An Analysis of Productivity and Efficiency of Pharmaceutical Industry in India, 1997 - 2011

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DECLARATION

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I hereby declare that, the work presented in the thesis entitled "An Analysis of Productivity and Efficiency of Pharmaceutical Industry in India, 1997 - 2011" has been carried out by me under the supervision of Professor Bandi Kamaiah, School of Economics, University of Hyderabad, and to the best of my knowledge no part of this thesis was earlier submitted for the award of any research degree or diploma of any University.

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This is to certify that, the research embodied in the present thesis entitled "An Analysis of Productivity and Efficiency of Pharmaceutical Industry in India, 1997-2011" has been carried out by **Mr. Aas Mohammad** under our supervision for the full period prescribed under Ph.D. ordinances of the University, and no part of this thesis was earlier submitted for the award of any research degree or diploma of any University.

As per the UGC regulations (2009) regarding the procedure for the award of Ph.D. Degree, one research paper should be published in a refereed journal before submitting the Ph.D thesis, I got the research paper published with my supervisor as a part of fulfilment of the above requirement; the detail is given in the appendix.

Signature of Supervisor | Dean of the School

(Professor B. Kamaiah) | Professor G Nancharaiah

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ABSTRACT

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1. CHAPTER

INTRODUCTORY BACKGROUND AND OBJECTIVES OF THE STUDY

1.1 Introduction:

Being healthy is a foundation for economic development and essential for a good quality of life. Better health has boosted rates of economic growth and overall development worldwide through improving productivity and thereby enhancing human capital. Therefore, health has been defined both as cause and effect of economic development. Pharmaceutical industry plays an important role in healthcare with the help of well-trained and motivated health professionals, medical innovation, and in particular, by improving access to medicines. Therefore, the pharmaceutical industry is specifically recognized in the UN Millennium Development Goals, as an actor that can contribute to economic development. Further, the pharmaceutical industry can play critical roles not only in improving access to medicines and quality care for citizens of developing countries, but also in expanding their economic opportunities. While the major focus of healthcare industry is to provide access to health services and quality medicines to the public, it also provides significant socio-economic benefits to society by expanding economic opportunities through job creation, supply chain, training and shaping public policy. The industry also plays an important role in technological innovation, which may reduce costs of economic activity in the economy.

There are expectations that pharmaceutical industry should contribute more to economic development, through their own activities and indirectly, through improvements in healthcare infrastructure and capacity building. These activities, though longer-term in nature, can lead to large-scale economic impact in developing countries. This reflects the complex role of companies in healthcare, as well as the special obligation inherent in a sector whose products and services are needed by people when they are most vulnerable. The main contributors in the healthcare sector particularly in the pharmaceutical industry are branded drug manufacturers, generic drug manufacturers, firms developing bio-pharmaceutical products, non-prescription drug manufacturers, firms undertaking contract research. In addition, there are also enablers of the industry such as universities, hospitals and research centres that play a role in R&D activities.

1.2 An Overview of Indian Pharmaceutical Industry:

Indian pharmaceutical industry is one of the largest and highly developed science-based industries among developing countries. Today the industry is the fourth largest pharmaceutical producer in the world, after USA, Japan and Germany, with around 8% share of global production in terms of volume and ranks 13th in terms of value, constituting around 1.5% of the world. The Indian pharmaceutical market reached US$ 22.86 billion in size in March 2010 of which the share of export is around 40% (around US$ 9.25 billion) and expected to grow by 14.1% per year in 20011-12 and 19% in 2013 (AR 2011-12). The total value of output of the Indian pharmaceutical sector grew more than tenfold from Rs. 5700 crores in 1991 to Rs. 61219 crores in 2006 and Rs. 104209 crores in 2010. The Indian pharmaceutical industry is growing very rapidly with increasing international presence and emerged as a technologically dynamic manufacturing industry in the recent years (Kumar and Pradhan, 2003). The industry has succeeded to achieve a significant scale and level of technological capability for manufacturing modern drugs cost effectively to emerge as a major force in the pharmaceutical products in the world. 70% of the India's domestic requirement of the bulk drugs (the active pharmaceutical ingredients) and almost 100% of formulations (the end products) are being procured by the Indian pharmaceutical industry (Pradhan, 2006). In addition to fulfilling the needs of domestic demand, the industry is also focussing on contract manufacturing, contract research, clinical trials, R&D activities, and direct exports to developing as well as developed nations. As a result, the industry today possesses the largest number of US Food and Drug Administration (FDA) approved manufacturing facilities outside USA.

The main activities of the Indian pharmaceutical industry can broadly be classified into the production of bulk drugs and formulations. The bulk drug business is essentially a commodity business, whereas the formulation business is primarily a market driven and brand-oriented business. The indigenous firms are engaged in producing both bulk drugs as well as formulations, whereas, the multinational companies (MNCs) have continued to focus only on the formulations business. India is known today for producing high quality generic medicines that are sold globally. Further, India is known to be one of the fastest growing pharmaceutical markets in the world. The following factors have fuelled the growth of drugs and pharmaceutical market in India;

(i) Rapidly growing population of over a billion;

(ii) Fast growing Indian economy with increasing incomes;

(iii) Changing disease profile and a huge patient base;

(iv) Improvement in healthcare infrastructure and penetration of health insurance;

(v) Enhancing technological base;

(vi) Increasing expenditure on R&D;

(vii) Low manufacturing cost;

(viii) Adoption of patented products;

(ix) Patent expiries and aging population in the US, Europe, and Japan.

Apart from the above factors there are various policies and laws introduced by the Government of India such as; Drugs and Cosmetics Act (1940), Drugs Policy (1986), Indian Patents Act (1970), Drug Price Control Order (1995), Pharmaceutical Policy (2002), Indian Patents (Amendment) Act (2005) etc which have played a major role in the growth of Indian pharmaceutical Industry to consolidate their position in a competitive environment. The soft patent regime prior to 2005 provided opportunities for this industry to witness significant growth particularly in generics production and exports. During this time, the industry prepared itself to surge ahead in the competitive global environment by adopting strategies such as increasing R&D activities, patent filings, inorganic growth strategy, contract manufacturing and research, co-marketing and co-licensing arrangements, and diversification of markets.

At present, India has become one of the leading global players in pharmaceutical sector with vast opportunities for both the domestic and foreign markets. The Indian pharmaceutical industry is entering an era in which it is not only going to play a crucial role in providing generics medicine to the world but also going to be a global hub for R&D activities, which may be in the area of new drug discovery or different stages of clinical trials. The industry is preparing itself to face the challenges of new patent regime and increasing competition from low cost manufacturing and R&D destinations like China. Such challenges are helping the industry to modify its business strategies and thereby to retain its competitive position in the pharmaceutical world. Many Indian pharmaceutical companies have adopted the strategy of inorganic growth through mergers and acquisitions (M&A). Such activities are enhancing the strengths of two entities to get market access, new technologies and also new products. Indian pharmaceutical industry has also been increasing the R&D related outlays significantly in the recent years. Another noticeable trend which has been observed in the industry in recent past is that it has emerged as an attractive destination for sourcing contract research, particularly clinical trials, as also contract manufacturing by many large firms from the developed countries. A well-developed manufacturing base, low cost R&D and large pool of skilled man-power are some of the factors which have contributed a lot in the growth of Indian pharmaceutical industry in these business segments.

The size of Indian pharmaceutical industry in 2005 reached the level of around 10,000 units of which around 300 units were large and medium pharmaceutical firms including both domestic and MNCs (GOI, 2009). Not only the number of units increased, the profitability of the sector also showed steady rise which acted as an incentive for increasing their investment in R&D related activities. The indigenous firms dominated the Indian market with more than 70% of the market size. Strong process R&D and low manufacturing cost helped domestic firms to perform well in the export markets. The Indian pharmaceutical industry has also shown good performance in terms of exports. It is one of the top export items from India accounting for more than 4% of India's total exports in 2006-07. Exports, which constitute around 40% of the industry's total production, have grown at a compound annual growth rate (CAGR) of 14% in the last decade. Export has also played an important role in accelerating growth of the indigenous pharmaceutical firms.

India exports its pharmaceutical products to more than 65 countries across the world. Major export markets include highly regulated markets such as USA, Germany, UK and Canada. Europe is the biggest export destination for Indian pharmaceuticals accounting for more than 30% of the total exports, followed by America (25%). Indian firms have a cost advantage that facilitates the production of drugs at much lower cost compared to other developed countries. During 2003-04 to 2007-08, the pharmaceutical industry of India has been identified as one of the main drivers of the high export-led growth of India (GOI, 2008) and an employment generator possessing enormous positive externalities (GOI, 2009). Since the GOI recognized the product patent in drugs after 2005, MNCs have started showing renewed interest in Indian market. Lower production cost in India is another reason for attracting the MNCs and Foreign Direct Investment (FDI) inflows in pharmaceutical sector. According to the Economic Survey (2006-07), pharmaceutical industry accounts for about 2.91 percent of total foreign direct investment into the country. The foreign direct investment in pharmaceutical sector is estimated to have touched US$ 172 million, thereby showing a compound annual growth rate of about 62.6 percent. Drugs and pharmaceuticals sector is at 8th rank in India's top 10 foreign direct investment attracting sectors.

Some of the big Indian MNCs like Dr. Reddy's Lab, Cipla Ltd, Torrent Pharmaceutical Ltd, Cadila pharmaceutical Ltd, Ind-Swift Laboratories Ltd, Ranbaxy Laboratories Ltd, etc have created awareness about the Indian market prospects in the international pharmaceutical market. Approvals given by Foods and Drugs Administration

(FDA) and Abbreviated New Drug Application(ANDA),Drug Master File (DMF) have also played an important role in making India a cost effective and high quality product manufacturer in the world. In addition, the changes that have taken place with regard to the patent laws in terms of change of process patent to product patent have helped the Indian pharmaceutical industry in reducing the risk of loss of intellectual property. At present, tremendous progress has been seen in the pharmaceutical industry related to infrastructure development, technology base creation, increasing expenditure on R&D related activities and manufacture of a wide range of products. Demand from the exports market has been growing rapidly due to the capability of Indian players to produce cost-effective drugs with world class manufacturing facilities. Bulk drugs of all major therapeutic groups, requiring complicated manufacturing processes are now being produced in India.

1.3 Structure of Indian Pharmaceutical Industry:

The Indian pharmaceutical industry consists of large, medium, and small enterprises and is one of the world's most price competitive. It is also highly fragmented industry in the world and is estimated to have over 10,000 manufacturing units in its organised and unorganised sector. There are around 250 to 300 players in the organised sector accounting for less than 5 percent only, whereas 95 percent of the units of the industry are in the unorganised sector. Most of the firms in the unorganised sector are small and medium enterprises and the contribution of this segment is estimated around 35 percent to the industry's total turnover. The organized sector of this industry has played very important role in promoting and sustaining development in this field and accounts for around 60 to 70 percent of products in the market with the top 10 firms representing 30 percent. Approximately 75 percent of India's demand for medicines is fulfilled by local production.[1]

The Indian pharmaceutical industry is basically consists of manufacturers of bulk drugs and the formulations. The bulk drugs are the active pharmaceutical ingredients (APIs) which are used as raw materials for manufacturing the formulations i.e. the end products in the form of tablets, capsules, and syrup etc. According to the estimates of 2005, the ratio of formulations and bulk drugs in the Indian pharmaceutical industry is in the order of 3:1.[2] In case of formulation, India has become self-sufficient; around 85 percent of the formulations produced in the country are sold in the domestic market, though some life saving, new-generation-technology-barrier formulations are still being imported from other countries. In case of bulk drugs, India has been the world’s third-largest API manufacturing industry valued at nearly $ 2 billion in 2005. Currently, India’s drug industry produces more than 400 different APIs and is among the world’s top five API producers accounting for approximately 6.5 percent of the world’s API production.[3] At present, the drug prices in India are amongst the lowest in the world. India now has become a source of relatively good quality and cheap medicines for the rest of the world which indicates a healthy growth of the Indian pharmaceutical industry.

1.4 Changing Pattern of the Indian Pharmaceutical Industry since Independence:

During the last four decades the Indian pharmaceutical industry has transformed itself from being almost none existing till 1970’s, to being a prominent provider of

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[1] The Organisation of Pharmaceutical Producers of India (OPPI)
[2] OPPI
[3] Patricia Van Arnum, “The Changing Fortunes for APIs,” Pharmaceutical Technology, Jan. 2, 2007.

pharmaceutical products to the world today. At the time of independence in 1947, the Indian pharmaceutical market was dominated by Western MNCs that controlled between 80 to 90 percent of the market primarily through importing most of the bulk drugs from their parent companies abroad and selling the formulations in India at unaffordable prices. During this period, the patent regime was based on the Indian Patents and Designs Act, 1911, which had recognized both product and process patents. This Act worked as major entry barrier for domestic firms to enter pharmaceutical manufacturing because most of the drugs and pharmaceutical patents in India during that time were held by foreign MNCs. As a result, the Indian pharmaceutical market remained import-dependent until the government of India initiated policy stand towards this industry with the objective of achieving self-reliance in healthcare sector through domestic production. In 1972, government of India relaxed the patent law and allowed the indigenous companies to reverse engineer the patented drugs and produce them using a different process that was not under patent. The government discouraged the entry of MNC's by imposing restriction on foreign equity up to 40% to encourage the domestic industry. The Act had contributed to significant reduction of share by MNCs in the total formulation production in the country and proved to be instrumental in the growth of indigenous pharmaceutical production. The number of domestic firms engaged in pharmaceutical production increased considerably and made strong manufacturing base to fulfil the domestic requirement of bulk drugs and formulations. During 1990s economic reforms were introduced which substantially relaxed barriers to business and trade and induced the new entry of firms into the pharmaceutical industry. FDI was also permitted up to 100% for the manufacture of drugs and pharmaceuticals.

In 1995, another change took place in Indian pharmaceutical industry with the establishment of the World Trade Organisation under which India became a signatory of the Trade-Related Intellectual Property Rights agreement and was supposed to introduced the product patent regime by 2005 (Exim, 2007). In the year 2005, India introduced the product patent and replaced the old process patent regime by the product patent regime. The Patent Amendment Act 2005, passed by the Parliament in its budget session of 2005, brought the Indian Patent Act in full conformity with the intellectual property system in all respects. Under the new product patent regime Indian firms were unable to copy and sell patented drugs. Therefore no patented drugs that were launched after 1st January 2005 could be copied and sold. After the implementation of the product patent in India, a number of domestic firms started setting up their own R&D units as they realized the importance of R&D related activities (Jha, 2007). The focus of pharmaceutical firms has come to be governed by the size of their operations, with large firms emphasizing on discovery and development of new drugs; medium firms stressing on producing generics and small firms opting for contract manufacturing (Rao, 2008). Thus, the product patent regime has created a competitive environment in the Indian pharmaceutical industry.

1.5 Problem Statement:

Indian pharmaceutical industry is going through a phase of transition due to policy changes. Under the process patent regime of 1970, the industry flourished with supportive policies of the Government of India that were in force for more than three decades. This situation has however, changed in the recent past under the TRIPS, in 1995, and subsequently in 2005, thereby paving the way for product patenting. The changes in various policies related to trade and entry of multinational companies in Indian pharmaceutical industry started during early seventies. However, the pace of growth of this industry has shown a remarkable upswing only after 1991 and it shows a major jump after the introduction of product patent regime in 2005. While these changes have intensified the competition in the pharmaceutical sector from the foreign multinational enterprises, it has also provided new opportunities for the Indian pharmaceutical firms. In order to compete effectively with the foreign MNCs, Indian firms need to change their age-old strategies. The new emphasis of the domestic firms should be on R&D related activities to come out with new products or process, to shift its operational base in the global market, to integrate with the raw-material industry and reduce transaction cost at different stages of manufacturing.

