Total factor productivitygrowth in Indian manufacturing: New Evidences using Data Envelopment Analysis

V Vijayalalitha*,J. K. Sharma, Tapan Kumar Nayak***, P. Sivakumar******
* V Vijayalalitha, Ph.D. Scholar, Amity School of Business, Amity University, Uttar Pradesh, India (corresponding author).

**Prof. (Dr.) J. K. Sharma, Acting Head, Amity School of Business, Amity University, Uttar Pradesh, India

***Prof. (Dr.) Tapan Kumar Nayak, Dean-Academics & Professor of Economics, Institute of Management Studies, Ghaziabad, Uttar Pradesh

****Prof. (Dr.) P Sivakumar, Director, I Business Institute, Greater Noida, Uttar Pradesh.

Abstract
The present paper evaluates the performances of manufacturing industries with respect to total factor productivity. TFP changesand its components are estimated for 68 three-digit manufacturing industries for the period from 2008-09 to 2017-18 using data from Annual Survey of Industry (ASI) by employingMalmquist Productivity Index based data envelopment analysis. The study uses gross value added based single deflation method as output using 2011-12 as a base period. Capital stock and labour are used as inputs. The paper uses Perpetual Inventory Method to derive the measure of capital input series. It was found that the year 2015-16 has reported highest TFP growth mainly due to technological changes. All the study period exhibits positive trend in TFP growth.In the case of industry-wise analysis, the study also found that the TFP growth is highest in the manufacturer of magnetic and optical media followed by manufacturer of jewelry and related articles. It is evident form the result that the increase in TFP growth is due to technological changes and decrease in TFP growth is due to technical efficiency change.
Keywords: Indian Manufacturing Industry, Data Envelopment Analysis, Malmquist index, total factor productivity, Technical Efficiency, Technological changes

Introduction:

The Indian manufacturing sector has followed diverse pathways to industrial development since independence in 1947. The Indian economy has undergone enormous changes in its underlying policy framework since 1991. The old industrial and trade policy regime was replaced by a set of more liberal economic policies in 1991. Based on the economic theory of production, productivity is generally 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. As part of reform process, India has liberalized its policies both in the internal and external sectors, in an effort to render Indian manufacturing sector more productive and competitive in international markers, and also to facilitate the more effective use of factor inputs.

The performance of the industrial sector has been a subject of great debate in India, particularly following the initial stage of liberalization. The conventional wisdom in favor of reforms was that it would result in significant improvements in productivity growth. Productivity growth is frequently considered to be a key factor in determining the growth of industry, and is generally through to enhance the growth of the economy in the aggregate.

India's economic policies are geared towards economic growth. There has been a spur of interest on the ongoing debate on productivity focusing on the Indian manufacturing industry. Productivity is a measure that attempts to capture the overallefficiency of inputs (capital, labour, intermediate inputs) use. However, productivity isdifficult to measure both in conceptual and practical terms. There is no single-best productivity measure,although total factor productivity is the most comprehensive one, as it attempts to capturethe increase in the output not accounted for by increase in factor input. There are different measures of productivity used in the empirical studies such as labour productivity and capital productivity, which are known as partial productivity measures since they relate output to single input such as labour and capital.

An alternative measure used in the empirical studies is the total factor productivity (TFP), which relates output to all the inputs used in the production process. The concept of TFP growth dates back to the work of Tinbergen (1942), Abramotivz (1956), Solow (1957), and Griliches and Jorgenson (1966) among many others. The concept TFP gained importance for sustaining output growth in the long run as input growth, which is subject to diminishing returns, is insufficient to generate more and more output growth, reflecting the potential for growth. Growth in TFP is typically estimated as the difference between the growth in output and the growth in the weighted average of labour and capital inputs. Since total factor productivity is a constructed measure, the analytical task at hand typically influences its estimation.

Earlier studies on productivity for the industrial sector have indicated that, increase in total factor productivity is an important source of industrial growth. The focus in these studies has been on the measurement of total factor productivity and very little attention has been paid to the causes of productivity changes. A number of earlier studies have estimated total factor productivity (TFP) growth for Indian manufacturing at the aggregate level. Most of the studies have concluded that the rate of TFP growth in Indian manufacturing has been very low and the contribution of TFP growth to output growth is quite small. No rigorous empirical analysis has been undertaken to explain the poor productivity performance of Indian manufacturing.The use of appropriate measurement techniques is, therefore, very important in understanding the industrial performance, thereby suggesting better policy implications for Indian manufacturing sector.

