radial and non radial measures of the component of TFP is insignificant and can be ignored.

Sources of TFP Growth

The aforementioned Malmquist TFP index can be decomposed into two separate effects: i) managerial effect explained by the Malmquist index obtained assuming variable returns to scale (i.e., MPI_{VRS}); and ii) scale effect obtained as the ratio of Malmquist CRS (i.e., MPI_{CRS}) to MPI_{VRS} .

Table 2: Managerial Components of TFP Growth in Public Sector Heavy Engineering Enterprises of India

Firms	Radial			Non-Radial					
	VRS Radial			SBM			Super SBM		
	PECH	PTECH	PMPI	PECH	PTECH	PMPI	PECH	PTECH	PMPI
F1	1.000	1.045	1.045	1.000	1.045	1.045	1.016	0.992	1.008
F2	1.000	1.086	1.086	1.000	1.086	1.086	1.056	1.031	1.089
F3	0.951	1.034	0.983	0.951	1.034	0.983	0.933	1.061	0.990
F4	0.877	1.022	0.896	0.877	1.022	0.896	0.834	1.067	0.890
F5	0.926	1.054	0.976	0.926	1.054	0.976	0.945	1.057	0.999
F6	0.931	1.061	0.988	0.931	1.061	0.988	0.947	1.062	1.005
F7	1.002	1.043	1.045	1.002	1.043	1.045	1.003	1.063	1.067
F8	0.852	1.021	0.870	0.852	1.021	0.870	0.847	1.052	0.891
F9	0.887	1.057	0.938	0.887	1.057	0.938	0.869	1.060	0.921
F10	0.932	1.031	0.961	0.932	1.031	0.961	0.919	1.050	0.965
F11	0.999	1.102	1.100	0.999	1.102	1.100	0.994	1.125	1.118
F12	0.925	1.102	1.020	0.925	1.102	1.020	0.909	1.119	1.018
F13	0.999	1.102	1.101	0.999	1.102	1.101	1.000	1.078	1.077
F14	1.019	1.031	1.051	1.019	1.031	1.051	0.998	1.059	1.057
F15	0.997	1.016	1.013	0.997	1.016	1.013	0.996	1.024	1.020
F16	0.977	1.048	1.023	0.977	1.048	1.023	0.976	1.064	1.038
F17	1.021	1.037	1.059	1.021	1.037	1.059	1.030	1.052	1.083
F18	0.806	1.105	0.891	0.806	1.105	0.891	0.814	1.107	0.901
F19	0.871	1.046	0.911	0.871	1.046	0.911	0.853	1.067	0.910
F20	0.871	1.052	0.916	0.871	1.052	0.916	0.867	1.069	0.927
F21	0.846	1.058	0.896	0.846	1.058	0.896	0.816	1.086	0.886
F22	0.990	1.034	1.023	0.990	1.034	1.023	0.976	1.059	1.033
F23	0.983	1.075	1.057	0.983	1.075	1.057	0.986	1.071	1.056
F24	1.085	1.085	1.177	1.085	1.085	1.177	1.078	1.074	1.158
F25	0.978	1.028	1.006	0.978	1.028	1.006	0.970	1.059	1.026
Average	0.947	1.055	0.998	0.947	1.055	0.998	0.942	1.064	1.002

Source: Authors' Calculations

Table 2 above provides the decomposition of MPI_{VRS} using radial and non-radial models. Both radial and non-radial models provide same average TFP growth of -0.2 percent per annum. Such a negligible growth rate of MPI_{VRS} reflects stagnation in managerial performance of heavy engineering PSEs. The MPI_{VRS} can also be decomposed into $TECH_{VRS}$ and ECH_{VRS} . The technical progress coefficient of MPI_{VRS} represents a parallel shift of technology in the industry* (*Parallel shift and technology is also known as Hicks Neutral type of technical progress) whereas, the index of pure efficiency change represents the changes in managerial practices. It has been observed from the table that 5.5 percentage points of 8.5 percent of technical progress have been contributed by Hicks neutral type of technical progress (given by PTECH). However, the regresses in managerial practices have been observed at the rate of -5.3 percent per annum. Therefore 5.3 percentage points of 6.1 percent efficiency regress have been contributed by the regress in the managerial efficiency. Thus the pure efficiency change is a dominant source and scale efficiency change is relatively a scant source of productivity growth in PSEs under evaluation.