Taking into consideration all these significant policy changes, that are expected to have important implications for operating performance of the pharmaceutical industry, it has become imperative to analyze the performance of the Indian pharmaceutical industry during the recent years and to find out factors responsible behind variation of industry's efficiency and productivity levels. It is also important to examine in the liberalized regime whether only a handful of firms performed better in maximizing their output while many others have lagged behind. This can be studied by undertaking an efficiency and productivity analysis because the efficiencies of firms play a very crucial role in dictating the survival and growth of companies in various segments of the industry particularly at the time when the industry is witnessing a dynamic structural transformation owing to external changes. It is also important to focus on the efficiency and productivity changes of various groups such as indigenous and MNC, big firms and small firms, firms with and without R&D expenditure and the firms targeting international market over a period covering both process and product patent regimes and to examine the overall relative performance of all firms of the Indian pharmaceutical industry.

1.6 Objectives and Hypotheses of the Study:

1.6.1 Objectives:

The study aims to evaluate the performance of Indian pharmaceutical industry by examining the levels of technical efficiency and total factor productivity (TFP) of individual firms from the industry using unit-level data from the Prowess Database of Centre for Monitoring Indian Economy (CMIE), for the period 1997 to 2011 which cover both the period of process patent regime and product patent regime. This permits us to examine how the levels of productivity and efficiency of the Indian pharmaceutical industry have changed over the years.

The specific objectives of the study are as follows:

(i) To present a brief background of pharmaceutical industry in India since independence and examine the implications of process patent regime and product patent regime.

(ii) To examine the levels of efficiency of pharmaceutical firms in India and discusses the determinants of efficiency.

(iii)To analyze the relative performance of Indian pharmaceutical industry in the process patent regime and in the product patent regime and undertake a comparison of efficiency gains across different groups of firms.

(iv) To examine the productivity change and its various components for the Indian pharmaceutical companies over the period of 2001 to 2011.

(v) To estimate the technical efficiency of Indian pharmaceutical industry from 1997 to 2011 using the parametric, Stochastic Frontier Analysis (SFA) and non-parametric, Data Envelopment Analysis (DEA) techniques.

1.6.2 Hypotheses:

In this study the following hypotheses are formulated,

(i) The MNCs group of firms is relatively more efficient compared to the indigenous firms.

(ii) The firms with R&D related outlays are technically more efficient compared to the firms without any R&D related outlays.

(iii) The big firms are more efficient compared to the small firms group.

(iv) The firms producing both bulk and formulation are technically more efficient compared to the firms producing only bulk drugs and only formulations.

(v) The high export intensive firms are more efficient compared to the low export intensive firms.

(vi) Technical efficiency of firms is not time invariant especially in the post TRIPS and post product patent regime.

1.7 Scope and Limitation of the Study:

The present study covers the post reform and post TRIPS period i.e. 1997-2011. The data on various inputs and outputs for estimating efficiency and productivity of the Indian pharmaceutical industry have been compiled from the “Prowess Database” published by the Centre for Monitoring Indian Economy. Both parametric, stochastic frontier approach (SFA) and a non parametric, data envelopment analysis (DEA) techniques have been used to estimate technical efficiency. Malmquist index, Fare-Primont index and Hicks-Moorsteen indices have been utilized for calculating productivity of the Indian pharmaceutical firms. In SFA four measures of outputs namely, total sales, foreign exchange earnings, profit after tax and total assets have been used. Raw material, wages and salaries of labour, marketing and advertising cost and capital have been used as inputs. In SFA the technical efficiency scores have been presented for different combinations of outputs and inputs. The firms have also been divided into different groups namely, indigenous, MNCs, big, small, producing bulk and formulation, only formulation, only bulk, having expenditure on R&D and non-R&D, high export intensive and low export intensive based on their size, origin, product varieties and R&D expenditure and export performance.

To estimate technical efficiency using DEA, two alternative combinations of inputs and outputs have been used however we have presented only one combination, because of space constrain and having more or less similar trend. The inputs considered are raw material, labour, power and fuel, marketing and advertising cost, capital and net fixed assets. The outputs considered are total sales, foreign exchange earnings, profit after tax and total assets. The technical efficiency under constant returns to scale (CRS), variable returns to scale (VRS), and scale efficiency, has been estimated for different groups of firms and the entire industry as a whole i.e. all firms together. To calculate the total factor productivity of the firms using various productivity indices as mentioned above, we have used total sales, foreign exchange earnings, profit after tax and total assets as output variables. The input variables are raw material, labour, power and fuel, marketing and advertising cost, net fixed assets and capital.

The main limitation of the study is that only technical efficiency measures are calculated. The other measures of efficiency such as allocative, cost or profit efficiencies have not been estimated in view of non-availability of consistent price data. For calculating total factor productivity, we have taken data from 2001 to 2011 because enough data was not available from 1997 to make the panel balanced.

1.8 Chapter Scheme

The present study is organized into five chapters. The first chapter gives the study background, objectives, hypotheses and limitations of the study. The second chapter discusses the evolution and growth of the Indian pharmaceutical industry. The third chapter presents a review of the relevant literature. The fourth chapter deals with the technical efficiency using DEA and SFA approaches. The fifth chapter presents the productivity analysis of the Indian pharmaceutical industry using Malmquist index, Fare-Primont index and Hicks-Moorsteen index. This is followed by summary and conclusion in the last chapter.

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2. CHAPTER

EVOLUTION AND GROWTH OF INDIAN PHARMACEUTICAL INDUSTRY

2.1 Evolution of Indian Pharmaceutical Industry

The pharmaceutical industry in India is nearly a century old phenomena though the traditional systems of Ayurveda, Siddha and Unani medicines have been in practice for many centuries. The pharmaceutical industry in India is basically an import by the British. In 1935 they set up a teaching institution at Calcutta for the purpose of training their medical practitioners. They used to ship the raw material from India to England and return the final products for the physicians' use. The domestic production of pharmaceutical products in India started in 1901 with establishment of the first Indian-owned drug factory the Bengal Chemical and Pharmaceutical Works at Calcutta with the pioneering efforts of Acharya P C Ray. During this time many British medical scientists came to India to study the tropical infectious diseases which were spreading among their armies. They established several pharmaceutical research institutes like the institute of tropical disease: King Institute of Preventive Medicine at Madras (1904); Haffkine Institute at Bombay (1904); the Central Research Institute at Kasauli (1905) and the Pasteur Institute at Coonoor (1907). However these units faced several problems like competition from foreign companies and lack of government support. Up to the beginning of World War II, England continued to exploit India and kept as its exclusive preserve for launching its pharmaceutical products in the Indian market. A few domestic enterprises had come up but could not make any significant impact in the Indian drug market. It is only from the Second World War onwards that the indigenous firms started producing conventional medicines like serums and vaccines. The shortage of imported drugs in the war times resulted in a number of small firms coming up by producing tablets and making other formulations.

The government was focusing to achieve self-sufficiency in healthcare sector in a systematic way by investing in pharmaceutical industry through importing pharmaceutical products and for which government did not discourage foreign firms from competing in India. More foreign firms started marketing their products in Indian drugs market and some of them started bulk import of raw material and producing tablets, capsules, syrups and other formulations. The indigenous firms also started producing formulation like tonics, cough syrups and protein foods. The Drugs Act of 1940 was enacted and rules were laid down in 1945 and 1948 authorising the states to implement the drug standards control. The Central Drugs Laboratory (1950) was set up as the appellate authority for drug standards control and the Central Drug Research Institute (1952) for stimulating research and development activities in this field.

At the time of independence, the Indian pharmaceutical industry was dominated by the foreign MNCs that controlled approximately 90% of Indian market through importation. During this period, the patent regime was based on The Indian Patents and Designs Act, 1911, which recognized both products as well as process patents. Most of drugs and pharmaceutical patents in India were held by foreign MNCs. They were importing most of the bulk drugs (active pharmaceutical ingredients) from their parents companies and selling the formulations (the final products) in India at unaffordable prices. The drug prices in India during this period were among the highest in the world. Therefore several public drug manufacturing units like Indian Drugs and Pharmaceutical Limited (IDPL), Hindustan Antibiotics Limited (HAL), Bengal Immunity Limited (BIL), Bengal Chemicals and Pharmaceutical Limited (BCPL) and Smith Stanistreet Pharmaceutical Limited (SSPL) were set up. Despite all these efforts the Indian pharmaceutical industry was still in its infancy and remained import dependent through the 1960s until the government started the policies aimed to achieve self-reliance through domestic production.

The experts blamed the existing IPR (intellectual property rights) regime for this continuous dependence on external supply. The existing IPR regime was inherited from the colonial days in fact the 1856 Act which was consolidated into the Design and Patent Act, 1911 implementing both process and product patents. The term of protection for these patents were 16 years and could be further extended for another 10 years if the patentee believed that he had not been adequately defrayed for his innovation (Lalitha, 2002). The Patent Enquiry Committee (1948-1950) specified that "the Indian patent system has failed in its main purpose, namely to stimulate inventions among Indians and to encourage the development and exploitation of new inventions for industrial purposes in the country so as to secure the benefits thereof to the largest section of the public" (Government of India, 1949, cited by Ramana, 2002). Therefore, it recommended amendments to the existing IPR regime and the establishment of a new institutional arrangement, more flexible in order to encourage the development of the domestic industry and ensuring self-sufficiency in healthcare sector and reduce the price of medicines affordable to people in India.

The decade of 1970's was a turning point for the Indian pharmaceutical Industry. In 1970, the Government of India introduced some policy changing regarding the patent laws. A new Patent Act was introduced which recognized only process patent and not product patent. This Act became effective from 20th April 1972 onwards, allowing Indian firms to reverse engineer the patented drugs and produce them using a different process that was not under patent. Moreover, the protection term of the patent was also reduced to seven years. The entry of MNC's was also discouraged by restricting foreign equity to 40%. The licensing policy was also biased towards indigenous firms and firms with lesser foreign equity. In addition, along with industrial policy measures, The Drug Price Control Orders (DPCO) was also established in 1970 in order to enhance people's access to quality drugs. There was very little incentive for MNCs to introduce new products in India. These policy measures taken by GOI provided conducive environment which laid foundations of a strong manufacturing base for bulk drugs and formulations and accelerated growth in the Indian pharmaceutical industry. All these steps were taken deliberately to develop and encourage the domestic health care industry in producing cheap and affordable drugs. As a result the Indian pharmaceutical industry not only met the domestic requirement but started exporting bulk drugs as well as formulations to the international market.

In 1995, when the World Trade Organization (WTO) came into being, India being one of its founder members automatically became a signatory of the Trade-Related Intellectual Property Rights (TRIPS) agreement and was under compulsion to introduce a product patent regime by 2005 (EXIM, 2007). Accordingly in the year 2005, the Government of India reintroduced the product patent and the 35-year old process patent regime was modified and replaced by the more rigorous product patent regime. It required patents to be provided to products as well and the TRIPS coverage was extended to food, drugs and medicines which were exempted earlier from the patent. The term of a patent protection has been extended to twenty years compared to the seven years which was provided by the act of 1970. Thus, with the introduction of product patent the importance of research and development (R&D) activities for the Indian pharmaceutical industry has gone up with a number of firms setting up their own R&D units (Jha, 2007), and collaborating with research laboratories (FICCI, 2005). Since the GOI recognized the product patent in drugs after 2005, MNCs have started showing renewed interest in Indian market and making a comeback attracted by India's traditional strengths in contract manufacturing as an outsourcing location for research and development activities, particularly for clinical trials and other services. Lower production cost in India is another reason for attracting the MNCs and Foreign Direct Investment (FDI) inflows in pharmaceutical sector. All these policies changes started from 1990s created a new chapter in the Indian Pharmaceutical sector where free imports, foreign investment and technological superiority determined the structure of the industry. Today the Indian pharmaceutical industry has achieved a significant scale and level of technological capability for manufacturing modern drugs cost effectively to emerge as a major force in the pharmaceutical products in the world.

The Evolution of Indian pharmaceutical industry can be classified into the following three phases; each phase is characterised by different policy regimes and industry's response to those policies:

(1) First Phase (Till -1970s)

(2) Second Phase (1970 to 1995)

(3) Third Phase (1995 onwards)

2.1.1 First Phase (Till -1970s):

During this phase, the Indian pharmaceutical industry was very small not only in terms of number of firms but also in terms of volume of production. The Indian pharmaceutical market was dominated by the foreign firms and India was dependent on the import. During this period, the patent regime was based on The Indian Patents and Designs Act, 1911, which was in favour of the foreign MNCs because it recognized both product and process patents and around 99% patents in pharmaceutical sector were held by those companies. In this way this act was a major hindrance for the Indian firms in manufacturing pharmaceutical products which needed to be relaxed to promote and encourage the domestic industry and local production in the country. During this time, the MNCs were taking advantage of the existing patent regime and exploiting the Indian drug market by selling their products at very high prices. In order to overcome the problem of high drug prices and low technical base of the domestic companies, the government of India set up some public sector drug manufacturing units with technical support from countries like Russia which played an important role in producing critical drugs at relatively lower prices for domestic market. MNCs were also encouraged to set up their manufacturing base in India in order to strengthen the domestic industry.

2.1.2 Second Phase (1970-1995):

The decade of 1970s witnessed many policy changes made by the Government of India towards the pharmaceutical industry regarding the patent regime in order to enhance the manufacturing base in the country. In the year 1970, the Government of India introduced a new Patent Act, which recognized the patent only on the process and not the product. According to this Act, drugs patented in other countries could be manufactured in India with a different process. Thus the Act encouraged reverse engineering and the development of alternative processes for products patented in other countries. The statutory term of a patent protection was shortened to seven years. The Drug Price Control Order was also established in 1970 to make essential medicines accessible and affordable to the Indian populace. In the year 1973 Foreign Exchange Regulation Act (FERA) was introduced to regulate the foreign MNCs in India by restricting them with holding foreign equity of not more than 40%. However the foreign pharmaceutical firms that involved in manufacturing bulk drugs with high technology were allowed to hold foreign equity more than 40% under FERA. In the year 1978, Government of India announced Drug Policy which played important role in reducing the MNCs dominance in Indian pharmaceutical market. The Drug Policy of 1978 was the first comprehensive drug policy enacted in India with the objective of achieving self-sufficiency in health care sector by promoting development of the domestic pharmaceutical industry. The policy was more concerned about the importance of R&D and technology and improved the technological capabilities of the industry by providing R&D promotional measures. The policy further strengthened the regulation on foreign firms with foreign equity of above 40%.[4] All these policy changes discouraged the MNCs to introduce new products in India and the share of MNCs in the total formulation production in the country also came down significantly. On the other hand, these measures accelerated the growth of the indigenous pharmaceutical industry. The size of the industry in terms of number of

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[4] Government of India 1982: Section II, 24-25

domestic firms engaged in pharmaceutical production increased over the period from 2200 units in 1969-70 to nearly 24000 in 1995-95.[5] The indigenous firms have also expanded their production capacity during this period. The production of bulk drugs, which increased from Rs. 18 crores in 1965-66 to Rs. 1518 crores in 1994-95. In terms of production of formulations it increased from Rs. 150 crores to Rs. 7935 crores during the same period. The growth in the production of formulation has been more compared to bulk drugs production because of the large scale generics production by indigenous firms. By 1991, domestic firms accounted for 70% of bulk drugs and 80% of formulations produced in the country.

The Indian drugs manufacturers started exporting to many developed as well as developing countries with the help of low cost and increased production capacity. From the 1990 onwards there has been a substantial growth in export of pharmaceutical products, especially for formulations. Since then, India has been maintaining a positive trade balance in pharmaceutical trade. The export of pharmaceutical products has increased from 2.0% of India's total exports in 1984-85, to more than 3% in 1995-96. The low priced generic export from India is playing a crucial role in making the Indian pharmaceutical industry more and more export oriented. There has been a substantial increase in the share of exports as percentage of total pharmaceutical production which increased from 3.22% in 1980-81 to 23.97% in 1994-95.

[5] Organisation of Pharmaceutical Producer of India

2.1.3 Third Phase (1995 onwards):

The year 1995 was very important in the history of Indian pharmaceutical industry because in this year World Trade Organisation (WTO) came into effect and the Trade Related Intellectual Property Right (TRIPS) was one of the agreements negotiated under WTO. The TRIPS agreement re-introduced the product patent regime in many countries including India. However developing nations were given ten years of transition period in order to make their patent policies TRIPS compliant. In the year 2005, India also introduced the product patent regime and became fully TRIPS compliant. The period after 1995 i.e. the Post-TRIPS period saw the strongest performance of the Indian pharmaceutical industry. The industry not only performed well in terms of production but also turned into a net foreign exchange earner during this period. Further, due to WTO initiatives, tariff and non-tariff measures affecting the world trade also came down that proved to be very helpful for Indian pharmaceutical industry to undertake activities such as clinical research, new drug development etc.