The literature abounds with rival definitions of productivity, which range from ‘getting work done’, ‘reduction in cost’, ‘utilisation of resources’, ‘efficiency of resources allocation’, to efficiency of production. A rigourous analytical approach to the measurement of efficiency in production originated with the work of Koopman (1951) and Debreu (1951). Koopman provided a definition of technical efficiency as, an input-output vector is technically efficient if, and only if, increasing any output or decreasing any input is possible only by decreasing some other output. The problem of measuring the productive efficiency of an industry is important to both the economic theorist and the economic policy makers. If the theoretical arguments to the relative efficiency of different economic systems are to be subjected to the empirical testing, it is essential to make some actual measurements of efficiency. Equally, if economic planning is to concern itself with particular industries, it is important to know how far a given industry can be expected to increase its output by simply increasing its efficiency, without absorbing further resources. A number of attempts have been made to solve this problem, but, although they usually produced careful measurements of some or all of the inputs and outputs of the industry, they failed to combine these measurements into any satisfactory measure of efficiency.

Literature Reviews

Measurement of total factor productivity growth is very important in understanding the performance of an industry. The present literature focuses on estimation total factor productivity and its components of few studies. Ahluwalia (1991) in her study to calculate the growth rate of TFP in Indian manufacturing industries during the period from 1964-65 to 1985-86 and uses the data from Annual Survey of Industry (ASI). The study found that the marked increase in the growth rate of TFP at 3.4 percent per annum of Indian Manufacturing. The estimates of translog production function using pooled data showed that the improvement in the rate of TFP growth. She attributed this observed ‘turnaround’ in productivity growth in Indian manufacturing in 1980s to liberalization of economic policies.

A study by ShalluSehgal and Suparn Sharma (2011)using panel data for the period of 1981-82 to 2007-08 for different categories of organized sector’s manufacturing industries for the sample state of Haryana, analyze the inter-temporal and inter-industry comparison of total factor productivity (TFP) measured by Malmquist productivity index (MPI), which is an application of DEA to calculate the indices of TFP change, technology change, efficiency change. The analysis of the discussion reflects that while the tertiary sectors have maintained its lion’s share in GDP of India and Haryana as well, the declining trend in the share of primary sector and more or less stable contribution of the secondary sector is noticeable. The study reveals that technical efficiency change is the key driver of TFPG in the manufacturing sector of Haryana during pre reforms period, however, the picture has turned around during the post reforms period. A positive impact of liberalization policy on technological advancement of the manufacturing sector of the state has been experienced.

Arnab K. Deb and Subhash C. Ray (2013) in their study analyses the performances of manufacturing industry in India using input-output data from the Annual Survey of Industry for the period 1970-71 through 2007-08. They compare the pre and post-reform performances of Indian manufacturing in terms of total factor productivity growth using DEA. Results show that at the all-India level, total factor productivity growth rate in manufacturing is higher during the post-reform period. Although the majority of states experienced accelerated productivity growth, some states experienced declines in productivity after the reforms. However, the regional variation in the rates of productivity change diminished during the post-reform years.

Another study by Muthusamy and Taegi (2012)attempted to assess the effect of economic reforms on productivity growth in Indian manufacturing industry for the period from 1980-81 to 2003-04. Data on value added, persons engaged, and capital for two-digit industries, were used to construct Malmquist productivity index. The estimates of productivity changes in the Indian manufacturing industries during the study periods reveals contradictory results at the aggregate and sectoral levels. The researchers assess the components of TFP, the reforms can be said to have had a positive effect on technological progress, but negative effect on efficiency improvement. The result of the study suggest the need for the implementation of specific policies to improve technical progress and efficiency change, in order to precipitate a long-run TFP growth.

A study by Anup and Vipin (2016) measured the performance and technological aspects of its major sub-sectors using DEA methodology for the period 2000-2015. Using data from PROWESS, the study employs two-stage methodology. On first stage DEA is used to find technical efficiency (TE) score of individual production units of the industry. Technology Closeness Ratio (TCR) was also measured to identify the inter-group (or Regional) variations in the productivity and TE. Both input and output oriented technical efficiency of six sub-sectors of the Indian food processing industry is measured with respect to both meta-frontier and group frontier for each of the sub-sector.

Gambhir and Sharma (2015) in their study compared productivity performance of textile manufacturing firms in India using DEA. The study found that there is no specific source of productivity gain during the study period for the Indian manufacturing industry. The pure efficiency change had shown deterioration at every scale of operation, reflecting wastage or loss of resources. The study suggest that moderated-size enterprises may be better as than too small or too large-sized enterprises for manufacturing operations.

A study by Mahajan, Nauriyal and Singh (2014) examines the efficiency of R & D and non- R & D firms in Indian Pharmaceutical firm from 2000 to 2010 comprising both pre- and post-product patent period by applying DEA. The efficiency is measured using one output and four inputs. Net sales revenue is taken as output and raw material cost, salaries and wages, advertisement and marketing cost and capital cost as inputs. The main data source of the study is Prowess complied by Center for Monitoring Indian Economy (CMIE). The sample of the study consists of data relating to financial statements of 141 firms of Indian pharmaceutical firms over 10-year period starting from 2000. The study found that efficiency of R & D intensive firms for all the years. The study has endeavored to capture the impact of R & D on efficiency scores of firms. It was found that after 1995, there was significant rise in R & D intensity, consolidations, merges and acquisitions among Indian companies though the R & D intensity was still far lower than the multinationals.

