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An Analysis of Total Factor Productivity of Manufacturing Sector among the Major States of India

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Abstract

The role of the manufacturing sector in the growth of an economy is indispensable. Total factor productivity is generally regarded as one of the important indicators for measuring productivity the competitiveness of the manufacturing sector. India is a federation of states and the role of the manufacturing sector differs substantially among the states. This is mainly because of total factor productivity. This paper examines the manufacturing sector's performance with respect to the total factor productivity of the manufacturing sector among the major states of India using Malmquist Productive Index-based data envelopment analysis. The paper uses the data from the Annual Survey of Industries (ASI) for the period from 1998 to 2017-18 and uses gross value added as an output whereas fixed capital and number of the person engaged are taken as input. It has been detected that on average TFP has grown by 6.1 percent during the period under consideration. The result of the Malmquist indices and its components shows that the productivity of the Indian manufacturing sector fluctuated over the years from 1998 to 2017 and the TFP growth ranged from -2.7 percent to 17.6 percent during the same period. The highest total factor productivity was noticed in the year 1999 and the change in total factor productivity due to technological change is 12.7 percent whereas 4.3 percent is due to efficiency. Similarly, the lowest TFP change (-7.9) was recorded in the year 2015 followed by (-2.7) in the year 2016. In both years, technological change (-7.6 percent in 2015 and -6.8 percent in 2016) was observed as the major factor for poor performance. The study also observed that higher the R&D expenditure of the states, higher the total factor productivity in the manufacturing sector of the states.

Key words: Total factor productivity, Data envelopment analysis, Malmquist index, Indian manufacturing industry

The manufacturing sector is generally recognized as the driving force towards sustainable economic growth. The manufacturing sector's involvement in economic progress, diversification, employment generation potential, reduction of regional inequalities, and higher export earnings is well recognized worldwide. The development of this sector is considered an indicator of the economic strength of an economy. Manufacturing holds a key position over the past few decades, it has become one of the most dynamic and lively sectors of the Indian economy. Productivity progress in the manufacturing sector is necessary not only to boost output but also to improve the competitiveness of industry both at the domestic and international levels. An economy's growth is determined by two growth drivers: productivity-driven and input-driven growth. Input-driven growth is achieved by increasing the factor of production, which is obviously prone to decreasing returns and is not long-term sustainable, as suggested by [1-2]. Productivity-driven growth is defined as output growth that cannot be explained by increases in total inputs. It is usually attributed to advancements in knowledge, organizational structure, human resource management, skill attainment, information technology, and efficient utilization of production factors. In recent years, productivity growth and capital accumulation have been assigned equal weight. Productivity is crucial to the outcome in both circumstances, whether the development outlook is structural or traditional.

There is not one ideal measure of productivity, however, total factor productivity emerges as the most comprehensive measure because it seeks to capture the increase in output that cannot be attributed to the rise in input factors [3]. Empirical studies employ diverse productivity metrics, including labor productivity and capital productivity, which are considered partial productivity measures since they connect the output to a singular input, such as labor or capital.

TFP is that part of output that cannot be explained by the amount of input used in manufacturing. As a result, its level is governed by how efficiently and intensively inputs are used in the manufacturing process. Total factor productivity comprises only the advancement of technology and human capital. The total factor productivity approach not only analyses the change in productivity but also enquires into the reasons behind these changes. TFP plays an important role in economic fluctuations, the advancement of the economy, and the disparities in per capita income across nations. Total factor Productivity is that portion of output that is not explained by the number of inputs used in production as forwarded by Solow residual. As such, its level is determined by how intensely and efficiently the inputs are utilized in production. The concept of productivity can be

