AN ANALYSIS OF TOTAL FACTOR PRODUCTIVITY GROWTH USING SEQUENTIAL MALMQUIST PRODUCTIVITY INDEX: A CASE OF HARYANA 2-DIGIT MANUFACTURING INDUSTRIES

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ABSTRACT

The study endeavours to analyze inter temporal and inter industry total factor productivity (TFP) growth of Haryana two digit manufacturing industries using non parametric sequential Malmquist productivity index on KLEMS database. The pragmatic analysis has been done during 1998-99 to 2018-19, in order to analyze the impact of global financial crises the total factor productivity of Haryana manufacturing industries is examined under two different economic scenarios i.e. pre financial crises (1998-99 to 2007-08) and post financial crises (2008-09 to 2017-18). The analyses reveal the improvement in total factor growth is attributed to technological change with regressive frontier change in entire and pre crises period. However, the technological change is of Hicks neutral type which indicates the presence of extensive rigidness in regard to the adoption of production mix. The manufacturing industry of coke, refined petroleum products and nuclear fuel is leading with high total factor productivity growth in each economic scenario as well as in the entire span of study.

Keywords: Total Factor Productivity, Non Parametric, Sequential Malmquist Productivity Index, KLEMS.

INTRODUCTION

The Global financial crises originated with US economy during the 2007 pushed the World economy into deep recession (Srinivas, 2018). However, Indian Economy was less affected in comparison to other economies by maintaining highest growth rate (Das *et al*., 2012). It is indeed important to know the resilience of World economic shock on the Haryana manufacturing sector. The relevance is plinth on the fact that Haryana industrial sector is one of the leading industrial sector of India in terms of annual production and its contribution is remarkable in terms of high gross state domestic product (GSDP), various policy incentives and creation of a hi – technology manufacturing hub (Narayan and Sidhanshu, 2018). The economic literature spells that without improvement in total factor productivity (TFP) a magnificent economic growth can't be sustained (Kumar, 2001). The TFP as defined by the Solow (1957) considered as an inspiration component for sustained output growth (Arora, 2013). TFP is a comprehensive measure of technological change and efficiency change for a production process (Ahluwalia, 1991). Thus, the present study has been undertaken to analyze the total factor productivity growth for Haryana two digit manufacturing industry.

This paper seeks to analyze the impact of global financial crises on the total factor productivity using KLEMS database on the Haryana manufacturing industry. The non parametric sequential Malmquist productivity index (MPI) is utilised to carry out the analysis. Sequential MPI means that the calculation of MPI is done by accumulating the prior knowledge (Tulkens & Eeckaut, 1995). The existing literature contains the extensive study on TFP at the national as well as on regional level (Balakrishnan & Pushpangadan, 1994; Goldar & Kumari, 2003; Neogi, Chiranjib and Ghosh, 1998; Sehgal & Sharma, 2012; Verma & Kaur, 2017). But with few exceptions, most of the studies are carried with two or three factors of production that is, capital, labour, material or energy. Moreover, a meagre attention is paid on the biased component of technical change (i.e. Hicks Neutral or non neutral technical Change). The present study bridges out these gaps and analyze an inter-temporal and inter-industry variations in TFPof Haryana manufacturing sector. To check whether the Haryana manufacturing industry is propelled by frontier effect or innovations, the total factor productivity growth is bifurcated into two components namely technical efficiency change (ECH) and technological change (TECH) (Deb & Ray, 2013). Moreover to check Hicks neutrality and non neutrality the TECH is further decomposed into magnitude and biased components (Surender Kumar, 2006).

To fulfil the said objectives, the remaining study is carried in the following manner: section 2 contains the brief review of earlier studies; section 3 is incorporated with the research design of the study and explaining the whole methodology undertaken; section 4 being empirical in nature consists of interpretation of the results; and finally the conclusion and relevant policy implications are carried out in section 5.