The size of pharmaceutical industry has increased not only in terms of the number of firms but at the same time, the profitability of the sector and the production level also has gone up during this phase. The introduction of the product patents in 2005 brought new business opportunities to the Indian pharmaceutical industry. During 2000s pharmaceutical outsourcing business increased in India. Earlier in the process patent regime, foreign pharmaceutical companies used to hesitate to manufacture new drugs in India because of the Patent Act of 1970, which did not recognise product patents on pharmaceutical products. However today they are increasing outsourcing manufacturing, drug discovery operations and clinical trials in India. In addition, the contract research and manufacturing services (CRAMS) business has also been growing rapidly in India. Many Indian companies have entered into CRAMS and the number of specialised CRAMS companies has also increased.

2.2 Growth and Major Changes in the Indian Pharmaceutical Industry since Independence:

Since independence, the growth pattern of the Indian pharmaceutical industry has been phenomenal despite the fact that this industry is the most regulated and controlled among all business segments. It has been a glowing example of success with the support of excellent performances of many factors including quality human resources, favourable policy environment, intellectual property rights (IPR) laws, national scientific and technological development, cost-effective manufacturing and proactive response to domestic and global business opportunities, institutional infrastructure etc.

However, after the introduction of WTO and TRIPS agreement, several new challenges have been posed before Indian pharmaceutical industry. The re-introduction of product patent is one of the challenges so as to meet the TRIPS obligations. Under such policy regime, Indian pharmaceutical firms are no longer allowed to exercise the reverse engineering process, which has been one of the major reasons for the growth of the industry since 1970. In addition, the economic reforms and liberalization process has reduced the tariffs and other trade barriers to a great extent thus making the imports cheaper in many countries. Under such environment, it is highly needed for Indian firms to be more innovative and also to explore overseas markets in order to remain globally competitive. Accordingly, to face all these challenges, the Indian pharmaceutical industry has been adopting a number of new business strategies to cope up with the changing scenario. Many Indian pharmaceutical firms have already adopted a number strategies at much earlier stage to deal with the new changes and challenges in the business environment. These strategies include increasing R&D activities, increasing patent filings, merger and acquisitions, contract research, contract manufacturing, diversification of market, contract research, and co-marketing alliances etc. Besides this, the government also took several policy measures in this direction such as simplifying various procedures and approvals regarding entry of foreign MNCs, approval of foreign direct investment up to 100 percent, promoting R&D technology transfer, approved new drugs and clinical trials etc, to make the industry more competitive.

2.2.1 Entry of Multinational Companies in Indian Pharmaceutical Industry:

Indian pharmaceutical industry started its business as importer of pharmaceutical products from western multinational companies. The technological base and infrastructure of Indian pharmaceutical industry was very poor at that time. Therefore, till 1970 Indian market remained dependent on import of medicines from countries like France Germany and UK. During this time, the foreign companies were enjoying the monopoly status and showing their interest in Indian market as their intellectual rights were protected by colonial patents laws. They were exploiting the indigenous market by charging high prices for their products in India. The government of India also did not discourage the entry of MNCs for competing in Indian market because during that period achieving self reliance in industrial sector was supposed to take place through the heavy investment in industries.

Though the multinational companies were continually showing their increasing participation in Indian market since the colonial period, however after the 1970s the entry and share of multinational companies in manufacturing drugs and pharmaceuticals started declining due to several policy changes on the part of the government. The government deliberately discouraged the entry and share of foreign multinationals by relaxing patent laws, pricing policy and several other measures in order to develop the domestic industry and local production of bulk drugs and formulations. But again the scenario changed in 1995 with the TRIPS agreement and the increased share of multinational companies in the Indian pharmaceuticals market with the reintroduction of product patents in the country from 2005. In addition the new price control order is expected to be passed soon and the coverage of drug price control order will be reduced significantly. The foreign multinational companies already started strengthening their business in India by restructuring their operations, increasing stakes in existing ventures, setting up new ventures or entering into collaboration with domestic firms. The automatic foreign direct investments approval up to 100 percent into the pharmaceutical industry in 2000 has also supported the growing interest of multinationals which is expected to increase investment in research and development infrastructure by those companies in India.

2.2.2 Foreign Direct Investment in Indian Pharmaceutical Industry:

The protection of IPR in the form of patents is necessary to attract foreign direct investment in a particular industry. The protection system influences the foreign direct investment inflows positively[6]. During the process patent regime, foreign direct investment had been very low in Indian pharmaceutical industry. The reasons for low

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[6] Lee J-Y and Mansfield E, Intellectual property protection and US foreign direct investment, The Review of Economics and Statistics, 78 (2) (1996) 181-186

levels of foreign direct investment in Indian pharmaceutical industry can be attributed to the absence of patent protection, bureaucratic delays, price controls etc during that time. But the benefits for the Indian pharmaceutical industry resulting from the policy environment change since the beginning of the 1970s also are important. It is also evident that the policies introduced by the Government during this period suited the industry by its performance over time. While the more protected environment in the 1970s and 1980s was helpful for the domestic firms to establish their presence in the industry, the adoption of an open economy framework in the 1990s promoted and encouraged the leading firms to expand their overseas operations. The latter aspect can be best understood by analyzing the performance of the leading firms in the industry.

During 1990s efforts were made by the government of India to attract the foreign direct investment in healthcare sector not only by abolishing licensing for pharmaceutical products but by allowing automatic foreign direct investment approvals up to 100 percent foreign ownership in this sector. India attracted foreign direct investment because of economic reforms, cheaper labour cost, lower country risk and geographic closeness to source countries. During the period of 1991-2004 the Indian pharmaceutical sector attracted around Rs 35 billion in foreign direct investment inflows, the risk of not recognizing product patents in India made multinational companies away from comprehensive technology transfer to their Indian affiliates. Regulations and controls, over the operations of foreign companies imposed by the Foreign Exchange Regulation Act (FERA) in 1973 were relaxed rapidly through the 1990s. The foreign firms started showing their real interest in Indian market when India adopted product patent in pharmaceuticals from 2005. The foreign direct investment inflows into Indian pharmaceutical industry during 2001-02 to 2004-05 were to the tune of Rs 1,671.4 crores. During 2005-06 to 2008-09 the amount of foreign direct investment inflows to the Indian pharmaceutical industry increased by 1.8 times to Rs 3,076.9 crore. As a proportion of total inflows, the share of Indian pharmaceutical industry declined to 0.7 per cent during 2005-06 to 2008-09 from 2.6 per cent during 2001-02 to 2004-05[7]. The foreign direct investment inflows into the Indian economy, including Indian pharmaceutical industry decreased during financial year 2010-11 with the decline becoming more pronounced towards the latter part of the year[8].

After the introduction of product patents in 2005 and the liberalized policy with regard to foreign direct investment in pharmaceutical sector, the western MNCs have largely turned towards India, the most recent being Merck & Co, which inaugurated its wholly owned subsidiary MSD India Pvt Ltd in July 2005 after being absent for approximately 20 years. Pfizer is one of the longest-established MNCs in India and was the first to set up R&D[9]. At present the FDI policy on pharmaceutical industry has become a matter of concern as abundant foreign investment is coming through the automatic (100%) route and the foreign companies do not require prior approval from the Foreign Investment Promotion Board (FIPB) to purchase as much as 100% of equity in the local drug market. The government allowed foreign investment in pharmaceutical industry up to 100% through automatic route in expectation of new investments to flow into this sector for further growth. However, the recent trend has shown that the foreign MNCs are

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[7] FDI in India statistics, 2010, http://dipp.nic.in/ fdi_statistics/india_fdi_index.htm. (12 January 2010).

[8] 43rd Annual Report 2008-09, Organisation of Pharmaceutical Producers of India (OPPI), New Delhi, 2009, p. 1-72.

[9] http://www.in.kpmg.com/pdf/Indian%20pharma%20outlook.pdf, 4th January, 2011

taking over the existing businesses from the local players to instantly grab a significant market share instead of making new investments that help in expanding the industry.

2.2.3 Research and Development (R&D) Expenditure in Indian Pharmaceutical industry:

The expenditure on R&D has great impact on the technological development and growth of a particular industry. Technology based improvements through innovations can be measured by the R&D related outlays made by pharmaceutical firms. Since the pharmaceutical industry is technology and innovation based, the R&D is the backbone of the industry. Since independence, India has been a net user rather than developer of R&D intensive pharmaceutical products because of several reasons such as inadequate investment resources, lack of sufficient skill in medical sector and poor R&D infrastructure in the country. During the process patent regime i.e. 1970s onwards, Indian pharmaceutical industry did not spend much on R&D related activities because of the absence of product patent for pharmaceutical products in India. The domestic Indian firms have grown their indigenous market through the creation of different processes of manufacturing the drugs. However after the introduction of TRIPS agreements in 1995, which made the product patent protection mandatory for the WTO member countries including India, the indigenous firms came to realize the important of R&D for the survival and growth of the company in the highly competitive environment from domestic and international MNCs. Therefore, since the implementation of product patent in 2005, domestic pharmaceutical companies have increased their allocation for R&D and their structure of R&D activities. Now they are more concerned about the R&D for new chemical entities and modification of existing chemical entities to develop new formulations and compositions. In addition, the incentives from the government for engaging in R&D activities also have increased significantly in the recent past.

The trend has changed as the amount of expenditure on R&D has gone up from Rs. 12crore in 1977 to 140 crore in 1994-95, 400 crore in 2001 and 2350 crore in 2006-07. However, the average R&D expenditure as percentage of sales turnover (R&D intensity) of Indian pharmaceuticals industry remained less than 2 per cent throughout the period till the beginning of the new millennium (2000-01) which is very less in comparison to the investment on R&D by foreign research intensive and innovative pharmaceutical companies, who spend 10 to 15 percent of the turnover on R&D[10]. However, the scenario is now changing as the leading pharmaceutical firms such as Ranbaxy, Dr. Reddy's, Cipla and Torrent etc are recognizing the importance of developing their own molecules to compete effectively in India and abroad. Therefore, they have been increasing their R&D budgets over the years. The research and development expenditure of the Indian pharmaceuticals industry increased up to 5% of the turnover in 2010-11[11]. The R&D expenditure, by top leading 30 Indian pharmaceutical companies has increased significantly Rs.5,360 crore during 2012-13 from Rs.4,478 crore in 2011-2012. This worked out to 7.8 per cent of their standalone net sales during 2012-13 as compared to 7.2 per cent in 2011-12. The consolidated R&D expenditure, including domestic and foreign subsidiaries, is much higher than standalone R&D expenditure[12].

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[10] Based on the data provided in The 2010 EU Industrial R&D Investment Scoreboard http://iri.jrc.ec.europa.eu/research/scoreboard_2010.htm).

[11] OPPI

[12] http://www.pharmabiz.com/NewsDetails.aspx?aid=78023&sid=1

2.2.4 Increasing Patent Filings:

The results of increasing R&D expenditure in the Indian pharmaceutical industry have been showing positive sign of growth particularly in case of the patents filed by and granted to Indian firms. The number of patents filed has been increasing significantly over the period of time. The Indian pharmaceutical firms have made large numbers of Drug Master Files and Abbreviated New Drug Application (ANDA) filing with US FDA over the years. However, over 90% of the patent filings by India are in the Indian patent office as resident. A significant number among them belong to the pharmaceutical industry. In the year 2005, regarding the patent filings outside India, USA was at the top the list with over 52% share, followed by European Patent Office (14%), China (7%), Japan (6%), Australia (4%) and UK (2%).

Indian pharmaceutical firms have comparative advantage in patent filings because of its high intellectual base and low cost R&D. According to the Global Competitiveness Report, 2006-07, India got high score for the parameter on capacity for innovation. Obviously, this was due to the high quality of scientific research and number of scientists and engineers available in the country. The sharp increase in R&D related outlays has shown considerable results in recent times in favour of the Indian pharmaceutical industry. Many Indian firms have introduced a number of new drugs in the domestic as well as in the international markets. Patent filing by Indian companies has also increased significantly. The Indian pharmaceutical industry has filed the largest number of Drug Master Files (DMFs) by 2005 with the USFDA[13]. The medium-sized pharmaceutical firms have accounted for significant share of DMF.

2.2.5 Contract Research and Manufacturing Services (CRAMS):

Basically, CRAMS can be classified into 3 segments: the production of intermediates, active pharmaceutical ingredients for new chemical entities, and the manufacture of generic drugs. In India, the CRAMS field has experienced a remarkable progress since the period of liberalisation i.e. 1990. Earlier the CRAMS focus was only on manufacturing but from the last 10 years the focus is towards chemistry services, finished dosage forms and drug delivery systems. However, at present the trends have changed from drugs manufacturer and marketing to an R&D solution providers. India has emerged as one of the world's leading CRAMS providers for MNC innovator companies. Many Indian CRAM companies have collaborated with global players. Globally India is the only country with more than 175 US FDA approved manufacturing units which makes it a preferred destination for MNCs to outsource their manufacturing services.

The Indian CRAMS market was estimated at $532 million in the year 2005, with 84 percent share of contract manufacturing and the remaining consisted mainly of contract research (not including clinical trials). The growth of the contract research and contract manufacturing has been around 40 percent in 2005 compared with 2004 and the industry experts estimated that the Indian companies have the capacity to gain between 35 percent and 40 percent of the global CRAMS market.[14] At present, the Indian

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[13] OPPI
[14] CRAMS: The Gateway to Indian Success, Focus Reports.net, Sept. 2006.

pharmaceutical industry has been generating $850 million per year by the contract research and manufacturing services (CRAMs). Around 8% of total Indian pharmaceutical business has been made by CRAMs over the last five years i.e. from 2007 to 2012[15]. Currently, the global CRAMS market is around US$ 60-70 billion (estimated to reach US$ 90 billion by 2015) of which contract manufacturing constitutes around 65 percent and contract research about 35 percent. Indian CRAMS business is around US$ 3.8 billion (estimated to reach US$ 8 billion by 2015). Global CRAMS market has grown (2005 - 2010) at the rate of 16 percent CAGR, while Indian CRAMS market has grown at 45 percent CAGR during the same period.

2.2.6 Contract Research:

Increasing drug discovery and development, complex review processes, rapidly escalating R&D expenditures and competition have created a situation where the pharmaceutical companies are compelled to outsource various R&D related activities to keep up the growth of the industry. It has pointed out by various studies that developing a new medicine is a long and costly process while the chances of success are very less. Statistics show that only 1 out of 5000 compounds tested eventually reaches the consumers and only 3 out of 10 drugs that reach the market would earn enough money to recover the cost incurred on R&D. Therefore the pharmaceutical companies are increasingly facing the pressure to bring out new products into the market with low cost of R&D. It is estimated that globally, around 20% of R&D related activities are undertaken outside the company either on a contract basis or investment basis. Such

[15] Reddy et al (2013), overview of CRAMS and its present status in India

trend provides possibilities of outsourcing the R&D related work to low cost destinations such as China and India.

The contract research includes drug discovery, pre-clinical as well as clinical research. The clinical trials are undertaken in order to determine whether a new drug or treatment is safe and effective. In India, the business of contract research has certain advantages in this regard such as; a well-developed pharmaceutical industry with strong manufacturing base; low cost of R&D; availability of qualified scientific man power; large patient population base for clinical trials etc. All these factors are responsible for India being an attractive destination for many foreign MNCs to source out their R&D related work particularly clinical trials. Further, India being a member of WTO, has moved forward towards the TRIPS compliance and clinical trials undertaken in India are now not only confined to evaluating new medicine for their own market but also many foreign companies are outsourcing contractual arrangement with Indian firms as also conduct R&D activities by setting up wholly owned Indian subsidiaries. Considering the current need of developing new drugs, many foreign big pharmaceutical companies are tying up with Indian producers to develop new chemical entities for global market.