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divided into two components: partial productivity and total factor productivity. Partial productivity measures the contribution of a single factor, such as capital or labor, to the growth of output while keeping all other factors constant. Labor productivity and capital productivity are commonly used concepts to assess the efficiency of resource utilization. However, partial productivity fails to accurately reflect whether the growth in productivity is due to increased input usage, technological advancements, or improvements in efficiency. It also overlooks the aspect of time, secondary products, inputs other than land, labor, and capital, as well as external factors, all of which should be considered in the measurement of partial factor productivity (PFP). PFP estimates the ratio of total output to a single input, typically referred to as labor. While Adam Smith's notion of productivity was limited and restrictive, the idea of productivity has always been used to emphasis that more output can be obtained by fewer input. When properly quantified, differences in productivity growth can explain a lot of the disparities in living standards and per capita incomes around the world [1]. Resource reallocation toward higher-productivity sectors and away from lower-productivity sectors has been a common theme in economic growth initiatives. This explains why low-income countries with low savings and limited income growth emphasize manufacturing over agriculture [2] while demand condition operates in the short run, productivity growth is the only way in long run for poor nation to increase rise standard of living [2]; In the long run, productivity of labor is almost everything for emerging economies, catching up with high-income economies is actually a process of eradicating the productivity gap [3].

The Indian manufacturing sector has pursued varied trajectories in its journey towards industrial progress since gaining independence in 1947. The Indian economy has witnessed substantial transformations in its fundamental policy framework since the year 1991.The old industrial and trade policy regime was replaced by a set of more liberal economic policies in 1991 in order to increase the competitiveness of the manufacturing sector. The success of the manufacturing sector is commonly measured by its productivity and productivity is defined in terms of the efficiency with which inputs are transformed into outputs in the production process. By measuring efficiency and productivity, one can separate their effects and be able to identify the role of industries in a country's growth.

In the context of Indian economy, total factor productivity of manufacturing has been wide and a controversial debate. The importance of productivity and its impact on the manufacturing sector in India mainly evolved during economic reforms of 1991. Consequently, India has liberalized its policies in an effort to make Indian manufacturing sector more productive and competitive in the international markets. Literature shows that different studies have adopted different methodologies and most of the studies have found that total factor productivity increased in the post reforms periods, however few studies forwarded that total factor productivity declined in manufacturing sector of India as well. Balakrishanan and Pushpangadan in 1994 pointed out that that results obtained from single deflation method are totally different from double deflation technique in the estimation of total factor productivity. Further studies found growth in total factor productivity and variation among states and industries in manufacturing sector of India [1-2]. The above paragraphs highlight that there are many studies focusing on the productivity of manufacturing sector among the major states of India. However, no studies were found which focus on analysis based on recent data and consequently, the current study examines the total factor productivity of the manufacturing sector for the selected states of India for the period 1998 to 2017.

There are a number of theoretical and empirical studies relating to productivity of the Indian manufacturing sector. The following paragraphs review some of the studies relating to the research issues of the present study. [1] in the study entitled "An Inter-State Analysis of Total Factor Productivity in India" examined the productivity growth in the Indian manufacturing sector. On the basis of the data collected from the Annual Survey of industries (ASI), it is found that there is productivity improvement in two-digit industries of India and the prime driving force behind the productivity growth over the post reform years. The study also found that inter-state variation in productivity growth exists in Indian two-digit manufacturing sector. [2] used ASI data to assess the productivity performance of Indian industry from 1980 to 2000. The study found that the TFP growth was 0.08 percent annually for 75 three-digit industries using growth accounting and econometric production function estimate. Similarly, Golder [3] made a comparative study on Indian manufacturing industries for the pre and post reform period. Using ASI data, he concluded that the growth rate of TFP of Indian manufacturing declined after 1991 reforms.

[4] attempted to estimate the different components of the total factor productivity in Indian fertilizer industry using the Translog cost function over a period from 1973-74 to 1997-98. The analysis shows that although technical advancement has occurred at a rising rate, the industry has shown falling returns to scale across the study period. The outcome also demonstrated that although energy and material inputs are complementary to one another, they serve as replacements for capital. [2] examined the TFPG and its components (technical efficiency change and technological change) in the sugar industry of Uttar Pradesh. The TFPG is estimated using SBM-DEA-based Malmquist productivity index (MPI) on the panel data of 36 sugar mills for the period 1996- 97 to 2002-03. The study showed that the average TFPG increased at a medium rate of 1/6 percent per annum during the period. The decomposition of TFPG disclosed that the TFPG was mainly contributed by technical change. The study observed that the mills with larger plant size had higher TFPG than the smaller-sized plants. Further, relatively higher TFPG was obtained during the later part of the study period implying that policy-induced factors like de-licensing and partial decontrol of the sugar sector had made direct effect on the TFPG.