LITERATURE REVIEW

Extensive research is done on total factor productivity growth in Indian (Tulpule & Datta, 1989, Kumari, 1993; Dholakia & Dholakia, 1995 ; Goldar & Kumari, 2003; Goldar, 2015a etc) as well as on international industrial sector (for instance Wolff, 1991; Hanel, 2000 etc.) through different methodology and procedure. But putting all in the brief is beyond the limit; therefore few of them are discussed as below Aluwalia (1991) had made an important move towards the productivity estimates for Indian manufacturing sector in the late 1980s using translog production function. The result of the study revealed that there was turnaround increase in the productivity growth of 3.4 percent in the 1980s as compared to negative growth of 0.3 percent during 1965-66 to 1979-80. Unni *et al*. (2001) attempted a comparative statistics in the productivity trends of the all India figures with one of the most industrially developed state Gujarat. The study was done for the period of 1978-1995 using the growth accounting methodology. The findings of the study stated that both at all India and in Gujarat organized sector had outperformed while the unorganized sector had performed well only in the initial phase of partial liberalization i.e. 1978-1985. However productivity performance of Gujarat manufacturing sector was more efficient than all India growth in all aspects for instance growth rate, employment, total factor productivity etc. It was because of the implementation of physical infrastructure development strategy by Gujarat in 1980s to promote industrialization. Chand & Sen (2002) investigated the impact of trade liberalization on the productivity growth with special reference to the Indian manufacturing sector. The study covered the period of 1973-74 to 1988-89 which was divided into three five year periods i.e. 1974-78, 1979-83 and 1984-88. Thirty industries were examined for the study from the three major industrial group i.e. consumer goods industries, intermediate goods industries and the capital goods industries. The total factor productivity growth was calculated using tornquist index formulae and concluded a significant positivity in the trends. However the last period of study showed much improvement as compared to the earlier two. Using Malmquist Productivity Index, Sehgal and Sharma (2011) measured the total factor productivity growth for Haryana manufacturing sector covering the time span of 1981-82 to 2007-08. The main objective of the study was to analyze the impact of economic reforms on the TFP of state manufacturing sector. The result showed that for the entire period of study the MPI has score less than one but the situation gets better in the post reform period. Moreover in the pre reform period technical efficiency change was the key driver of TFPG in pre reform period while in the post reform period the technological change took the place of efficiency change.

RESEARCH METHODOLOGY

The present analysis is confined to the period of 21 years from 1998-99 to 2018-19. The time period is selected to analyse the impact of Global financial crises of late 2007 on the total factor productivity of two digit Haryana manufacturing sector. Therefore the whole study is divided into two sub periods: I) pre crises period (1998-99 to 2007-08) and II) post crises period (2008-09 to 2018-19). The required data have been collected from the reports of Annual Survey of Industries (ASI) published by "Central Statistical Organisation, Government of India under Ministry of Statistics and Programme Implementation (MOSPI)". It is worth to mention here that ASI delivers data of the particular industry as per the respective National Industrial Code (NIC). Since the present study covered the time span of 1998-99 to 2018-19, the NIC codes of series 1998, 2004 and 2008 has been used. However a concorded series is formed as per the NIC-1998. Almost all two digit manufacturing industry of Haryana has been selected for the study but to make comparable concordance data of some industries have been merged with another industry. Therefore, a total of eighteen DMUs are examined, the detail of which is provided in appendix (A).

The calculation of total factor productivity is based on one output (O) and five inputs, i.e. KLEMS or (Capital, Labour, Energy, Material and Services). The value of gross output represents the output (O), total number of persons engaged represents the Labour (L) input, value of fuel consumed is taken as Energy (E) input and material consumed in the ASI data defines the Material (M) input. Following Banga & Goldar (2004), the Service input (S) has been calculated as the subtracted value of fuel consumed and material consumed from the total input variable of ASI. The calculation of capital (K) input is little bit complicated as it is obtained through Perpetual Inventory Method (PIM) of capital stock (P. Balakrishnan & Pushpangadan, 1994; Goldar, 2015). The whole process is described in appendix (B).

The nominal gross output is deflated using the wholesale price index (WPI) of concerned industry with the common base of 2011-12 or (2011-12 = 100). Using input output table published by Central Statistical Organisation (CSO) weighted price index has been formed to generate the real values of energy, material and services. Theweighted price index of energy material is constructed using price indices from the whole sale price index for coal, mineral oils and electricity and the weights are obtained from the input output table as the expenses incurred on "coal & lignite, natural gas, petroleum products and electricity" by the concerned industry.. The care should be taken while selecting the industries as for few industries these components are raw material rather than energy. Similarly the real values are generated for material input but the difference is that the weights are obtained as the expenses of the concerned industry on the purchase of raw material and the price indices is obtained from the WPI for the individual industry. The real values of services has been calculated using weighted index of expenses on various services used like hotels, transportation, post, telecommunication , transportation etc and the implicit GDP price deflator.