Mazumdar, Rajeev, and Subhash C. Ray (2011) in their paper examines the firm's heterogeneity in Indian pharmaceutical industry by measuring their input and output efficiencies for the period 1991 to 2005. Firm level information for the years 1991 to 2005 are collected from the PROWESS database. The study revealed that use of imported technology enhances efficiency as firms importing foreign technology also benefit from the training and knowledge transfer commonly imparted from the foreign seller. The result also implied that vertical mergers can be strategic option for firms to grow and gain efficiency in production. The new firms tend to use advanced technology. This was resulted in higher efficiency. The result found that increased investment in R&D will be a beneficial strategy for large sized firms.

It is evident from the litereature that the measuremt of total factor producvity growth is important in analysing performance of the industry.

A study by *Sun, Hone and Histor (1999)*, analyses the performance of technical efficiency of industries in China, using data for 28 manufacturing industries across 29 provinces by employing DEA. The technical efficiency of each industry is measured and compared across regions and provinces. The results suggest that there is a considerable potential for savings in resource use in many industries. Significant savings were indicated for most industries operating in the Central and Western regions of the country. The factor associated with differences in technical efficiency between industries found that, there is a positive relationship between export orientation, foreign investment and technical efficiency in Chinese manufacturing industries. The findings lend support to the hypothesis of a positive relationship between economic openness and technical efficiency.

GhulamMujaddad and Hafiz Khalil Ahmad (2016)in their studyanalyzes the technical efficiency and its sources for the large-scale manufacturing industries (LSMI) of Pakistan using DEA double bootstrap technique. The data has been collected from the Census of Manufacturing Industries (CMI) for 65 manufacturing industry for the period of 1995-96, 2000-01 and 2005-06. The study found that the industries should reduce their size as there was evidence of diseconomies of scale and there was a positive impact on technical efficiency.

A study by Ching-Cheng Chang and Yir-HueihLuh (1999) focused on identifying the sources of productivity growth in Asian countries. The study used distance-function-based Malmquist Productivity Index to calculate productivity growth and its components. The data for the study was taken from Penn World Tablesover the period of 1965-90. Using Real GDP as output, labour and non-residential capital as the inputs, the result is quite inspiring because it implies that NIEs not only are good at moving towards the frontier, they have potential to be innovate.

A study by Ephraim W. Chirwa (2001) evaluates the impact of privatization on the technical efficiency of six privatized enterprises using DEA. The study used enterprise level data in the manufacturing sector spanning the period 1970-97, by selecting industries in which privatization took place during the period 1984-91 in Malawi, in which privatized enterprises have been under private ownership for at least 5 years. The study is motivated by the existing empirical research gap on the effect of privatization on efficiency in small development countries.

Boon (2014) in his paper measures the productivity change and technical efficiency of manufacturing sector and its determinants for the period of 2001-10 using DEA based Malmquist Productivity Index. The finding of the study reveals that growth in TFP was attributed to efficiency change with no technical progress. Also sources of efficiency were attributed to quality of worker and flexible work arrangements while the use of foreign workers lowered efficiency. In the case of determinants, export-orientation, capital intensity, and quality of workers are significant. Bootstrap truncated regression approach was conducted to quality sources of efficiency for 2009. The study observed that no improvement in technical change and there was lack in innovation and diffusion of new technologies.

It is evident from the litereature that the measuremt of total factor producvity growth is important in analysing performance of the industry. Study related to India and other counties shows mixed results. In India, study reveals that there is decreasing trend of TFP growth observed during post reform periods. It is evident that these studies emphasis on measurement of productivity and efficiency using DEA method.

Data and Methodology:

Productivity can be measured as an alternative measure of performance, which is the relation between inputs and the resulting outputs. In the case of multiple inputs and outputs, Total Factor Productivity (TFP) is used as measure for productivity, which is defined as the ratio of aggregated output to aggregated input at a given point of time.Though the researchers have propounded several theories and methods to total factor productivity measurement over the decades, the empirical literature spells out two basic approaches to measure TFP growth, parametric and non-parametric techniques. One of the extensively used non-parametric approaches is Data Envelopment Analysiswhich employs mathematical linear programming model to measure efficiency of Decision Making Units (DMUs) and it has capacity to consider multiple inputs and output calculating relative efficiency scores of DMUs. DEA also identifies, for inefficient DMUs, the sources and level of inefficiencies for each of the inputs and output. In DEA, the performances is evaluated in terms of its ability to either shrink usage of an input or expand the output level subject to the restrictions imposed by the best observed practices. Efficiency of each DMU is evaluated against the most efficient DMU, and it is measured by the ratio of actual output to maximum potential output.