The Government of India is also supporting such strategies by taking some initiatives to encourage contract R&D and strengthening up the infrastructure for pre-clinical research for vaccine and drug development in the country. The Indian Council of Medical research (ICMR) has set up two such large facilities, one in Mumbai and the other in Hyderabad. In addition the Government of India has also simplified and reduced the time taken for regulatory clearances to conduct clinical studies in India. Some of the

Indian pharmaceutical companies that have entered into contract research business are; GSK, Ranbaxy, Nicholas Piramal and Dr. Reddy Laboratories etc.[16]

2.2.7 Contract Manufacturing:

A number of pharmaceutical companies of the world are undertaking their manufacturing activities along with R&D activities to the low cost destinations such as India and China as a result of increasing pressure on the margins. It has been estimated that approximately 30 percent of global manufacturing activities are outsourced in the pharmaceutical sector. Out of the total manufacturing activities undertook more than two-thirds are related to outsourcing of primary manufacturing in the form of APIs and intermediates and the remaining one-third is related to outsourcing of secondary manufacturing in the form of formulations. It is estimated that the cost of setting up of a FDA approved manufacturing unit in India is almost half of the cost to be incurred in USA. The labour cost in India is cheaper by around 20 to 30 percent in comparison to the developed countries. Moreover the initial capital expenditure for starting the business is also much lower in India when compared to other developed countries. India has the largest number of US-FDA approved manufacturing units outside USA. Further, the automatic approval of foreign direct investment up to 100 percent in this sector has encouraged the outsourcing trend. These are the factors that have encouraged many large producers of the developed nations to outsource manufacturing of pharmaceuticals in India.

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[16] IDMA, 2007

The contract manufacturing includes manufacturing of Active Pharmaceutical Ingredients (API) for New Chemical Entities (NCEs) or generics. Indian pharmaceutical firms are engaged in the contract manufacturing of patented drugs, custom synthesis and scale-ups, specialized generics, old generics and old molecules. There are many Indian firms which are providing these services such firms include; Nicholas Piramal, Torrent Pharmaceuticals, Dishman Pharmaceutical and Chemical Ltd, Matrix Laboratories Ltd, IPCA Laboratories, and Divi's Laboratories etc.

2.2.8 Co-Marketing Alliances:

The co-marketing alliances with foreign companies are another growth strategy which is being followed by many Indian pharmaceutical firms to market their products in various markets of the world. Such kinds of alliances are expected to provide benefits to both the parties. Wockhardt, for example, has entered into a marketing arrangement with Bayer AG for marketing anti-diabetic drug Acarbose. The co-marketing alliances are taking place not only among Indian and foreign producers, but also among Indian producers. For example, Jupiter Bioscience entered into a 10-year co-marketing agreement with Ranbaxy under which the company would license out to Ranbaxy five generic peptide drugs worth US$ 3 billion at innovators price. It is believed that this tie-up helps Jupiter Biosciences to bring its products to international market rapidly as Ranbaxy already has strong presence in the global pharmaceutical market.

2.2.9 Export Scenario after Economic Liberalization:

Since the beginning of economic liberalization and establishment of World Trade Organization (WTO) the Government of India has reduced restrictions significantly on trade in the form of lowering tariffs and non-tariff barriers, controls on foreign direct investment and opened the market for free flow of foreign capital and firms. Less restrictions on trade has resulted in increase the number of new entry of foreign firms in the domestic market leading to growth and overseas expansion of business activities. Since, India initiated to deregulate its economy in the early 1990s, the industrial regulations have been reduced gradually, tariffs on imports have been cut down and rules for foreign investment relaxed substantially and the resulted high technology revolution has lowered costs in many industries. All these measures play important role in worldwide integration of financial system, trade liberalizations, deregulation and industrial developments. The Indian pharmaceutical industry adopted the internationalization process of production and business activities as an important part of strategy to succeed in the new liberalized economic environment.

2.2.10 Export Performance of Indian Pharmaceutical Industry

The Indian pharmaceutical industry has shown commendable export performance from the beginning of 1990 and since then India has been maintaining a positive trade balance in pharmaceutical trade. The pharmaceutical sector is one of the top export items from India which is around 4% of India's total exports in 2006-07. The exports within industry which constitute around 50% of the industry's total production have grown at a compound annual growth rate of 14% during the last decade. The Indian pharmaceutical industry has gradually become more and more export oriented with the help of low cost and high production in terms of volume. Thus, the Indian pharmaceutical industry has emerged from highly import dependent till 1970 to one that generates increasing export surplus for the country. The high growth of Indian pharmaceutical export has contributed in India's total export, as the share has increased from 0.55 percent in 1970-71 to around

5 percent by 2009-10. Some of the Indian pharmaceutical firms like Dr. Reddy, Cipla, Nicholas piramal, Ranbaxy and Wockhardt etc have been performing impressively in the developed markets of the US and Europe. The quality of the products is also reflected with the fact that India is having maximum number of manufacturing plants approved by US FDA (Food and Drug Administration).

2.2.11 Export of Bulk Drugs and Formulation:

The export market of Indian pharmaceuticals can be divided into two subsectors; the bulk drug segment and the other is formulations. The industry produces approximately 60000 finished medicines and around 400 bulk drugs which are used in the formulations. India is one of the top five producers of bulk drugs in the world. During the period 1996 to 2010 India's cumulative export of pharmaceutical products was around US$ 100 billion. On an annual basis, the total exports of this sector increased from Rs. 128 billion in 2002-03 to Rs. 293 billion in 2007-08 and Rs. 475 billion in 2010-11. The maximum growth in India's pharmaceutical products has been observed in the year 2008-09 i.e. 35.66 percent[17]. Within the pharmaceutical sector the two sub sectors i.e. bulk drugs and formulations also have shown similar growth trend. The contribution of formulations in total pharmaceutical exports grew at the rate of 8.2 percent per annum during the period of 1996 to 2001 and the pace of growth accelerated to an annual growth rate of 21 percent during the subsequent period from 2002 to 2010. Whereas in case of bulk drugs sub sector, the annual growth rate of the export was 9.1 percent during 1996 to 2001 which has escalated to 20.7 percent during 2002 to 2010. The

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[17] Directorate General of Commercial Intelligence and Statistics (DGCIS), Kolkata

export of formulations and bulk drugs has been increasing over the last three decades. The export of formulations has grown from Rs. 35 crore in 1980-81 to Rs.3194 crore in 1998-99, Rs. 16807 crore in 2007-08 and Rs. 25147 crore in 2009-10. So far as for bulk drugs is concerned, it has increased from Rs. 11 crore in 1980 -81 to Rs.2764 crore in 1998-99, Rs. 12547 crore in 2007-08 and Rs. 17309 crore in 2009-10. The share of formulation in total pharmaceutical export has been more than that of bulk drugs export.

2.2.12 Diversification of the Market:

Over the period of time the export of Indian pharmaceutical products is increasing to a large number of countries. The Indian pharmaceutical firms have been successful in increasing its exports to the traditional export destinations as well as entering into newer markets. During 1990s, Russia was the largest market for Indian pharmaceutical products accounting for 25% of India's total pharmaceutical exports. However over the years, there has been a decline in India's pharmaceutical exports to Russia to reach a level of 5% share in India's total pharmaceutical exports in 2006-07. Recently, USA has emerged as the largest export market for Indian pharmaceutical products. USA being the largest pharmaceutical market in the world is obviously a target market for most of the Indian firms also.

India exports its pharmaceutical products many countries which include highly regulated markets such as USA, France, Germany, UK and Canada. The top ten export markets for India's pharmaceutical exports accounted around 40 percent of India's total pharmaceutical exports. Europe, as a region, is the top most export destination for Indian pharmaceuticals with around 30 percent share of total pharmaceutical exports. The Americas (North and South American countries) come as next major region accounting for 25% and the USA, as an individual country, alone has a share of 14 percent of India's total pharmaceutical exports. Among South American countries Brazil and Mexico are important export markets for Indian pharmaceutical products and a share of 21 percent goes to Asian countries excluding Middle East[18]. Over the period, Indian pharmaceutical firms have been emerging as the competitive suppliers in the world of large number of generic drugs which has resulted a remarkable growth of India's export of pharmaceutical products.

2.2.13 Imports Scenario in Indian Pharmaceutical Industry:

Since beginning Indian pharmaceutical industry has been important dependent up to 1970 and thereafter the situation changed as India started exporting. During the last three decades the import of Indian pharmaceutical industry has grown from Rs. 112 crore in 1980-1981 to Rs. 5300 crore in 2006-2007 and Rs. 10947 crore in 2010-11. The cumulative import of Indian pharmaceutical products was around US$ 91 billion during the period 1996 to 2010. On an annual basis the total imports of this sector increased from US$ 2.5 billion in 1996 to US$ 15.1 billion in 2010. The share of bulk drugs and formulations in the total pharmaceutical import from India has been showing a similar trend. The import of formulation has increased at a rate of 11 percent annually during the period 1996 to 2001 and in the subsequent period from 2002 to 2010 the pace of growth accelerated significantly with an annual growth rate of 26 percent. In case of bulk drugs import, this sub sector has witnessed a growth of 1.9 percent annually during 1996 to 2001 and then jumped to 23.2 percent during the period of 2002 to 2010.

[18] Exim Bank Report, 2007

2.2.14 Current Issues and Challenges in Indian Pharmaceutical industry

During the last two decades particularly after TRIPS agreements, the pharmaceutical companies have gone through a situation where shareholders, the market, and regulators have created significant pressures for change within the institutional framework of the industry. The major issues that have been faced by most of pharmaceutical firms are declining R&D productivity, expiring patent term of many block buster drugs, increasing legal and regulatory concern, and drug pricing issue. Therefore, the big firms are shifting to new business strategies with greater outsourcing of drug discovery, clinical research and manufacturing. The major global pharmaceutical companies have recognized that there is a need for transformational changes in their organizations. It may be either due to the fear of a broad recession or the current global financial conditions. Such transformations in the business model can create more opportunities for Indian firms as the pharmaceutical production costs in India are almost 50 percent lower compared to the western countries, while overall R&D costs are about one-eighth and clinical trial expenses around one-tenth of western levels. At the same time, the Indian pharmaceutical industry would have to face several challenges particularly the following:

(i) Effects of new product patent

(ii) Pricing Strategies

(iii) Regulatory reforms

(iv) Strengthening Infrastructure

(v) Strengthening R&D expenditure and productivity

(vi) Skill development and quality management

(vii) Conformance to global standards

One of the effects of the product patent regime is that the firms are investing in technology based activities like R&D works. Technical knowledge is flowing more rapidly from university laboratories to the market place and the local firms are also spending in such activities to remain in the competitive market created by the new patent regime. The cost of R&D is increasing which is acting as entry barrier for new firms in the market and therefore, only large firms are investing more in industrial inventive activities. In developing countries like India only few firms have sophisticated R&D facilities and others benefit from spillovers of the resultant R&D. but in order to survive and grow in the market, firms need to invest in R&D related activities which is very crucial for their growth.

Because of the process patent regime since 1970, the R&D investment in Indian pharmaceutical industry has been very low and started increasing only after TRIPS agreement. With escalating R&D costs only big companies, with good R&D, marketing and financial capabilities would be able to afford new drug developments and commercialization. Since in India most of the firms are small in global standard, therefore, it is very difficult for each firm to invest in R&D, economize on scare R&D resources, then in such situation, mergers of firms is the possible solutions. Hence in order to face the new challenges the Indian pharmaceutical companies are adopting many strategies to grow and compete in the world market. The merger and acquisitions is also one of the business strategies which is being increasingly followed by the firms in various industries over the last two decades.

2.2.15 Merger and Acquisitions:

In the post globalization period, the corporate world is changing their operations and business strategies to face the new challenges in the highly competitive environment in national and international markets. The mergers and acquisitions is also one of the strategies adopted by the companies especially after liberalization. Generally, a merger takes place when two firms are combined in order to make a single company or in other word merger is a component of corporate strategy which includes the formulation of single new company by the collaboration of two different firms. This action allows the mutual ownership and operation of the two firms rather than an independent functioning. Whereas, acquisition is the process of taking over of one company by another company and establishing itself as a rightful new owner of the company. The Indian corporate sector is also witnessing a boom in the practices of mergers and acquisitions. The companies are adopting such strategies in order to achieve the growth and diversification of manufacturing, business and services activities. The main objectives of the firms behind the adoption of such practices like mergers and acquisitions are operating synergies, diversification, growth, increasing market power and market dominance, consolidation of production capacities, economies of scale, removal of inefficient firms, providing greater protection to investor, achieving optimum size of business, improves global competitiveness, tax saving, creating and entering new markets etc. Additionally, there are some others objectives of merger and acquisitions such as technological advancements and changes, economic policy changes across countries leading to liberalized capital flows, financial industrial and fiscal policy regime, capital market and capital account liberalizations and global integration.

The trends of merger and acquisitions have been increasing over the time in order to create more competitive, efficient and larger players in each industry leading to increasing cross border industrial restructuring and foreign direct investment across the world. In case of India also, the practice of cross border mergers and acquisitions is increasing very rapidly since the policy liberalization in the 1990s. The Indian firms are competing successfully both with domestic and multinational competitors in internal and international markets resulting in technological up gradation and enhancement to increase competitive viability and consolidate their positions. In the post globalization period i.e. from 1991 onward, the Indian companies have been facing increasingly the competition from both domestic and international market and the competitiveness has become very important for the growth and survival of the industry. Therefore, in recent times the Indian companies have started to restructure their business operations by adopting the practice of merger and acquisitions.

2.2.16 Merger and Acquisition in Indian Pharmaceutical Industry:

In case of pharmaceutical industry, mergers and acquisitions are dominating the world pharmaceutical industry in order to achieve the economies of scale and to search new markets and products for the growth of the industry. During last two decades, the Indian pharmaceutical industry also has witnessed a progress in merger and acquisitions in order to strengthen the technological base and research and development productivity. Since the introduction of product patent regime in 2005, the Indian pharmaceutical companies started moving toward the merger and acquisitions with many western multinational companies. As the India's changing therapeutic requirements and the relaxation in patent laws have been providing new business opportunities for foreign multinational companies for launching their patented molecules in Indian market. At the same time India's strong manufacturing base stands global generic companies in good position as a low-cost manufacturing destination. In recent times, the Indian multinational companies are aggressively focusing on global acquisition and following the strategy of acquiring existing generic drug marketing firms with valid drug licenses. During the last ten years, most of the overseas acquisitions by the Indian firms like Dr. Reddy's Laboratory, Cipla Pharmaceuticals, Ranbaxy, Sun Pharma etc have been made in the generics space to gain the access of manufacturing facilities especially in the US and Europe. The total number of mergers and acquisitions deals that have taken place in Indian pharmaceutical industry is 264 during the period of 2001-2010. Out of the total 264 deals, the number of mergers is 99 (37.5 percent) whereas the number of acquisitions is 165 (62.5 percent)[19]. The share of pharmaceutical industry is also highest among all the other industries participating in merger and acquisitions in manufacturing sector during this period.

2.3 Policies and Regulatory Environment in Indian Pharmaceutical Industry:

The Indian pharmaceutical industry has witnessed remarkable growth due to a favourable policy environment provided by the government. Some of the major policies like, Drug and Cosmetic Act (1940), Indian Patent Act (1970), Drug Policy (1986), Drug Price Control Order (1995), Pharmaceutical Policy (2002), Indian Patent Amendment Act (2005) and the Draft National Pharmaceutical Policy (2006) have not only helped in improving the healthcare scenario in India but also accelerated the growth of the

[19] CMIE (Centre for Monitoring Indian Economy)

pharmaceutical industry. Most importantly, the patent activities and pricing issues have been influencing the growth of the industry over the period of time.