Total Factor Productivity: Malmquist Productivity Index

The total factor productivity can be measured through the parametric as well as non-parametric approach. The former involves the econometric estimation of production function while the latter is free from any functional form and utilise the linear programming mathematical modelling. The literature elucidates the Malmquist Productivity Index (MPI) as the best tool to measure total factor productivity in non-parametric framework. In the present analysis MPI has been selected to analyze the inter-temporal and inter-industry total factor productivity indices of various two -digit manufacturing industry of Haryana. The choice of MPI proposed by Caves, D.; Christensen, L.and Diewert, (1982) is due to the fact it comprehensively defines the productivity changes by decomposing the same into two mutually components namely technical efficiency change and technological change. Moreover it is free from the price data. Further it allow multiple sets of inputs and outputs can run on input (aiming minimising resources given the level of output) as well on output orientation (with the objective of maximising output for given bundle of inputs). However the main limitation of the selected index is that it cannot separate the stochastic error term from the modelling procedure (Arora, 2013b)

The present analyses aims to utilise the output oriented distance function MPI for measurement of

TFP as the normal tendency of Haryana manufacturing industry is to maximise their outputs instead of minimising the input level. The upcoming paragraphs describe the Malmquist productivity index in details with all its components. But before moving ahead there is first need to define the technology set having the standard properties of convexity and strong disposability . Let there is a sample of N industries using $x^t \in K_+^l$ inputs in the manufacturing of $y^t \in K_+^m$ output in t years, t = 1........, T. Thus technology set (S) can be written as

$$S^t = \{(x^t, y^t), x^t \text{ can produce } y^t\}, t = 1, \ldots, T \quad \text{....(1)}$$

The equation(1) represents the technology set of one input and one output. The same can be represent with the production possibility set of multiple inputs and outputs specified in the form of S^t as

$$P^t(x^t) = \{y^t : (y^t, x^t) \in S^t\}, t = 1, \ldots, T \quad \text{.... (2)}$$

According to Shephard (1970) output oriented distance function with given technology set can be written as

$$D_o^t(x^t, y^t) = \min_\varphi \varphi : \frac{y^t}{\varphi} \in P^t(x^t), \varphi > 0 \quad \text{.... (3)}$$

The distance function $D_o^t(x^t, y^t) \leq 1$ is subject to the condition that y pertains to the output set (Fare et.al, 1998)

Caves *et al.* (1982) proposed two theoretical indexes namely Malmquist input and output productivity indexes based on the comparison of two input-output vectors with the reference technology utilising the radial input and output scaling. This is explained as follows:

Let t and t+1 be the time period for which the TFP change is measured using MPI. The MPI calculated for t period technology in the output orientation is represented as

$$M_o^t(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \quad \text{.... (4)}$$

Subscript o in M_o^t indicates the output orientation. Similarly the MPI for period t+1 technology is described as:

$$M_o^{t+1}(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \quad \text{.. (5)}$$

Since the choice between the above two i.e. equations(4) and (5) is unaccountable, Fare *et al* (1994) recommended to calculate MPI using Geometric mean of equations (4) and (5). Therefore,

$$M_o^t(x^{t+1}, y^{t+1}, x^t, y^t) = \sqrt{\frac{D_o^t(x^{t+1}, y^{t+1}) D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t) D_o^{t+1}(x^t, y^t)}} \quad \text{.... (6)}$$

Equation (6) can also be written in the following form as

$$M_o^t(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \sqrt{\frac{D_o^t(x^{t+1}, y^{t+1}) D_o^t(x^t, y^t)}{D_o^t(x^{t+1}, y^{t+1}) D_o^{t+1}(x^t, y^t)}} \quad \text{.... (7)}$$

Now the equation (7) is decomposed into two parts, that is the first ratio on the right hand side measures the technical efficiency change (EFC) between t and t+1 year, this effect is also known as catching up or the frontier effect. The second ratio of this equation measures the technological change (TECH) in two adjacent periods also known as innovative index. Moreover changes in the former ratio leads to movement along the production frontier curve whereas the changes effects in latter shift the frontier curve.

$$EFC = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \quad \text{.... (8)}$$

$$TECH = \sqrt{\frac{D_o^t(x^{t+1}, y^{t+1}) D_o^t(x^t, y^t)}{D_o^t(x^{t+1}, y^{t+1}) D_o^{t+1}(x^t, y^t)}} \quad \text{.... (9)}$$

The measurement of MPI for n industries of Haryana manufacturing industries between the two consecutive period t and t+1 is the average geometric product of two components namely technical efficiency change (EFC) and technological change (TECH). A value of MPI index equals, less and more than unity implies that there is no change, decline and improvement respectively in the total factor productivity. A similar interpretation is applied to the EFC and TECH.