[3] using panel data from 1981-82 to 2007-08, a study conducted on various categories of organized manufacturing industries in the state of Haryana revealed that the primary factor behind the improvement of total factor productivity growth (TFPG) in the manufacturing sector of Haryana during the pre-reforms period is the alteration in technical efficiency. However, the scenario changed during the post-reform period. This is based on a comparison of total factor productivity (TFP) measured by Malmquist productivity index (MPI). [1] attempted to examine the productivity trends of twenty-seven Indian industries using CMIE and ASI data from 1953 to 1965. The findings show a significant disparity among the industries in terms of labor and capital productivity trends. Labor productivity has increased significantly in industries such as vegetable oil, chemical, tanning, glass and glassware whereas insignificantly in matches, iron and steel and cement industries. However, capital productivity has not increased noticeably in most of the industries. The TFP of Indian manufacturing sector declined during the study period and most of the industries exhibited constant return to scale. The magnitude of

substitutability was determined to be significantly distinct from zero and one across numerous sectors.

[1] conducted a study entitled "Productivity Trends in Indian Manufacturing Industry, 1951-1978" to analyze the productivity trend in the manufacturing sector of India. The results of the study shows that there was a remarkable increase in industrial production during this period which was associated with marked changes in the industrial structure in favor of basic and capital goods industries.

MATERIALS AND METHODS

This paragraph develops the methodology to examine the total factor productivity change and its various sources in aggregate Indian manufacturing sector and at disaggregate level for 23 major Indian states, i.e. (Maharashtra, Gujarat, Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Karnataka, West Bengal, Haryana, Punjab, Rajasthan, M.P, Jharkhand, Odisha, Kerala, Chhattisgarh, Uttarakhand, Himachal Pradesh, Goa, Assam, Bihar, J&K, Meghalaya and Tripura). The study is based on secondary sources of data. Here it is important to note that total person engaged and gross fixed capital has been taken as the proxy for input and gross value of output in manufacturing has been taken as proxy for total output of organized manufacturing sector at aggregate level for the following reasons.

Gross value of output: For MFP estimates, number of studies have used the value-added approach, although there are theoretical grounds for selecting the gross output approach, particularly at the industry level. Under the value-added approach, improvements in the efficiency of use of intermediate inputs are overlooked. The gross output-based measure is potentially a better indicator of the full extent of disembodied technological change. On the other hand, gross output-based measures do not provide as reliable an indication of the relative importance of industry productivity performance for aggregate MFP trends. There are examples of studies that have used the gross output approach to compute MFP at the industry level [4-6]. In the present study, gross value of output is used as aggregate output for manufacturing industry among the states considered for the study.

Total person engaged: Total person engaged included total person engaged, directly or indirectly with the manufacturing process whether for wages and other purposes. In this study, we used the total person engaged because it is more suitable for the total factor productivity measurement. This variable is used in the literature for the estimation of total factor productivity by Sehgal and Sharma [7].

Gross fixed capital: In this study, gross fixed capital is used as input of capital because this variable is used by most of the literature i.e. [8-11. It is normalized by the appropriate price deflator.

The data for the said variables are collected from Annual Survey of Industries (ASI) complied by Central Statistical Organization (CSO). In the next step, Data Envelopment Analysis[1] (DEA) with Malmquist Productivity Index[2] (MPI) has been employed to analysis the total factor productivity and its sources in manufacturing sector of India at aggregate and disaggregate level. The reason behind using this technique over other method of measuring TFP i.e., Solow residual index, translog index etc. because this technique can handle multiple input and output with different units and also it does not require any assumption of a functional form relating inputs to outputs. It can be applied to profit as well as non-profit making entities. It sets targets for inefficient decision-making units DMUs to make them efficient. It also identifies slacks in inputs and outputs. Furthermore, it does not require any prior judgment regarding the relative importance of the various outputs or knowledge of input prices.

