Indian Software Companies productivity performance measurement using Data Envelopment Analysis and Ratio Analysis

By

Sheetal Pednekar

Masters of Science in Finance

The National College of Ireland

Research Supervisor

Ciara Deane

Submitted to the National College of Ireland, August 2019

Abstract

Ratio analysis is the simplest and traditional method of performance efficiency. However, the study showed that there many limitations to ratio analysis when performance measurement is undertaken. To overcome this difficulty a non-parametric method called DEA is developed where multiple inputs and outputs can be considered to evaluate efficiency. This study has considered the Malmquist Productivity Index to measure productivity efficiency of the Indian SoftwareIndustry. The results showed that the SoftwareIndustry is consistently efficient under productivity performance. The technical efficiency component of MPI is inefficient whereas technological efficiency change is efficient under productivity performance. The hypothesis test undertaken for technical and technological efficiency difference between largeand small scale companies showed that companies are producing the same level of output whereas large scale companies are more technology innovation-oriented. The further results of ratio analysis were significantly different from the Malmquist Index. This study is beneficial to understand the efficient and inefficient companies in the Software sector. The managers, shareholders would be helpful to locate inefficiencies and take a suitable initiative to improve.

Key words: Data Envelopment Analysis, Ratio Analysis, Productivity Performance Measurement

Submission of Thesis and Dissertation

National College of Ireland

Research Students Declaration Form

(Thesis/Author Declaration Form)

Name: Sheetal Sharad Pednekar

Student Number: x18132235

Degree for which thesis is submitted: MSc in Finance

Material submitted for award

(a) I declare that the work has been composed by myself.

(b) I declare that all verbatim extracts contained in the thesis have been distinguished by quotation marks and the sources of information specifically acknowledged.

(c) My thesis will be included in electronic format in the College Institutional Repository TRAP (thesis reports and projects)

(d) ***Either*** *I declare that no material contained in the thesis has been used in any other submission for an academic award.

Or *I declare that the following material contained in thethesis formedpart of a submission for the award of

_____

(State the award and the awarding body and list the material below)

Signature of research student:

_____

Date: 21st August, 2019

Submission of Thesis to Norma Smurfit Library, National College of Ireland

Student name: **Sheetal Sharad Pednekar** Student number: x18132235

School: **National College of Ireland** Course:**MSc in Finance**

Degree to be awarded: **MSc in Finance**

Title of Thesis:**Indian Software Companies productivity performance measurement using Data Envelopment Analysis and Ratio Analysis**

One hard bound copy of your thesis will be lodged in the Norma Smurfit Library and will be available for consultation. The electronic copy will be accessible in TRAP (http://trap.ncirl.ie/), The National College of Ireland's Institutional Repository. In accordance with normal academic library practice all thesis lodged in the National College of Ireland Institutional Repository (TRAP) are made available on open access.

I agree to a hard-bound copy of my thesis being available for consultation in the library. I also agree to an electronic copy of my thesis being made publicly available on the National College of Ireland's Institutional Repository TRAP.

Signature of Candidate:

_____

For completion by the School:

The aforementioned thesis was received by_____

Date:_____

This signed form must be appended to all hard bound and electronic copies of your thesis submitted to your school

Acknowledgment

This research been developed out of concepts that I have learned during MSc Finance, and the new methodology I came across at the proposal stage. Having opportunity to study with The National college of Ireland with amazing professors has been one of the most fulfilling experiences for me.

I am grateful to god for blessing me more than I deserve and giving me courage and faith.

My sincere thank to my supervisor; Ciara Deane, for her valuable guidance and her assistance in preparation of this research. I would like to include a special thanking note for Dr. Corina Sheerin and Dr. Deirdre Bane for their precious guidance during the proposal stage. I have learned so much from your experience, advice, and guidance. I know I will carry the things I have learned here with me to my next venture and will always look back on this experience with a lot of fondness.

Last but not the least; I would like to express my gratitude towards my family for encouraging and believing in me, which helped me during the course. My dearest friends, Mr. Dhiraj Shetty, Mr. Anubhav Singhvi & Mr. Himanshu Davda who always stood next to me guided and inspired whenever needed.

Contents

List of Tables

List of Abbreviations

DEA	Data Envelopment Analysis
DMU	Decision Making Unit
IO	Input Oriented
OO	Output Oriented
CCR	Charnes- Cooper-Rhodes
BCC	Banker-Charnes-Cooper
CRS	Constant Return to Scale
VRS	Variable Return to Scale
MPI	Malmquist Productivity Index
teffch	Technical Efficiency change
Techch	Technological Change
Pech	Pure Efficiency Change
Sech	Scale Efficiency change
Tfpch	Total Factor Productivity Change
INR	Indian Rupees

1. Introduction

1.1 Background

As per the 2017 GDP reports published by the Indian government, the service sector of India contributes around 61.5% to GPD. The Indian service sector includes many industries such as real estate, pharmaceutical, power, Information technology (IT) and many more. Out of all the industries, IT is the largest sector. As mentioned in the reports of IBEF (India Brand Equity Foundation) dated May 2019, India is the world's largest outsourcing destination accounts for approximately 55% of the U.S. market. The reason behind is the wage bill of India which makes the investments in the country less costly. This led to employment creation and nearly 3.97 million people are employed in the Indian IT sector. Not only employment but Software and hardware Industry had attracted nearly US$ 35.82 billion Foreign Direct Investment (FDI) between the periods from April 2000 to March 2018. Market capital investment as on August 2019 of SoftwareIndustry stood 2nd with 16,766 Billion Indian rupees (INR). Jain et al. (2019) have mentioned that the reason behind the success of the SoftwareIndustry is the speed of delivery, rapid internationalization and continuous innovation in the technology. They further state that this makes the Industry more competitive yet growing rapidly.

While looking at the growth in the Indian IT sector it will more insightful to see the performance of a particular sector. Indian IT sector is huge and also comprises of different areas like hardware, Software, online services. This study has considered Software companies since this is the biggest area in the IT sector. Productivity growth in any Industry is the major source of economic development. Therefore, the performance will be measured on the terms of productivity. This measure will provide information on the Industry's efficient use of resources to generate maximum revenue.

1.2 Research question and objective

The question under the proposed study is to inspect the performance of the Indian SoftwareIndustry for the last 9 years concerning productivity. Also, there might not be wide and up to date research undertaken on the particular Industry with the proposed technique called Malmquist Productivity Index (MPI) under non-parametric method Data Envelopment Analysis (DEA).

The traditional performance method called Ratio Analysis which is used widely by the analyst has limitations hence it will be enlightening to see the additional information obtained with the proposed technique when compared to the traditional technique.

The research objective of the study is as follows:

1) To identify the efficient and inefficient areas under the productivity performance of Indian Software Companies.

2) To identify efficiency differences between two company segments as per the Indian Market Capitalization called large scale and medium scale.

1.3 Methodology

This study has considered a sample of 20 companies with panel data from Financial Year 2009-10 to 2017-18. Mohindra & Kaur (2015) considered non-parametric method DEA using Malmquist productivity index for the panel data study.They stated that, for the productivity performance, MPI findings are useful in identifying sources of efficient and inefficient performances. It also enables managers to focus on functioning and take suitable initiative for further improvement. This research is also measuring the productivity performance of Indian SoftwareCompanies and considers the MPI method under DEA to see the efficiencies in the Software Industry. Further research with hypothesis testing will enable to understand the efficiency difference between large and medium scale companies of the Indian Software Industry.

Further profitability and efficiency ratio analysis is considered to see whether results are similar under both the parametric and non-parametric method and additional information received over ratio analysis.

1.4 Framework for the research

This study is for the evaluation of the productive efficiency of 20 Indian Software Companies over the 9 years. The traditional parametric method, ratio analysis is used by most of the analyst to see the performance of the company or Industry. However, there many limitations to in the traditional method like a comparison of two industries are not possible, complicated interpretation when more ratios considered, limitations in dimensions (Altman, 1968). Charnes et al. (1978) developed the Data Envelopment Analysis (DEA) technique which is a non-parametric method to measure efficiencies. Further development in DEA was taken by many researchers which resulted in various models such as slack-based measure (Tone and Tsutsui, 2009), hybrid network DEA model (Chenand Yan, 2011), panel stochastic frontier systems estimator (Sickles and Streitwieser, 1992) and so on. All the different methods have their purpose and result pattern.

Thore et al. (1994) have conducted research on the productive efficiency of a U.S. computer Industry and used the Malmquist Productivity Index model under DEA. The result of research on U.S. computer industry has shown that few corporations were product efficient throughout the time period whereas other corporations were successful but not consistent with performance. The study also identified the areas where companies were weak and strong in productive efficiency.

To analyze the productive efficiency of Indian Software Companies, MPI is the suitable DEA model. It is also a model that computes the efficiency of panel dataset. MPI has also provided information about the company's sales maximization efficiency and inefficiency, manager's efficient use of resources & level of scale operations efficiency (Mohindra & Kaur, 2015). With the help of MPI it is possible to identify efficient and inefficient companies.

The focus of this research is on the evaluation of the productivity efficiency in Indian Software Companies over last 9 years and their efficiency as per market capitalization.

1.5 Structure of the Dissertation

The Dissertation is divided into six chapters. Chapter two literature reviews are the study of scholarly articles and academic journals. The literature will provide an understanding and purpose of the current research; it's methodology along with the findings of the previous research done. In Chapter three i.e. methodology is a detailed review of the considered quantitative method and its application on the dataset under research. Under chapter four results and analysis is done on the finding of the dataset. Chapter five i.e. discussion is about the comparison of research analysis with the academic findings. The sixth and the last part of the dissertation is the conclusion of research.

2. Literature Review

This section is the review of scholarly articles and academic journals about use and limitations of ratio analysis, DEA as a performance analysis method, application of DEA in different sectors, results of Malmquist index under DEA and use of DEA with ratio analysis.

2.1 Use and limitations of Ratio Analysis

Financial ratios are used for the firm's performance evaluation. Ratios are also helpful for firms to compare their financial performance with Industry (Barnes, 1987). There is significant evidence that, assessing the failure of the firm is possible with the help of ratio analysis. Johri & Maheshwari (2015) have mentioned that ratio analysis is helpful to a layman in business valuation. However, their hypothesis testing proves that in the case of business performance measurement ideal ratios are not comparable. Also, in most of the business conditions, ratio analysis being tool of fundamental analysis is not applicable.

Altman (1968) have criticized that the results of individual ratio analysis do not provide analytical reasoning. But their combined analysis gives great statistical significance. Even after multiple attempts of combining ratios, it was examined that ratios do not yield satisfactory measures because of the inherent limitations. The limitations are the assumption of constant return to scale, variables (numerator & denominator) linear relationship, and difficulties with negative numbers (outliers) (Smith, 1990). Every ratio explains the different efficiency parameter of a firm i.e. profitability, liquidity and so on. Therefore, while measuring the performance of firms overall efficiency it is difficult to understand the results of ratio analysis (Yu et al., 2014).