Table 3 provides the scale components of TFP growth in heavy engineering PSEs. The figures of SMALM represent Malmquist productivity index obtained as the ratio of MPI_{CRS} to MPI_{VRS} . The scale component of MPI to the tune of 1.021 reflects that 2.1 percentage points of 1.9 percent

TFP growth has been contributed by improvements in scale components. It simply reflects that scale component has contributed significantly and accelerated the TFP growth of production by 2.1 percent per annum in the industry. The observed change in scale is relied upon expanding the technology base at the rate of 2.9 percent per annum. A positive (negative) growth of the scale component of technical progress represents a capital (labour) deepening type of technical progress. Thus, a biased technical progress to the tune of 2.9 percent per annum accompanied with a Hicks neutral type of technical progress at the rate of 5.5 percent per annum also contributes the technical progress significantly. Moreover the scale efficiency has worsened with an insignificant average annual growth rate of -0.8 percent per annum.

In sum, the analysis reveals that a substantial technical progress contributed in the form of Hicks-neutral and non-neutral type of technical progress has augmented TFP growth in heavy engineering PSEs. Despite of this high rate of technical progress, the 25 PSEs are unable to catch-up the rate of technical progress. The inability of these PSEs to catch-up the technology frontier has been reflected through the negative efficiency change, caused primarily by managerial inefficiency. Hence, steps must be undertaken to improve the efficiency performance of these PSEs so as to obtain substantial TFP growth.

Table 3: Scale Components of TFP Growth in Public Sector Heavy Engineering Enterprises of India

Firms	Radial			Non-Radial					
	SCALE Radial			SBM			Super SBM		
	SEFFICH	STECH	SMALM	SEFFICH	STECH	SMALM	SEFFICH	STECH	SMALM
F1	1.000	1.041	1.041	1.000	1.040	1.040	1.017	1.042	1.060
F2	1.012	1.008	1.020	1.016	1.034	1.050	0.973	1.069	1.040
F3	0.978	1.051	1.028	0.972	1.046	1.017	0.991	1.018	1.009
F4	0.956	1.046	1.000	0.953	1.059	1.009	1.001	1.014	1.015
F5	1.016	1.035	1.052	1.027	1.018	1.045	1.006	1.016	1.022
F6	1.022	1.039	1.062	1.021	1.019	1.041	1.005	1.018	1.023
F7	1.003	1.041	1.044	1.000	1.036	1.036	0.999	1.016	1.015
F8	1.003	1.046	1.050	0.998	1.049	1.047	1.003	1.018	1.022
F9	0.995	1.021	1.016	0.980	1.014	0.993	1.000	1.011	1.011
F10	0.968	1.033	0.999	0.957	1.047	1.002	0.971	1.028	0.997
F11	1.000	1.001	1.001	0.995	1.059	1.054	1.000	1.023	1.023
F12	1.000	1.000	1.000	0.987	1.012	0.999	1.000	0.999	0.999
F13	1.000	1.000	1.000	1.002	0.996	0.998	1.001	1.019	1.020
F14	0.964	1.049	1.011	0.960	1.050	1.008	0.980	1.023	1.003
F15	0.964	1.062	1.024	0.978	1.046	1.023	0.980	1.030	1.009
F16	0.992	1.024	1.016	0.994	1.021	1.016	0.995	1.006	1.001
F17	0.983	1.045	1.027	0.977	1.046	1.022	0.968	1.031	0.998
F18	1.000	1.004	1.003	1.010	0.994	1.003	1.000	0.992	0.992
F19	0.991	1.037	1.028	0.986	1.032	1.017	0.999	1.015	1.014
F20	1.009	1.040	1.049	0.998	1.036	1.034	1.003	1.019	1.022
F21	1.000	1.018	1.018	0.977	1.017	0.994	1.011	0.993	1.004
F22	0.975	1.048	1.022	0.969	1.048	1.016	0.984	1.023	1.007
F23	1.001	1.002	1.003	1.002	1.007	1.009	0.999	1.011	1.010
F24	0.998	1.012	1.010	0.995	1.001	0.997	1.002	1.012	1.013
F25	0.970	1.031	1.000	0.978	1.046	1.023	0.987	1.015	1.003
Average	0.992	1.029	1.021	0.989	1.031	1.020	0.995	1.018	1.013

Source: Authors' Calculations

The relative comparison of the TFP scores obtained from the radial and non-radial measures of MPI although reveals insignificant difference between the average growth rates of TFP components yet it contains a healthy discussion regarding the performance of the PSEs to adjust the output slacks over the given period of time. Table 4 provides the information regarding the performance of the 25 PSEs at the front of the improvements of output slacks.

The PSEs with the '+' symbol indicates an improvement in the TFP components when non-radial slack based model (SBM) is applied. An improvement in the TFP components reveals that the PSEs is improving at the front of slack adjustment and working in the direction to improve the input mix to attain the maximum levels of output. However, a symbol '-' indicates a deterioration in the performance of the given PSE to introduce an improved input output mix. The sign of '×' indicates neutrality in the slack adjustment process. In such case both the radial and non-radial additive models provide same estimates of the components of TFP growth.