The MPI is decomposed in two components: changes in technical efficiency and changes in technological Change. Further technical efficiency is decomposed into change in pure efficiency and change in scale efficiency [12-13].

$$M_{0\,t+1}(y_{t+1}, x_{t+1}, y_t, x_t)/MPI = \left\{\frac{d_0\,t\,(x_{t+1}\ y_{t+1})}{d_0 t(x_t,\ y_t)} * \frac{d_0\,t+1\,(x_{t+1}\ y_{t+1})}{d_0 t+1(x_t,\ y_t)}\right\}^{1/2} \quad \text{(eq. 1.1)}$$

Where; X and Y denote inputs and output respectively. t and t+1 denote the time period of production. The ratio measures the change in relative efficiency tells that the change in how far observed production (X_{t+1}, Y_{t+1}) is from maximum potential production (X_t, Y_t) between the time period t and t+1. This index is a geometric mean of two output based on Malmquist indices (technical efficiency and technological change between two periods). A unit value of Malmquist *(MPI=1)* indicates that there has been no change in inputs ($X_t = X_{t+1}$) and output ($Y_t = Y_{t+1}$) values between two periods of time. These indices can be interpreted as progress in total factor productivity, when a value is greater than one (MPI>1) then this shows an improvement in productivity whereas value less than one implies deterioration in productivity.

The change in total factor productivity (TFPCH) is a geometric mean of change in technical efficiency (EFFCH) and change in technological progress (TECHCH). The EFFCH index captures changes in technical efficiency between period t and t+1, which compares to the closeness of a firm in each period to that period's efficient boundary. The TECHCH index measures shift in technology frontier between time period from t to t+1. The progress is expressed by these indices when the value is greater than 1, no change when the value is equal to 1 and regress when the value is less than 1.

*TFP Growth = Technical Efficiency Change*Technological Change*

$$MPI = \frac{d_0\,t+1\,(x_{t+1}\ y_{t+1})}{d_0 t\,(x_t,\ y_t)} * \left[\frac{d_0\,t(x_{t+1}\ y_{t+1})}{d_0 t+1\,(x_{t+1},\ y_{t+1})} * \frac{d_0\,(x_t y_t)}{d_0 t+1\,(x_t,\ y_t)}\right]^{1/2} \quad \text{(eq.1.2)}$$

Efficiency change (EFFCH)

$$\frac{d_0\,t+1\,(x_{t+1}\ y_{t+1})}{d_0 t\,(x_t,\ y_t)} \quad \text{eq.1.3)}$$

Technological change (TECHCH)

$$\left[\frac{d_0\,t(x_{t+1}\ y_{t+1})}{d_0 t+1\,(x_{t+1},\ y_{t+1})} * \frac{d_0\,(x_t y_t)}{d_0 t+1\,(x_t,\ y_t)}\right]^{1/2} \quad \text{(eq.1.4)}$$

Let us suppose that there are 'n' number of Decision-Making Units (DMUs). Each of them uses m inputs, x_i, (i = 1, ……, m) to produce s outputs y_r, (r = 1, ……………., s) and t and t+1 two time periods. To calculate the Malmquist index or

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[3] The DEA technique is a non-parametric method that transforms multiple input and output measures into a unified measure of productivity. This is done by linear programming which constructs the frontier technology from data.

[2] MPI is based on the distance function approach, which is defined in terms of inputs or output. With the given input vector, an output distance function maximizes the proportional expansion of the output vector, while an input distance function minimizes the input vector (x), given the output vector (y).

Eq. 1.1 four distance functions or linear problems must be calculated for every firm. Two single period and two-mixed period linear problems can be calculated. In equation 1.1 two single-periods{ $d_0 t(x_t, y_t)$ and $d_0\, t+1\, (x_{t+1}\; y_{t+1})$} measures that can be obtained by using CCR-DEA (CCR 1978).

$d_0 t(x_t\,,\; y_t)$ = Max Ø

s.t.

$$\sum_{j=1}^{n} e_j x_{ij}^{t} \geq \emptyset x_{i0}^{t}\; i = 1,2 \ldots \ldots \ldots \ldots m$$

$$\sum_{j=1}^{n} ʎ_j y_{rj}^{t} \geq \emptyset y_{r0}^{t}\; r = 1,2 \ldots \ldots \ldots \ldots m$$

$ʎ_j \geq 0, j = 1,2, \ldots \ldots .., n$(eq. 2.1)

$d_0\, t+1\, (x_{t+1}\; y_{t+1})$ = Max Ø

s.t.

