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TOTAL FACTOR PRODUCTIVITY GROWTH ANALYSIS OF SELECTED INDIAN OIL AND GAS COMPANIES: A MALMQUIST PRODUCTIVITY INDEX APPROACH

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KEYWORDS:

data envelopment analysis; malmquist productivity index; total factor productivity and efficiency change and technical change; Indian oil and gas companies

ABSTRACT

The Present study examines the levels and trends in output and productivity of the selected Oil and Gas companies (BPCL, HPCL, IOCL, ONGC, OIL, and RIL) that account the major portion India's total oil and gas production. We have collected the data from Prowess, Capitaline and annual reports of the selected companies and the study covers the period from 1991-2017. The study uses Data Envelope Analysis (DEA) based Malmquist productivity Index (MPI) to analyse the total factor productivity growth of the selected oil and gas companies. The study examines the trend in productivity; technical change (innovation) and technical efficiency change (catch up). The study shows rises and falls in the TFP growth; no explicit trend in the TFP growth rates is observed.

JEL Classification: D24, L7

INTRODUCTION

Technical and scale efficiencies of Petroleum companies analysed in this study are static in nature as these efficiencies for a firm are estimated in relation to the best practices firms in a given year. The efficiency measurement approach does not take into account the dynamic changes that occur due to shift in the production frontier over the time period. Total Factor Productivity (TFP) measurement approach not only takes into account changes in the technical and scale efficiencies but also the dynamic shift in the production frontier. No need to emphasize that TFP growth is one of the key factors in raising the competitiveness and profitability of a company. Since, the resources at the disposal of a firm are limited and have competitive uses, it becomes essential for the firm to improve its TFP. A higher TFP growth rate may lower the prices of products and services; provide better remunerations and working conditions to the employees; ensure better returns on investment and generate adequate surplus for firm's expansion and modernization. The TFP has two main components, namely, technical change (innovation) and technical efficiency change (catch up). A study of these two components is essential to know whether the TFP growth in any firm is due to technological improvement or due to increase in the technical efficiency or due to both. Keeping these aspects in view, this chapter examines the TFP growth and its sources in the petroleum companies. For this purpose, a panel data of 6 petroleum companies for the period 1991-2017 (27 years) have been collected from the PROWESS (a product of CMIE) database. Malmquist Productivity Index (MPI) is applied on the panel data to estimate trends in the TFP growth, technological change and technical efficiency change in the Petroleum companies.

REVIEW OF LITERATURE

Productivity Measurement Approaches

In the literature on productivity, two concepts of productivity are commonly used. They are partial factor productivity (PFP)/single factor productivity (SFP) and total factor productivity (TFP). Single factor productivity is measured by dividing the total output of a firm/industry from the quantity or number of the factor for which SFP is to be estimated. There are two main factors of production—labour and capital. Under the SFP approach, labour productivity is measured by the ratio of total output to the total workers. It is, thus, a per worker output. Similarly capital productivity is measured by dividing the total output from the number of machines used in the production process. It is, thus, a per machine output. It may be relevant to note that the SFP may provide a distorted view about the contribution of a factor to the total production. For example, sometimes an increase in labour productivity may not be desirable for the economy or society if it is accompanied by unemployment. Labour productivity can be enhanced without increasing the total output but by retrenching workers and increasing quantity of capital. The PFP cannot consider input bundles together. Therefore, concept of TFP is more relevant in context of resource use efficiency. It has advantage over the PFP approach since it considers multiple inputs and outputs. TFP is defined as the ratio of weighted sum of output to the weighted sum of inputs. A value of TFP index greater than 1.0 indicates an improvement in the TFP, whereas, a value of TFP index less than one shows a decline in it. If value of TFP index is equal to 1.0, it means that there is no change in the TFP.

Researchers have developed various theories and methods for estimation of TFP over the last four decades. Earlier studies mostly applied the growth accounting approach (GAA) to compute the TFP (Hsiao and Park, 2002). The GAA is based on unrealistic assumptions of perfect competition and constant returns to scale. According to this approach, TFP growth in any industry occurs only due to upward shifting of production frontier (technological change). It assumes that all decision making units (firms) operate on the production frontier (100% technical efficiency). Thus, TFP growth measured through this approach is due to technological change (innovation), not due to technical efficiency change (Mawson, et al., 2003). In recent years, stochastic frontier analysis (SFA) and DEA-based MPI have become popular approaches which use panel data for estimation of TFP of individual firms. According to these approaches, a firm may operate below the production frontier and thus may have technical efficiency score less than 1.0. These approaches consider both technological change (shift in the production frontier) and technical efficiency change (catch up) in estimation of TFP of any firm or industry. In this study, we apply the DEA-based MPI approach to estimate the TFP growth in the petroleum companies.