Maniadakis & Thanassoulis (2004) have also mentioned that the parametric method required the link between inputs and outputs and because of that; they are more on the assumption basis. Feroz et al. (2003) explained that ratios have drawbacks like specific ratio can be applied to the specific Industry because of its

measuring criteria. They further criticized the stochastic approach ratios on the subjectivity that to assess the overall performance of the company an analyst required choosing between ratios.

2.2 DEA as a performance analysis measure

Krivonozhkoet al. (2011) have compared the ratio analysis and DEA as a performance analysis tool. They stated that from the economic point of view, all the units are equivalent to each other if ratios have the same values for every DMU. The domain of ratio is non-convex disconnected set and therefore they are problematic to use as guidance in decision making. DEA considers an economic interpretationi.e. to reach an optimal level (efficiency frontier), it evaluated which unit expenses to decrease or which output production to increase. DEA also helps to calculate economic factors such as return to scale, efficiency analysis of production and marginal rate of substitution. It is possible with DEA to develop production efficiency in the multidimensional attribute of Input and output. It can be concluded that the Ratio analysis helps in analyzing data, but its drawback is it fails to consider the technical and comparative analysis which can be explained or understood in detail under DEA method.

2.3 Use of DEA Method under different sector

Chen and Yan (2011) have analysed the relationship among the three different organizations mechanism. Also, the relationship between supply chain and its divisions considering supply chain as a decision-making unit. They also analyzed internal resource waste in supply chain causing from the variance between supply and demand in internal process and found that decentralized (divisions are not controlled by anyone central position) mechanism will give input efficiency at a given output whereas centralized mechanism overrates efficiency. Hence decentralization is not advisable in supply chain performance evaluation. Also, there is a positive relationship between supply chain division efficiency. They further claimed that two divisions will be either belongs to one decision-maker or two

decision-makers, but the output level will differ with the decision-maker. The output will depend on inputs in one decision-maker whereas in two decision-maker only one component will be preferential i.e. either input or output. The analysis states that the more the unit is self-controlled higher the efficiency instead of controlled by a single unit.

Zhu et al. (2017) have built a cross-like efficiency model under DEA for non-homogeneous Decision-making units (DMU). Non-homogeneous means a DMU which used different resources to generate output as compare to other DMU's of Industry. Under their research they considered 39 companies to see the highest low-carbon investment performance. As per them the traditional DEA measures the direct compatibility among DMU's. However, all the DMU's do not share similar input and output. With their new model, they were able to handle missing data problem also generated unique ranking to DMU's. The study found the companies or sector that has low carbon technology to strengthen corporate sustainability. It is identified that with this model of DEA it is possible to evaluate performance efficiency even with the missing values.

2.4 Malmquist index under DEA

Fare et al. (1994) analyzed the productivity growth of OECD countries. To measure the productivity, they consider output oriented Malmquist index using non-parametric programming method. They stated that the considered method provides important complementary information over traditional approach i.e. ratio analysis. Concerning Total Factor Productivity (TFP) they defined productivity growth is the product of efficiency change and technological change. Efficiency change components are proof of catching up which means the inverse correlation between low-level TPF and TFP growth. And technological change is proof of innovation. They further mentioned that if there will be any difference between technological and allocative (consumer preference equal to production) efficiency of both the traditional method and Malmquist Index approach then there is a possibility of getting different results of productivity.

The non-parametric version was further used by researches as it is efficient in giving insights into productivity efficiency parameters like technological effect. Maniadakis & Thanassoulis (2004) have considered the study of Fare et al. (1994) to calculate Cost Malmquist productivity index. They have used input-oriented Malmquist productivity index to see allocative efficiency when input price is available. The Malmquist index calculated by Fare et al (1994) was calculated with the help of input quantity. However, they evaluated Malmquist index with input cost. They considered input-oriented measure for the industries where management is cost minimizer. As per their results, allocative efficiency is important and can improve performance with input mix change rather than decreasing price of input.

Pannu et al. (2011) have measured the efficiency and productivity of the Indian pharmaceutical Industry with DEA BCC and Malmquist productivity index. They considered 10 years period (1998-2007) for 146 firms in the pharmaceutical Industry. With the BCC VRS model, they found efficiency and productivity leaders and laggards. They found increasing productivity trend due to technical change. They segregated firms into multinationals and indigenous to see the average efficiency and productivity change. They examine efficiency between 1998 & 2007 with the hypothesis test. Results showed that average efficiency is higher in Multinational companies whereas there is no difference in productivity change in both the type of companies. They further found with MPI that innovative firms are more efficient than non-innovative firms.

Baten et al. (2014) have analyzed and forecasted productivity change for Central Bank of Malaysia. The study considered output oriented MPI model to measure efficiency and productivity change. Their results showed that decreasing productivity efficiency in inputs over 12 years. To analyze the future performance, they used Brownian motion for forecasting efficiency with the same input output variable. Brownian motion is a mathematical characteristic where statistics can be estimated with accuracy (Sasikumar, 2011). The results of Brownian motion showed the increasing trend in productivity in next 10 years. This explains that though MPI gives efficiency results on the basis of past performance, it is possible to forecast the efficiency with the Brownian motion with same DEA variables.

2.5 Use of DEA with ratio analysis

Application of DEA to predict bankruptcy is used by Altman (1968), Wilson & Sharda (1994), and Bell (1997) as cited in Shetty et al. (2012). Assessment of Indian IT/ITES Company's bankruptcy is measured by Shetty et al. (2012). Their study is an alarm for those IT companies who have the possibility of becoming bankrupt. The research was undertaken in two-part; one with statistical technique i.e. ratio analysis and another was DEA. However, to calculate DEA results they consider financial ratios as input and output variables. The ratios (Example: Total debt to total asset, Current liabilities to total asset) with higher values were input variable as the higher value can cause financial distress. The ratios working capital to total assets, returns to total asset, etc are used as output. They develop a model which can measure worst performing DMU and inefficiency frontier. The model was built in such a way that the units which are consuming maximum input and minimum output will lead to bankruptcy. The results showed the worst-performing units, but those units were not necessarily declared bankrupt. The worst-performing units were under financial distress and possible to become bankrupt in the future. They further stated that the MPI can be useful for advanced studies in bankruptcy to evaluate the changes over time and shift in the frontier.

Feroz et al. (2003) have studied that DEA can complement the results provided by ratio analysis. Also, DEA can give additional information over ratio analysis with a single index number. They applied the DEA method to the oil and gas Industry taking into consideration 26 firms with 20 years data (ratios). However, the decision was undertaken with hypothesis testing. The null hypothesis was there is no relationship between DEA efficiency scores and financial ratios. However, the result was to reject the null hypothesis which means there is a significant relationship between DEA and ratio analysis. They further mentioned that with index ranking, an analyst can easily measure and compare the performance of firms.

Yu et al. (2014) analyzed the efficiency of Taiwan public limited companies with the comparison between Ratio analysis and DEA. For the assessment first ratio analysis has been conducted however they state that the efficiency failed when

multiple units considered simultaneously. Further performance evaluation has been done with DEA considering CCR and BCC methods where they considered variables of input and output from the ratios selected under the study. They found that under the selected dataset, all the companies were showing efficiency above average efficiency. However, ratios were showing results that only few companies are efficient. Further they mentioned that with the help of slack variable analysis it was possible to understand the excess input and shortages in output of each company. This results state that because of the limitations of ratio analysis it is not always possible to get performance report whereas DEA can measure efficiency with the selected ratios variables.

Anthony et al. (2019) have measured the financial performance of seven Indian companies DEA and ratio analysis. DEA weight additive model is used to measure efficiency and, on that basis, ranking the companies. They mentioned that simple ratios do no lead to performance comparison and ranking to the companies. The input and output parameters of DEA are selected from liquidity, turnover, solvency and profitability ratios. Their results concluded that profits as output and expenses as inputs under DEA are correct variables when consider evaluating performance.

2.6 Conclusion

A literature review has shown that the ratio analysis is one of the simple and most used methods in performance measurement. However, it is difficult to evaluate performance with ratios because of its two variables approach which is numerator and denominator. As Ratios Analysis is a parametric method it has its assumptions and therefore traditional method fails under performance measurement.

The non-parametric method which compliments Ratio Analysis called DEA is considered as efficient in performance measurement evaluation. Where ratios give different types of results under different types of calculations, DEA provides only one index to measure the results. It is therefore easy to understand and examine the results of the DEA. It is seen that DEA has been used under different sectors for

research. Also, there are multiple models available under DEA which can be suitable as per the requirement of the study.

For the productivity efficiency measurement, MPI methodology which falls under DEA is considered as appropriate for evaluation. It is possible to understand results more economically and in a detailed manner of productivity. MPI is the hybrid version of the two main basic models called CCR and BCC. MPI considers the effect of constant return to scale as well as variable return to scale. The variables of MPI gives the inside information about the productivity change such as efficiency in output in relation to input, managers efficiency and companies operating scale efficiency. With the help of MPI index, managers will be able to more concentrate on inefficient as well as slow moving or constant growth areas. The study has also shown that it is possible to forecast the results with the help of variables used under DEA.