Charnes, Cooper, and Rhodes first originated DEA in the literature in1978 and since then this model is known as CCR model. Later, Bankar, Charnes, and Cooper (1984) extended CCR model to allow variable return to scale. The CRS assumption of DEA is suitable only when all DMUs are operating at an optimal scale. There are basically two types of DEA model: those that maximize output, leaving the input vector fixed (output-oriented), and those that minimize inputs, keeping the output vector constant (input-oriented). Input oriented technical efficiency addresses the issue related to how much can input quantities be proportionally reduced without changing the output quantities produces. On the other hand, output oriented technical efficiency addresses the issues related to by how much can output quantities be proportionally expanded without altering the input quantities used. The output and input oriented measures will only provide equivalent measures of technical efficiency when CRS exists, but will be unequal when IRS or DRS are present (Fare & Lovell, 1978).

A ratio of technical efficiency scores obtained under CRS and VRS assumption measures scale efficiency. This scale efficiency measure can be interpreted as the ratio of average product of a firm operating to the average product of the other firm operating at a point of a technically optimal scale. A value of scale efficiency equal to 1 implies that the firm is scale efficient and the value less than 1 suggests the firm is scale inefficient. A firm operating under DRS conditions means that it is operating under super optimal conditions. On the other hand the firm operating under IRS is operating under sub optimal conditions.

Original DEA specification has been extended in several ways and multistage models were developed to identify the nearest efficient points and to make the model invariant to units of measurement. Coelli (1996) developed such a multi stage methodology and a computer program which implements a robust multi-stage model among other options.

When one has a panel data, one may use DEA-like linear program and Malmquist Index to measure productivity change and to decompose productivity change into technical change and technical efficiency change as discussed in Fare, Grosskopf, Norris & Zhang (1994). DEA approach is to use industry data to derive the practice production frontier, against which to evaluate the technical efficiency of each industry. By allowing the production frontier to shift over time due to technical change, the malmquist index can then be derived to measure efficiency change for one year relative to the prior year. Correspondingly, TFP change, which is the product of the efficiency change and technical change, can also be estimated.

Fare et al (1994) specifies an output-based Malmquist productivity changes index as:

$$m_0\left(y_{t+1}, x_{t+1}, y_t, x_t\right)=\left[\frac{d_o^t\left(x_{t+1}, y_{t+1}\right)}{d_o^t\left(x_t, y_t\right)} \times \frac{d_o^{t+1}\left(x_{t+1}, y_{t+1}\right)}{d_o^{t+1}\left(x_t, y_t\right)}\right]^{1/2} \cdots\cdots\cdots\cdots\cdots (1)$$

Equation (1) represents the productivity of production point (x_{t+1}, y_{t+1}) relative to the production point (x_t, y_t). A value greater than one will indicate positive TFP growth from period ‘t’ to period ‘t+1’. This index is the geometric mean of two output based Malmquist TFP indices, one uses period ‘t’ technology and the other period ‘t+1’ technology.

Equation (1) can be decomposed as follows……

$$m_0\left(y_{t+1}, x_{t+1}, y_t, x_t\right)=\frac{d_o^t\left(x_{t+1}, y_{t+1}\right)}{d_o^t\left(x_t, y_t\right)} \times\left[\frac{d_o^t\left(x_{t+1}, y_{t+1}\right)}{d_o^{t+1}\left(x_{t+1}, y_{t+1}\right)} \times \frac{d_o^t\left(x_t, y_t\right)}{d_o^{t+1}\left(x_t, y_t\right)}\right]^{1/2} \cdots\cdots\cdots\cdots\cdots (2)$$

Ratios outside the brackets in equation (2) implies the measurement change in relative efficiency in the output based technical efficiency between periods ‘t’ and ‘t+1’. On the other hand, the terms inside the brackets indicates the geometry of two ratios in the equations, which indicate the shift in technology of two industry. Efficiency change is obtained by calculating the ratio of efficiency in ‘t+1’ period in proportion to efficiency in ‘t’ period.

Malmquist total productivity index may be divided into two as of the change in technical efficiency and technological change.