The MPI accounts for both the technological change and technical efficiency change for measuring the TFP growth. According to the MPI approach, TFP of any industry/firm can be increased due to technological change or due to technical efficiency change or due to both. Although MPI is DEA-based approach, it is not static in nature like DEA. It accounts for the shift of frontier overtime. Since it is capable of decomposing the productivity growth into technical efficiency change and technical progress, it is able to shed light on the mechanism of productivity change.

RESEARCH METHODOLOGY AND DATA BASE OF THE STUDY

Research methodology and data base are very important part of a scientific research. A well planned methodology can enrich a research study through systematic collection and compilation of data along with their meaningful analysis and interpretation to find out the truth of a social or physical phenomenon or problem. As stated earlier, the six companies that have selected are Oil and Natural Gas Corporation of India Ltd. (ONGC), Indian Oil Corporation Ltd. (IOCL), Oil India Limited (OIL), Bharat Petroleum Corporation Ltd. (BPCL), Hindustan Petroleum Corporation Ltd. (HPCL) and Reliance Industries ltd (RIL). The time period of the study is 27 years i.e. from 1991 to 2017. The data which have been used in this study are collected from secondary sources i.e. PROWESS (a product of CMIE), published annual reports of the selected public sector oil and gas companies under the study, official sources pertaining to the Department of Public Enterprises, Government of India, New Delhi, Ministry of Petroleum and Natural Gas, Government of India.

Malmquist Productivity Index (MPI)

The MPI was initially introduced by Caves, Christensen and Diewert (CCD) in 1982 and was applied in number of studies, including Fare, Grosskopf, Lindgren and Roos (1992) and Fare, Grosskopf, Norris and Zhing (in 1994,). Ray and Desli (1997), Grifell-Tatje and Lovell (1999), Balk (2001), Kumar and Russell (2002) and Chem and Ali (2004), Singh and Agrawal (2006). The MPI is based on the distance functions. Distance functions allow us to describe multiple input-output production technology without the need to specify a behavioural objective such as cost minimization or profit maximization (Coelli, et al., 1998). Distance function can be defined in terms of inputs or outputs. With the given input vector, an output distance function maximizes the proportional expansion of the output vector, while an input distance function minimises the input vector, given the output vector.

Malmquist profitability record of efficiency change is a multiplicative composite of efficiency and technical change as the major reason for productivity changes can be found out by looking at the estimations of the productivity change and system change indexes. Put in an unexpected way, the profitability misfortunes depicted can be the aftereffect of either efficiency decays, or technique regresses, or both. The output-based Malmquist profitability record is characterized as takes after (Caves et al. 1982):

$$MPI = \left[\frac{d_0^s(xt,yt)}{d_0^s(xs,ys)} \times \frac{d_0^t(xt,yt)}{d_0^t(xt,yt)}\right]^{1/2}$$

Where d_0^s is a distance function measuring the efficiency of conversion of inputs xs to outputs ysin the period s. [Note that DEA efficiency is considered a distance measure in the literature as it reflects the efficiency of converting inputs to outputs (Fare et al. 1994)]

Importantly, if there is a technical change in period t,then

$d_0^t(xt, yt) =$ Efficiency of conversion of input in period s to output in period $s \neq d_0^s(xs, ys)$

Malmquist productivity index is a geometric average of the efficiency and technical changes in the two periods being considered. Following Grosskopf et al. (1994), the Malmquist productivity index in (3.15) in Grosskopf et al. (1994) can thus be written as

$$MPI = \frac{d_0^t(xt,yt)}{d_0^s(xs,ys)} \left[\frac{d_0^s(xs,ys)}{d_0^t(xs,ys)} \times \frac{d_0^s(xt,yt)}{d_0^t(xt,yt)}\right]^{1/2} \text{------------------(8)}$$

Malmquist productivity Index was utilized to evaluate changes in the general efficiency of every pharmaceutical organization after some time. MPI > 1 implies that efficiency increases; MPI = 1 implies that efficiency does not change; MPI < 1 demonstrates that efficiency diminishes. Productivity change is called "catch-up effect" and the productivity change term identifies with how much a DMU enhances or exacerbates its effectiveness. Proficiency change >1 demonstrates progress in relative productivity from period 5Ø`Ü to 5ØaÜ, while effectiveness change = 1 and productivity change <1, individually, demonstrate no change and regress in efficiency. Technical change is called "frontier-shift effect" (or development impact). The technical change term mirrors the change in the productive boondocks between the two eras. Specialized change >1 stands for technical progress; technical change <1 indicates technical regress.

DATA AND VARIABLES

The study is based on panel data collected from the 6 petroleum companies for the period 1991-2017. Since DEA efficiency scores are more sensitive to the inclusion of outlier firms in the analysis, we first identified the outlier firms which influenced the relative efficiency and productivity of other firms in the data set and adversely affected the average efficiency and productivity in the petroleum companies.