3. Research Methodology

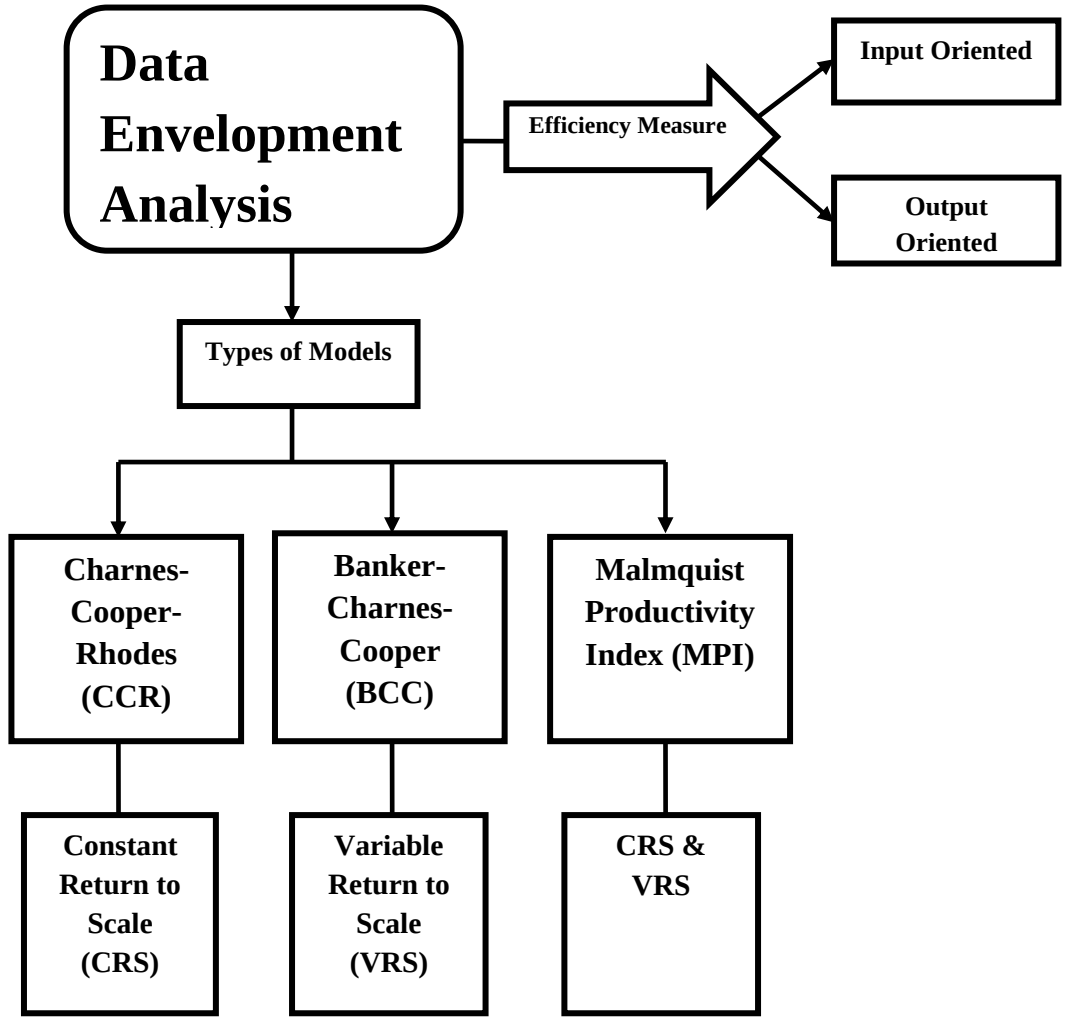
3.1 History of DEA

Under this section, a detailed description of Data Envelopment Analysis (DEA) and the most suitable method under DEA for this particular research will be given. The productivity performance analysis will be undertaken with the help of DEA and Ratio Analysis of Financial Statements. Charnes, Cooper, and Rhodes (1978) first developed the DEA technique to evaluate efficiencies in activities of Not-for-profit entities participating in public programs. However, the method is further developed for performance measurement and applied into private sector and service operations. Pannu et al. (2011) have used DEA for efficiency and productivity analysis of Indian Pharmaceutical Industry whereas Thore et al. (1994) have to measured productivity efficiency of U.S. Computer Industry with DEA of financial statement.

3.2 Comparison between DEA and Ratio Analysis

Feroz et al. (2003) have mentioned that financial ratio is also a measure of performance analysis. However, ratio analysis and interpretation of ratios become complicated when two or more ratios provide conflicting results. Smith (1989) has explained that limitation of ratios is their two dimensions i.e. numerator and denominator which limits the examination of output with input. Inputs are the resources or services used by the firm to produce a final product called as output. Under the performance measurement, capital investment or employee cost will act as an input to generate maximum output i.e. sales or earnings to investors. With the help of DEA, it is possible to eliminate the limitation of ratio analysis which is the interpretation of results and number of input and output. Results of the ratios can be in terms of percentage, a number of days or ratio between two variables and therefore it is difficult to generalize them in one particular format. However, a result of DEA (CCR and BCC method) lies between 0-1 and their interpretation is simple and easy to understand.

DEA programming is a non-parametric method whereas ratio analysis is a parametric method. Halkos&Salamouris (2004) have mentioned the advantages of non-parametric method like it possible to use multiple inputs and outputs, efficiency comparison of a large number of samples with simultaneous use of multiple efficiencies determining criteria. It is also assumed that relationship between the variables in a parametric method is linear (on a straight line) whereas DEA is known as efficiency frontier analysis (Stancheva&Angelova, 2004) (measured on a curve).



3.3 Background of DEA

DEA is a linear programming technique used to evaluate the efficiency of each Decision-Making Unit (DMU). DMU is the set of peer units on which performance evaluation will be implemented. Under this report, per units/DMU will

be the Software Companies on which the productivity performance evaluation will be undertaken. Charnes et al, 1978 have mentioned that multiple inputs and output of

the DMU are characterized as an efficiency measuring parameter. Under this study also selected inputs and outputs of each Softwarecompany will be productive efficiency measuring parameter. The productive efficiency of DMU will be evaluated by comparing with other best performing units. All the best units will lie down on the efficiency frontier whereas the units outside the efficient frontier will be considered as inefficient units.

The DEA technique developed by Charnes et al. (1978) is also known as CCR (Charnes-Cooper-Rhodes) model and it is based on the assumption of Constant Return to Scale (CRS). Later on, Banker et al. (1984) developed Banker-Charnes-Cooper model (BCC), a DEA model from the evaluations of CCR considering the assumption of the Variable Return to Scale (VRS). Both CCR & BCC models are further divided into Input oriented (IO) & Output oriented (OO) measures to evaluate performance efficiency. IO measures the change or reduction in input quantity with fixed output quantities whereas OO measures the change in output quantity with fixed Input quantity (Coelli, 1996).

To measure productive efficiency changes over several years which is also called as panel data; evaluation with only CCR and BCC model was insufficient and therefore Malmquist Productivity Index (MPI) was developed. MPI was introduced by prof. Malmquist and Fare et al. (1989) further developed it with the use of non-parametric mathematical programming model called DEA. Under this research selected period is 9 years which is panel data; therefore, the MPI model is considered to evaluate productivity performance efficiency. It is further explained in detailed MPI methodology and why MPI is a suitable model for this study under the Background of the MPI section.

(Note: Consistent development in DEA has been noticed by literature review and there are multiple DEA models are available for different types of studies. Under this study, the focus is given on the original (CCR & BCC) and suitable (MPI) DEA models.)

3.4 Selected of Model and variables for this study

There are around 126 Software companies listed on Bombay stock exchange however this analysis has considered 20 Indian Software companies from both small (less than (INR) 100 billion) and large capital (more than INR 100 billion) investment segment to see the overall productive efficiency of the SoftwareIndustry. The primary reason for the selection of 20 companies is the availability of data. Also, few companies were using different financial year till March 2013 which was voiding the principle uniformity in data. The period considers under the analysis is 9 years starting from 1st April 2010 to 31st March 2018. Financial year in India is 1st April to 31st March.

As already discussed above, the MPI will be an appropriate model for the study of Software companies' performance measurement. The primary reason is the partial outcome of CCR and BCC methods. As mentioned above CCR works on an assumption of constant return to scale therefore this method will be appropriate when all the companies operate at an optimum scale. Imperfect competition and financial restrictions may cause companies to be not operating at optimum scale. CRS measures technical efficiency but because of the difference in companies scale, it is necessary to measure efficiency after considering the difference in scale. Therefore, VRS is useful which calculates technical efficiency along with scale efficiency. The combination of both the CRS and VRS methods is MPI which measures productivity change between two different periods or production points (Coelli, 1996). Another requirement in the calculation of productivity is input price however, MPI does not require that.

Several studies have shown the use of MPI for efficiency measurement like Doraisamy and Azad (2014) have measured the technical efficiency of the pharmaceutical Industry whereas Patel and Ranjith (2018) measured productivity change if private sector hospital. There are further elements which need to consider before proceeding for computation. Since the DEA model is based on inputs and outputs, and selection of them will express the performance of a DMU therefore appropriate consideration to input and output is important. Under this study selection of input and output has been done by taking into consideration that DMU belongs to

the service Industry. By analysing the financial statements, it is observed that the major cost to the Software companies is employee salary and requirement of huge capital investment, unlike the manufacturing Industry. Therefore, this study has considered those variables as input and output which mainly affects the productivity of the company and also, they are available in all the Software companies. There is no parameter of selection of input and output.

Therefore, below are the inputs and outputs: -

Inputs: -Capital Employed, Average total Assets, and Employee Cost

Outputs: -Net Sales, Earnings before interest and Tax and Net profit available to common shareholders

The proposed study is based on secondary data. As mentioned earlier productivity performance measurement will be done with the help of DEA and ratio analysis, details of financial ratios and input-output variable for the DEA have been taken from www.morningstar.com & annual reports of companies. The selection of ratios has been done based on inputs and outputs used in the DEA so that they can complement each other, and analysis will be at the same level. Ratios fall under the category of profitability and efficiency which is similar tothe selected input and output under DEA. Below are ratios considered under analysis: -

Return on Capital Employed, Return on Equity and Asset turnover

The profitability ratio Return on Capital Employed will measure the profit generated by the company before taking into consideration of interest and tax from capital employed. Another profitability ratio called Return on Equity measures the company's ability to generate returns for its shareholders. And the efficiency ratio, Asset turnover measures the sales generated from assets employed in the business.

It was difficult to find a few Input-output variables and ratios from financials hence they are calculated manually by keeping uniformity in the calculation for each DMU. Below is the list of manually calculated items however, numbers used under calculation are taken from Morningstar or annual report.

1. Capital Employed = Total Assets – Current liabilities
2. Average total Assets = (opening total Assets + closing total assets)/2
3. Return on capital employed = (Earnings before interest & Tax / Capital employed)*100

3.5 Background of the Malmquist Productivity Index

As mentioned above MPI is useful in case of panel data analysis. Panel data means data for several years. MPI is also called as total factor productivity (tfpch). MPI is a product of technical efficiency change (teffch) & technological change (techch). Further technical efficiency change is decomposed into pure technical efficiency change (pech) and scale efficiency change (sech).

MPI measures the productivity change it is the geometric mean of two MPI index. As MPI does not require price to compute productivity Daneshwar and Izbirak (2013) have explained the efficiency calculation which takes place under MPI.

Consider, P is the production set of the Industry which produces output $y^t$with input x^t in year t. Therefore, the output can be calculated as:

$$D^t(x^t,y^t) = \min\{\theta|(x^t,y^t/\theta) \in P^t\} \qquad \textbf{Equation (1)}$$

P is the proportional increase of all output for the production frontier. To calculate MPI i.e. distance function it required two periods such as:

$$D^t(x^{t+1},y^{t+1}) = \inf\{\theta|(x^{t+1},y^{t+1}/\theta) \in P^t\}$$

$$D^{t+1}(x^{t+1},y^{t+1}) = \inf\{\theta|(x^{t+1},y^{t+1}/\theta) \in P^{t+1}\} \qquad \textbf{Equation (2)}$$

First part of equation (2) measures maximum proportional change in output to reach (x^{t+1},y^{t+1}) in relation to technology at time t. Second part measures maximum proportional change in output to make (x^t,y^t) feasible under the technological at time t+1.