2.3.1 Patents Activities in Indian Pharmaceutical Industry before and after Independence:

A patent is an exclusive right by the government granted to a person or a company for an invention of a new and useful article or an improvement of an existing article or a new process of making an article. It allows the inventor to exclusively manufacture and market the patented product for a specified period of time. It was introduced with the purpose of promoting and encouraging inventions and also to act as an incentive for inventors to disclose the information that would become a substantive database for technical information which might otherwise have remained a secret. During the term of the patent, a patentee can enjoy the exclusive right to prevent the third party from unauthorized act of making, using, selling or importing the patented product or process within the country. A patented invention becomes free for public use after expiry of the term of the patent of any particular product or the process of making the product.

The first law in India relating to patents was the Act VI of 1856 with the objective encouraging inventions of new and useful manufactures and to induce inventors to disclose secrets of their inventions. The Act was subsequently repealed by the Act of 1859 with certain exclusive privileges to inventors of new manufacturers for a period of 14 years and then in 1872 to provide protection relating to designs. This Act remained in force for about 30 years without any change. In 1911, the Indian Patents and Designs Act, 1911, came by replacing all the previous Acts under the management of Controller of Patents for the first time. This Act recognized product as well as process patent for a period of 16 years which could be extended for another 10 years if the patent holder believed that he had not been adequately defrayed for his innovation (Lalitha, 2002). This law was applicable in India till 1970. During this period MNCs dominated the Indian pharmaceutical market as most of the patents were held by these firms and the drug prices were very high during this period.

After Independence, it was observed that the Indian Patents & Designs Act, 1911 was not fulfilling its objective. It was found desirable to enact comprehensive patent law owing to substantial changes in political and economic conditions in the country. Accordingly, the Government of India constituted a committee under the Chairmanship of Justice Bakshi Tek Chand, a retired Judge of Lahore High Court, in 1949, to review the patent law in India in order to ensure that the patent system is conducive to national interest. The Committee submitted its report on 4th August, 1949 with recommendations for prevention of misuse or abuse of patent right in India to ensure the food and medicine availability to the public at the cheapest price. Based on the recommendations of the Committee, a bill was introduced in the Parliament in 1953 which lapsed on dissolution of the Lok Sabha. In 1957, the Government of India appointed Justice N. Rajagopala Ayyangar Committee to examine the question of revision of the Patent Law. This report recommended major changes in the law which formed the basis of the introduction of the Patents Bill, 1965. This bill was introduced in the Lok Sabha in 1965 and again lapsed. In 1967, an amended bill was introduced which was referred to a Joint Parliamentary Committee and on the final recommendation of the Committee, the

Patents Act, 1970 was passed. This Act repealed and replaced the 1911 Act so far as the patents law was concerned[20].

2.3.1.1 The Patent Act 1970:

The patent Act 1970 came into force on 20th April 1972 with publication of the Patent Rules, 1972. The Act relaxed the patent regime in the country to a great extent and gave a major boost to pharmaceutical industry in India. The salient features of the Patents Act 1970 are

(i) There would be no more product patent for pharmaceuticals, food and chemical based products.

(ii) The term of the patent was 7 years from the date of application or 5 years from the date of sealing of patent whichever was less;

(iii) Automatic licenses of right could be issued three years after the granting of the patent;

(iv) For licenses of right, the royalty ceiling was stipulated at 4%.

The objective of the Act was to foster the development of indigenous pharmaceutical industry and to guarantee that the Indian public had access to low-cost drugs. Indian companies are now among the world leaders in the production of bulk drugs from basic stages. In the absence of product patent, Indian pharmaceutical firms started producing generics through 'reverse engineering process' and were developing alternative processes for the patented drugs. Indian scientists developed new processes for 107 drugs. Moreover, as a result of the automatic license of right, the firms were interested in

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[20] Draft Manual of Patent Practice & Procedure, The Patent Office,(CGPDTM), India, 2008

exploiting the patent process. Such policy initiatives by the government increased the production particularly in the formulations segment by Indian firms significantly.

However, the impact of the Indian patent Act 1970 on the patenting activity in Indian pharmaceutical industry during the period 1972–2000 has been negative as the number of patents in force has declined considerably. The patent regime created a narrow mindset regarding the innovations and their protection using the patent system. During this period, efforts were made for the development of alternative cost-effective manufacturing processes for molecules which were already invented and patented in other countries. On the other hand, lesser efforts were made to invest in R&D for inventing new molecules or products. As a result, the development of professional expertise in drafting patents in the areas of new chemical entities, genetic engineering, and natural products, etc., as opportunities to deal with patent-related matters in such areas were practically non-existent.

2.3.1.2 Amendments to the Indian Patent Act 1970:

The patent Act of 1970 remained in force for about 24 years without any change till December 1994. An ordinance with some changes in the Act was issued on 31st December 1994, which operated for six months. In 1999 another ordinance was issued which was replaced by the Patents (Amendment) Act, 1999 that came into force from 1st January, 1995. This amended Act provided for filing of applications for product patents in the areas of drugs, pharmaceuticals and agro chemicals though such patents were not allowed. The second amendment to the 1970 Act was made through the Patents (Amendment) Act, 2002 which came into force on 20th May 2003 with the introduction of the new Patent Rules, 2003 by replacing the earlier Patents Rules, 1972. The third amendment to the Patents Act 1970 was introduced through the Patents (Amendment) Ordinance, 2004 w.e.f. 1st January, 2005. This Ordinance was later replaced by the Patents (Amendment) Act 2005 on 4th April, 2005 which was brought into force from 1st January, 2005.

2.3.1.3 The Patent (Amendment) Act 2005:

Following the third Amendment to the Patent Act 1970, the Indian parliament gave its approval to India's product patent legislation in March 2005 which established the product patent protection for pharmaceuticals in India. Now as per the new patent law, the manufacturers of the new drugs can apply for product patents. This law has allowed for only two types of generic drugs in the Indian market i.e. off-patent generic drugs and the generic versions of drugs patented before 1995. The salient features of this amendment act are as follows,

(i) Product patent will be allowed to all products including drugs, food, chemicals and micro organism.

(ii) Patent term for all existing and future patents extended to twenty years from seven years which was provided by the patent act of 1970.

(iii) Patentee can import the patented drug and has no obligation to produce it locally. In case of process patent the burden of proof lies with alleged infringer.

(iv) Deletion of the provisions relating to Exclusive Marketing Rights (EMRs)

(v) Provisions for enabling grant of compulsory license for export of medicines to countries which have insufficient or no manufacturing capacity to meet emergent public health situations

The Patent Act, 2005 marked the beginning of a new era in the Indian pharmaceutical industry with significant impact on the domestic drugs manufacturers, particularly the generics manufacturers who benefited greatly from the process patent regime of 1970. This Act prevents them from producing generics of patented drugs using different process. Under this new product patent regime, it is highly needed for the Indian pharmaceutical firms to invest more in R& D related activities and come up with new drugs in order to survive and compete with domestic and foreign players in the national and international market.

2.3.2 Price Regulations in Indian Pharmaceutical Industry:

The price control has been major concern in case of the pharmaceutical products during the last three decades. The purpose of price control has been to ensure the availability, accessibility and affordability of quality medicines to the mass people in the country. During the decade of 1960s the drugs prices in India were among the highest in the world, since then the government of India initiated efforts to reduce the prices by establishing many public enterprises and introducing policy measures like drug prices control orders. The drugs price control order is an order issued by the government of India in order to regulate the prices of the drugs. The order provides a list of price-controlled drugs, procedures of fixing the drug prices and the method for implementing the prices fixed by the government. The National Pharmaceutical Pricing Authority (NPPA) has been given the power of implementing the provisions of drug price control order. Since the period of economic reforms in 1991, the government of India started relaxing the control on prices, trade and foreign capital and the price control in a large number of industries has been abolished during this period.

2.3.2.1 Drugs Price Control Order, 1970:

For the first time the price controls on pharmaceutical products in India started in 1962 with the introduction of Drug (Display of prices) Order 1962. Later on such controls of prices on drugs were changed many times in 1963 and then in 1966 in the form of Drugs (Display and Control) order 1966, when the government asked the Tariff Commission to examine the prices of 18 bulk drugs and their single ingredient formulation. In 1968, the commission submitted its report to the government on the basis of which the government introduced a price regulatory policy known as the Drug Price Control Order 1970. This was the first comprehensive order introduced under Section 3 of the Essential Commodities Act, 1955 which was suppose to have direct control on the profit margin of a producer of the pharmaceutical products, and an indirect to regulate the prices of pharmaceuticals in the country. The government fixed that a company‘s profit before tax from its pharmaceutical business should not exceed 15% of its pharmaceutical sales (net of excise duty and sales tax). In case the profits exceeded this limit, the companies were supposed to deposit the surplus with the government. The main purpose of this policy was to protect the interests of consumers and ensure a restricted but reasonable margin to producers. Under the purview of drug price control order 1970, 18 essential bulk drugs have been brought which accounted for less than 9 percent of total value of drugs marketed in the country. The policy has been modified in the subsequently periods in 1979, 1987, 1995 and in 2013.

2.3.2.2 Drugs Prices Control Order, 1979:

The government of India appointed a parliamentary committee which is known as the Hathi Committee in the mid 1970s which recommended the revision of the drug price control order 1970. Accordingly the government revised the drug price control order 1970 in the year 1979 and the coverage of drug price control order was extended to 347 drugs accounting for 90 percent of the industry. All the drugs were grouped under four categories namely life saving, essential, less essential and non essential/simple remedies. The first three groups were subjected to price controls and the non-essential drugs were kept out of the purview of price controls. The main purpose of this order was that the lower profit margins from life-saving and essential drugs (Categories I and II) would be compensated for by the higher margins for Categories III and IV drugs. However, the result was totally against the plan and the drug companies reduced and even stopped the production of life-saving and essential drugs and focused on the more profitable drugs. While fixing the prices, the government advocated for profitability ceiling which badly affected the multinational companies and their profitability fell sharply. As a result new investments in the sector dropped and many multinational companies discontinued their products. However the policy supported the growth patterns of domestic firms.

2.3.2.3 Drugs Price Control Order, 1987:

In 1986 the government of India introduced the drug policy with the objectives of ensuring abundant availability, at reasonable prices, of essential life saving drugs of good quality and strengthening the system of quality control over drug production and promoting the rational use of drugs in the country. Keeping these objectives in view and to make the price control system less cumbersome but more effective by reducing the span of control, the drug price control order was again modified in the year 1987. This order was supposed to ensure a reasonable return to the producers of essential drugs, while at the same time restricting the undue increase in their prices. Under the new modified version of drug price control order, the number of drugs under price control was reduced significantly from 370 to 143. In addition this drug price control order clubbed the drugs into two lists with different Maximum Allowable Post manufacturing Expenses: drugs required for National Health Programme with 75 percent mark up and others with 100 percent mark up.

2.3.2.4 Drugs Price Control Order, 1995:

The drugs price control order in 1995 has been modified two times but the basic structure of the order has remained similar to the earlier two orders i.e. 1979 and 1987. Under this order by liberalizing the span of the control only 74 out of 500 commonly used bulk drugs are brought under the preview the price control. Apart from this, the prices of other drugs can be regulated, if they are warranted in public interest. In addition, the policy provided a single list of the drugs whose prices are supposed to be controlled with a maximum allowable post manufacture expenses of 100 percent. The exemption period has also been increased to 10 years from 5 years in earlier orders for new drugs manufactured by the indigenous research and development. The small scale firms have not been exempted from price control and 40 percent of the market has covered by price control, under this order of 1995. The National Pharmaceutical Pricing Authority was established in 1997 as an independent body of experts for fixing the prices of pharmaceutical products, enforcing the provisions of the drugs prices control order and monitoring the prices of controlled drugs.

2.3.2.5 Drugs Price Control Order 2013:

A new Drug Price Control Order has been announced by the government of India in 2013, with the objective to improve the basic health care and availability of basic medicines at an affordable price across the country. The new order empowers the National Pharmaceutical Pricing Authority (NPPA) to regulate prices of 348 essential drugs and the pricing of the drugs have been fixed on the basis of manufacturing costs declared by the drug manufacturers. According to the DPCO 2013, all strengths and dosages specified in the National List of Essential Medicines (NLEM) will be under price control. The scope of drug price control order has been decreasing over time. However, there could be significant changes in the functioning of drug price control order in the product patent regime. The price monitoring and control in the Indian pharmaceutical industry would continue to evolve as dynamics of the industry change in the coming years.

2.3.3 Strengths and Weaknesses of Indian Pharmaceutical Industry:

At present, the Indian pharmaceutical industry is one of the emerging markets in the world. There are a number of factors that have increased the strength of the industry. First and most important is the cost advantage particularly the labour cost which is around 50 to 55 percent lower than in the other developed countries. In case of infrastructure, the industry experts indicate that the costs are approximately 40 percent lesser than that is incurred in the US and Western Europe. With this cost advantages, India can manufacture bulk drugs at 60 percent less cost than in the western countries and can establish a manufacturing unit in India at 40 percent cheaper than in the developed nations[21]. Because of all these advantages, the drug prices in India are one of the lowest in the world.

Further, Indian pharmaceutical firms can operate at much lower profitability than the companies in the Western countries. In addition, there are some more factors that are strengthening the domestic industry such as, favorable policy environment, TRIPS compliance, free flow of foreign capital, well developed infrastructure, availability of less expensive highly qualified scientific and engineering workers, strong marketing and distribution network, largest number of US FDA approved facilities, reverse engineering skills, largest number of DMFs, lower cost of R&D, clinical trials etc.

On the other hand, the Indian pharmaceutical industry is highly fragmented into micro, small, medium and large sized firms with more regulations and controls by the government. Most of the Indian companies are small by world standard. The Indian firms are spending lesser amount of their turnover on R&D related activities (5 percent approximately) compared to the developed countries which spend around 10 to 15 percent of their total sales. The Indian pharmaceutical industry needs to strengthen the system of quality control over drug production and promoting the rational use of the drugs in the country. There are still some shortcomings or weaknesses in the Indian pharmaceutical industry which need a proper attention to overcome such as, weak domestic market, government price controls, high tariff and taxations, substandard drugs and counterfeiting, lack of experience in drug discovery, corruption, low level of per capita medical expenditure, low margins etc.

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[21] Ashok Ram Kumar, "Impact of TRIPs on Indian Pharma," Pharmabiz, Dec. 2, 2004.

2.4 Concluding Remarks:

The Indian pharmaceutical industry has been one of the most successful industries of the country's manufacturing sector with supportive government policies and initiatives over the years. The growth momentum of the industry has been continued in spite of changes and challenges posed by the WTO regime. Today the Indian pharmaceutical industry has become one of the top global players by adopting strategies such as increasing expenditure on R&D related activities, patent filings, contract manufacturing, contract research, merger & acquisitions, co-marketing and co-licensing arrangements etc. However, in future, there are challenges also for the domestic industry due to the changing pattern of global trends and the TRIPS compliant patent regime in India. The impact of IPR will depend to a great extent on the developmental status of the economy including the availability of technical manpower, infrastructure and overall capacity of the domestic industry. The Indian pharmaceutical industry has relatively advantageous position than a country where domestic industry does not have much presence and depends on multinationals. Further there is a need to focus on the R&D work for developing new products. As the R&D activities are crucial for the growth of pharmaceutical industry, thus success of pharmaceutical industry largely depends on successful R&D activities. This factor is more relevant in case of India since the product patent regime has been introduced to comply with TRIPS Agreement. Further merger & acquisitions also can play an important role in pooling in human and financial resources to strengthen R&D and overall growth of the industry. At the same time the quality and safety of products produced and marketed is also important factor for future growth of the industry. In order to remain viable in the competition the Indian pharmaceutical industry needs to focus on pricing strategies as well. Therefore it is crucial to consider optimal pricing strategies while launching a drug in the market. In addition there is need to strengthen the regulatory system in context of new patent regime. There are several other factors which are to be focused for the future growth of the Indian pharmaceutical industry such as skill development, more thrust on patent filings, enhanced medical infrastructure and technological development, outsourcing, clinical trial and contract manufacturing etc.