Although the selected firms are diverse in their sizes, origin and presumed abilities, all firms are in the same line of business (i.e., oil and gas) and are working under similar market conditions. The variables that we have taken for our study are as follows-

Output Variable- a) Profit after Tax (PAT) or Net Profit

Input Variable- a) Crude Oil Price, b) Total Capital, c) Total Assets

TOTAL FACTOR PRODUCTIVITY GROWTH IN SELECTED INDIAN OIL AND GAS COMPANIES

First, we discuss the trend in the TFP based on the average growth estimated from the data collected for 6 petroleum companies for the period of 27 years (1991-2017). Since, the MPI considers the preceding year as base for the current year to compute TFP change, the MPI does not provide TFP change for the first year of the data set. Table 1 shows the trend in the average TFP growth in the Oil and Gas Companies. The TFPCH estimates the change in the TFP index of an individual firm relative to the best practice firms that are in its peer group. To estimate the TFP growth rate one is subtracted for the TFPCH index and then the value is multiplied by 100 to express the growth rate in percentage. A value of TFPCH index greater than one indicates positive growth in TFP, while a value of less than one points to the negative growth. For example, an average TFPCH index for the year 2010-11 is 1.054. The growth rate is estimated as (1.054 -1)100 = 5.4 percent. This implies that the productivity in the industry increases at the rate of 5.4 percent in 2010-11 over the preceding year.

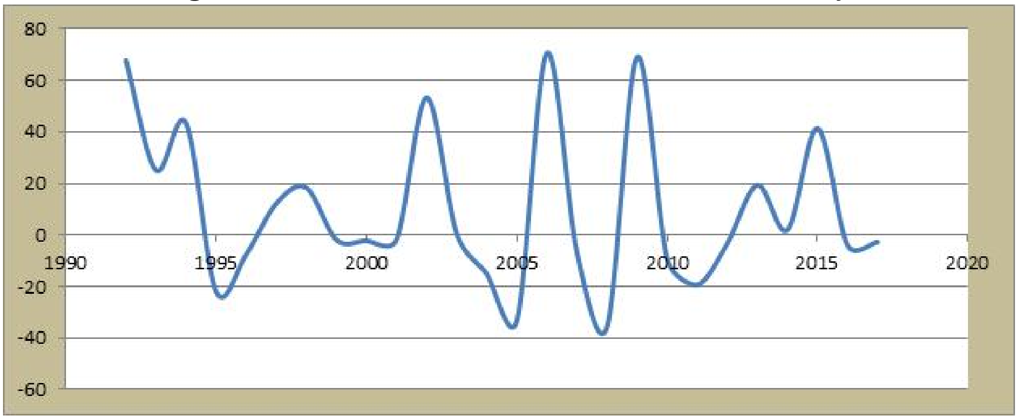
Table-1 shows that the TFP growth rates in the petroleum companies vary significantly across years. The high growth rate is estimated for the 2006 over 2005. Comparing the year 2005, the TFP grows at the rate of 70.5 percent in 2006. One of the reasons for the highest growth rate in this year seems to be due to the poor performance of the industry in 2005. For the next two consecutive years, average growth rates in TFP have been negative. There has been poor performance of the petroleum companies in terms of TFP growth during these years. The industry grows at the rate of 69 percent in the year 2009 over the preceding year. The industry again experiences negative growth rates in the net consecutive years. Last two years of the study period show the positive and significant growth rates in the industry. Figure-1 demonstrates that there are rises and falls in the TFP growth; no explicit trend in the TFP growth rates is observed.

Table-1: Trend in Average TFP Growth of the Oil and Gas Companies

Year	tfpch	Trend in Average TFP Growth of the Oil and Gas Companies	Year	tfpch	Trend in Average TFP Growth of the Oil and Gas Companies
1992	1.678	67.8	**2005**	0.667	-33.3
1993	1.251	25.1	**2006**	1.705	70.5
1994	1.434	43.4	**2007**	0.933	-6.7
1995	0.781	-21.9	**2008**	0.643	-35.7
1996	0.924	-7.6	**2009**	1.69	69
1997	1.122	12.2	**2010**	0.907	-9.3
1998	1.183	18.3	**2011**	0.806	-19.4
1999	0.981	-1.9	**2012**	0.967	-3.3
2000	0.978	-2.2	**2013**	1.193	19.3
2001	0.981	-1.9	**2014**	1.02	2
2002	1.533	53.3	**2015**	1.414	41.4
2003	1.005	0.5	**2016**	0.96	-4
2004	0.849	-15.1	**2017**	0.973	-2.7

Note: **tfpch**- Total Factor Productivity Change

Figure-1: Trend in TFP Growth in the Petroleum Industry



Company-wise annual TFP growth rates are demonstrated in Figure-2, Figure-3 Figure-3, Figure-4, Figure-5, Figure-6, Figure-7. In BPCL, the highest TFP growth is 413.7 percent in 2006 and lowest TFP growth is -70.8 percent in the year 2005. In HPCL, the highest TFP growth is 273.2 percent in 2006 and lowest TFP growth is -73.2 percent in the year 2005. In IOCL, the highest TFP growth is 186.8 percent in 2009 and lowest TFP growth is -58.8 percent in the year 2008. In ONGC, the highest TFP growth is 103.9 percent in 1993 and lowest TFP growth is -39.1 percent in the year 1995. In OIL, the highest TFP growth is 260.9 percent in 1994 and lowest TFP growth is -70.9 percent in the year 1995. In RIL, the highest TFP growth is 219.4 percent in 1991 and lowest TFP growth is -13.8 percent in the year 2008.