The present study also endeavours to decompose the technical change (TECH) following the Fare and Grosskopf, (1996) into bias component (BTECH) and magnitude component (MATECH). The bias component is the product of input bias component (IBTECH) and output biased component (OBTECH). However the latter is relevant only when there are multiple outputs unlike present analysis where only one output is taken into consideration (Fousekis, 2003).

$$TECH = \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)} \sqrt{\frac{D_o^t(x^t, y^t) D_o^t(x^{t+1}, y^t)}{D_o^t(x^t, y^t) D_o^{t+1}(x^{t+1}, y^t)}} \quad \text{.... (10)}$$

The main objective to consider these components into the analyses is to check the Hicks neutral and non-neutral technical progress. The magnitude component (MATECH) of the technical change defines the scale technological progress irrelevant to the slope change. Therefore value of MATECH greater than one indicates the neutral shift in frontier and the positive growth in total factor productivity. The IBTECH equals unity defines the Hicks neutral technical progress and if the IBTECH value exceed (fall short) from unity indicates the Hicks non neutral technical progress and simultaneously suggest that the bias of technical change prompted (restrained) the TFP (Sun & Ji, 2022). Thus, the overall examination of present study decomposes the MPI as

$$MPI = EFC * IBTECH * MATECH \quad .... (11)$$

The Sequential Malmquist Index

The idea of sequential Malmquist index is based on the cumulative previous knowledge in which no technical regress is allowed (Baležentis, 2014). In the above methodology it has been discussed that the value of technological change greater or less than unity will shift the production frontier curve outward or inward. Since this framework envelops the data of t period only and does not accumulates the previous data, the inward shift of the frontier curve is usually temporary (Shestalova, 2003). Tulkens & Eeckaut (1995) described three types of indices for TFP in their research namely contemporaneous, sequential and inter-temporal with reference to shift in production set. Dealing with panel data if there is a full use of data set on a single inter-temporal production set there would be no shift in frontier curve, secondly, using the data set for t period only that is, contemporaneous observation constructed for each time period don't encompass the previous knowledge allow the frontier curve to shift in any direction but the construction of sequential frontier fully dependent on previous knowledge believe that the remaining things which could be possible in past can be fulfilled in future. This strong assumption amounts to the outward shift in frontier curve. The technology set for sequential frontier is defined as:

$$\bar{P}^t(x^t) = \{\bar{y}^t : (\bar{x}^t, \bar{y}^t) \in S^t\}, t = 1, ..., T \quad .... (12)$$

Where $\bar{x}^t = (....., x^{t_0}, ... x^{t-1}, x^t) = (\bar{x}^{t-1}, \bar{x}^t)$ .... (13)

$$\bar{y}^t = (....., y^{t_0}, ... y^{t-1}, y^t) = (\bar{y}^{t-1}, \bar{y}^t) \quad .... (14)$$

't_0' in equations (9) and (10) is the time period for first year for which inputs and output observations are available. The problem arises in the formulation of last set as there is no information prior to time t_0. Absence of information pushed to truncate set $\bar{P}^t(x^t)$at some t_0. The distance function for this modelling is defined as:-

$$D_o^t(x^t, y^t) = \min_{\varphi} \varphi : \frac{y^t}{\varphi} \in \bar{P}^t(x^t), \varphi > 0 \quad ....(15)$$

Each distance function is calculated through respective linear programming equationsand all the calculations based on biased and sequential MPI are carried out in R package "deaR"

EMPIRICAL RESULTS

Using KLEMS data this section aims to analyze the empirical results calculated for Haryana two digit manufacturing industries for 21 years, that is, from 1998-99 to 2018-19. Moreover in order to examine the impact of Global financial crises of late 2007 on the total factor productivity and other corresponding components the study has been bifurcated into two sub periods namely pre crises period i.e. from 1998-99 to 2007-08 and post crises period i.e. from 2008-09 to 2018-19. The Table 1 and Table 2 provide the average inter-temporal estimates and inter-industry estimates respectively for Malmquist productivity index, efficiency change and technical or technological change. The bias and magnitude component of technical change is also presented in table 1. Using the MPI, the growth of total factor productivity has been calculated as (MPI-1)*100, therefore, for the entire period total factor productivity growth (TFPG) has been found to be in tune of 4.9 percent. The TFPG has been increased from 4.7 percent in pre crises period to 5.1 percent in post crises period. The TFPG during the post period is increasing at the mild speed of 0.4 percent. However, in the pre crises period there was regress of 0.8 percent and 6.4 percent in TFP during the year 2003-04 and 2005-06 respectively. The interesting point noticed here is that the regress of 6.4 percent during 2005-06 has been fallen from the highest TFP growth of 10.96 percent in the year 2004-05.