MPI OR tfpch = technical efficiency change (teffch) * technological change (techch)

teffch = pure technical efficiency change (pech) * scale efficiency change (sech)

$$\boldsymbol{Technicalefficiencychange(teffch)} = \frac{\boldsymbol{D^{t+1}(x^{t+1}, y^{t+1})}}{\boldsymbol{D^{t}(x^{t}, y^{t})}}$$

$$\boldsymbol{Technological\ change\ (techch)} = \left[\frac{\boldsymbol{D^{t}(x^{t+1}, y^{t+1})}}{\boldsymbol{D^{t+1}(x^{t+1}, y^{t+1})}} * \frac{\boldsymbol{D^{t}(x^{t}, y^{t})}}{\boldsymbol{D^{t+1}(x^{t}, y^{t})}}\right]^{1/2}$$

Therefore, MPI can also be calculated as

MPI/tfpch = techch * pech * sech

$$\boldsymbol{MPI\ or\ Total\ factor\ productivity\ change\ (tfpch)} = \left[\frac{\boldsymbol{D^{t}(x^{t+1}, y^{t+1})}}{\boldsymbol{D^{t}(x^{t}, y^{t})}} * \frac{\boldsymbol{D^{t+1}(x^{t+1}, y^{t+1})}}{\boldsymbol{D^{t+1}(x^{t}, y^{t})}}\right] \mathbf{1/2}$$

Here, D = Distance function, y = Output, x= Input, t = current period, t+1= succeeding period

(Note:-Formula and analysis for Input oriented and output oriented is different. Under this study focus is given only on output-oriented measure)

All the terms are explained by Fare et al (1994) an originator of the non-parametric version of Malmquist index. **Technical efficiency (teffch) means producing maximum output at a minimum input whereas technological efficiency (techch) means inventions and innovations in the process.** This will help to know the productivity growth and identification of innovation. Kumar & Gulati (2008) have explained that under MPI technical efficiency states the potential use of inputs to generate maximum output from period t to t+1. This study will see how Indian Software companies are efficient in maximizing their output at a minimum level of input and the level of innovation in productivity. Software

companies will be considered as technically efficient if they fall on the efficient frontier or else inefficient in productivity if they fall below the efficient frontier.

Kumar & Gulati (2008) further explained the pure technical efficiency and scale efficiency under the assumption of CRS. Pure technical efficiency and scale efficiency is a decomposition of overall technical efficiency under CRS. This decomposition will help to understand the source of inefficiencies. **Pure technical efficiency (pech) helps to understand the managerial performance inefficiencies.** It shows how the managers are efficient in input management.

Scale efficiency (sech) is management skills in the selection of the size of an organization to reach a maximum production level. While setting targets management need to look at its size and resource availability. Software companies can fail in scale efficiency if they are too big or too small in size against their expected level of production. Scale inefficiency is the difference between VRS and CRS technical efficiency. Scale efficiencies are further divided into Increasing Return to Scale (IRS), Decreasing Return to Scale (DRS) and Constant Return to Scale (CRS). With the help of CCR, BCC developed a concept the return to scale. If a company falls under CRS, it means it is efficiently using its resources. Whereas IRS means the organization is using their resources efficiently even after being a small-scale organization and vice versa in case of DRS. In the case of MPI, selection of CRS or VRS will not have any influence because Malmquist uses both to construct the productivity efficiency index (Coelli, 1996).

The DEA can be evaluated from input oriented or output oriented perspective. Under this study, the output-oriented measure is considered for the analysis purpose. Which means results will explain efficiency and inefficiency of DMU at a constant input. To simplify more, if results of MPI under output-oriented measure is more than 1 then the DMU is considered to be efficiently producing outputs at constant input. If the result is less than 1 then DMU is not producing optimum output at constant input. This means under output-oriented measure input is considered to 1 to examine the efficient production of outputs (Fare et al. 1994).

3.6 Use of DEAP Software

As per the above formula of MPI, it is a four-component distance function which means calculation of four linear programming equation problems (Coelli, 1996). He further mentioned the formula is developed to calculate multiple equations in case of number of DMU's and several periods. The formula is N * (4T-2) where N is the number of DMU, T is period.

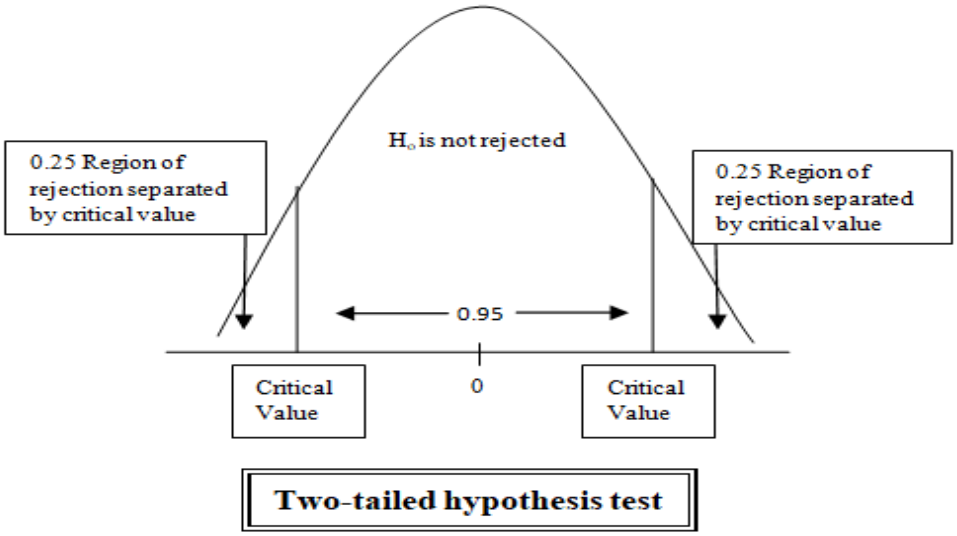
Under this study, the total number of linear equations will be 20 * (4*9-2) = 680 Linear programming equation. To deal with the multiple equations, he wrote a DOS-based program for DEA namely DEAP Software. To deal with 680 linear programming equations under this study, DEAP Software 2.1 is used and it is available on The University of Queensland, Australia website. Below is the link:

https://economics.uq.edu.au/cepa/Software

The use of this Software was also seen in Mohindra& Kaur (2015)

3.7 Hypothesis Testing

Hypothesis testing is a method to evaluate the population with the help of evidence from the sample. Null hypothesis (H_o) is a parameter developed for testing the evidence whereas alternative hypothesis (H_a) is a statement saying the null hypothesis is false. Sampling always consists of some level of uncertainty. Normally 95% or 99% confidence level is used with 5% or 1% significance level respectively. Under this study t-test of sample means from the independent population is considered. The t-test considered is two-tail at a 5% level of significance. It means there is 95% confidence in the level of results. Below is the graphical representation of t-test analysis.



Two-tailed hypothesis test

Under this study, hypothesis test will be undertaken for the large and medium scale companies of the Indian Software companies to see the difference between their technical and technological efficiency change. The results of this study will show that, out of two main elements of MPI namely technical efficiency and technological change, the company size did not matter in 9 years.

In India, Large scale companies are those which have a market capitalization of 200 billion Indian rupees whereas below than the threshold is medium scale.

4. Results and Analysis

In the section of Results and Analysis, the results are analysed into multiple sections as per the requirement of the study. The First analysis is done on a yearly index to see year over year performance of DMU under different parameters of MPI. This will help to understand DMU's consistency in performance. Next analysis shall be annual means of MPI. This will help to understand the year over year performance of SoftwareIndustry based on the selected 20 sample DMU's. After the yearly analysis, average MPI index of each DMU will be analyzed. This section will help in understanding DMU's overall performance in 9 years.

After analysing the results of DEA, analysis of DMU wise financial ratios will take place. This analysis will give information about each DMU's financial performance and SoftwareIndustry performance in 9 years.

Based on Malmquist and Ratio analysis, hypothesis test will be undertaken to see the difference between Medium and large-scalecompany's technical efficiency change and technological change.

Before starting analysis, it is important to know how to read the Malmquist productivity index. The index will be read as (Index-1)*100. So, if the index is 1.102 then the company is [(1.102-1)*100] 10.2% efficient. As already mentioned, if the index is 1then it means constant efficiency. So, index 1 will be termed as [(1-1)*100] which means 0% efficiency. If the index is less than 1, let's say 0.975, it means the company is inefficient by 2.5%.

Below is the descriptive statics table of 9 years dataset of this research:

(The figures are in INR million)

Table 1: Descriptive statistics of Input and Output

Descriptive Statistics						
	Output			**Input**		
	Net Sales	**Operating Profit (EBIT)**	**Net Income (PAT)**	**Capital Employed**	**Average Total Asset**	**Employee Cost**
Mean	104,191	24,830	20,504	85,005	104,220	50,282
Standard Deviation	218,008	57,392	47,435	175,019	212,219	106,584
Minimum	562	6	19	693	741	125
Maximum	1,231,040	307,080	262,890	887,400	1,047,740	663,960

4.1 Analysis as per DEA

4.1.1 Yearly Malmquist Index

Since Malmquist measures index from one year to next year, the productivity index for all the companies in the first year will be 1. **Table 2 to Table 9** is the list of tables in Appendix showing each year company-wise MPI starting from 2nd year i.e. March 2011.

a) Detailed analysis of March 2011 index

In March 2011, average technical efficiency (teffch) is 0.996 which is near to 1 which means the SoftwareIndustry was constant in producing maximum output at the given input level. Since the technical efficiency (teffch) is the product of pure technical efficiency (pech) and scale efficiency (sech), the average sech index is 1.009 in March 2011 which is contributing majorly in teffch. Average technological efficiency change (techch) is 0.924 which means inventions and innovation in the SoftwareIndustry is inefficient by 7.6%. The productive efficiency of SoftwareIndustry measured by MPI or total factor productivity change (tfpch) which

is 0.921 in March 2011 shows that Industry performance was inefficient by 7.9%. This inefficiency is majorly coming from technological efficiency change. The efficiency index shows that the managers of the SoftwareIndustry need to focus more on innovation for constant performance.

Looking at DMU's of Software industries performance in March 2011, Vakrangee Software has achieved 1.841 MPI which means company shows a growth of 84.1% in March 2011. The growth is purely coming from technological change (techch) since in other efficiency parameters the company is showing index 1 which means constant in performance. Whereas Nucleus Software exports show the productivity index of 0.47 which means the company is inefficient by 53%. All the productivity efficiency parameters of the company are showing that the company is below the performance level. In March 2011, 0ut of total 20 Software companies only 8 have performed efficiently i.e. having productivity index above 1. While comparing to average total productivity of 0.921 only 12 companies have performed above the index.