Table-2 Trends in TFPCH Indices in Petroleum Companies

Year	BPCL	HPCL	IOCL	ONGC	OIL	RIL
1992	0.908	1.57	0.839	1.994	2.927	3.194
1993	1.307	1.241	1.182	2.039	0.652	1.506
1994	1.003	1.094	0.945	1.503	3.609	1.55
1995	1.178	1.125	0.994	0.609	0.291	0.97
1996	0.874	0.926	1.033	0.916	0.881	0.922
1997	1.214	1.073	1.238	1.311	1.001	0.942
1998	1.224	1.18	1.484	1.228	1.006	1.038
1999	0.844	0.847	0.691	1.077	1.277	1.314
2000	0.687	0.976	1.078	1.116	1.018	1.063
2001	1.021	0.724	1.06	1.184	1.017	0.945
2002	1.424	1.879	2.11	1.553	1.495	0.991
2003	1.35	1.214	0.787	0.75	0.941	1.135
2004	0.546	0.659	0.64	1.297	0.941	1.327
2005	0.292	0.268	0.893	0.952	1.275	1.039
2006	5.137	3.732	1.491	0.857	0.886	1.131
2007	0.874	0.721	0.909	1.071	1.056	1.02
2008	0.457	0.5	0.412	0.821	1.06	0.862
2009	2.219	2.387	2.868	1.281	1.036	1.156
2010	0.928	1.087	0.635	0.883	1.011	0.974
2011	0.78	0.543	0.503	1.175	1.131	0.967
2012	1.177	0.995	1.248	0.816	0.658	1.038
2013	1.504	1.916	1.369	1.011	0.714	1.013
2014	1.265	1.577	0.806	0.822	0.824	1.031
2015	1.398	1.411	2.481	1.173	0.855	1.627
2016	0.879	0.875	1.493	1.024	0.576	1.158
2017	0.971	1	0.972	0.972	1	0.923

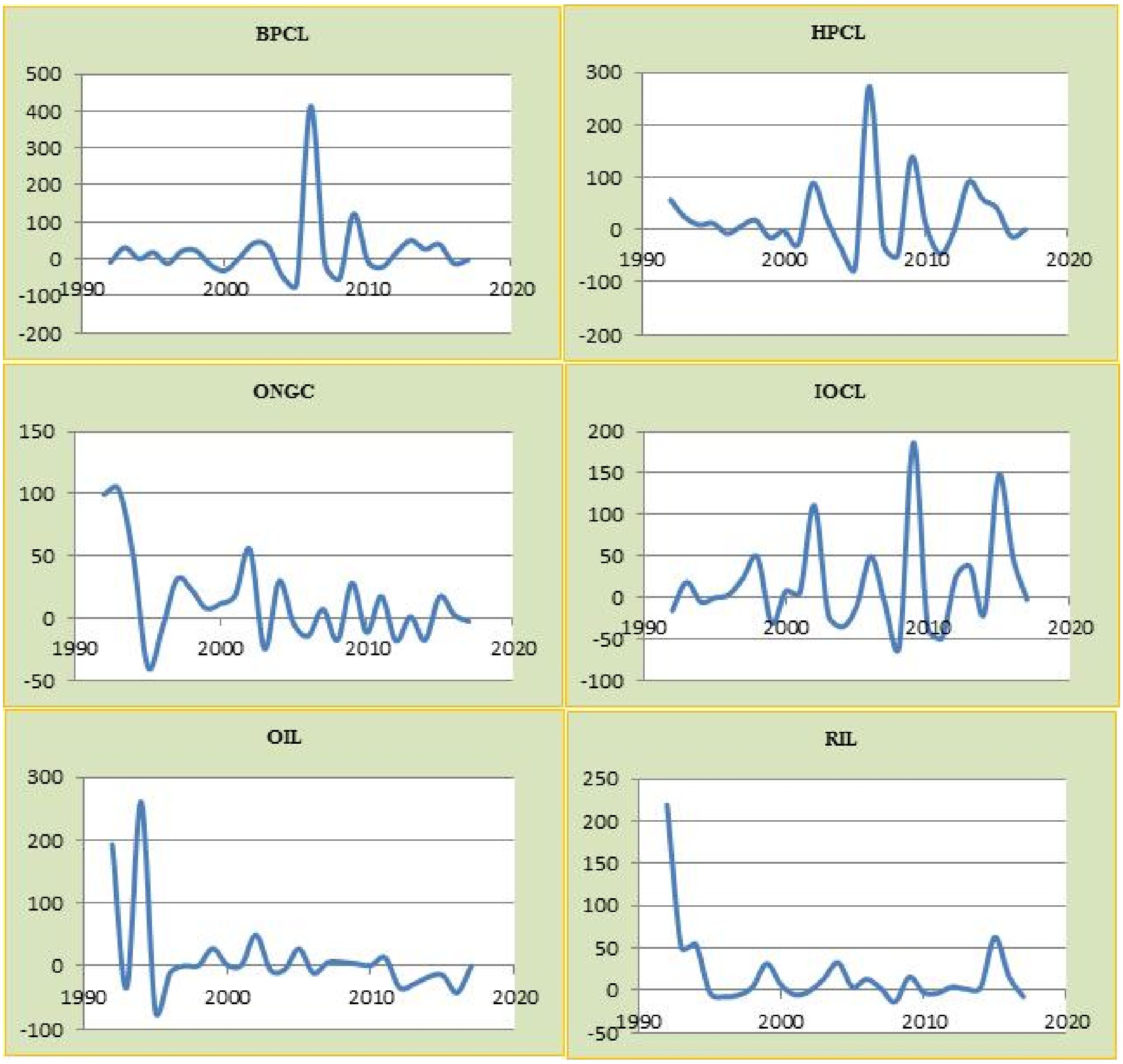
Table-3 Company-wise Average TFP Growth Rates