Table 4: Differences Among the Components of Radial and Non-Radial TFP Scores

Firms	CRS			VRS			Scale		
	EFFICH	TECH	MALM	EFFICH	TECH	MALM	EFFICH	TECH	MALM
F1	×	-	-	×	×	×	×	-	-
F2	+	+	+	×	×	×	+	+	+
F3	-	-	-	×	×	×	-	-	-
F4	-	+	+	×	×	×	-	+	+
F5	+	-	-	×	×	×	+	-	-
F6	-	-	-	×	×	×	-	-	-
F7	-	-	-	×	×	×	-	-	-
F8	-	+	-	×	×	×	-	+	-
F9	-	-	-	×	×	×	-	-	-
F10	-	+	+	×	×	×	-	+	+
F11	-	+	+	×	×	×	-	+	+
F12	-	+	-	×	×	×	-	+	-
F13	+	-	-	×	×	×	+	-	-
F14	-	+	-	×	×	×	-	+	-
F15	+	-	×	×	×	×	+	-	-
F16	+	-	-	×	×	×	+	-	×
F17	-	+	-	×	×	×	-	+	-
F18	+	-	-	×	×	×	+	-	×
F19	-	-	-	×	×	×	-	-	-
F20	-	-	-	×	×	×	-	-	-
F21	-	-	-	×	×	×	-	-	-
F22	-	-	-	×	×	×	-	×	-
F23	+	+	+	×	×	×	+	+	+
F24	-	-	-	×	×	×	-	-	-
F25	+	+	+	×	×	×	+	+	+
Average	-	+	-	×	×	×	-	+	-

Notes: i) + represents improvement in TFP scores when non-radial model is applied; ii) - represents deterioration in TFP scores when non-radial model is applied; and iii) × represents neutrality in TFP scores when non-radial model is applied.

Source: Authors' Calculations

Given the MPI_{CRS} , there are six PSEs (i.e., Bharat Heavy Electricals Ltd.(F2), Bharat Wagon and Engineering Corporation Ltd. (F4), Andrew Yule and Company Ltd. (F10), Balmer Lawrie

nad Company Ltd. (F11), Rajasthan Electronics & Instruments Ltd. (F23), and Vighyan Industries Ltd. (F25) with the '+' symbol. These PSEs have been observed to be working in the direction of improving input-output mix to achieve the maximum possible output. Thus, the management of these PSEs has found to be active in the process of slack adjustments. Except, these PSEs all the remaining PSEs have been observed ignorant on the slack adjustment front. Further, the number of PSEs with '+' symbol in MPI_{VRS} and MPI_{scale} amount to be 0 and 6, respectively.

CONCLUSION AND POLICY IMPLICATIONS

The present study has been conducted with the prime objective to analyze the status of productivity growth in public sector heavy engineering enterprises of India. Using the data set for 25 heavy engineering PSEs over the period of 1991 to 2008, the total factor productivity (TFP) growth has been obtained applying Malmquist TFP index based upon two different DEA based radial and non-radial models. The radial measure of Malmquist productivity index (MPI) provides a TFP growth to the tune of 1.9 percent per annum. Thus the average annual growth of TFP in these PSEs is found to be near 2 percent per annum. The comparison of Radial Malmquist productivity index with the additive modes slack based models (SBM) and super slack based models (Super-SBM) represents that there exists diminutive difference between the Radial measures and Non-Radial measures of TFP growth. The search for the source of TFP growth depicts that the technical progress at the rate of 8.5 percent per annum is the driving source of productivity growth in heavy engineering PSEs. However, the potential TFP growth in these PSEs has been restricted by the negative growth of efficiency component.

Further, the decomposition of MPI_{CRS} into MPI_{VRS} and MPI_{scale} (i.e., scale effect) reflects a negligible growth rate of MPI_{VRS} reflecting stagnation in managerial performance of PSEs under evaluation. The decomposition reveals that Hicks neutral type of technical progress is relatively dominant source of technical progress and the Hicks non-neutral type of technical progress is relatively meager source of technical progress in these PSEs producing heavy engineering goods. Moreover, the decline in managerial efficiency is a major cause of deterioration of the overall technical efficiency of these sampled PSEs and scale efficiency change is relatively feeble source of it. In sum, the managerial components of MPI_{CRS} (i.e., two components of MPI_{VRS}) are the driving sources of TFP growth in selected heavy engineering PSEs. The technical progress is substantial enough in both terms (i.e., Hicks neutral and non-neutral). However, the catching-up (i.e., efficiency change) is fragile and the matter of prime concern to augment the TFP growth in heavy engineering PSEs. Any policy with the spirit of improving the technical efficiency can improve the performance of the industry and helps to achieve it the maximum potential growth of TFP in general and output in particular.

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