Technical efficiency change between the period’s ‘t+1’ and ‘t’ can be defined as follows,

$$TE\Delta=\frac{d_0^{t+1}\left(y_{t+1,} x_{t+1}\right)}{d_0^t\left(y_{t,} x_t\right)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Technological change is defined,

$$T\Delta = \left[\frac{d_0^t(y_{t+1,}x_{t+1})}{d_0^{t+1}(y_{t+1t,}x_{t+1})} \times \frac{d_0^t(y_{t,}x_t)}{d_0^{t+1}(y_{t,}x_t)} \right]^{1/2} \text{.................................(4)}$$

TFP Growth = Technical Efficiency change × Technological Change
(Catching up Effect) (Frontier Effect)

Technical efficiency change is described as the efficiency in approximating to the production limit and the technological change is described as curve shift in production limit. On the other hand, multiplication of the change in technical efficiency and technological change yields the change in the total factor productivity growth. Technical efficiency change more than 1 depicts the organization being able to satisfy its production limit. Technological change shows the aggregate change in technology of a industry from time ‘t’ to‘t+1’ can also be viewed as technology frontier shift between the time periods. Technological change greater than 1 indicates a positive shift in the production function or technical progress, less than 1 indicates a negative shift or technical regress. That is to say, the frontier has moved onward, generating more output but with less input. The negative change value of the technological change index means that there has been a reduction on the output produced by similar amount of input. On the other side, technical efficiency change is divided into two in itself as pure technical efficiency change and scale efficiency change. The pure technical efficiency measure is obtained by estimating the efficient frontier under the assumption of variable return to scale. It is a measure of technical efficiency without scale efficiency and purely reflects the managerial performances to organize the inputs in the production process. Thus, it has been used as an index to capture managerial performances. The ratio to technical efficiency change to pure technical efficiency change provides scale efficiency change. The measure of scale efficiency provides the ability of management to choose the optimum size of resources, in other words to choose the scale of production that will attain the expected product level. Inappropriate size of a industry, whether too large or too small may sometimes be a cause of technical inefficiency. This is referred as scale inefficiency and takes two forms: decreasing return-to-scale and increasing return-to-scale. Decreasing return-to-scale implies that the industry is too large to take full advantages of scale and has supra-optimum scale size. On the other hand the industry experiencing increasing return-to-scale is too small for its scale of operation and thus operates at sub-optimum scale size. The industry is scale efficient if it operates at constant return-to-scale.

Two basic sources of production data are the Index of Industrial production (IIP) and Annual Survey of Industries (ASI). The index deals with only selected products and selected firms. ASI collects and provides industry wise data on value added, wages, output, capital stock, depreciation etc, at current prices for the factory registered under the Indian Factory Act 1945, i.e., those which use power and employ at least 10 workers and those which do not use power and employ at least 20 workers.

To estimate technical efficiency level, annual data on value added, fixed capital, number of workers etc., are collected for the organized manufacturing sector from the Annual Survey of Industries for the period of 10 years from 2008-09 to 2017-18 for 68 three digit industries. Data on value added and capital stock are on gross basis inclusive of depreciation.

Our estimation on gross value added function is based on single deflation method. The WPI for the years 2008-09 to 2016-17 was given at the base 2004-05, whereas, rest of the period the base year is 2011-12. The whole series has converted into the 2011-12 base year before deflating the value added series. Perpetual Inventory Method (PIM) is used to derive the measure of capital input series. According to this method, capital stock for a given period is traced by adding the previous investment starting from a benchmark year, converting to constant value by a price index for capital asset. Following Benerji (1975), Goldar (1986) and Balakrishnan and Pushpangadan (1994), double of the book value of the fixed capital is taken as a measure of capital stock for the benchmark year.

Capital stock for the benchmark year is,

$K_0 = 2(B_t)$ where t = 2008-09.

For the subsequent years, gross real investment has taken as a measure of capital stock. The gross real investment for the year ‘t’ is obtained by,

$$I_t = (B_t - B_{t-1} + D_t)/P_t \quad \text{----------(5)}$$

where B_t is the book value of the fixed capital in the year ‘t’.

B_{t-1} is the depreciation in the year ‘t’.

P_t is the index for machinery and machine tools for the t^{th} year with base year 2004-05.

The capital input, gross capital stock at the constant prices (1980-81) at the year ‘t’ derived as,

$$K_t = K_0 + \sum_{i=0}^{t} I_{t-i} \quad \text{-------------------(6)}$$

The labor input is used for the analysis is that the total employees including wage earners and the salaried classes.

Results and discussions

Table- 1: Summary Statistics

Variables	Minimum	Maximum	Mean	Standard Deviation
Gross Value Added	75.96	9176309.77	925544.31	1343028.68
Number of workers	21.00	1141984.00	142106.98	194615.45
Capital	2611.20	34180004.22	2754979.21	5231481.81
Total Number	680	680	680	680

of observation				

Source: Author calculations

The measurement of Total Factor Productivity and its corresponding changes in its components from 2008-09 to 2017-18 using DEAP 2.1 program developed by Tim Coelli (1996b) is reported in the following table. 68 three-digit industries consisting balanced panel data of 680 observation where included in this study. The estimates of Malmquist Productivity Index components which are used in performance measurement like changes in technical efficiency (EFFCH), technological change (TECHCH), changes in pure technical efficiency (PECH), changes in scale efficiency (SECH) and changes in total factor productivity growth (TFPCH) are discussed in this section. The annual average of total factor productivity changes and its components are presented in the table-2.