$$\sum_{j=1}^{n} e_j x_{ij}^{t+1} \geq \emptyset x_{i0}^{t+1} i = 1,2 \ldots \ldots \ldots \ldots m$$

$$\sum_{j=1}^{n} ʎ_j y_{rj}^{t+1} \geq \emptyset y_{r0}^{t+1} r = 1,2 \ldots \ldots \ldots \ldots m$$

$ʎ_j \geq 0, j = 1,2, \ldots \ldots .., n$(eq. 2.2)

In equation 1.1 two mixed-periods {$d_0\, t(x_{t+1}\; y_{t+1})$ and $d_0 t+1(x_t\,,\; y_t)$ } measures that can be obtained by using CCR-DEA (CCR, 1978).

$d_0\, t(x_{t+1}\; y_{t+1})$ = Max Ø

s.t.

$$\sum_{j=1}^{n} ʎ_j x_{ij}^{t} \geq \emptyset x_{i0}^{t+1} i = 1,2 \ldots \ldots \ldots \ldots m$$

$$\sum_{j=1}^{n} ʎ_j y_{rj}^{t} \geq \emptyset y_{r0}^{t+1} r = 1,2 \ldots \ldots \ldots \ldots m$$

$ʎ_j \geq 0, j = 1,2, \ldots \ldots .., n$ (eq. 2.3)

$d_0 t+1(x_t\,,\; y_t)$

s.t.

$$\sum_{j=1}^{n} ʎ_j x_{ij}^{t+1} \geq \emptyset x_{i0}^{t}\; i = 1,2 \ldots \ldots \ldots \ldots m$$

$$\sum_{j=1}^{n} ʎ_j y_{rj}^{t+1} \geq \emptyset y_{r0}^{t}\; r = 1,2 \ldots \ldots \ldots \ldots m$$

$ʎ_j \geq 0, j = 1,2, \ldots \ldots .., n$ (eq. 2.4)

The efficiency change can be further decomposed into scale change (CRS) and pure change efficiency (VRS) by involving an additional two constraints or linear problems [12].

RESULTS AND DISCUSSION

The present study examines the total factor productivity of the manufacturing sector for twenty-three states of India for the period 1998 to 2017 using Malmquist productivity index of data envelope analysis. The summary statistics of variables used in the study and explanation of total factor productivity of manufacturing sector among the 23 major states of India are presented in (Table 1-2).

Table 1 Trends and patterns of Malmquist productivity index in states of India

FIRM	EFFCH	TECHCH	PECH	SECH	TFPCH	TFPCH (%)
Maharashtra	0.998	1.054	1.000	0.998	1.052	5.20
Gujarat	1.020	1.062	1.000	1.020	1.082	8.20
Tamil Nadu	1.001	1.057	1.010	0.991	1.058	5.80
Uttar Pradesh	1.027	1.051	1.016	1.011	1.079	7.90
Andhra Pradesh	1.001	1.067	0.999	1.002	1.068	6.80
Karnataka	1.025	1.055	1.013	1.012	1.081	8.10
West Bengal	1.000	1.060	0.990	1.010	1.060	6.00
Haryana	1.001	1.059	1.006	0.995	1.060	6.00
Punjab	0.997	1.032	1.000	0.997	1.028	2.80
Rajasthan	1.006	1.057	1.003	1.003	1.063	6.30
M.P	1.024	1.050	1.012	1.012	1.075	7.50
Jharkhand	1.029	1.063	1.011	1.018	1.094	9.40
Odisha	1.052	1.067	1.034	1.017	1.123	12.30
Kerala	0.995	1.023	0.996	0.999	1.018	1.80
Chhattisgarh	1.013	1.061	1.003	1.010	1.075	7.50
Uttarakhand	1.017	1.061	1.023	0.995	1.079	7.90
Himachal Pradesh	1.011	1.057	1.009	1.002	1.069	6.90
Goa	1.000	1.056	1.000	1.000	1.056	5.60
Assam	0.972	1.044	0.973	0.999	1.015	1.50
Bihar	0.993	1.035	0.994	0.999	1.028	2.80
Jammu and Kashmir	0.985	1.031	0.985	1.000	1.015	1.50
Meghalaya	0.999	1.067	1.000	0.999	1.066	6.60
Tripura	1.061	1.001	1.077	0.985	1.062	6.20
Mean	1.01	1.051	1.007	1.003	1.061	6.10