Table 1: Malmquist Index for March 2011

March 2011					
Companies	**teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	1	1.013	1	1	1.013
Infosys	0.952	1.031	0.963	0.988	0.981
Wipro Limited	1.098	0.878	0.985	1.115	0.965
Tech Mahindra	1.102	1.015	1.087	1.014	1.119
Oracle Financial ServicesSoftware	1.211	0.929	1.104	1.097	1.125
Mphasis	0.745	0.933	0.77	0.967	0.695
Mindtree Limited	1	0.671	1	1	0.671
NIIT Technologies	1.413	0.839	1.408	1.004	1.185
Cyient	1.035	0.926	1.011	1.024	0.958
Zensar Technologies	1	0.754	1	1	0.754
Tata Elxsi	1.068	0.839	1	1.068	0.895
Persistent Systems	1.007	0.941	0.992	1.015	0.948
Sasken Technologies	0.711	0.765	0.727	0.978	0.544

Expleo Solution	0.953	0.898	1	0.953	0.856
Vakrangee Software	1	1.841	1	1	1.841
Birlasoft	1.066	0.939	1.034	1.031	1.001
Nucleus Software Exports	0.554	0.85	0.631	0.877	0.47
R Systems International	1.415	0.831	1.252	1.13	1.176
Virinchi	1.029	1.051	1	1.029	1.081
Saksoft	0.977	0.931	1.051	0.93	0.91

b) Concise analysis for the period March 2012 to March 2018

In the above section of the analysis, a detailed review has been done on each component of the March 2011 index. The author wanted to explain how different variables of MPI affect productivity efficiency. From here brief analysis will be done for the rest of the years to get the overview of each year and information is available under **Table 3 to Table 9**. This section will provide information about consistent performing DMU's and movements of efficient and inefficient DMU's.

Vakrangee Software has again achieved the highest technological efficiency change in March 2012, 2014 in 2015. The company missed the technological efficiency twice in overall 9 years. March 2012 is the highest total factor productivity performance of Vakrangee Software with 91.1% growth. This states that the company is highly focused on innovations to get maximum output out from their investments/inputs. The productivity index got by Vakrangee Software is the highest in all the DMU's.

In March 2015 Mphasis total productivity index is 1.922 which means 92.2% productive efficiency. This the highest number of productivity efficiency growth achieved by any Software company seen in overall nine years. Mphasis has performed efficiently by 71.6% in technical change with 99% growth in pure efficiency. The pure efficiency changes and technical efficiency change obtained by Mphasis is the highest efficiency growth at DMU level seen in overall 9 years period.

4.1.2 Annual means of Malmquist Index

Abbott and Wu (2002) while measuring the Australian airport efficiency have considered the analysis of annual malmquist index. They mentioned that technical efficiency is related to CRS whereas pure efficiency and scale efficiency is related to VRS.

Annual means of Malmquist index is available in **Table 10.** This table states the average of MPI in each year. Average MPI is the geometric mean of all DMU's index. Technical Efficiency change (teffch) is most efficient in March 2015 with 3.2% growth. This means in the March 2015 SoftwareIndustry can generate maximum output with input available. Since technical efficiency (teffch) is a product of pure efficiency (pech) and scale efficiency (sech), this growth is majorly from pure efficiency change i.e. 7.9%. However, the regression in technical efficiency is because of scale inefficiency. Scale efficiency is showing negative growth of 4.4%. This shows that the SoftwareIndustry's managerial performance was efficient in March 2015 however there is inefficiency in the size of companies and their use of resources to reach a maximum output level. Not only technical efficiency but the MPI/total factor productivity (tfpch) of March 2015 is the maximum productivity efficiency in the total period of 9 years i.e. 6.7%. It can be also noticeable from the table that, only in 2015 the SoftwareIndustry has crossed the pure efficiency change above efficient level and regressed after that in the following years.

Most regressed technical efficiency has seen in March 2018 with index 0.914. Again, here also the reason behind inefficiency is pure efficiency change with index 0.922. It's the least pure efficiency index in the whole 9 years. Technological inefficiency with index 0.915 can be seen in March 2017. It is the least total factor productivity index year with 0.919.

The average technological efficiency index for the 9 years is 1.025 which means the growth of 2.5%. Out of a total 9 nine years only in March 2011 and March 201 technological efficiency is regressed. Average total factor productivity efficiency states the result of March 2011 year productivity performance. Average tfpch is 1.001 which means the overall Industry in 9 years was constant in productivity efficiency. This consistency is the result of technological change efficiency. It means

the Industry is more focused on innovations and adapting changes. Whereas less concentrating on generating maximum output since the average technical efficiency change is 0.977 for 9 years. And the reason behind technical inefficiency is the average pure inefficiency observed in whole 9 years which is 0.984.

The results of inefficiency reflect that year over year there is a regression in productivity efficiency of the Indian SoftwareIndustry. It is observed from total factor productivity that from March 2012 to March 2015 the SoftwareIndustry was efficient in productivity. However, the major downfall in 2017 has affected the overall productivity efficiency index of 9 years.

Table 10: Malmquist Index of annual means

MALMQUIST INDEX OF ANNUAL MEANS					
year	**teffch**	**techch**	**pech**	**sech**	**tfpch**
March 2011	0.996	0.924	0.987	1.009	0.921
March 2012	0.958	1.103	0.969	0.989	1.057
March 2013	1.023	0.999	0.984	1.039	1.022
March 2014	0.947	1.11	0.974	0.973	1.051
March 2015	1.032	1.034	1.079	0.956	1.067
March 2016	0.947	1.027	0.989	0.958	0.973
March 2017	1.005	0.915	0.975	1.031	0.919
March 2018	0.914	1.107	0.922	0.991	1.011
mean	**0.977**	**1.025**	**0.984**	**0.993**	**1.001**

4.1.3 DMU wise average Malmquist Index

At this stage, it is clear that how the Indian SoftwareIndustry has performedevery year in 9 years. However, it is important to know the efficient and inefficient companies in the Industry. The information is available in **Table 11** which is a table of DMU wise average MPI summary. Expleo Solutions has achieved maximum technical efficiency index with 1.038 which means 3.8% average efficiency in 9 years. The efficiency is the result of scale efficiency since technological efficiency change and pure efficiency change both are constant. The scale efficiency change of

Expleo Solutions is the maximum efficiency change in all the 20 companies over 9 years. This means in spite of the smaller scale of operations, the company is achieving maximum output from the available inputs.

Technological efficiency change index is higher in Vakrangee Software which is 1.256. This means the company has achieved a 25.6% average growth in 9 years. Vakrrangee Software is the highest total factor productivity efficient company in 20 Indian Software companies. The company has maintained pure technical efficiency change and scale efficiency change constant throughout 9 years. This means Vakrangee Software not only trying to maximize their output level at available inputs but also focusing on the innovations to make their productivity efficient.

Looking at technical efficiency it is observed that only 4 companies have performed efficiently in the entire period of 9 years. This shows that only 20% of Software companies out of sample 20 Software companies have achieved efficiency in producing maximum output with their inputs.

The deconstructed variables of technical efficiency are pure technical efficiency and scale efficiency of which highest scale efficiency is already discussed above. Under pure efficiency change, Tech Mahindra has achieved the highest index of 1.018 which shows the average year over year growth of 1.8%. It is also observed from the table that many companies couldn't achieve both the efficiency parameters of technical efficiency change simultaneously. However, those companies, who have achieved both the index simultaneously, resulted efficient in productivity performance, for example, Oracle financial services, Tata Elxsi and so on.

The company which appears to be most inefficiently in 9 years period is Sasken Technologies. Its average technical efficiency index is 0.904 which means the company is inefficient by 9.6%. The major inefficiency is coming from pure efficiency change. It shows that managers are not efficiently able to fully utilize the inputs to maximize the output. The average MPI index is 0.891 which is very low in all the selected 20 companies whereas, the average Industry MPI index is 1.001. The technological inefficiency has seen in Tata consultancy services with index 0.981 because of which the productivity is also got affected.

Table 11: Malmquist Index summary of Firms means

MALMQUIST INDEX SUMMARY OF FIRMS MEANS					
Company	**teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	0.995	0.981	1	0.995	0.976
Infosys	0.986	1.004	1.004	0.982	0.99
Wipro Limited	0.966	0.995	1.011	0.955	0.961
Tech Mahindra	0.97	1.018	1.018	0.953	0.987
Oracle Financial ServicesSoftware	1.01	0.996	1.001	1.009	1.006
Mphasis	0.922	1.033	0.927	0.995	0.952
Mindtree Limited	0.971	0.992	0.971	1	0.964
NIIT Technologies	0.977	1.026	0.977	1	1.002
Cyient	0.989	1.031	0.986	1.003	1.02
Zensar Technologies	0.956	1.004	0.957	0.999	0.961
Tata Elxsi	1.008	1.033	1	1.008	1.042
Persistent Systems	0.979	1.035	0.972	1.007	1.013
Sasken Technologies	0.904	0.986	0.924	0.978	0.891
Expleo Solution	1.038	1.003	1	1.038	1.041
Vakrangee Software	1	1.256	1	1	1.256
Birlasoft	0.984	1.018	0.981	1.003	1.002
Nucleus Software Exports	0.905	0.989	0.936	0.967	0.896
R Systems International	1.02	1.04	1.012	1.008	1.061
Virinchi	0.984	1.061	1	0.984	1.044
Saksoft	0.988	1.019	1.008	0.98	1.007
mean	**0.977**	**1.025**	**0.984**	**0.993**	**1.001**

The selected companies are from large to small market capitalization. A Tata consultancy service is the company which holds the largest market capitalization of 8426.35 billion Indian rupees in the SoftwareIndustry. However, as per the results of DEA, the company is inefficient in productivity efficiency. The average MPI is inefficient by 2.4% in the overall period of 9 years. In contrast, Vakrangee Software

whose market capital investment is 37.66 billion Indian rupees is the most efficient under productivity in the sample selected companies.

After analysing the results of DEA, it is important to know the results of financial statement analysis i.e. Ratio Analysis. As stated by Halkos and Salamouris (2004) results of DEA compliments Ratio Analysis as DEA provide additional information over Ratio Analysis.

4.2 Performance analysis as per Ratio Comparative

Mean of all the ratios is available in **Table 12.** To keep the consistency geometric mean is considered for ratios as well. Return on capital employed (ROCE) and Return on equity (ROE) of Tata consultancy services is the highest in all the companies. The company has achieved a 41% average returns on capital investment whereas 39% on equity capital. The average Industry return on the capital employed ratio is 20% and return on equity is 19%. Tata consultancy services generating 200% more returns on the capital investment and their shareholder's equity than the average Industry level.