Year	BPCL	HPCL	IOCL	ONGC	OIL	RIL
1992	-9.2	57	-16.1	99.4	192.7	219.4
1993	30.7	24.1	18.2	103.9	-34.8	50.6
1994	0.3	9.4	-5.5	50.3	260.9	55
1995	17.8	12.5	-0.6	-39.1	-70.9	-3
1996	-12.6	-7.4	3.3	-8.4	-11.9	-7.8
1997	21.4	7.3	23.8	31.1	0.1	-5.8
1998	22.4	18	48.4	22.8	0.6	3.8
1999	-15.6	-15.3	-30.9	7.7	27.7	31.4
2000	-31.3	-2.4	7.8	11.6	1.8	6.3
2001	2.1	-27.6	6	18.4	1.7	-5.5
2002	42.4	87.9	111	55.3	49.5	-0.9
2003	35	21.4	-21.3	-25	-5.9	13.5
2004	-45.4	-34.1	-36	29.7	-5.9	32.7
2005	-70.8	-73.2	-10.7	-4.8	27.5	3.9

2006	413.7	273.2	49.1	-14.3	-11.4	13.1
2007	-12.6	-27.9	-9.1	7.1	5.6	2
2008	-54.3	-50	-58.8	-17.9	6	-13.8
2009	121.9	138.7	186.8	28.1	3.6	15.6
2010	-7.2	8.7	-36.5	-11.7	1.1	-2.6
2011	-22	-45.7	-49.7	17.5	13.1	-3.3
2012	17.7	-0.5	24.8	-18.4	-34.2	3.8
2013	50.4	91.6	36.9	1.1	-28.6	1.3
2014	26.5	57.7	-19.4	-17.8	-17.6	3.1
2015	39.8	41.1	148.1	17.3	-14.5	62.7
2016	-12.1	-12.5	49.3	2.4	-42.4	15.8
2017	-2.9	0	-2.8	-2.8	0	-7.7

Source: *Computed*

Figure-1 Company-wise Average TFP Growth Rates



SOURCES OF TOTAL FACTOR PRODUCTIVITY GROWTH

The MPI decomposes TFPCH into technical efficiency change (EFFCH) and technical change (TECHCH). The first term defines the change in technical efficiency from period t to t+1, i.e. moving closer to frontier or 'catching up'. The second term represents changes in technology, i.e. a shift in the frontier from period t to period t+1. Thus, TFPCH is equal to EFFCH multiplied by TECHCH. EFFCH can further be broken into pure technical efficiency change (PECH) and scale efficiency change (SECH). Hence, the TFPCH can be written as:

$$TFPCH = PECH \times SECH \times TECHCH$$

All the above indices can be interpreted as progress, no change and regress when their values are greater than one, equal to one and less than one, respectively. Table-6 shows the trend in EFFCH, TECHCH, PECH and SECH indices for the petroleum companies during 1991-2017. The decomposition of the TFPCH index identifies the main sources of the productivity growth. Table-6 shows that this TFP growth is due to progress in the technical efficiency (EFFCH) rather than the technical change (TECHCH). Technical efficiency increases the productivity by 5.0 percent per annum and the positive growth in the technical change increases the TFP by 7.8 percent per annum on an average. It is obvious that the industry does not evince any significant improvement in the productivity. However, whatever gain in the productivity is occurred, it is only due to progress in the technical efficiency (i.e., catch up). Technical change, which refers to the upward sifting of production frontier (innovation), shows a negative change. Further decomposition of technical efficiency change into pure technical efficiency change (PECH) and scale efficiency change (SECH) reveals that the index of PECH is greater than the index of SECH. Although values of both PECH and SECH indices show progress, it is the PECH index that contributes more to the EFFCH index. The overall conclusion that emerges from the analysis is that during the last 10 years, the TFP growth in the industry is only due to technical efficiency progress (catch up), not due to improvement in technical change (innovation). Further, pure technical efficiency change contributes more to the TFP growth than the scale efficiency change. However, if we look at the year-wise pattern of these indices, we find that the EFFCH and TECHCH indices in different years are found to move in opposite direction. A perusal of Figure 7.8 reveals that during the first three years, average EFFCH indices shows progress, while at the same time, TECHCH indices show regress. Similar pattern is also observed in other years. If in a particular year, EFFCH index shows positive growth, TECHCH index shows a negative growth. The possible reason for this seems to be the fact that the Petroleum industry is a dynamic industry and faces lots of challenges due fluctuations in the external and internal demands. If some technological innovations are made in the industry, it would push up the cost in that year and thus affecting the technical efficiency of that year, while the R&D investment made in the current year may shift the production frontier with a time lag and therefore it may positively affect the next year TFP growth.

Table-4 Malmquist Index Summary

	firm	effch	techch	pech	sech	tfpch		firm	effch	techch	pech	sech	tfpch
1992	BPCL	0.778	1.168	1	0.778	0.908	2006	BPCL	6.064	0.847	1	6.064	5.137
	HPCL	1.292	1.216	1	1.292	1.57		HPCL	4.387	0.851	1	4.387	3.732
	IOCL	1	0.839	1	1	0.839		IOCL	1.786	0.835	1	1.786	1.491
	ONGC	1.925	1.036	1	1.925	1.994		ONGC	1	0.857	1	1	0.857
	OIL	2.039	1.435	1	2.039	2.927		OIL	1	0.886	1	1	0.886
	RIL	3.251	0.982	1	3.251	3.194		RIL	1.306	0.866	1	1.306	1.131
1993	BPCL	1.132	1.155	1	1.132	1.307	2007	BPCL	0.925	0.944	1	0.925	0.874
	HPCL	1	1.241	1	1	1.241		HPCL	0.761	0.947	1	0.761	0.721
	IOCL	1	1.182	1	1	1.182		IOCL	0.992	0.916	1	0.992	0.909
	ONGC	1	2.039	1	1	2.039		ONGC	1	1.071	1	1	1.071
	OIL	0.715	0.912	1	0.715	0.652		OIL	1	1.056	1	1	1.056
	RIL	1.031	1.46	1	1.031	1.506		RIL	1	1.02	1	1	1.02
1994	BPCL	0.446	2.249	1	0.446	1.003	2008	BPCL	0.38	1.202	1	0.38	0.457
	HPCL	0.498	2.197	1	0.498	1.094		HPCL	0.414	1.207	1	0.414	0.5
	IOCL	0.657	1.438	1	0.657	0.945		IOCL	0.374	1.1	1	0.374	0.412
	ONGC	1	1.503	1	1	1.503		ONGC	1	0.821	1	1	0.821
	OIL	1.399	2.579	1	1.399	3.609		OIL	1	1.06	1	1	1.06
	RIL	0.88	1.76	1	0.88	1.55		RIL	1	0.862	1	1	0.862
1995	BPCL	2.539	0.464	1	2.539	1.178	2009	BPCL	2.134	1.04	1	2.134	2.219
	HPCL	2.008	0.56	1	2.008	1.125		HPCL	2.281	1.046	1	2.281	2.387
	IOCL	1.522	0.653	1	1.522	0.994		IOCL	2.33	1.231	1	2.33	2.868
	ONGC	1	0.609	1	1	0.609		ONGC	1	1.281	1	1	1.281
	OIL	1	0.291	1	1	0.291		OIL	1	1.036	1	1	1.036
	RIL	1.136	0.854	1	1.136	0.97		RIL	0.968	1.194	1	0.968	1.156