Table 1 : Inter-temporal Variations in MPI and its Components

	MPI	EFC	TECH	IBTECH	MATECH
1999-00	1.094	0.985	1.111	1.059	1.049
2000-01	1.031	0.976	1.057	1.035	1.021
2001-02	1.109	0.912	1.217	1.048	1.161
2002-03	1.055	1.013	1.042	1.036	1.006
2003-04	0.992	0.992	1.000	1.000	1.000
2004-05	1.110	0.932	1.191	1.005	1.185
2005-06	0.936	0.932	1.005	1.000	1.004
2006-07	1.070	1.035	1.034	1.021	1.013
2007-08	1.039	1.036	1.003	1.002	1.001
2008-09	1.027	1.024	1.003	1.003	1.000
2009-10	1.079	1.071	1.007	1.005	1.002
2010-11	1.079	1.065	1.013	1.010	1.004
2011-12	1.028	1.018	1.010	1.008	1.002
2012-13	1.032	1.008	1.023	1.020	1.003
2013-14	1.053	1.035	1.018	1.012	1.006
2014-15	1.047	1.009	1.037	1.017	1.020
2015-16	1.073	0.899	1.193	1.074	1.111
2016-17	1.010	0.950	1.063	1.021	1.041
2017-18	1.035	1.007	1.028	1.028	1.000
2018-19	1.102	1.064	1.036	1.025	1.011
Average					
Entire Period	1.049	0.997	1.053	1.021	1.031
Pre crises period	1.047	0.978	1.071	1.023	1.047
post crises period	1.051	1.012	1.038	1.020	1.018

Note: the estimates are presented for 20 years as MPI is based on the calculation of two adjacent periods
Source: Author's Calculations

Table 2:Inter-industry Variations in Malmquist Productivity Index and its Components

	Entire Period (1998-99 to 2018-19)					Pre Crises Period (1998-99 to 2007-08)					Post Crises Period (2008-09 to 2018-19)				
	MPI	EFC	TECH	IBTECH	MATECH	MPI	EFC	TECH	IBTECH	MATECH	MPI	EFC	TECH	IBTECH	MATECH
FOD	1.048	0.994	1.054	1.009	1.045	1.051	0.993	1.059	1.002	1.057	1.045	0.996	1.050	1.014	1.035
TOB	1.100	1.000	1.100	1.081	1.017	1.104	1.000	1.104	1.084	1.019	1.096	1.000	1.096	1.079	1.016
TEX	1.037	1.007	1.030	0.997	1.034	1.045	1.003	1.041	0.993	1.049	1.031	1.009	1.022	1.000	1.022
LET	1.045	1.009	1.035	1.005	1.031	1.031	0.975	1.058	1.008	1.049	1.057	1.038	1.018	1.002	1.016
WOD	1.032	0.996	1.036	1.003	1.033	1.063	1.008	1.055	1.006	1.049	1.007	0.987	1.021	1.001	1.020
PAP	1.014	0.980	1.034	1.004	1.030	1.033	0.973	1.062	1.011	1.051	0.998	0.986	1.012	0.999	1.013
PPM	1.065	0.988	1.078	1.053	1.023	1.093	0.998	1.095	1.083	1.011	1.042	0.980	1.064	1.030	1.033
CPF	1.217	0.995	1.223	1.208	1.012	1.164	0.955	1.218	1.186	1.028	1.263	1.029	1.227	1.227	1.000
CHM	1.019	0.983	1.036	0.999	1.037	1.005	0.965	1.042	0.994	1.048	1.030	0.998	1.032	1.003	1.029
RUB	1.028	0.997	1.031	0.999	1.032	1.026	0.986	1.041	1.001	1.039	1.030	1.007	1.023	0.998	1.025
ONM	1.026	0.992	1.034	1.005	1.030	0.999	0.940	1.063	1.011	1.051	1.050	1.037	1.012	1.000	1.012
BML	1.027	0.990	1.038	1.016	1.021	1.023	0.963	1.062	1.036	1.025	1.030	1.012	1.018	1.001	1.017
FMP	1.027	0.989	1.038	0.999	1.038	1.016	0.972	1.045	0.995	1.051	1.035	1.003	1.032	1.003	1.028
MEQ	1.027	1.003	1.024	0.999	1.025	1.013	0.969	1.046	0.998	1.048	1.040	1.032	1.007	1.001	1.007
EMA	1.044	1.017	1.027	1.001	1.026	1.052	1.005	1.047	0.997	1.050	1.038	1.027	1.011	1.004	1.007
MTS	1.036	0.996	1.040	0.999	1.040	1.034	0.971	1.065	0.998	1.067	1.036	1.017	1.019	1.000	1.019
OTE	1.066	1.005	1.061	1.009	1.051	1.117	1.012	1.104	1.010	1.093	1.026	0.998	1.028	1.009	1.018
FUR	1.043	1.000	1.043	1.016	1.027	0.995	0.924	1.077	1.018	1.058	1.085	1.067	1.017	1.014	1.003
All#	1.049	0.997	1.053	1.021	1.031	1.047	0.978	1.071	1.023	1.047	1.051	1.012	1.038	1.020	1.018