From the analysis of ROCE variables (numerator & denominator) of Tata consultancy services, it is observed that year over year earnings before interest and tax is decreasing except in March 2016 whereas capital employed is fluctuating over 9 years. Here it is noticed that financial ratios are giving minimum information about the performance of Tata consultancy services. As per the ratios company generated maximum returns on capital and equity. However, with DEA there is additional information that the company failed to maximize the output (profit) from the available resources (capital employed) also the company is not growing.

Looking at Vakrangee Software, the ratios show that the company is just above the Industry standards and not achieving the maximum percentage of profit where DEA has showed that it is the most efficient company in utilizing its resources. From the analysis of ratios variables, it is seen that in most of the year's the company is maximizing the output (sales, earnings) and minimizing its inputs (capital employed & total assets).

Table 12: Average ratios for the period 2010 to 2018

DMU wise mean of Ratios			
DMU	**ROCE (%)**	**ROE (%)**	**Asset Turnover (%)**
Tata Consultancy Services	41	39	128
Infosys	31	25	89
Wipro Limited	20	22	83
Tech Mahindra	23	25	108
Oracle Financial ServicesSoftware	26	22	56
Mphasis	16	15	83
Mindtree Limited	24	25	153
NIIT Technologies	22	19	127
Cyient	18	18	114
Zensar Technologies	27	26	161
Tata Elxsi	36	28	177
Persistent Systems	20	20	110
Sasken Technologies	9	16	84
Expleo Solution	18	17	133
Vakrangee Software	29	22	149
Birlasoft	21	20	136
Nucleus Software Exports	10	12	70
R Systems International	16	16	158
Virinchi	9	8	75
Saksoft	15	15	106
Mean	**20**	**19**	**110**

4.3 Hypothesis testing between large scale and medium scale companies

One of the objectives of this study is to see the difference in technical efficiency and technological change efficiency between 2010 and 2018. For that, the hypothesis test has been undertaken. As mentioned in Pannu et al. (2011) to see the difference between variance (especially in the case of average efficiency) t-test with a different variance will be logical. Under this study also to test the hypothesis, student t-test with the difference in variance is considered. The level of significance is 5% i.e. 0.05.

The t-test formula is as below:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where $\bar{x}_1$&s_1^2 are the mean and standard deviation values of medium and large-scale companies.

The results are evaluated by Excel data analysis tool-pack is used.

Hypothesis 1

H_0 = There is no difference between the **average technical efficiencies** of large and medium scale companies.

H_a = There is a significant difference between the **average technical efficiencies** of large and medium scale companies.

Table 13: Technical Efficiency change Hypothesis

Technical Efficiency change		
t-Test: Two-Sample Assuming Unequal Variances		
	Medium	***Large***
Mean	0.975	0.9904
Variance	0.001527	0.00026
Observations	15	5
df	17	
t Stat	-1.24145	
P(T<=t) two-tail	0.231295	
t Critical two-tail	2.109816	

Results of Hypothesis testing

Table13 is showing the results of hypothesis testing. The P-value 0.231295 is greater than the significance level i.e. 0.05. Therefore t-test failed to reject the null hypothesis at 0.05% significance level. This means there is no difference between average technical efficiency of large and medium scale companies.

Hypothesis 2

H_0 = There is no difference between **average technological change** of large and medium scale companies.

H_a: There is a significant difference between the **average technological change** of large and medium scale companies.

Table 14: Technological Efficiency change hypothesis

Technological change		
t-Test: Two-Sample Assuming Unequal Variances		
	Medium	***Large***
Mean	1.035067	0.9914
Variance	0.004182	0.000102
Observations	15	5
df	16	
t Stat	2.524313	
P(T<=t) two-tail	0.022543	
t Critical two-tail	2.119905	

Results of Hypothesis testing

Results are shown in **Table 14** which states that the P-value which is 0.022543 is less than the significance level i.e. 0.05, therefore, the t-test is rejecting the null hypothesis. This means there is a difference between large and medium scale companies technological change.

Conclusion of Hypothesis testing

Hypothesis testing shows that between large scale and medium scale companies, average technical efficiency performance is similar. The level of output maximization from the input is similar in both types of companies. However, the hypothesis test of technological changes states that both the group of companies are different. Medium-scale companies are more efficient in innovation as compare to large scale companies.

4.4 Limitations of study

Every study has some limitation which could be out of the research control which limits the results and conclusion drawn. This study also has a few limitations. The sample selected under this study is 20 whereas around 126 companies are listed on the Bombay stock market under the Indian SoftwareIndustry. But while considering inputs and output for the DEA, it came under observation that many companies are loss-making for years. Halkos and Salamouris (2004) have mentioned the problem of negative numbers in ratio analysis and DEA. The negative numbers in financial reports states the losses. Negative numbers are also called as outliers (observations at an abnormal distance). They further stated that the problem of the

outlier is also seen in DEA methodology. This means DEA cannot work for the companies whose variable are showing loss or excess expenses.

Smith (1990) stated that if negative numbers arise in numerator or denominator of ratio analysis then there is a problem in analysis. The analysis could be misleading as well as it is assumed that the companies who are making losses are inefficient. Also, the treatment of outliers is not straightforward. This limits the number of sample companies under consideration for this study.

4.5 Conclusion

The efficiency of financial ratios has failed because of its univariate nature. The numerator and denominator are restricted which limits the company's assessment. It is also difficult to merge the selected ratios under this study. However, the ratios and MPI give results in different parameters.Ratios can be explained in the form of percentage, number of day or just a number whereas MPI is explained by an index. Ratios can give the information about the specific area of operation of the company. Like, Capital employed ratio can explain the efficiency of company or management in using the capital to generate maximum profits as the main motive is to generate shareholders wealth. Therefore, it can be said that ratios are useful in giving the information about a particular business activity or trend line of a company's results to its internal management and external investors.

However, the MPI gives information about the productivity of the company. The result of MPI is one index number which explains the overall performance of the company. The decomposition of MPI like technological efficiency or technical efficiency gives information about the area in which company is working efficiently or inefficiently. MPI gives further information to company's internal managements about the efficiency or inefficiency in the area of production, scale of operation or the managers administration.

Hence it can be stated that MPI is providing additional information about companies' efficiency over Ratio Analysis. The managers can take advantage of the MPI index to further enhance their financial position in the Industry. Also, the availability of MPI index to investors can enhance trust in the company as well as it will be easy to raise capital for expansion.

5. Discussion and future research direction

This section will support the finding of this study with the help of the literature and scholarly articles.

Abbott and Wu (2002) have mentioned that DEA will always find at least one DMU being the best out of the sample selected. In this research, Vakrangee Software is the efficient DMU. He further states that there is a possibility that all the DMU's are inefficient or efficient to some degree. Therefore, index derived by DEA is relative efficiency index. The MPI results of this study have expressed a relative efficiency within the Software Industry.

The application of DEA on U.S. Computer Industry's financial statement is undertaken by Thore et al. (1994) with the help of Malmquist methodology. They claimed of getting unexpected and new insights into efficiencies of technology changing the world. The well-managed companies were showed constant and no productivity over time. Companies with the characteristics of growing sales, increasing market shares, and market capitalization were inefficient all over time. The same kind of results was also seen in the current study. As we noticed in Tata consultancy services that the company seems to be growing and profitable however productivity efficiency was low all over the years. Another company called Wipro with the market capitalization of 1560 billion Indian rupees shows 9 years average MPI 0.961. This means the company is inefficient by 3.9% whereas ratios of the company meet the Industry standards.

Mohindra& Kaur (2015) have performed Malmquist analysis majorly focusing on pure technical efficiency change on rural banks of India. Their database of 50 rural banks showed high-frequency fluctuation in pure efficiency. The reason behind the fluctuation was mentioned as managerial incapability. As a suggestion, they mentioned that inefficient banks should merge also separate institute should set up to educate and train staff. This suggestion could be applicable for Indian Software industries too as under this study also the inefficient managerial performance has been observed.

Doraisamy et al. (2014) have performed an MPI analysis of the pharmaceutical Industry of Bangladesh. The MPI approach and selection of variables of study is nearly similar to this study. They found MPI slightly upward-moving during the study period whereas the major effect was from technological change (techch). Technical efficiency was seen regressed during the period. They mentioned that sustainability in the long-term using innovation may not be possible. They further observed that big size companies invested in innovation for production improvement, yet production did not change significantly. However, the cost of automation is not seen in production. The results of this study are similar to this study. Looking at the data it is observed that companies falling into large market capital (Eg. Tech Mahindra, Mphasis, Mindtree limited) are more focused on technological changes. However, that change is not turning into productive efficiency.

As mentioned above, Outlier is the limitation of this study and while performing analysis it is important to remove them. Outliers can produce unrealistic results in productivity efficiency. Daniel et al. (2013) under their analysis of public health care services used outlier corrected model. They mentioned that the influence of outlier was beyond an acceptable level of efficiency frontier. Therefore, this study has also not considered outlier i.e. input and output variable of loss-making company.

Baten et al. (2014) have measured DEA efficiency on Malaysian banks with the help of MPI. However, they further forecasted productivity with Brownian motion approach. The above study can be further carried on with Brownian motion approach to analyse the productivity of Software companies. With the help of that, the future inefficient DMU's can be captured and managers can act proactively to increase the efficiency.

Yu et al. (2014) measured the efficiency of Taiwan Public Companies with DEA and compared the results with Ratio Analysis. Their DEA CCR and BCC results were complimenting results of ratio analysis, therefore, they further provided information on the amount of inefficiency in inputs and outputs. This research is similarto the study of Taiwan Public Companies. Also, the results of MPI are

complimenting ratio analysis and giving the additional information. Under the study of Taiwan Public Companies, they have also provided results of a slack variable. Slack variables give the information of excess inputs used and shortages in outputs. Because of the time restriction for this study, the slack variable analysis is not considered here. However, further research can be done by using the slack variable methodology to see the amount of inefficiency in inputs used and output generated.

Pannu et al. (2011) measured the average technical and average productivity efficiency of indigenous and multinational companies with the hypothesis analysis. In the case of average technical efficiency t-test rejected the null hypothesis at 5% significance level whereas; in the case of productivity change, the results were to reject the null hypothesis. They stated that the hypothesis test was helpful in testing the similarity between the two types of companies in the pharmaceutical Industry. Therefore, hypothesis also adopted under this study to see the difference between large and medium scale companies of the SoftwareIndustry within their technical and technological efficiency change as these are the parameters of productivity efficiency change.

5.1 Conclusion

The research papers have given the information about how to analyse productivity under MPI stating that the MPI methodology of DEA is the informative approach for productivity performance measurement. MPI methodology is used for the panel database. If the database is not panel then the researcher can use the CCR & BCC models of DEA. This study will be beneficial for the managers of inefficient as well as efficient companies to improve them in their weak areas. Also, the above-mentioned future research direction will give managers additional information over this study.