The highest TFP growth is reported in the year 2015-16 to extend of 19.3% and the changes in TFP growth is due to technological change to extent of 59.4%. The year 2009-10 recorded TFP growth of 14.6% mainly due to 353.5% growth in technological change. The lowest TFP growth is recorded in the year 2013-14 to extend of 2.1 % followed by 4.1% in the year 2010-11.It is clear from the table that the changes in total factor productivity growth are more than 1 in all the study period. The changes are mainly due to the technological changes, which are reported in six-study period. The changes in technological is mainly due to pure efficiency changes rather than scale efficiency changes. Hence the total productivity growth changes are mainly due to pure technical efficiency changes in the manufacturing industries in India during the study period.

Table-2: Averages of TFP Growth and its components among manufacturing industries in India.

Year	EFFCH	TECHCH	PECH	SECH	TFPCH
2009-10	0.324	3.535	0.976	0.332	1.146
2010-11	2.118	0.491	0.991	2.137	1.041
2011-12	1.359	0.812	1.126	1.262	1.086
2012-13	0.829	1.328	0.999	0.829	1.071
2013-14	0.941	1.085	1.082	0.870	1.021
2014-15	1.582	0.724	1.115	1.539	1.133
2015-16	0.765	1.594	0.903	0.864	1.193
2016-17	0.892	1.177	1.026	0.870	1.051
2017-18	0.919	1.151	0.997	0.922	1.058

Source: Authors own calculations

The measurement of TFP change and its corresponding changes in its components from 2008-09 to 2017-18 for different industries are reported in the tabel-3. The highest TFP growth is recorded in the manufacturer of magnetic and optical media to extent of 21.3% is mainly due to technological change to the extent of 25.9%.

Manufacture of jewellery and related articles reported 15.1% TFP growth, which is mainly due to 16.6% technological change. The lowest factor productivity growth is reported to extent of 16% which is mainly due to technical change to the extent of 24.3% in reproduction of recorded media. Installation of industrial machinery and equipment recorded the lowest TFP growth to extend of 11% mainly due to decrease in the technical change to the extent of 21.8%.

It is clear from the table that TFP changes are due to changes in the technological changes. Industries like Processing and preserving of meat, manufacturing of vegetables and animal oils and fats, manufacturing of beverages, reproduction of recorded media, manufacture of coke oven products, manufacture of communication equipment, manufacture of consumer electronics, manufacture of optical instruments and equipment, building of ships and boats and insulation industry machinery and equipment are showing negative TFP growth. Most of the three-digit industries exhibit positive TFP changes during the study period.

Industries like manufacture of prepared animal feeds, manufacture of basic chemicals fertilizers and nitrogen compounds, manufacture of basic precious and other non-ferrous metals, manufacture of computer and peripheral equipment, manufacture of irradiation and electro medical equipment and manufacture of motor vehicles are exhibiting positive technical efficiency change.

Industries like manufacturing of watches and manufacturing of irradiation electro medical industries exhibits positive scale efficiency changes.

Table-3: Industry average of Efficiency scores

INDUSTRY	EFFCH	TECHCH	PECH	SECH	TFPCH
101	0.864	1.143	0.927	0.933	0.988
102	0.997	1.165	1.063	0.938	1.161
103	0.977	1.166	1.074	0.91	1.14
104	0.895	1.116	0.959	0.934	0.999
105	0.901	1.156	0.996	0.905	1.042
106	0.874	1.177	0.966	0.905	1.03
107	0.912	1.148	0.983	0.928	1.047
108	1.026	1.151	1.088	0.943	1.181
110	0.889	1.107	0.951	0.935	0.984
120	0.911	1.1	0.998	0.913	1.003
131	0.928	1.137	1.019	0.91	1.055
139	0.929	1.18	1.038	0.895	1.096
141	0.923	1.156	1.008	0.915	1.067
143	0.983	1.156	1.076	0.913	1.136
151	0.937	1.153	1.015	0.924	1.08
152	0.96	1.161	1.053	0.911	1.114
161	0.905	1.178	0.91	0.995	1.066

162	0.954	1.16	1.039	0.918	1.107
170	0.96	1.098	1.019	0.942	1.054
181	0.934	1.114	1.006	0.928	1.04
182	0.757	1.109	0.789	0.96	0.84
191	0.878	1.098	0.901	0.974	0.964
192	1	1.023	1	1	1.023
201	1.008	1.046	1.026	0.983	1.055
202	0.942	1.122	1.019	0.924	1.056
203	0.989	1.06	1.04	0.951	1.048
210	0.958	1.093	1.017	0.942	1.047
221	0.915	1.138	1.007	0.908	1.041
222	0.921	1.139	1.03	0.894	1.049
231	0.988	1.086	1.045	0.945	1.072
239	0.907	1.116	0.984	0.921	1.012
241	0.971	1.052	0.98	0.991	1.022