Source: Author's Computation Using DEAP 2.1

Data depicted in (Table 1) presents the score of total factor productivity change (TFPCH) and its components i.e., technical change (TECHCH) and efficiency change (EFFCH) along with the components of efficiency change, pure change (PECH) and scale change (SECH) of the manufacturing sector for twenty-three Indian states by applying the generalized output-oriented Malmquist productivity index based on non-parametric approach of Data Envelopment Analysis (DEA) for the period 1998-2017. Again, it is to be noted that technical efficiency (EFFCH) shows how well the production process converts inputs into output between previous and current years while technological change (TECHCH) represents the improvement of technology involved in the production process between two time periods. Further, sub-components of efficiency change are pure efficiency change (PECH) and scale efficiency change (SECH) where pure efficiency change highlights how well the managerial performance in converting the inputs into the output during production process and scale change efficiency is the ability to determine the optimum production scale which helps to avoid the condition where scale of production is too high or small than efficient or optimal level. In percentage, formula can be written as:

Total factor productivity change (percent) = (TFPCH-1) × 100

On the bases of results of above table, we find that India experienced improvement in total factor productivity of manufacturing from 1998 to 2017, and on an average TFP increased at an annual rate of 6.1 per cent during the period under consideration. Decomposition results show that TFP improvement is mainly driven by better performance of technological changes in manufacturing sector of Indian states. The average annual improvement in TECHCH (that is effect of new technology) is 5.1 per cent for all the states of India. Technical efficiency improved during the period under study with average annual growth rate of 1 per cent (out of which 0.7 per cent average annual changes in these states was due to pure efficiency (Managerial efficiency) and 0.3 per cent growth due to scale efficiency (scale of DMU) in Indian manufacturing) during this period. The results of study also depict that both total factor productivity change and technological change are improving in manufacturing sector among all the states of India. However, there is a huge variation in the total factor productivity change and technological changes among the India states**.** Total factor productivity growth rate is slow in Assam (1.5 per cent), Jammu and Kashmir (1.5 per cent), Kerala (1.8 per cent), Bihar (2.8 per cent), Punjab (2.8 per cent), Maharashtra (5.2 per cent) and Tamil Nadu (5.8 per cent) and these states have less total factor productivity growth than the average mean of total factor productivity of all selected states in this study. On the other hand, states like Odisha (12.3 per cent), Jharkhand (9.4 per cent), Gujarat (8.2 per cent), Karnataka (8.1 per cent), Uttar Pradesh (7.9 per cent), Uttarakhand (7.9 per cent), M.P (7.5 per cent), Chhattisgarh (7.5 per cent), Himachal Pradesh (6.9 per cent), Andhra Pradesh (6.8 per cent), Meghalaya (6.6 per cent) and Tripura (6.2 per cent) have recorded higher total factor productivity growth than the average mean of total factor productivity of all selected states of this study. The results also reflect that the technical efficiency is improving in all the states of India except Maharashtra, Punjab, Kerala, Assam, Bihar, Jammu & Kashmir and Meghalaya [13].

Maharashtra has the highest manufacturing value added but the technical inefficiency of Maharashtra is only 0.2 percent and this is due to the inefficiency in scale of manufacturing. It means that TFP growth can be enhanced by improving the scale or size of this industry. Punjab is also performing quite similar to Maharashtra and technical inefficiency in the manufacturing industry of this state, is also directly associated with the scale inefficiency. TFP growth can be increased in these states by increasing the size of the industry. Haryana is also showing scale inefficiency in manufacturing sector during the study period and increase in size of industry will help to enhance the total factor productivity of Haryana's manufacturing sector as well. The impact on TFP growth of technological change and technical efficiency changes for Maharashtra and Haryana is positive. Thus, we find that both technological change and technical efficiency changes have resulted in TFP growth and a 5.4 per cent change in technology resulted 5.2 per cent change in overall TFP growth of Maharashtra's manufacturing sector and a 5.9 per cent change in technological change resulted in 6 per cent growth in total factor productivity of Haryana.