1996	BPCL	0.922	0.949	1	0.922	0.874	2010	BPCL	0.987	0.941	1	0.987	0.928
	HPCL	1	0.926	1	1	0.926		HPCL	1.146	0.949	1	1.146	1.087
	IOCL	1	1.033	1	1	1.033		IOCL	0.792	0.802	1	0.792	0.635
	ONGC	1	0.916	1	1	0.916		ONGC	1	0.883	1	1	0.883
	OIL	1	0.881	1	1	0.881		OIL	1	1.011	1	1	1.011
	RIL	1	0.922	1	1	0.922		RIL	1.033	0.943	1	1.033	0.974
1997	BPCL	1.09	1.114	1	1.09	1.214	2011	BPCL	0.739	1.056	1	0.739	0.78
	HPCL	1	1.073	1	1	1.073		HPCL	0.513	1.059	1	0.513	0.543
	IOCL	1	1.238	1	1	1.238		IOCL	0.499	1.007	1	0.499	0.503
	ONGC	1	1.311	1	1	1.311		ONGC	1	1.175	1	1	1.175
	OIL	0.975	1.026	1	0.975	1.001		OIL	1	1.131	1	1	1.131
	RIL	0.878	1.073	1	0.878	0.942		RIL	1	0.967	1	1	0.967
1998	BPCL	1	1.224	1	1	1.224	2012	BPCL	1.774	0.663	1	1.774	1.177
	HPCL	1	1.18	1	1	1.18		HPCL	1.795	0.554	1	1.795	0.995
	IOCL	1	1.484	1	1	1.484		IOCL	1.239	1.008	1	1.239	1.248
	ONGC	1	1.228	1	1	1.228		ONGC	1	0.816	1	1	0.816
	OIL	0.945	1.065	1	0.945	1.006		OIL	1	0.658	1	1	0.658
	RIL	0.963	1.078	1	0.963	1.038		RIL	1	1.038	1	1	1.038
1999	BPCL	1	0.844	1	1	0.844	2013	BPCL	1.534	0.981	1	1.534	1.504
	HPCL	1	0.847	1	1	0.847		HPCL	1.833	1.046	1	1.833	1.916
	IOCL	1	0.691	1	1	0.691		IOCL	1.373	0.997	1	1.373	1.369
	ONGC	1	1.077	1	1	1.077		ONGC	1	1.011	1	1	1.011
	OIL	1.085	1.177	1	1.085	1.277		OIL	0.936	0.763	1	0.936	0.714
	RIL	1.157	1.135	1	1.157	1.314		RIL	1	1.013	1	1	1.013
2000	BPCL	0.757	0.907	1	0.757	0.687	2014	BPCL	1.152	1.098	1	1.152	1.265
	HPCL	0.876	1.114	1	0.876	0.976		HPCL	1.33	1.185	1	1.33	1.577
	IOCL	0.952	1.132	1	0.952	1.078		IOCL	0.834	0.966	1	0.834	0.806
	ONGC	1	1.116	1	1	1.116		ONGC	1	0.822	1	1	0.822
	OIL	1	1.018	1	1	1.018		OIL	0.97	0.85	1	0.97	0.824
	RIL	0.84	1.267	1	0.84	1.063		RIL	1	1.031	1	1	1.031
2001	BPCL	0.861	1.185	1	0.861	1.021	2015	BPCL	1	1.398	1	1	1.398
	HPCL	0.611	1.185	1	0.611	0.724		HPCL	1	1.411	1	1	1.411
	IOCL	0.895	1.185	1	0.895	1.06		IOCL	1.934	1.283	1	1.934	2.481
	ONGC	1	1.184	1	1	1.184		ONGC	0.996	1.178	1	0.996	1.173
	OIL	1	1.017	1	1	1.017		OIL	0.687	1.245	1	0.687	0.855
	RIL	0.862	1.096	1	0.862	0.945		RIL	1	1.627	1	1	1.627
2002	BPCL	0.849	1.677	1	0.849	1.424	2016	BPCL	1	0.879	1	1	0.879
	HPCL	1.141	1.647	1	1.141	1.879		HPCL	0.958	0.913	1	0.958	0.875
	IOCL	1.174	1.798	1	1.174	2.11		IOCL	1.421	1.05	1	1.421	1.493
	ONGC	1	1.553	1	1	1.553		ONGC	0.972	1.054	1	0.972	1.024
	OIL	1	1.495	1	1	1.495		OIL	0.616	0.935	1	0.616	0.576
	RIL	0.597	1.658	1	0.597	0.991		RIL	1	1.158	1	1	1.158
2003	BPCL	1.68	0.804	1	1.68	1.35	2017	BPCL	1	0.971	1	1	0.971
	HPCL	1.535	0.791	1	1.535	1.214		HPCL	1	1	1	1	1
	IOCL	1	0.787	1	1	0.787		IOCL	1	0.972	1	1	0.972

	ONGC	1	0.75	1	1	0.75
	OIL	1	0.941	1	1	0.941
	RIL	1.554	0.73	1	1.554	1.135
2004	BPCL	0.38	1.436	1	0.38	0.546
	HPCL	0.516	1.278	1	0.516	0.659
	IOCL	0.474	1.35	1	0.474	0.64
	ONGC	1	1.297	1	1	1.297
	OIL	1	0.941	1	1	0.941
	RIL	1.041	1.275	1	1.041	1.327
2005	BPCL	0.272	1.074	1	0.272	0.292
	HPCL	0.255	1.052	1	0.255	0.268
	IOCL	0.884	1.009	1	0.884	0.893
	ONGC	1	0.952	1	1	0.952
	OIL	1	1.275	1	1	1.275
	RIL	1.119	0.928	1	1.119	1.039