Table-3: Industry average of Efficiency scores (continued…)

INDUSTRY	EFFCH	TECHCH	PECH	SECH	TFPCH
242	1.017	1.052	1.042	0.976	1.07
243	0.888	1.134	0.967	0.919	1.007
251	0.898	1.155	0.985	0.912	1.038
259	0.938	1.151	1.052	0.892	1.079
261	0.906	1.142	0.981	0.924	1.035
262	1.063	1.076	1.068	0.995	1.143
263	0.920	1.078	0.97	0.948	0.992
264	0.904	1.064	0.909	0.995	0.962
265	0.929	1.166	1.005	0.924	1.083
266	1.045	1.099	1.038	1.007	1.149
267	0.856	1.135	0.855	1.001	0.971
268	0.964	1.259	0.993	0.971	1.213
271	0.875	1.145	0.965	0.906	1.002
272	0.950	1.109	1.026	0.926	1.053
273	0.940	1.123	1.033	0.91	1.055
274	0.938	1.161	1.023	0.917	1.089
275	0.927	1.122	1.004	0.923	1.04
279	0.916	1.152	0.998	0.918	1.055
281	0.894	1.149	1	0.894	1.026
282	0.941	1.127	1.037	0.907	1.061
291	1.019	1.049	1.047	0.973	1.069
292	0.98	1.126	1.056	0.929	1.104
293	0.954	1.148	1.079	0.884	1.095
301	0.844	1.077	0.851	0.992	0.909

302	0.941	1.162	1.014	0.928	1.093
303	0.967	1.131	1.017	0.951	1.093
304	0.864	1.193	0.898	0.961	1.03
309	0.945	1.155	1.049	0.901	1.092
310	0.952	1.157	1.025	0.929	1.101
321	0.987	1.166	1.081	0.913	1.151
323	0.961	1.156	0.961	1	1.111
324	0.924	1.166	0.924	1	1.077
325	0.931	1.14	1.007	0.924	1.062
329	0.95	1.163	1.034	0.919	1.105
331	0.907	1.14	0.968	0.937	1.034
332	0.792	1.124	0.794	0.998	0.89

Source: Authors own calculations

Summery and conclusion:

Total factor productivity is an important source of industrial growth. Various studies have estimated total factor productivity growth for Indian manufacturing sector at the aggregate level. Most of the studies have concluded that the rate of TFP growth in manufacturing sector in India has been very negligible and the contribution of TFP growth to output growth is quite small. The present paper estimates total factor productivity and its components for 3 digit manufacturing industry.

The estimates of total factor productivity and its components for the period of 2008-09 to 2017-18 of Indian manufacturing industries at 3-digit level using Data Envelopment Analysis are reported in this paper. It is evident from the results that the increase in total factor productivity growth is mainly due to technological progress. The maximum total factor productivity growth is reported in the year 2015-16 and followed by 2009-10. TFP growth is positive for all the study period. Increase in TFP growth is due to technological change in most of the study period. The year 2010-11, 2011-12 and 2014-15 have reported positive TFP growth changes,which is mainly due to technical efficiency change. The increase in the technical efficiency change is due to increase in scale efficiency change in these years.

In the case of industry-wise TFP growth, the manufacturer of magnetic and optical media reported highest TFP growth. The highest growth is mainly due to technological changes. Manufacturer of jewelry and related articles have reported the second highest TFP growth, which is mainly due to technological change. The lowest TFP growth has reported in reproduction of recorded media followed by installation of industrial machinery and equipment. The lowest TFP growth in these industries is mainly due to decrease in technical change.

It is clear from the result that the total factor productivity growth is positive for all the study period and increase in TFP growth is due to technological changes. Most of the industries have reported positive total factor productivity growth during the study period and increase in the TFP growth is mainly due to technological changes.

Reference:

Abid, B. (1998), “Measuring Production efficiency in small firms in Pakistan”, *World Development*, Vol. 26 (1), Pp. 155-169.

Amemiya, T. (1981), “Quantitative response models: a survey”, *Journal of Economics Literature*, Pp.1483-1536

Anup, K. B. &Vipin, V. (2016),” Efficiency and Related Technological Aspects of the Indian Food Processing Industry: A Non-Parametric Analysis”, *The Journal of Developing Areas,* Vol. 50 (6), Pp: 227-243

Banker, R.; D, Charnes, A. & Cooper, W.W. (1984), “Some models for estimating technical and scale in-efficiency in data envelopment analysis”, *Management Science,* Vol. 309, Pp. 1078-1092.