Table 2 Malmquist index summary of annual means

Year	EFFCH	TECHCH	PECH	SECH	TFPCH	TFPCH (%)
1998	…	…	…	…	…	….
1999	1.043	1.127	1.051	0.993	1.176	17.6
2000	0.986	1.076	0.990	0.996	1.061	6.1
2001	1.026	0.979	0.982	1.045	1.005	0.5
2002	1.115	0.975	1.041	1.071	1.087	8.7
2003	0.980	1.177	1.009	0.972	1.154	15.4
2004	1.002	1.148	0.981	1.022	1.151	15.1
2005	0.950	1.089	1.036	0.917	1.035	3.5
2006	0.932	1.154	1.007	0.926	1.076	7.6
2007	1.103	0.960	1.018	1.083	1.058	5.8
2008	0.806	1.308	0.994	0.811	1.055	5.5
2009	0.958	1.082	0.855	1.121	1.037	3.7
2010	1.189	0.951	1.162	1.024	1.131	13.1
2011	0.972	1.113	0.950	1.023	1.081	8.1
2012	1.021	1.023	1.006	1.015	1.044	4.4
2013	1.014	1.000	1.004	1.010	1.014	1.4
2014	1.018	1.000	1.034	0.984	1.017	1.7
2015	0.997	0.924	0.964	1.034	0.921	-7.9
2016	1.043	0.932	0.997	1.046	0.973	-2.7
2017	1.088	1.026	1.076	1.011	1.116	11.6
Mean	1.010	1.051	1.007	1.003	1.061	6.1

Source: Author's Computation Using DEAP 2.1

North eastern states of Assam and Meghalaya both have technical inefficiency of -2.8 per cent and -0.1 per cent respectively. Assam has a technological change of 4.4 per cent annually whereas Meghalaya's performance is better and is 6.7 per cent. The results indicates that technological change has a positive impact in determining the total factor productivity of the respective states manufacturing sectors, especially in Meghalaya. In case of Tripura, technical efficiency change has played an important role in determining the total factor productivity growth and 6.1 per cent change in efficiency resulted in 6.2 per cent change in the overall productivity growth of the manufacturing sector during the study period. Although there is an improvement in technological change but this is less than 0.1 per cent [14-16].

The above table also shows that though some states like Kerala, Bihar and Jammu and Kashmir have positive technological change in production but they are lagging in efficiency change. The following (Table 2) presents the mean of total factor productivity and its components of manufacturing sector for all the selected states over the years.

The mean estimate (geometric means) of Malmquist indices of total factor productivity change (TFPCH) and its component i.e., technical efficiency change (EFCH) and technical change (TECHCH) of manufacturing sector of India are presented in the above (Table 2). The Malmquist index is greater than unitary for most of the years and this explains improvement in the level of productivity of manufacturing sector in India over the period under study. Productivity deteriorated only in two years, i.e. 2015 and 2016 and the average growth in the total factor productivity is 6.1 per cent for the period of 1999 to 2017. The result of the Malmquist indices and its components shows that productivity in Indian manufacturing sector fluctuated over the years from 1998 to 2017 and the TFP growth ranged from -2.7 per cent to 17.6 percent during the period under study. The highest total factor productivity was noticed in the year 1999 and the change in total factor productivity due to technological change is 12.7 per cent whereas 4.3 per cent due to efficiency. Similarly, the lowest TFP change (-7.9) was recorded in the year 2015 followed by -2.7 in the year 2016. In both the years, technological change (-7.6 percent in 2015 and -6.8 percent in 2016) was observed as the major factor for poor performance [17].

The paper examines the factors responsible for change in total factor productivity in the manufacturing sector of India zone wise as well. The classification for zone is adopted from Ministry of Home Affairs, Government of India and five zones[1] have been selected i.e., north zone, west zone, south zone, east zone and northeast zone for the study. The classification shows that the variation in total factor productivity among the different zones is not substantial. This can be made clearer from the (Table 3).