6. Conclusion of the research

The Indian Information Technology Industry is growing from the past few years. The Industry is earning attention because of its outsourcing abilities and persistent innovation in technology. The statics shows that the Industry is not the grooming but creating employment opportunities in the country. The Software sector holds huge market capital investment. Software is the biggest sector of the Indian IT Industry. Therefore,Software sectors performance efficiency will be insightful information to see the year over year growth.

This research has considered a specific area of performance measurement i.e. productivity. The most common and traditional method; Ratio Analysis has certain limitations. Therefore, to measure the performance of any sector or Industry, previous researches have shown that DEA, a non-parametric methodology is appropriate. However, for the measurement of productivity performance, the MPI under DEA is a suitable method. Under this study, with MPI it was possible to evaluate performance for 9 years.

The productivity performance results of MPI under DEA were efficient in stating inside information where ratios failed. The results of MPI are explained in multiple directions of productivity i.e. technical efficiency, pure efficiency, scale efficiency, technological efficiency, and total factor productivity. As per the results derived from MPI under this study, the overall SoftwareIndustry was consistent in total factor productivity efficiency. Further to total factor productivity, it is seen that before March 2015 the sector has consistently performed above efficiency level except in Match 2011. However, after March 2015, there is regress in performance. The regress is the effect of technical inefficiency this states that the companies are not producing optimal output from the input available. However, the technological change is constant overall 9 years that highlights that the sector is more innovation-oriented rather than output maximization.

The analysis of each DMU under the study showed that out of 20 selected sample companies, 11 were above the efficiency level. The MPI results as per the DMU's states that not all the companies are achieving the same level of efficiency. The overall average MPI is constant because of few companies performing

efficiently above the average level. It is also observed that the large-scale companies are less efficient as compared to medium scale companies. Tata Consultancy Services is one of the large companies from the Software sector whereas Vakrangee Software is a medium scale company. However, the productivity performance as per MPI shows that the Tata Consultancy services were less efficient than Vakrangee Software. Vakrangee Software is the most productivity efficient performing Software Company for over 9 years.

The large and medium scale company's performances of technical and technological aspects were tested by hypothesis with a 5% significance level. The results of technical efficiency hypothesis test showed that there is no difference between large and medium scale companies. This states that all the companies of Software industries are at an optimum level of output maximization. However, the opposite results were obtained under technological efficiency. It is seen that the large-scale companies are more technological innovation-oriented than medium scale companies.

The results obtained from ratio analysis were not as per the MPI. As per the ratios, Tata consultancy Services is the most efficient company under financial performance whereas, the Vakrangee Software is the above-average level. However, it is evidenced that to get the additional information over ratios, MPI under DEA methodology can be considered.

7. References

Abbott, M., Wu, S. (2002) 'Total Factor Productivity and Efficiency of Australian Airports', *The Australian Economic Review*, 35(3), pp.244-60.

Altman, E. (1968) 'Financial Ratios, Discriminant Analysis and the prediction of corporate bankruptcy', *The Journal of Finance,* XXIII(4), pp.589-609.

Anthony, P., Behnoee, B., Hassanpour, M. and Pamucar, D. (2019) 'Financial Performance Evaluation of Seven Indian Chemical Companies', *Decision Making: Applications in Management and Engineering*, 2(2), pp.19-37.

Barnes, P. (1987) 'The Analysis and use of Financial Ratios: A Review Article', *Journal of Business Finance and Accounting*, 14(4), pp.449-461.

Baten, A., Kasim, M. and Ramli, R. (2015) 'Efficiency and productivity change in Central Bank of Malaysia: Evidence from stochastic frontiers and brownian motion, *International Journal of Applied Mathematics and Statistics*, 53 (1).

Charnes, A., Cooper, W.W. and Rhodes, E. (1978) 'Measuring efficiency of decision-making units', *European Journal of Operational Research',* 2, pp.429-444, Business Source Complete. doi.org/10.1016/ 0377-2217(78)90138-8.

Chen, C. and Yan, H. (2011) 'Network DEA model for supply chain performance evaluation', *European Journal of Operational research*, 213, pp. 147-155.

Chen, Y., Iqbal Ali, A. (2004) 'DEA Malmquist productivity measure: New insights with an application to computer Industry', *European Journal of Operational Research*, 159, pp.239-249.

Coelli, T. (1996) 'A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program', *CEPA Working Paper'*,8,pp.1-50.

Daneshvar, S. and Ibrahim, M. (2018) 'Efficiency analysis of Healthcare System in Lebanon using Modified Data Envelopment Analysis', *Journal of Healthcare Engineering*, pp.1-6. https://doi.org/10.1155/2018/2060138

Daniel, L., Gomez, A. and Braga, M. (2013) 'Evaluating the performance of Public healthcare services provision: An analysis of the Municipalities of Mato Grosso State, Brazil'.

Doraisamy, S. and Azad, A.K. (2014)'Efficiency measurement of pharmaceutical industry using the malmquist total productivity index', pp.162-173

Fare, R., Grosskopf, R., Norris, M., Zhang, Z. (1994) 'Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries', *The American Economic Review*,84(1), pp.66-83

Feroz, E.H., Kim, S. and Raab, R.L. (2003) 'Financial Statement Analysis: A Data envelopment analysis approach', *Journal of the Operational Research Society*, 54, pp.48-58.

Jain, N. K., Celo, S., Kumar, V. (2019) 'Internationalization speed, resources and performance: Evidence from Indian SoftwareIndustry', *Journal of Business Research*, 95, pp.26-37.

Jayamaha, A., Mula, J. M. (2011) 'Productivity and Efficiency Measurement Techniques:
Identifying the Efficacy of Techniques for Financial Institutions in Developing Countries', *Journal of Emerging Trends in Economics and Management Sciences (JETEMS)*, 2(5), pp.454-460.

Johri, S., Maheshwari, T. (2015), 'An Empirical Study on the Practical Efficacy of Ideal Financial Ratios', *Pranjana*, 18(1), pp.41-52.

Halkos, G. and Salamouris, D. (2004) 'Efficiency measurement of the Greek commercial banks with the use of financial ratios: a data envelopment analysis approach', *Management accounting research,* 15, pp.201-224.

India Brand Equity Foundation (2019) *Indian IT, ITes& BPM Industry Analysis.* Available at: https://www.ibef.org/Industry/indian-iT-and-iTeS-Industry-analysis-presentation/ [Accessed 19August 2019]

Krivonozhko, V., Piskunov, A., and Lychev, A. (2011), 'On Comparison of ratio analysis and data envelopment analysis as performance assessment tool', *IMA Journal of Management Mathematics,* 22, pp.357-370.

Kumar, S., Gulati, R. (2008), 'An Examination of Technical, Pure Technical, and Scale Efficiencies in Indian Public Sector Banks using Data Envelopment Analysis', *Eurasian Journal of Business and Economics,* 1(2), pp.33-69.

Maniadakis, N., Thanassoulis, E. (2004), 'A cost Malmquist productivity index', *European Journal of Operational Research,* 154, pp.396-409.

Mishra, D., Mahalik, D. K. (2019), 'Examining the Efficiency of Outsourcing in India's Healthcare Sector Using Data Envelopment Analysis', *The IUP Journal of Supply Chain Management,* 16(1), pp.8-21.

Mohindra, V., Kaur, G. (2015), 'Pure Efficiency Change Growth of Regional Rural Banks in India-Using Malmquist Productivity Index', *Productivity,* 55(4), pp.319-325.

Pannu, H.S., Kumar, D. and Farooquie, J. (2011) 'Efficiency and productivity analysis of Indian Pharmaceutical Industry using data envelopment analysis', *Int.J.operational Research,* 10, pp.121-136.

Patel, P. and Ranjith, VK.(2018), 'Measuring efficiency and productivity change of multi-specialty private sector hospitals in India: A DEA based Malmquist

productivity index approach', *Indian Journal of Finance*, 12(5), pp.25-42. https://doi.org/10.17010/ijf/2018/v12i5/123691

Piskunov, A. and Lychev, A. (2011) 'On comparison of ratio analysis and data envelopment analysis as a performance assessment tools', *IMA Journal of management mathematics,*22, pp.357-370.

Sasikumar, R. (2011), 'An enhanced application of Brownian motion to mathematical finance in stochastic modeling', *Journal of Interdisciplinary Mathematics*, 14(4), pp.471-481.

Shetty, U., Pakkala, T.P.M., Mallikarjunappa, T. (2012), 'A modified directional distance formulation of DEA to assess bankruptcy: An application to IT/ITES companies in India', *Elsevier Ltd.*, 39.

Sickles, R. C., Streitwieser, M. L. (1992), 'Technical Inefficiency and Productive Decline in the U.S. Interstate Natural Gas Pipeline Industry Under the Natural Gas Policy Act' *Kluwer Academic Publishers*, 3, pp.119-133.

Smith, P. (1990) 'Data Envelopment analysis applied to financial statement', *Omega int. j.mgmt sci.*, 18(2), pp.131-138.

Stancheva, N., and Angelova, V. (2004) 'Measuring the efficiency of university libraries using Data Envelopment Analysis. In Forum 2004 – Conference on professional information resources, *Proceedings*, Prague.

Thore, S., Kozmetsky, G. and Phillips, F. (1994)'DEA of Financial Statements Data: The US Computer Industry', *Journal of Productivity Analysis*, 5(3), pp.229-248.

Tone, K. andTsutsui, M.(2010)'Dynamic DEA: A slacks-based measure approach', *Omega, Elsevier*, 38(3-4), pp. 145-156.

Yeh, QJ. (1996) 'The application of Data envelopment analysis in Conjunction with Financial ratios for bank performance evaluation', *Journal of the operational research society,* 47, pp.980-988. Doi:https://doi.org/10.1057/jors.1996.125

Yu, Y., Barros, A., Tsai, C., Liao, K. (2014), 'A Comparison of Ratios and Data Envelopment Analysis: Efficiency Assessment of Taiwan Public Listed Companies', *International Journal of Academic Research in Accounting, Finance and Management Sciences,* 4(1), pp.212-219.