	ONGC	1	0.972	1	1	0.972
	OIL	1	1	1	1	1
	RIL	1	0.923	1	1	0.923
	mean	**1.113**	**1.088**	**1**	**1.113**	**1.17**
	max	**6.064**	**2.579**	**1**	**6.064**	**5.137**
	min	**0.255**	**0.291**	**1**	**0.255**	**0.268**
	sd	**0.631**	**0.31**	**0**	**0.631**	**0.623**

Note: **effch**- efficiency change (innovation), **techch**- technological efficiency change (catch up), **pech**- pure efficiency change, **sech**- scale efficiency change, **tfpch**- total factor productivity change

Table-6: Trends in EFFCH, TECHCH, PECH and SECH for all the companies

Year	effch	techch	pech	sech
1992	1.53	1.097	1	1.53
1993	0.97	1.29	1	0.97
1994	0.751	1.91	1	0.751
1995	1.437	0.543	1	1.437
1996	0.986	0.937	1	0.986
1997	0.989	1.135	1	0.989
1998	0.984	1.202	1	0.984
1999	1.039	0.945	1	1.039
2000	0.9	1.087	1	0.9
2001	0.86	1.14	1	0.86
2002	0.938	1.635	1	0.938
2003	1.26	0.798	1	1.26
2004	0.678	1.252	1	0.678
2005	0.64	1.043	1	0.64
2006	1.99	0.857	1	1.99
2007	0.942	0.991	1	0.942
2008	0.624	1.03	1	0.624
2009	1.491	1.134	1	1.491
2010	0.987	0.919	1	0.987
2011	0.758	1.064	1	0.758
2012	1.257	0.769	1	1.257
2013	1.239	0.963	1	1.239
2014	1.037	0.984	1	1.037
2015	1.048	1.349	1	1.048
2016	0.967	0.993	1	0.967
2017	1	0.973	1	1
Mean	**1.050077**	**1.078462**	**1**	**1.050077**
Max	**1.99**	**1.91**	**1**	**1.99**
Min	**0.624**	**0.543**	**1**	**0.624**
S.D	**0.307153**	**0.268371**	**0**	**0.307153**

Note: effch- Efficiency Change, techch- Technological Change, pech- Pure Efficiency Change, sech- Scale Efficiency Change, tfpch- Total Factor Productivity Change

Table-6: Company-wise Average EFFCH, TECHCH, PECH and SECH Indices

firm	effch	techch	pech	sech	tfpch
BPCL	1	1.042	1	1	1.042
HPCL	1.008	1.053	1	1.008	1.062
IOCL	1	1.048	1	1	1.048
ONGC	1.024	1.062	1	1.024	1.088
OIL	0.991	1.005	1	0.991	0.996
RIL	1.048	1.084	1	1.048	1.135
Mean	**1.011833**	**1.049**	**1**	**1.011833**	**1.061833**
Max	**1.048**	**1.084**	**1**	**1.048**	**1.135**
Min	**0.991**	**1.005**	**1**	**0.991**	**0.996**
S.D	**0.020904**	**0.026062**	**0**	**0.020904**	**0.046812**

Note: **effch**- efficiency change (innovation), **techch**- technological efficiency change (catch up), **pech**- pure efficiency change, **sech**- scale efficiency change, **tfpch**- total factor productivity change

CONCLUSION

TFP growth rates in the petroleum companies vary significantly across years. The high growth rate is estimated for the 2006 over 2005. Comparing the year 2005, the TFP grows at the rate of 70.5 percent in 2006. One of the reasons for the highest growth rate in this year seems to be due to the poor performance of the industry in 2005. For the next two consecutive years, average growth rates in TFP have been negative. There has been poor performance of the petroleum companies in terms of TFP growth during these years. The industry grows at the rate of 69 percent in the year 2009 over the preceding year. The industry again experiences negative growth rates in the next consecutive years. Last two years of the study period show the positive and significant growth rates in the industry. The lowest growth rate was found in the years 2007-08. It may be due to the global financial crises. There are rises and falls in the TFP growth; no explicit trend in the TFP growth rates is observed. It is evident from the results that the free economic environment has benefited only in technology not in efficiency of Indian manufacturing industry. The Government of India invited foreign companies only to meet the investment requirements, to facilitate the transfer of technologies through direct and indirect spillovers to the domestic industries and to make the domestic firms more competitive and productive. But in reality, the domestic firms could not benefit much out of these reform measures. Efficiency change has been identified as a deteriorating factor for productivity change in Indian oil refinery industry both at the aggregate and company level. The study suggests that while formulating policy for an industry, this heterogeneity at the company level must be considered for the effective use of factor inputs.

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