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3. CHAPTER

REVIEW OF LITERATURE

3.1 Introduction:

In the previous chapter, we have discussed the evolution and growth of Indian pharmaceutical industry. The evolution of the industry was classified into three phases where the first phase was characterized with dominance of foreign multinational companies; the second phase marked the expansion of the industry with supportive government policies and the third phase was about the liberalisation, deregulation and introduction of product patent in the Indian pharmaceutical industry. Subsequently the growth and major changes in the industry have been discussed by highlighting the export performance, expenditure on R&D, FDI inflows and various issues, challenges and changes in policies and regulatory environment with regard to the pharmaceutical industry. In the third phase i.e. after deregulation and the product patent regime the industry has been exposed to competition in domestic as well as international market where domestic firms had to compete with leading pharmaceutical players of the world. To face such competition the firms have to focus on efficiency and productivity aspects to reduce the cost of production and for their survival and future growth. Therefore, measurement of efficiency and productivity of firms has been a very important issue to assess the performance of any particular industry. In the present study, we are focussing on this issue in the context of Indian pharmaceutical industry.

In this chapter we aim at reviewing the previous work so as to provide the necessary background to the present study. The relevant literature especially in the context of the pharmaceutical industry has not been truly abundant. Though the parametric and non-parametric approaches for efficiency and productivity measurement have been widely used but as far as the efficiency and productivity issues are concerned, only few studies have examined this issue in the context of pharmaceutical industry in India as well as in other countries. In this connection, this chapter first presents an overview of studies conducted outside India using parametric and non-parametric approaches to the analysis of efficiency and productivity of pharmaceutical industry followed by the similar review of studies carried out in Indian context.

3.2 An Overview of Studies outside India:

In this section we review selected studies that were carried out in other countries to highlight various aspects of efficiency and productivity measurement.

We start with Comanor (1965) who examined the relationships among firm size, R&D inputs, and technical change in the United States pharmaceutical industry for the period 1955-1960. The study tried to investigate the effect of firm size on the productivity and relationship between research and the rate of technical change experienced by the US pharmaceutical firms. The study utilized multiple regression techniques on a cross-sectional basis at the firm level. He examined the impact on technical change of a number of variables associated with the character of a firm's research and development effort. From the empirical evidence, there appeared to be a fairly sustained association between research input and new product output. Within the industry, research expenditures are not undertaken merely with the hope of some distant but unknown returns but rather with expectation that profitable gains will accrue within a reasonable period of time.

The analysis provided some evidence that in the pharmaceutical industry there are substantial diseconomies of scale in R&D which are associated with large firms and that these disadvantages are encountered even by moderately sized firms. One implication of this finding is that an actively enforced pro-competitive policy in this sector is not likely to dampen the rate of technical change and may well stimulate it. While little is known about the extent to which this result is applicable to the economy at large, it does appear that there are grounds for considerable doubt that large firm size is always a necessary condition for rapid technical advance.

Vernon and Gusen (1974) tried to examine this issue that the output of R&D varies with size of firm for an industry in which unusually good data are available. They analysed the elasticity of technical change with respect to firm size. The results of the study indicated that larger pharmaceutical manufacturers appear to be advantageous over smaller ones in accomplishing technical change. These results did not appear to be unreasonable when it is realized that the very largest firms in the industry are still relatively small when compared with American manufacturing in general. The results of the study have shown that the elasticity of technical change with respect to firm size increases with size. The elasticity attains the value of unity for firms slightly smaller than the median firm size in the sample.

Fare et al (1992) computed the total factor productivity for a sample of Swedish regional pharmacies over the 1980-1989 periods. The technique they used was non-parametric input oriented DEA Malmquist productivity index introduced by Caves, Christensen and Diewert (1982). The study found five pharmacies among 42 to be efficient in all time periods. For the other 37 pharmacies the study found periods with declines in efficiency as well as periods with improvements in efficiency. The study found no pharmacy with only progress or only regress in efficiency during the period 1980 to 1989. Between 1981 and 1982 the overall average fall in efficiency was 6.5 percent. This was followed by a 5.5 percent improvement in efficiency. For the remaining periods they found small changes in efficiency. The study calculated productivity changes also in pharmacies as represented by the Malmquist input based productivity index which is a combination of the efficiency and technical change components. For all pharmacies in all periods the study found productivity gains 68 percent of all cases. For the period 1985 to 1989 the study found progress in 78 percent of all cases. The study noted that on an average, progress in productivity during the latter part of 1980's is mainly explained by positive shifts of the frontier.

Lothgren and Tambour (1999) presented a DEA network model that allows inclusion of customer satisfaction in efficiency and productivity measures. The network consists of a production node and a consumption node and offers flexibility in modelling the production and consumption process where a firm-specific allocation of input resources to production and customer oriented activities are allowed. The proposed model is applied on a sample of 23 Swedish pharmacies with organizational objectives that necessitates a monitoring of efficiency and productivity as well as customer satisfaction. The results from the network model and a direct productivity model (without customer satisfaction) have been similar in some respects. In both models the estimated average productivity change is positive. The network model, however, has shown a lower productivity progress than the standard model. Both the efficiency and technical change components in the Malmquist index decomposition indicated progress in productivity.

González and Gascón (2004) analyzed the evolution of the productivity patterns in a sample of 80 pharmaceutical laboratories that operated in Spain from 1994 to 2000. They estimated Malmquist productivity indexes and decomposed them into four sources of productivity change i.e. technical change, efficiency change, scale efficiency change and total factor productivity. The results suggested that pure technical efficiency change and the scale change of the technology explain most of the productivity growth observed during the period. The contribution of technical efficiency change to productivity growth is more important in the group of Small labs, precisely the group that may be most affected by the new situation. In contrast, technical change has been the main source of productivity growth in the group of Large labs, reflecting their ability to expand their production possibilities through innovation. Within the group of Medium-sized labs, both factors have contributed to productivity growth in more or less the same proportion. Vernon et al. (2005) tried to investigate the effect of real drug prices on the R&D spending of U.S. pharmaceutical companies. Theoretically, drug prices are expected to influence R&D spending directly because of both derived-demand and cash-flow effects. Using industry-level data for the period 1952–2001, their multiple-regression findings supported this expected direct effect. Specifically, the estimated coefficient on the drug price variable suggests that a 10 percent increase in real drug prices results in a nearly 6 percent increase in pharmaceutical R&D spending. Simulations based on these multiple-regression results indicate that the capitalized value of pharmaceutical R&D spending would have been about 30 percent lower if the federal government had limited drug price increases to the same rate of growth as the general CPI during the period 1980–

2001. Moreover, this drug price control would have resulted in 330–65 fewer new drugs being brought to market during that same time period.

Taewoo et al (2010) conducted a study to measure the efficiency of pharmaceutical firms and to identify their determinants using Korean and American samples from 1992 to 2004. The study employed the DEA technique for estimating the production frontier and for computing various efficiency scores for both Korean and American pharmaceutical firms. The study documented some stylized facts in the patterns and sources of efficiency change in Korean and American pharmaceutical firms. The evidence has shown that ownership structure can substantially influence the efficiency of pharmaceutical firms. The evidence seemed to be somehow divergent between Korean and American pharmaceutical industries. In particular, the level of cost inefficiency for Korean pharmaceutical firms was related to the level of allocative efficiency, while the level of cost efficiency for American firms was associated with the level of technical efficiency. The study detected significant evidence that R&D intensity is associated with ownership structure for Korea, not for the US. Relatively strong is the evidence that the largest ownership rate is positively related to the R&D intensity for Korean pharmaceutical firms, but such evidence is weak for American sample.

Chia-Nan et al (2011) focused on how to utilize intellectual capital more efficiently, in order to strengthen the competitiveness of enterprises in Taiwanese pharmaceutical industry. A total of 12 major companies of Taiwan's pharmaceutical industry were chosen as empirical samples for the period 2005 - 2008. They used DEA's Malmquist model by using pharmaceutical information of vendors to analyze efficiency change for all pharmaceutical companies and to measure technical efficiency scores during two particular periods. Secondly, the study analyzed technical change and measured the condition of efficiency frontier-shift between two particular periods. Finally, the study analyzed Malmquist productivity index and found out the main reason of Malmquist productivity decline.

Moreover, this study also carried out a comparison between the period efficiency and productivity change, in order to understand the situation of every annual growth and decline of efficiency and productivity. They established a novel assessment model to measure the performance of intellectual capital management into two aspects by using grey relational analysis to measure operational performance and Malmquist productivity index to judge productivity evolution. The results demonstrated that this novel assessment method really identify the relative advantages and benchmarking for pharmaceutical companies. F8 was found to be the best company both in terms of operational performance and productivity improvement.

Hashimoto and Haneda (2008) analysed the change in R&D efficiency at both firm and industry levels using DEA. Letting each of ten firms in each year be a separate decision-making unit, the study has employed one input i.e. R&D expenditure and three outputs; patents, pharmaceutical sales and operating profit in a DEA case of R&D activity input–output lag. They measured total factor R&D efficiency change of Japanese pharmaceutical firms for decade 1983–1992 as defined by the period of R&D input. Decomposing Malmquist index into catch-up and frontier shift components and using cumulative indices proposed in this study they evaluated R&D efficiency change for each firm and empirically shown that R&D efficiency of Japanese pharmaceutical industry has almost monotonically got worse throughout the study decade. They found a great R&D efficiency loss by the Japanese pharmaceutical industry for the decade. They results revealed that the industry's R&D efficiency had dropped by 50% in 1992 of 1983 efficiency level. The firms continued to increase R&D expenditure every year despite which R&D efficiency has not improved.

Shu-Chuan Yang (2011) analyzed the performance of Taiwan's pharmaceutical industry. The study tried to combine balance scorecard with system dynamics in order to explore Taiwan's pharmaceutical industry that had set up the relevant strategies of its development since 1982, but its contribution is still remains limited. The study aimed to investigate and build the complex system of Taiwan's pharmaceutical industry and amend the policy direction to enhance its performance. The results of the simulation analysis revealed that the policy of drug-cutting prices rate results in the obvious slow-down of the domestic pharmaceutical market. The study indicates that the most important fund sources of R&D mainly come from enterprise and venture capitals in the long term, reducing 10% marketing funding and using this 10% to invest in R&D area can bring better performances in new drug development and sales value. The R&D funding is the best effective driving force for the increasing R&D capability and new drugs appear in the market; while training is the most important factor in the dimension of learning and growth for improving sales value. These are the key decision points in policy testing.

Eshref Trushin (2011) examined the development of incentives for pharmaceutical R&D. He estimated the short-term effects of the recent cost-containment reforms on seven financial indicators related to firm‘s R&D in Denmark, Germany, France, Japan, and US. The dataset represents a panel data of financial statements of 1306 pharmaceutical firms for the period 1997-2007. National pharmaceutical expenditures, population, availability of credit, patent applications, and regulatory quality have been controlled for. Impacts of liquidity constraints on R&D and investment are estimated with dynamic panel methods. Using frontier modelling, technical production inefficiencies are estimated and tested for independence from the stringency of national regulation. He found that the R&D indicators tend to be persistent despite regulatory changes; tighter cost-containment regulations appear not to be associated with technical efficiency or R&D intensity of firms; cash flow has a positive effect on pharmaceutical R&D of small and young firms but not on physical investment.

For Iranian pharmaceutical industry, Hamid et al (2012) analysed the relationship between intellectual capital components namely, human, structural, and physical capitals with the traditional measures of performance of the firm (profitability, productivity and market valuation) within the pharmaceutical sector of Iran. The empirical data were drawn from pharmaceutical companies listed in the Iranian Stock Exchange (ISE) over the six-year period of 2004 to 2009. The analysis of correlation, simple linear multiple regression and artificial neural networks (ANNs) were applied for analyzing any existing relationship between variables in the present study. The analysis indicates that the relationships between the performance of a company's intellectual capital and conventional performance indicators are varied. The findings suggest that the performance of a company's intellectual capital can explain profitability but not productivity and market valuation in Iran. Also the empirical analysis found that physical capital was the one which was seen to have the major impact on the profitability of the firms over the period of study; in addition the result of ANN method also confirmed findings of multiple regressions.

For Indonesia, Suyanto and Salim (2013) analysed the spillovers effect of foreign direct investment on technical efficiency of the pharmaceutical firms using a unique unbalanced panel of highly disaggregated 210 firms over the period 1990–1995 with a total of 1001 observations. The stochastic production frontier and the DEA based on Malmquist productivity indices have been used to test the spillovers effects of FDI on technical efficiency. The empirical results from the stochastic production frontier have shown that foreign firms have been more efficient than domestic competitors, and the presence of the former increases the inefficiency of the latter. Similarly the results from the Malmquist productivity index demonstrate that foreign direct investment has a negative and significant impact on technical efficiency changes in domestic competitors but generate positive spillovers to domestic suppliers.

3.3 An Overview of Studies in Indian Context

We start with Saranga and Phani (2004) who examined the efficiency of the pharmaceutical industry of India using DEA on a sample of 44 companies for the period 1992- 2002. The inputs for the application of DEA in the study have been chosen the major cost elements which contribute towards 70% of the operating cost of a pharmaceutical firm in India, they are: (i) cost of production and selling (ii) cost of material and (iii) cost of manpower. The outputs considered are (i) profit margin (ii) net sales and (iii) exports. They analyzed the results of DEA along with their compounded annual growth rate (CAGR) to see whether internal efficiencies and growth rate are related in the Indian pharmaceutical industry. The study also used regression analysis to see the correlations between various inputs/outputs and the growth rates. Various models of DEA like Constant Returns to Scale (CCR), Variable Returns to Scale (BCC) and Assurance Region (AR) have been used in order to find scale efficiency and pure technical efficiencies of the sample firms.

They have divided the results of the sample into three groups, group one consisting of top efficiency ranking firms, group two consisting of medium efficiency rankings and finally group three consisting of the least efficient companies. With the help of the DEA results, the study indicated that the size of a company does not dictate the internal efficiency ratings; however indigenous firms which are in the business of both bulk & Formulations have an edge over MNCs and firms with only Formulations business. The comparative analysis between efficiency scores and growth ratings of all the three groups of companies establish the fact that there is a direct relationship between internal efficiencies and higher growth rates except for a few instances where companies which were in the mode of expansion may not have achieved full efficiencies (Cipla, Nicholas Piramal and Wockhardt). On the whole, they have concluded that the internal efficiencies established by the indigenous companies in bulk drug and formulation businesses, which have helped them to grow so far, will also play a major role in grabbing the new opportunities of product patent era to survive and grow in future.

Mazumdar et al (2009) examined the competitiveness of Indian pharmaceutical firms by computing their technical efficiency for the period 1991 to 2005 using the non–parametric approach of DEA. The number of firms in the sample varies from 70 to 289 over the years and in total there is an unbalanced panel of 2492 firms for 15 years. The firms considered in the study together account for about 80 percent of the total output and 87 percent of the input usage for the sector for almost all the years. Thus the sample of firms considered in the study can be viewed as representative of the sector. The output in the model is the value of total output defined as the total sales of the firms plus the change in the stock of output measured in terms of the opening stock minus the closing stock in output. The inputs in the model are (i) labour; measured in terms of wages and salaries for the workers (ii) material inputs; measured in terms of the companies' expenditure for raw material, (iii) energy input; measured in terms of the expenditure for power and fuel and (iv) capital; the book value for plant and machinery and building. To bring the variables in real terms each variable was appropriately deflated.

The study has indicated that even though the output efficiency levels of firms have shown a declining trend, firms have been able to make efficient use of labour and raw material inputs. A look into the determinants of efficiency of the firms indicates that large firms are more efficient than small firms. It is also clear from the study that MNCs are more efficient than domestic firms. The Indian firms can enter into technological collaboration with MNCs to gain more efficiency. The study also established that exporting to the global market always improves the efficiency. The study revealed that adopting capital-intensive techniques or importing technology and investing more in R&D does not improve output efficiency of firms because it takes time to realise the benefits of new technology or R&D. Finally, it is well known that pharmaceutical firms spend heavily on marketing activities. The study found that spending more for promotional activities improves the technical efficiency of firms. Also when competition is more and rivals also spends for marketing related outlays the demand for the product increases which in turns also brings higher returns to the firms and its efficiency improves.