Zhu, W., Yu, Y. and Sun, P. (2017) 'Data Envelopment analysis cross-like efficiency model for non-homogeneous decision-making units: The case of United States companies' low –carbon investment to attain corporate sustainability', *European Journal of Operational Research,* 269(1), pp.99-110. Doi: https://doi.org/10.1016/j.ejor.2017.08.007

8. Appendix

Table 1: Malmquist Index for March 2011

March 2011					
Companies	**teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	1	1.013	1	1	1.013
Infosys	0.952	1.031	0.963	0.988	0.981
Wipro Limited	1.098	0.878	0.985	1.115	0.965
Tech Mahindra	1.102	1.015	1.087	1.014	1.119
Oracle Financial ServicesSoftware	1.211	0.929	1.104	1.097	1.125
Mphasis	0.745	0.933	0.77	0.967	0.695
Mindtree Limited	1	0.671	1	1	0.671
NIIT Technologies	1.413	0.839	1.408	1.004	1.185
Cyient	1.035	0.926	1.011	1.024	0.958
Zensar Technologies	1	0.754	1	1	0.754
Tata Elxsi	1.068	0.839	1	1.068	0.895
Persistent Systems	1.007	0.941	0.992	1.015	0.948
Sasken Technologies	0.711	0.765	0.727	0.978	0.544
Expleo Solution	0.953	0.898	1	0.953	0.856
Vakrangee Software	1	1.841	1	1	1.841
Birlasoft	1.066	0.939	1.034	1.031	1.001
Nucleus Software Exports	0.554	0.85	0.631	0.877	0.47
R Systems International	1.415	0.831	1.252	1.13	1.176
Virinchi	1.029	1.051	1	1.029	1.081
Saksoft	0.977	0.931	1.051	0.93	0.91

Table 2: Malmquist Index for March 2012

March 2012					
Companies	**teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	1	0.964	1	1	0.964
Infosys	1.047	0.998	1.049	0.998	1.045
Wipro Limited	0.9	1.085	1.008	0.893	0.977
Tech Mahindra	0.742	1.016	0.737	1.008	0.754
Oracle Financial ServicesSoftware	0.815	0.878	1	0.815	0.716
Mphasis	0.884	1.086	0.929	0.952	0.96
Mindtree Limited	1	1.105	1	1	1.105
NIIT Technologies	0.901	1.085	0.897	1.005	0.978
Cyient	1.083	1.064	1.085	0.998	1.153
Zensar Technologies	0.999	1.155	1	0.999	1.153
Tata Elxsi	1	1.269	1	1	1.269
Persistent Systems	1.059	1.051	1.019	1.039	1.114
Sasken Technologies	0.917	1.093	0.927	0.989	1.002
Expleo Solution	1.228	1.1	1	1.228	1.351
Vakrangee Software	1	1.911	1	1	1.911
Birlasoft	0.948	1.086	0.949	0.999	1.03
Nucleus Software Exports	0.926	1.062	0.97	0.955	0.983
R Systems International	0.907	1.192	0.921	0.985	1.081
Virinchi	0.947	1.047	1	0.947	0.991
Saksoft	0.957	1.083	0.936	1.023	1.037

Table 3: Malmquist Index for March 2013

March 2013					
Companies	**teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	1	1.006	1	1	1.006
Infosys	0.882	0.991	0.887	0.994	0.874
Wipro Limited	1.12	0.987	0.889	1.26	1.105
Tech Mahindra	0.988	1.016	0.984	1.005	1.004
Oracle Financial ServicesSoftware	0.995	1.032	0.997	0.999	1.027
Mphasis	0.921	0.998	0.886	1.04	0.919
Mindtree Limited	0.977	1.063	1	0.977	1.038
NIIT Technologies	0.981	1.04	0.981	1	1.02
Cyient	1.048	1.034	1.042	1.006	1.083
Zensar Technologies	1.001	1.041	1	1.001	1.043
Tata Elxsi	1	1.061	1	1	1.061
Persistent Systems	1.067	1.021	1.067	1	1.089
Sasken Technologies	0.868	0.989	0.864	1.005	0.858
Expleo Solution	1.151	1.029	1	1.151	1.184
Vakrangee Software	1	0.809	1	1	0.809
Birlasoft	1.048	1.024	1.047	1.001	1.073
Nucleus Software Exports	0.981	0.966	0.999	0.982	0.948
R Systems International	1.102	1.093	1.086	1.015	1.205
Virinchi	1.217	0.886	1	1.217	1.079
Saksoft	1.195	0.934	0.996	1.199	1.115

Table 4: Malmquist Index for March 2014

March 2014					
Companies	**teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	1	1.076	1	1	1.076
Infosys	0.836	1.118	0.825	1.014	0.935
Wipro Limited	0.881	1.08	0.929	0.948	0.951
Tech Mahindra	1.391	1.078	1.525	0.912	1.499
Oracle Financial ServicesSoftware	0.963	1.181	1.003	0.96	1.137
Mphasis	0.451	1.063	0.444	1.015	0.479
Mindtree Limited	0.953	1.09	1	0.953	1.039
NIIT Technologies	0.883	1.102	0.966	0.914	0.974
Cyient	0.905	1.095	0.967	0.935	0.99
Zensar Technologies	0.913	1.103	1	0.913	1.007
Tata Elxsi	1	1.243	1	1	1.243
Persistent Systems	0.968	1.077	0.971	0.996	1.042
Sasken Technologies	0.97	1.084	1.015	0.956	1.052
Expleo Solution	0.919	1.086	1	0.919	0.998
Vakrangee Software	1	1.244	1	1	1.244
Birlasoft	0.872	1.108	1.013	0.861	0.966
Nucleus Software Exports	1.042	1.062	1.109	0.939	1.106
R Systems International	1	1.22	1	1	1.22
Virinchi	1.279	1.043	1	1.279	1.333
Saksoft	1.097	1.072	1.088	1.008	1.175

Table 5: Malmquist Index for March 2015

March 2015					
Companies	**teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	1	0.904	1	1	0.904
Infosys	1.196	0.852	1.4	0.854	1.019
Wipro Limited	0.952	0.992	1.102	0.864	0.945
Tech Mahindra	0.775	1.019	0.934	0.83	0.789
Oracle Financial ServicesSoftware	1.275	1.026	1	1.275	1.309
Mphasis	1.716	1.12	1.99	0.862	1.922
Mindtree Limited	0.94	1.006	0.992	0.947	0.945
NIIT Technologies	0.911	1.016	0.928	0.982	0.926
Cyient	0.972	1.032	1.022	0.951	1.003
Zensar Technologies	0.962	1.011	1	0.962	0.973
Tata Elxsi	1	0.998	1	1	0.998
Persistent Systems	0.962	1	0.969	0.993	0.962
Sasken Technologies	1.462	0.968	1.628	0.898	1.415
Expleo Solution	0.87	0.999	1	0.87	0.869
Vakrangee Software	1	1.753	1	1	1.753
Birlasoft	1.235	1.055	1.104	1.118	1.303
Nucleus Software Exports	0.937	0.979	0.994	0.942	0.917
R Systems International	1	1.019	1	1	1.019
Virinchi	0.978	1.099	1	0.978	1.074
Saksoft	0.877	1.054	0.979	0.896	0.924

Table 6: Malmquist Index for March 2016

March 2016					
Companies	**teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	1	1.006	1	1	1.006
Infosys	0.869	1.071	1	0.869	0.931
Wipro Limited	0.873	1.022	1.209	0.722	0.892
Tech Mahindra	0.975	1.008	1.071	0.91	0.982
Oracle Financial Services Software	0.978	0.979	1	0.978	0.958
Mphasis	0.965	1.026	0.977	0.988	0.991
Mindtree Limited	0.917	1.063	1.008	0.909	0.974
NIIT Technologies	0.983	1.018	1.008	0.975	1
Cyient	0.927	1.038	0.963	0.963	0.962
Zensar Technologies	0.914	1.012	0.994	0.92	0.925
Tata Elxsi	1	1.047	1	1	1.047
Persistent Systems	0.908	1.058	0.998	0.91	0.961
Sasken Technologies	1.246	1.169	1.039	1.199	1.456
Expleo Solution	1.253	0.999	1	1.253	1.252
Vakrangee Software	1	0.994	1	1	0.994
Birlasoft	0.821	0.964	0.987	0.831	0.792
Nucleus Software Exports	0.729	1.034	0.725	1.007	0.754
R Systems International	0.799	1.022	0.862	0.927	0.816
Virinchi	0.996	1.029	1	0.996	1.025
Saksoft	0.941	0.994	1.022	0.921	0.935

Table 7: Malmquist Index for March 2017

March 2017					
Companies	**Teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	1	0.889	1	1	0.889
Infosys	0.957	1.014	1	0.957	0.97
Wipro Limited	0.962	0.925	1	0.962	0.89
Tech Mahindra	1.104	0.861	1	1.104	0.951
Oracle Financial Services Software	1.026	1.065	1	1.026	1.093
Mphasis	1.043	0.978	0.997	1.046	1.02
Mindtree Limited	1.174	0.87	1	1.174	1.022
NIIT Technologies	0.988	0.942	0.892	1.107	0.931
Cyient	1.175	0.886	1.05	1.119	1.041
Zensar Technologies	1.16	0.849	0.98	1.184	0.984
Tata Elxsi	1	0.869	1	1	0.869
Persistent Systems	1.112	0.958	1.038	1.071	1.065
Sasken Technologies	0.461	0.856	0.572	0.806	0.395
Expleo Solution	1.053	0.814	1	1.053	0.857
Vakrangee Software	1	0.953	1	1	0.953
Birlasoft	1.131	0.832	0.954	1.186	0.94
Nucleus Software Exports	1.157	0.974	1.167	0.991	1.126
R Systems International	1.107	0.842	1.039	1.066	0.933
Virinchi	0.75	1.077	0.953	0.787	0.808
Saksoft	1.102	0.897	1	1.102	0.988

Table 8: Malmquist Index for March 2018

March 2018					
Companies	**Teffch**	**techch**	**pech**	**sech**	**tfpch**
Tata Consultancy Services	0.962	1.006	1	0.962	0.967
Infosys	1.224	0.981	1	1.224	1.201
Wipro Limited	0.97	1.008	1	0.97	0.978
Tech Mahindra	0.835	1.153	0.961	0.869	0.963
Oracle Financial Services Software	0.895	0.906	0.914	0.979	0.811
Mphasis	1.103	1.07	0.996	1.108	1.18
Mindtree Limited	0.84	1.178	0.792	1.061	0.989
NIIT Technologies	0.847	1.208	0.828	1.024	1.023
Cyient	0.815	1.204	0.784	1.039	0.981
Zensar Technologies	0.752	1.192	0.725	1.038	0.897
Tata Elxsi	1	1.022	1	1	1.022
Persistent Systems	0.788	1.197	0.758	1.04	0.943
Sasken Technologies	0.97	1.027	0.932	1.041	0.996
Expleo Solution	0.947	1.144	1	0.947	1.083
Vakrangee Software	1	1.054	1	1	1.054
Birlasoft	0.834	1.178	0.796	1.048	0.982
Nucleus Software Exports	1.091	1.006	1.035	1.054	1.098
R Systems International	0.939	1.178	0.984	0.953	1.105
Virinchi	0.791	1.301	1.05	0.753	1.029
Saksoft	0.816	1.224	1	0.816	0.999