Bhandari, A. K. &Maiti. P. (2007), “Efficiency in the Indian manufacturing firms: textile industry as a case study”, *International Journal of Business and Economics,* Vol. 6(1), Pp. 71-80.

Boon, L. (2014), “Efficiency and productivity of Singapore’s Manufacturing Sector 2001-2010: An Analysis Using Bootstrapped Truncated Approach”,*The Singapore Economic Review*, Pp. 1-17

Charnes, A.; Cooper, W. & Rhodes, E. (1978), “Measuring the efficiency of decision-making units”, *European Journal of Operational Research,*Vol.2(6), Pp. 429-444.

Ching-Cheng, C. & Yir-Hueih, L. (1999), “Efficiency change and growth in productivity the Asian growth experience”, *Journal of Asian Economics*, Vol. 10, Pp. 551-570

Coelli, T. (1996), “The guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program”, *CEPA Working Paper 96/08*, University of New England, Australia.

Deb Kusum Das (2004), “Manufacturing Productivity under Varying Trade Regimes”, 1980-2000, *Economics and Political Weekly,* Pp. 423-433

Dhwani, G. &Seema, S. (2015), “Productivity in Indian manufacturing: evidence from the textile industry”,*Journal of Economic and Administrative Science,* Vol. 3 (20), Pp. 71-85.

Duzakin, E. &Duzakin, H. (2007), “Measuring the performance of manufacturing firms with super slacks based model of data envelopment analysis: an application of 500 major industrial enterprises in Turkey”, *European Journal of Operational Research,* Vol. 182 (3), Pp. 1412-1432.

Ephraim, W. C. (2001), “Privatization and Technical Efficiency: Evidence from the Manufacturing Sector in Malawi”,*African Development Bank.*

Geraint, J. (1995), “Scale and technical efficiency in the production of economic research”,*Applied Economics Letters,* Vol. 2, Pp. 7-11

Hafiz, G. M. & Hafiz, K. A. (2016),” Measuring Efficiency of Manufacturing Industries in Pakistan: An Application of DEA Double Bootstrap Technique”,*Pakistan Economic and Social Review*, Vol. 24(2), Pp. 363-384

Haishun, S. ; Phillip, H. &Hristos, D. (1999), “Economic openness and technical efficiency: A case study of Chines manufacturing industries”,*Economics of Transition*, Vol. 7 (3), Pp. 615-636

Hemal, P. (2011), “Productivity, Performance and work culture in Iron and Steel Industry of India”, *International Journal of Business Economics and Management Research*, Vol. 2 (7), Pp. 73- 92

Hidenobu, O. &Daiju, A. (2016), “Determinants of Operational Efficiency and Total Factor Productivity Change of Major Cambodian Financial Institutions: A Data Envelopment Analysis During 2006-13”, *Emerging Markets Finance and Trade*, Vol. 52, Pp. 1455-1471

Joshi, R. N & Singh, S. P. (2009), “Estimation of total factor productivity in the Indian garment industry”,*Journal of Fashion Marketing and Management,* Vol. 14 (1), Pp. 145-160.

Lee, Y. H.; Tan, H. B. &Cassey, L. (2014),” Productivity, Efficiency and Privatization in the Malaysian Water Industry”,*Journal of Southeast Asian Economics*, Vol.31 (2), Pp. 292-312

Muthusamy, S. (2012),” The Impacts of Economic Reforms on Efficiency Improvement and Technological Progress in Indian Manufacturing*”, The Journal of Developing Areas,* Vol. 46 (1), Pp. 315-329.

Rolf, F.; Grosskopf, S. & Lovell, C. A. K. (1983),” The Structure of Technical Efficiency”,*Scand. J. of Economics*, Vol. 85 (2), Pp. 181-190.

Rolf, F.; Grosskopf, S.; Norris, M. &Zang, Z. (1994), “Productivity Growth, Technical Progress, and Efficiency change in Industrialized Countries”, *American Economic Review*, Vol. 84, Pp. 66-83.

Siddharthan, N.S. &Lal, K. (2004), “Liberalisation, MNE and Productivity of Indian Enterprises”,*Economic and Political weekly*, Pp. 448-452

Sudhee, G. B. &Pramod, S. (2018), “Productivity Analysis- Study of Indian Pharmaceutical Industry”, *IJBIT*, Vol. 11 (1), Pp. 16-21

Veeramani, C. &Goldar, B. (2005),” Manufacturing Productivity in Indian States: Does Investment Climate Matter?”,*Economic and Political Weekly*, Pp. 2413-2420.

Wang, K. L.; Tseng, Y. T. &Weng, C. C. (2003), “A study of production efficiencies of integrated securities firms in Taiwan”,*Applied Financial Economics,* Vol. 13, Pp. 159-167.

Zhu, J. (2003), “Quantitative models for performance evaluation and benchmarking”, Kluwer-Academic Publishers, London.