In an another study, Mazumdar and Rajeev (2009) tried to explore the efficiency related issues by not only estimating the efficiency of the pharmaceutical firms but also their technological and the productivity changes of Indian pharmaceutical firms across different groups. More precisely, they tried to examine how the adoption of new strategies affects the efficiency and technical change of the firms. They formed the groups of the firms based on their size, strategies and product varieties. There were firms with R&D expenditure, with larger market share, firms serving the markets abroad and producing different product varieties. The non-parametric approach of DEA introduced by Charnes, Cooper, and Rhodes (1978) was used to compute the technical inefficiency of the firms. In order to construct the group specific frontiers the study conceptualized a single output (y) and four inputs technology. The elements of the input bundle (x) are labour, raw material, power-fuel and capital.

The study indicated that vertically integrated firms that produce both bulk & formulation exhibit higher technological innovation and efficiency. However, in contrast to the popular belief, the analysis revealed that increased export earnings do not necessarily lead to higher efficiency. They also found that installing capital-intensive techniques or imported technology propel the technological growth of firms. A cross comparison of efficiency and technical change indicated that most of the large firms are efficient and have experienced technological innovation for greater number of years. However, a few small firms have also experienced technological progress mainly by importing foreign technology and by complying with the good manufacturing requirements set by the government. The study also indicated that exporting in the global market without any discrimination does not help firms realize higher efficiency; it also depends on the type of market a firm targets.

Using the DEA technique, Subhash et al (2011) attempted to examine the firm's heterogeneity in the Indian pharmaceutical industry by measuring their input and output efficiencies for the period 1991 to 2005. Based on the analysis they concluded that with policy changes the output efficiency of the Indian pharmaceutical sector has declined during the study period. It is indicated from the analysis that few large firms have been able to take the benefit of a liberalized regime, but rest of the large number of small firms in the industry lagged behind. Further, analysis of the input and output efficiency revealed that even though firms have been able to use their inputs efficiently, there has been a persistent decline in the output efficiency of firms.

They argued that such circumstances arise because of the economies of scale in production and thus one possible route to improve their efficiency would be to encourage merger to reap the benefit of economies of scale. The analysis also revealed the importance of firm specific characteristics to achieve higher efficiency. They found that increased investment in R&D would be a better strategy for large firms. Thus, one possible way to encourage firms to do more of R&D investment would be to involve in more of private-public partnership in R&D. However, in India, public-private co-operation is currently not significant and it is necessary to improve such cooperation for development of the industry.

Tripathy et al (2010) examined the levels and determinants of efficiency of firms of the Indian pharmaceutical industry using firm-level data. For this purpose, a two stage data envelopment analysis has been used for the period from 2001-02 to 2007-08. In the first step, they have undertaken technical efficiency analysis of 90 sample firms. One output, viz. sales of the sample firms, and three inputs; viz. (i) raw material cost; (ii) cost of salaries and wages; and (iii) cost of advertising and marketing; have been considered in the study. In the second step, the efficiency scores obtained from the first step were regressed on external environmental factors like the age of the firms, export of goods, import of capital goods, profit rate, R&D intensity, ownership, patent regime and foreign direct investment using a censored regression model, viz. tobit model.

The efficiency analysis revealed that during the period of the study the performance of a large number of sample firms was sub-optimal, ranging between 68% and 78%. Almost throughout the study period, the average efficiency of the R&D-intensive firms was higher than that of non-R&D firms and the difference between the two was statistically significant. The Malmquist productivity index indicated that the total factor productivity of the sample firms remained at the same level during the period of study. The important determinants of pharmaceutical firms' efficiency are the new patent regime, export of goods, presence of foreign direct investment, the profitability of firms and R&D intensity.

The study recommended that the GOI should provide more opportunities to foreign investors. Attracting further funds from abroad may prove to be advantageous for the indigenous pharmaceutical industry. The GOI's role in encouraging pharmaceutical firms to take up R&D activities has been overwhelmingly positive. The importance of encouraging pharmaceutical firms to invest in R&D assumes importance not only because R&D is considered the backbone of the pharmaceutical industry, but also because results of the study indicated that R&D intensity has a positive and significant influence on the firms' efficiency. Therefore, the task for GOI in promoting this sector and creating an environment where the internal efficiencies can be maintained will definitely be a challenging one in near future.

Chaudhuri and Das (2006) estimated the output efficiency of the Indian pharmaceutical industry using stochastic frontier production function. Using firm level data the study has been conducted for the period 1990 to 2001. The study has shown that the mean efficiency scores of the industry had improved over the sub–period 1999 to 2001 against the sub-period 1990-1998. Further, the study has shown that large sized firms and firms exporting more of their product in the international market have reduced their inefficiency.

Kaur and Kumar (2010) evaluated the extent of technical, pure technical and scale efficiencies of 36 Indian pharmaceutical firms categorized on the basis of ownership pattern as private domestic firms, private foreign firms and public sector firms. They have applied the DEA framework in the study in which the estimates of technical, pure technical and scale efficiencies for individual firms have been obtained by CCR and BCC models at three points of time i.e. 1990 (indicating the pre-reform period) and 2000 and 2004 (indicating the post-reform period). Three input variables (raw material cost, wages and salaries and fixed assets) and one output variable (net sales) have been used in the study.

The analysis revealed that the overall technical efficiency of private domestic firms ranges between 38.3 percent and 100 percent for the year 1990. The magnitude of overall technical inefficiency is 21.4 percent in this case. The magnitude of overall technical efficiency of the private foreign firms of the Indian pharmaceutical industry is 21.7 percent for 1990, which is marginally higher than that of private domestic firms. A comparative analysis for the years 1990 and 2000 have shown that average overall technical efficiency scores have decreased in the case of all three groups in the post-reform years. The highest decrease in efficiency is in the case of private domestic firms followed by public sector firms and private foreign firms. Overall from the whole analysis it can be observed that overall technical inefficiency is both due to poor input utilization (i.e. managerial inefficiency) and the failure to operate at the most productive scale size (i.e. scale inefficiency), although managerial inefficiency dominated all three years among these groups of the firms.

On the basis of the finding of the study, they have rejected the argument that the foreign firms are more efficient than domestic firms and that private firms are more efficient than the public sector firms. The significant difference in overall technical efficiency in the pre-reform year indicates that there might be significant difference in the technology being used by the domestic and foreign firms. However, after the reforms the non-significant difference in technical efficiency in the case of domestic, foreign and public sector firms may imply that there might be speedy technological spillovers among the firms in India. It can therefore be argued the Indian firms are catching up with foreign firms quite well after the liberalization process. The study have suggested that there is ample scope for increasing the efficiency of the firms in Indian pharmaceutical industry by choosing correct input output mix and selecting appropriate scale size. The spillover effects can be boosted by creating a better business environment and developing human capital so that there is no mismatch between domestic human capital and foreign technology.

Pannu et al (2011) analysed the relative efficiency and productivity change of 146 Indian pharmaceutical companies between 1998 and 2007 which covers the post-TRIPS and post Indian Patent Act Amendment period. They have used BCC DEA model and Malmquist productivity index to estimate the relative efficiency and productivity change of Indian pharmaceutical companies over the 10 years period. They have proposed and tested several hypotheses on the average efficiency and the productivity change of Indian pharmaceutical industry to check if the indigenous and multinational companies differ in their efficiency and productivity change over the aforementioned period. Also, they have analysed the effect of firm size on several performance measures.

The study indicates that over all the average productivity change has shown an increasing trend starting from 1998 which is mainly due to the technical efficiency. They found the efficiency and productivity change leaders and laggards over 10 year's period. They also proved that the average efficiency of MNCs between 1998 and 2007 is higher than the efficiency of indigenous companies. However, there is no difference between multinational and indigenous companies in the average productivity change between 1998 and 2007. The study also observed that close to 70% of indigenous companies have average efficiency scores less than the worst efficiency score among MNCs. This basically indicated that the input–output balance among multinational companies is better than that of Indian companies.

The study also noticed that the CAGR (compound annual growth rate) of efficient companies is higher than that of inefficient companies. Also, they have analysed the effect of firm size and found that larger firms posted a higher CAGR, efficiency and relative efficiency change score as compared to small and micro firms. However, smaller firms led the larger firms in productivity change and technical change. The study has found that efficiency of innovative firms was higher than non-innovative firms on a year to year basis for the ten year period though it is declining for both the groups after 2004.

Pradhan (2003) attempted to empirically verify the impact of economic liberalization on the R&D behaviour of Indian pharmaceutical firms controlling for the effects of several firm specific characteristics including firm size. The results from the Tobit analysis for a sample of firms over the period 1989-90 to 2000-01 indicated that competitive pressure generated by liberalization has worked effectively in pushing Indian pharmaceutical firms into R&D activity. A host of firm characteristics like firm age, size, profitability, intangible assets, export orientation and outward foreign direct investment have been found to be important determinants of innovative activity in the industry. The study suggested several policy measures to further indigenous technological efforts of pharmaceutical firms, which include, removing obstacles that inhibit outward orientation of firms, providing special scheme for small size firms in the overall technology policy for the industry, intensifying collaborative research efforts between private sectors and government research institution, and utilizing flexibilities in the TRIPs agreements to persuade foreign firms to relocate their R&D units into the country.

Chadha (2009) studied the impact of the strict patent regime on the patenting activity of Indian pharmaceutical firms and found that patenting activity of these firms has increased after the signing of TRIPs. The study was conducted for 65 pharmaceutical firms for the period 1991 to 2004 using different parametric and semi-parametric count panel data models. The results across different count data models indicated a positive and significant impact of the introduction of stronger patents on patenting activity. Further, the results have shown a gestation lag of 2 years between R&D spending and patent applications. Thus, there is a role for the government to help pharmaceutical firms to speedily file patents after R&D and reduce the gestation lag. This can be done by creating greater awareness about the patent filing process as well as streamlining the lengthy filing procedures. The study found that a stricter patent regime has indeed stimulated patenting activity in the Indian pharmaceutical industry.

In another study, Chadha (2009) studied the product cycle and neo-technology theories of trade in the context of generic pharmaceuticals. The study analyzed the export performance of 131 Indian pharmaceutical firms for the period 1989–2004. The results indicated that technology proxied by foreign patent rights has a positive impact on exports. This suggests that developing countries with innovation skills for process innovations are capable of penetrating international markets in the later stages of the product cycle by using patents, which were the barriers to trade in the early stages of the product cycle. The study found that the export market is substantially dynamic and that the results have significant implications for government policy. The results show that innovations do not merely reflect the extent of technological opportunity, but are a strategic tool for gaining market share in world markets

Dubey et al (2011) analyzed the performance of Indian pharmaceutical industry post TRIPs. The study revealed that pharmaceutical companies are changing their strategies to meet the new competitive business environment and as a result Indian pharmaceutical industry currently has strong linkages with the global pharmaceutical market. The study suggested that the pharmaceutical industry needs to focus more on R&D and better productivity to capitalize on the immense existing opportunities. India with its inherent competitive advantages and cost-effective manufacturing capabilities has now become one of the most preferred destinations for Contract Research and Manufacturing Services (CRAMS).

Kiran R. (2009) tried to analyse the Post TRIPS Patenting, Exports and R&D scenario in pharmaceutical industry of India. Factor analysis was done to study the Impact of TRIPS on Indian pharmaceutical sector. The results of the study highlight that the new patent regime has encouraged innovation and greater investment in R&D. Patents are the most efficacious and indispensable tool to secure strategic competitive advantage in the market. The impact of TRIPS compliance is becoming increasingly visible, on the pharmaceutical industry in India. Factor analysis of Impact of TRIPS on Indian pharmaceutical sector revealed that six factors namely: i) TRIPS, R&D and new opportunities, ii) products under DPCO and performance of R&D, iii) product category, nature of order & threats, iv) changes in tech, and tech personnel employed, v) changes in total sales and exports and vi) preparedness for TRIPS extracted together account for 76.39 percent of variation. The results od the study revealed a tendency to shift to excise free zones. Sales, exports, R&D and patenting have increased in the post-TRIPS period. The large and the medium scale firms accepted of having shifted to better technology. So the pharmaceutical industry of India is changing itself to suit the global scenario.

Saranga and Phani (2009) explored the effects of managerial and strategic parameters on the degree of operational efficiency achieved by a firm in the Indian pharmaceutical industry using DEA. During the period 1992–2002, the relaxation of import restrictions and foreign direct investment, along with a major change in the regulatory norms, resulted in increased competition from firms with superior resources in this industry. The findings of the study indicated that domestic firms, most of which are controlled by family-based governance structures, enjoy higher efficiencies than affiliates of multinational pharmaceutical majors. After controlling for firm size and initial efficiency levels, they found that firms with higher levels of innovation through higher R&D investments and older establishments are associated with higher efficiencies, when compared with their less R&D intensive and younger counterparts, respectively.

In another study, Kiran and Mishra (2009) examined the impact of new Patent Act on Pharmaceutical Industry of India especially on R&D. They seek to evaluate the performance of a few leading pharmaceutical firms' especially in terms of their ANDA filings and approvals as well as DMF (drug master files) filings with US FDA in post-TRIPS period. The study indicated that the period of the 1995-2008, i.e., the post-TRIPS period saw the strongest performance of the Indian pharmaceutical industry on several fronts. The industry improved its production performance by a significant margin. The pharmaceutical industry turned into a net foreign exchange earner during the Post-TRIPS era. India is fast emerging as a power house of active pharmaceutical ingredients (APIs) production. The study found that the growth was remarkable for the period 2000-08. R&D expenses have increased at a higher rate in the Post-TRIPs period growing at a rate of 5.07 against 3.88 in Pre-TRIPS period. According to industry reports, the share of Indian companies in the total DMF filed with the US FDA increased to 50 per cent in 2007 from 14 per cent in 2000. Indian companies have been at the forefront both in terms of DMF and ANDA filings.

Nauriyal and Sahoo (2008) evaluated the performance of the Indian pharmaceutical industry during the deregulated regime from 1995 to 2006. They found that the new IPR regime helped the firms of the drug and pharmaceutical industry to perform better if the performance is measured in terms of their sales revenue. The study confirmed that even though the R&D expenditure of the firm is less effective than the advertisement and marketing expenditure, expenditure of the firm on this head in the long run can be more productive in the form of more commercial patent patents and higher revenue. Furthermore, the study also calls for more marketing and advertisement expenditure on the part of the firms to create a 'niche market' for their product with 'brand loyalty' among the consumers. The data presented in the study also highlighted that major thrust on R&D began since 1996 as from this year onward, firms substantially pegged up their R&D expenditure and that there was heavy concentration of R&D expenditure around 16 firms which share over 90% of R&D expenditure incurred by all the sample firms. It further brought to the fore that there is no close connection between high export performance and R&D expenditure. It was found that only four (Ranbaxy, DRL, Cipla, Lupin) out of top ten exporters were also among the top ten firms with maximum R&D intensity.

Pradhan (2006) tried to explore the trends and strategies in the global competitiveness of the Indian pharmaceutical industry in terms of pharmaceutical value- added, productivity, research and development and trade performance. He found that strategic government policies have been the main factors that transformed the status of the Indian pharmaceutical industry from a mere importer and distributor of drugs and pharmaceuticals to an innovation driven cost effective producer of quality drugs.

India emerged as one of the fast growing pharmaceutical industry in the world with growing trade surpluses and exports. However, there are certain limitations that the government policies need to address like low productivity and R&D intensity. A host of competitive strategies, like Greenfield direct investment, overseas acquisitions, strategic alliances and contract manufacturing have emerged as favorites of Indian pharmaceutical firms recently.

Neogi et al (2012) assessed the performance of Indian pharmaceutical industry during the recent years and tried to find out the factors responsible behind the variation of industry's efficiency and productivity. The Stochastic Frontier Analysis (SFA) has been used to estimate the efficiencies of firms using the unit level panel data for the period of 2000 to 2005 of Indian pharmaceutical industry. Total factor productivity also has been estimated using the same data. Finally, some analyses have been made to find out the forces of variation of efficiencies and productivities of these industrial units. The study found that technical efficiencies and total factor productivity of firms are increasing over the years but not without fluctuation. However, the level and growth of efficiencies differs in a considerable ways among the type of ownerships of firms.