Note: Represents The Geometric Mean Of All The Manufacturing Industries Of Haryana
Source: Author's Calculations

The study reveals that eight out of 18 industries in Haryana experienced negative TFPG during the post-crisis period, with the manufacturing industry of other transport equipment (OTE) experiencing the worst impact. The MPI score of OTE decreased from 1.117 to 1.026, resulting in an average decrease of 9.13%. CPF recorded a 9.86% TFP growth, followed by furniture with 8.98%.

Efficiency Changes in Haryana Manufacturing Sector

The Malmquist productivity index is divided into efficiency change and technical change, with the efficiency change effect indicating the movement of Haryana manufacturing two-digit industries towards the best practice frontier. The overall two-digit industries in Haryana fail to catch up with the best production possibilities set, with a regress in efficiency change. However, post-financial crises, there is a positive growth of 1.2% in efficiency change, with the highest regress of 10.11 percent during 2015-16. Few industries have improved technical efficiency change, with the highest improvement seen in the electrical machinery and apparatus industry. The extent of regression in post-crisis periods is somewhat reduced, with food industry having an average efficiency change value less than unity.

Decomposition of Technical Change into Magnitude Component (MATECH) and Input Biased Component (IBTECH).

Technical change (TECH) is a key component of the Malmquist productivity index, assessing production process innovation. In Haryana, the two-digit manufacturing industries made 5.3% technical improvement over the period, with the greatest technological progress being 21.7% in 2001-02. Post-crisis, there was a 3.25 percent drop in technical change, indicating the recession's impact on the manufacturing sector. Tobacco products (TOB) came in second with the highest TECH growth, then the manufacturing of coal, petroleum, and fuel (CPF). Textile and industrial and equipment manufacturers were slow to adopt new technology. MATECH, which is greater than IBTECH, contributes 58.87 percent to technical progress. However, MATECH has a major role in explaining technical progress, with only the publishing, printing, and recorded media (PPM) and coal, petroleum, and nuclear fuel industries experiencing Hick neutral progress.

CONCLUSION

Total factor productivity for Haryana two digit manufacturing sector is analyzed using sequential MPI based on KLEMS database reveals that there is an annual average growth rate of 4.9 percent during 1998-99 to 2018-19. The catching up effect contributed a regressive effect of 0.3 per cent on total factor productivity; therefore the productivity is mainly driven by the technological or innovation change for the entire period of study. The comparative analysis of two sub periods is also indicating the same directional change in total factor productivity. However the frontier change has positive effect in post crises period. To be specific, the technological change has a major role in improvement of total factor productivity whereas the frontier or efficiency change has negative impact in earlier phase but in the latter phase it is contributing positively but has a relatively scant role. As far as inter industry analysis is concerned the manufacturing industry of coke, petroleum products and nuclear fuel leads in all the examined period.

Moreover the improvement in technical change is driven by MATECH and the Haryana manufacturing sector is dominated by Hicks neutral progress. The same trend is seen in pre crises period but the post crises period is of Hicks non neutral type. The inter industry analysis is expressing that most of the industries are in the pattern of hicks neutral technological progress which directly indicating the adoption of rigid production mix.

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