Table 3 Zone wise total factor productivity of Indian manufacturing during 1998-2017

Zone	EFFCH	TECHCH	PECH	SECH	TFPCH
North zone	1.011	1.036	1.011	1.001	1.048
West zone	1.000	1.061	1.000	1.000	1.061
South Zone	0.996	1.028	0.998	0.999	1.024
East Zone	1.011	1.057	1.007	1.004	1.069
Nort east zone	0.975	1.018	1.000	0.975	0.992
Mean	0.999	1.040	1.003	0.996	1.039

Source: Author's Computation Using DEAP 2.1

This table summarizes the components contributing to total factor productivity (TFP) for various geographical regions with respect to Indian manufacturing sector. It provides valuable insights into factors like efficiency, technological advancements, and overall productivity trends during the specified time frame. This data enables a comparative analysis of changes in manufacturing productivity across these regions. According to the results presented in the table, all regions in India, except the Northeast zone, witnessed an enhancement in the total factor productivity of their manufacturing sectors from 1998 to 2017. The North East zone is experiencing a decline in TFP primarily due to a lag in improving efficiency. On average, TFP showed an annual growth rate of 3.9 percent during this period. A detailed examination of the data decomposition reveals that the primary driver of TFP improvement across different regions was the performance of technological advancements within India's manufacturing sector. On average, technological progress (TECH) contributed significantly, with an annual improvement rate of 4.0 percent for all Indian zones. In terms of the relative contribution to the total factor productivity change, the East zone exhibited the highest TFP change at 6.9 percent, closely followed by the West zone at 6.1 percent. This can be attributed mainly to their superior technological performance [18-19].

It's important to note that Research and Development (R&D) plays a crucial role in industrial activities, particularly in the context of growing global competition. R&D activities are vital for generating the knowledge required for producing high-quality products, enhancing efficiency, boosting exports, and achieving technological self-reliance, which is essential for a country's progress. The zone-wise analysis shows that the zones with higher R&D expenditure are also the zones with higher total factor productivity in manufacturing sector. According to the Ministry of Science and Technology's report for the year 2017-18, state governments collectively accounted for a significant portion of R&D expenditure, with more than 55 percent for two zones i.e., the east and north zone [20]. The west zone alone received nearly 30 percent of the total R&D expenditure, followed by the north and south zone, which is approximately 29.4 and 24.3 percent, respectively. On the other hand, north east zone received only 6 percent of R&D expenditure. The results show that regions with higher R&D investments exhibited improvement in total factor productivity growth over the year; in the case of north east zone, there is deterioration in total factor productivity over the years, and it can be observed that this zone received the lowest R&D expenditure among all zones.

CONCLUSION

India experienced improvement in total factor productivity of manufacturing from 1998 to 2017, and on an average TFP increases at an annual rate of 6.1 per cent during the period under consideration. Decomposition results show that TFP improvement is mainly driven by better performance of technological changes in manufacturing sector of Indian states. The average annual improvement in TECHCH (that is effect of new technology) is 5.1 per cent for all the states of India. Technical efficiency improved during the period under

[1]North zone (Uttar Pradesh, Haryana, Punjab, Uttarakhand, Himachal Pradesh & J&K)
West zone (Maharashtra, Gujrat, Rajasthan, Madhya Pradesh, Chhattisgarh & Goa
South zone (Tamil Nadu, Andra Pradesh, Karnataka & Kerala)
East zone (West Bengal, Jharkhand, Odisha & Bihar)
North east zone (Assam, Meghalaya & Tripura)

study with average annual growth rate of 1 per cent (out of which 0.7 per cent average annual changes in these states was due to pure efficiency (Managerial efficiency) and 0.3 per cent growth due to scale efficiency (scale of DMU) in Indian manufacturing) during this period. The results of study also depict that both total factor productivity change and technological change are improving in manufacturing sector among all the states of India. This is support when by zone wise results as well. The zones with higher R&D expenditure are the zones with higher total factor productivity in manufacturing sector. However, there is a huge variation in the total factor productivity change and technological changes among the India states. The results also reflect that the technical efficiency is improving in all the states of India except Maharashtra, Punjab, Kerala, Assam, Bihar, Jammu & Kashmir and Meghalaya. Maharashtra has the highest manufacturing value added but the technical inefficiency of Maharashtra is only 0.2 per cent and this is due to the inefficiency in scale of manufacturing. It means that TFP growth can be enhanced by improving the scale or size of this industry. Punjab is also performing quite similar to Maharashtra and technical inefficiency in the manufacturing industry of this state, is also directly associated with the scale inefficiency. TFP growth can be increased in these states by increasing the size of the industry.

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