The study further found that the private players are doing significantly better compared to other type of ownerships. A positive association was found between the size of firms and their technical efficiencies and the total factor productivity. So the study concluded that scale of economies is prevailed in the pharmaceutical industries in India. Since the market of pharmaceutical industries become more competitive the firms with low efficiencies and low productivity cannot survive and either they merged with other firms or they are compelled to discontinue their operation. Managerial skill and wage rates have significant effect for the betterment of performance of these firms. Some of the newly identified areas with special facilities are found conducive for the better performance of pharmaceutical industries.

Saranga and Banker (2010) studied the productivity change and factors driving this change in the Indian pharmaceutical industry during 1994–2003. They have used a non-parametric DEA based-methodology to estimate productivity change and decompose it into technical and relative efficiency changes. They found that higher R&D investments and switching to higher value-added products by few innovative firms pushed the production frontier upwards with increasing technical and productivity gains. The higher technical and R&D capabilities and wider new product portfolios of multinational companies also have contributed to the positive technical and productivity changes in the Indian pharmaceutical industry.

Fujimori et al (2010) estimated a stochastic frontier production function using data of small scale Indian pharmaceutical industry. In this study they used a dataset of the 56th round of the NSS for manufacturing enterprise survey dataset. The NSS 56th round has been done in 1999 and 2000. In the study they found that the small scale pharmaceutical industry (SSPI) has inefficiency in their production activity. At the same time, the study has shown the evidence that the SSI supporting policy improves the technical efficiency in some extent. In other words, it could be said that the SSPI supporting policy has improved efficiency of the SSPI enterprise.

Pattnayak et al (2009) estimated the technical efficiency using the stochastic frontier production function for 76 Indian pharmaceutical firms during 1991-2003 in the light of policy changes in the international and domestic environment since 1995. The results of the analysis revealed that for the industry as a whole, there is evidence of time-varying technical efficiency for the sample firms and the overall technical efficiency has improved over the period 1991 to 2003. In addition, the study has found increasing returns to scale for the sub-sample of patenting firms, indicating that firms that successfully undertake R&D activities get high returns in developing countries like India. The main hypothesis that the setting up of the WTO and the deregulation of the pharmaceutical industry in India has improved the efficiency of the industry is supported by the results of the study. The favorable impact of the WTO and liberalization of the industry on output is evident from the positive and significant sign of the WTO dummy**.** Moreover, the results on technical efficiency show that patenting firms are close to the frontier and utilize the factor inputs efficiently. Thus, it seems that the new WTO regime of stricter patent rights has provided a stimulus to patenting firms to undertake greater R&D activities in order to effectively compete with pharmaceutical MNCs. The study suggested that the larger firms with potential for R&D will survive the enforcement of product patents through collaborations with MNCs concerning research joint ventures and contract research. For the pharmaceutical firms engaged in only manufacturing and marketing activities without any focus on research activities, the competition from MNCs could be fierce and may stimulate them to become more research-oriented firms in the long run. In the final analysis, the stronger patent laws may stimulate even the non-patenting firms to become more research -oriented and efficient in the long run.

Sharma (2012) examined the impact of research and development (R&D) activities on firms’ performance for the Indian pharmaceutical industry by utilizing the data of the post-reform period (1994–2006). For this purpose, he constructed two empirical frameworks, namely growth accounting and production function. The results of the study based on the growth-accounting framework indicate that R&D intensity has a positive and significant effect (15%) on total factor productivity. The results also confirm that the performance of foreign firms operating in the industry is more sensitive toward R&D than the local firms. Furthermore, the estimation results of the production function approach indicate that the output elasticity to R&D capital varies from 10% to 13%. In view of these findings, the study proposes further encouragement and incentives for doing in-house innovative activities in the Indian pharmaceutical industry.

Manohar Rao (2008) examined the issues concerning the rise of pharmaceutical industry in the emerging economies: the strategic response of the emerging-country pharmaceutical firms to the new patent regime that recognizes and enforces product patents; and its implications for multinational enterprise (MNE) strategies. The study found that the strategic response of pharmaceutical firms in the emerging economies, like India and China, to the new patent regime is to develop multiple competencies and position themselves to simultaneously compete and collaborate globally with the MNEs. The study indicates that the large firms rapidly moving towards discovery and development of new drugs, whereas, the medium and small firms engaged in the production of off-patent generics and contract manufacturing respectively.

Further the study revealed that firms in all groups, regardless of their strategic focus, appear to have developed multiple competencies to compete and collaborate globally. However, the new IPR regime poses a serious threat to the large firms competing on the basis of innovation of new drugs notwithstanding their cost advantage unless they invest heavily in R&D on diseases in the Indian market neglected by the MNEs and develop strength in niche markets for the traditional drugs. The study suggests that the focus on neglected diseases would require a much greater degree of public-private partnership than either the Indian firms or the MNEs are used to.

In the recent study Tripathy et al. (2013) examined the technical efficiency and productivity of 81 firms of the Indian pharmaceutical industry. The study found that technical efficiency and productivity are higher in the product patent regime than in the process patent regime. The analysis of Malmquist productivity index indicates that despite regression in technical change, firms' productivity improved as a result of technical efficiency gains. The results of three stages DEA identified firm specific factors, such as age, R&D intensity, ownership, capital imports and foreign direct investment as the determinants of technical efficiency.

Sakthivel (2011) attempted to analyze the value creation in Indian pharmaceutical industry from 1997-98 to 2006-07 by using regression analysis. Based on the analysis, the study found that the total factor productivity does not have explanatory power on value creation in short-term, but it has some influence on value creation in the long-run in respect of pharmaceutical companies. It is found that the companies with high level of EVA (economic value added) are very highly valued and differ from valuation of companies with low and moderate EVA groups. So it is clear that there is significant association between MVA (market value added) and EVA for companies under pharmaceutical industry. The study concluded that there is significant difference in mean value creation across low, moderate and high total productivity for pharmaceutical companies.

Das and Patel (2013) assessed the performance of the Indian pharmaceutical firms using the non-parametric DEA technique to find out the efficiency of firms and the peers of inefficient firms. The inputs considered in the study are; expenditure on R&D cost of materials, weighted average cost of capital (WACC). The outputs variables are; sales in million INR, net profit, earning per share (EPS), and the export. The study found that all companies are above 70 percent BCC efficient. There is a tremendous scope to reduce the R&D spent. It can be inferred that even though the spent on R&D is more but not yielding enough. The cost of materials also needs to be reduced. The inference is that these firms are using cost plus margin system and there is good scope for backward negotiations with vendors to reduce the cost of raw materials which can help society in large to produce drugs at affordable prices. The results derived through Tobit regression analysis highlights that the efficiency of pharmaceutical firms is mainly impacted either by output variables namely profit and export or by input variables i.e. R&D and WACC.

Kamiike et al. (2012) examined the effects of plants' dynamics on productivity growth in the Indian pharmaceutical industry across five regions: north, north-west, west, south and the rest of India during the period from 2000-01 to 2005-06 using the unit-level panel database drawn from the Annual Survey of Industries. The selected regions differ in the degree and age of agglomeration of the pharmaceutical industry. The empirical analysis is based on the decomposition methodology of aggregate productivity growth. This methodology decomposes productivity growth between two points in time into the contribution from four broad factors: improvement in productivity (within effect), reallocation of resources from less productive to more productive producers (reallocation effect), entry of more productive firms (entry effects), and exit of less productive firms (exit effect).

The empirical findings of the study reveal that productivity growth is relatively higher in the agglomerated regions. Further, the effects of plant dynamics on productivity growth differ depending on the age and dynamism of agglomerations. Rather large positive entry effects are found in the region where the formation of agglomeration is a recent phenomenon. In the mature and most dynamic region reallocation effects of surviving plants are large and robustly positive. In other areas however “within effects” of surviving plants are robustly positive.

3.4 Concluding Remarks:

From the foregoing review it is clear that there are quite a few interesting issues associated with measuring the productivity and efficiency of pharmaceutical industry. These include:

i) Selection the inputs and outputs variables for implementing the DEA and SFA technique and for productivity indices.

ii) Choosing the type of efficiency such as technical, allocative, profit, cost, advances, and productive efficiencies.

iii) Decomposition of productivity into various components like technical change, efficiency change, scale efficiency change, pure technical efficiency change and total factor productivity change.

iv) Identification of determinants of efficiency and productivity measures which would explain the efficiency and productivity differences among the selected firms. This may be done using tobit analysis and regressions analysis.

v) Specifying the functional form of the frontier – flexible or translog or multi – product cost function.

In the above studies the input variables that have been chosen for DEA, SFA and other methodologies to analyse the performance of the pharmaceutical industry include labour in terms of wages & salaries, raw materials, energy inputs, capital, fixed assets, cost of production and selling, marketing & advertising cost and expenditure on R&D. Similarly, the output variables considered in the above studies include net sales, net profit, export income, total assets, patents, operating profit etc.

The important determinants of the pharmaceutical firms' efficiency and productivity that have been identified in the above studies are; ownership structure, size of the firm, government pricing policies, deregulation, business strategies, the new patent regime, export of goods, presence of foreign direct investment, the profitability of firms and expenditure on R&D related activities etc.

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4. CHAPTER

EMPIRICAL ANALYSIS OF TECHNICAL EFFICIENCY OF INDIAN PHARMACEUTICAL FIRMS: DEA APPROACH

4.1 Methodology:

The modern concept of efficiency which started with the work of Farell (1957) who drew from the earlier work of Debreu (1951) and Koopmans (1951) defined the simple measure of efficiency which could account for multiple inputs. The concept of firm's efficiency relates how well a firm employs its resources relative to existing production possibilities frontier. An upward change in efficiency measures the increment in output without a rise in input or the amount by which inputs may be reduced without reducing the output. Farell proposed that efficiency of a firm consists of two components namely, technical efficiency which reflects the ability of firm to obtain maximal output from a given set of inputs, and allocative efficiency which reflects the ability of a firm to use inputs in optimal proportions given their respective prices. In the present study we have confined to the analysis of technical efficiency only, as consistent price data is not available for studying allocative, profit and cost efficiencies. The present study has utilised the nonparametric and parametric technique to estimate a production frontier which will serve as a benchmark to estimate the technical efficiencies of the Indian pharmaceutical industry for the period 1997 to 2011. The non-parametric, non-stochastic approach developed by Charnes (1978) known as data envelopment analysis (DEA) uses non-parametric linear programming technique. The parametric technique known as stochastic frontier analysis (SFA) is based on the econometric method. Both DEA and

SFA assume that the production frontier is known but in practice this is not the case, it must be estimated. Similarly efficiency measures may obtain under the assumption of constant returns to scale or variable returns to scale for the frontier. We now discuss the DEA methodology adopted in this study. The DEA is used for the analysis of relative performance of the firms within the institutional framework.

4.2 Data Envelopment Analysis (DEA):

Data Envelopment Analysis (DEA) is a mathematical programming technique which is used to measure technical efficiency of the firms. DEA provides the efficiency of each of the firms relative to a given set of firms. These firms are assumed to be in the business of producing various outputs by consuming a set of inputs. DEA computes the efficiency of a firm in transforming inputs into outputs in relation to its peer group. Charnes et al. (1978) first developed the DEA technique based on the same concept of technical efficiency given by Farrell (1957). “DEA in essence is a linear programming technique that converts multiple inputs and outputs into a scalar measure of efficiency. Each firm is evaluated against a hypothetical firm with an identical output mix that is constructed as a combination of efficient firms. DEA identifies the most efficient firms in a population and provides a measure of inefficiency for all others. The most efficient firms are rated to have an efficiency score of one, while the less efficient firms score between zero and one. Though DEA does not give a measure of optimal efficiency, it however differentiates the least efficient firms from the set of all firms. Thus, the efficient institutions calculated using DEA establish the best practice frontier” (Siems and Thomas, 1992).

Efficiency of a firm in the DEA technique can be measured as the maximization of a set of outputs (output-oriented) for a given set of inputs or minimization of a set of inputs (input-oriented) for a given set of outputs. These two methods provide the same value of technical efficiency under constant return to scale but unequal value when increasing or decreasing return to scale is assumed. The input-oriented DEA methods are similar to their output-oriented counterparts. Both the methods estimate the same frontier, and hence would identify the same set of firms being efficient. It is only the efficiency measure associated with inefficient firms that might differ between the two methods. In the present study, we have adopted the input-oriented method.

Traditional financial indicators are calculated using single input / output measures like operating profit margins, net profit margins, fixed asset turnover, working capital intensity, inventory holding period, etc. However, parameters like margins, returns and debt ratios can only describe various performance characteristics in isolation, as only one input and one output a reconsidered at a time. Comparison of these parameters in isolation across firms for a given industry might provide a biased picture of a firm's efficiency vis-à-vis other firms in the same industry. DEA overcomes this problem by simultaneously analyzing multiple inputs and outputs, to come up with a single scalar value as a measure of efficiency. The weights corresponding to each input and output are chosen in such a way that the best practice of each firm gets highlighted in the efficiency evaluation. The technical efficiency may be measured under the assumptions of either constant returns to scale (CRS) or variable returns to scale (VRS). The CRS assumption is only appropriate when all the firms are operating at an optimal scale. Imperfect competition, constraints on finances, and other limitations may be hinder firms to operate at optimal scale. An extension of the CRS DEA model to account for variable returns to scale has been suggested by Banker, Charnes and Cooper (1984). Use of CRS specification, when all firms are not operating at the optimal scale, might confound the measure of technical efficiency (TE) by scale efficiencies (SE). In this context, use of VRS specification would permit the calculation of TE devoid of these SE effects. While TE efficiency refers to manager's capability to utilize firms' given resources, SE refers to exploiting scale economies by operating at a point where the production frontier exhibits constant returns to scale. In the present study, we have used in addition to CRS, the VRS specification to measure TE and SE.

4.2.1 DEA Model:

The DEA model developed by Charnes, Cooper and Rhodes (1978) (input based) in ratio form may be explained as follow:

Consider n decision-making units (DMU) (here DMU refers to pharmaceutical firms) producing s outputs using m inputs.

$$\text{Max } Z_m = \sum_{j=1}^{J} v_{jm} y_{jm} \Big/ \sum_{i=1}^{I} u_{im} x_{im}$$

$$\text{subject to } 0 \le \sum_{j=1}^{J} v_{jm} y_{jn} \Big/ \sum_{i=1}^{I} u_{im} x_{in} \le 1;\ n = 1, 2, \ldots N \qquad \ldots(4.1)$$

$$v_{jm}, u_{im} \ge 0;\ i = 1, 2, 3, \ldots, I;\ \ j = 1, 2, 3, \ldots, J$$

Where,

Z_m is the efficiency of the mth firm,
y_{jm} is the function output j from firm *m*,
v_{jm} *is* weight of that output,
x_{im} is the amount of input *i* to firm m,
u_{im} is weight chosen for input i
y_{jn} *and* x_{in} are the jth output and ith input respectively of nth firm, n=1,2,....N.
Note that here n includes m.

Z_m is the objective function (defined as the ratio of weighted output and weighted input) of firms m.

The above equation, when solved, gives the values of weights u and v that will maximize the efficiency of the firm. These weights are unknown but to be obtained through optimization. To measure technical efficiency optimization has to be performed separately for each firm as a unit. If the efficiency is unity, then the firm is said to be efficient and will lie on the frontier. Otherwise the firm is said to be relatively inefficient.

The problem setting in equation (4.1) is a fractional program, which can be transformed into a linear programming problem (LP) by restricting the denominator of the objective function Z_m to unity, and adding this as constraint to the problem. This can be mathematically shown as:

$$\begin{aligned} \text{Max } Z_m &= \sum_{j=1}^{J} v_{jm} y_{jm} \\ \text{s.t } & \sum_{i=1}^{I} u_{im} x_{im} = 1 \\ & \sum_{j=1}^{J} v_{jm} y_{jn} - \sum_{i=1}^{I} u_{im} x_{in} \leq 0 \qquad \text{....(4.2)} \\ & \text{j} = 1, 2, 3, ..., J; i = 1, 2, 3, ...I, \text{ and} \\ & \text{n} = 1, 2, 3, ..., N \end{aligned}$$

The linear programming setting in equation (4.2) assumes constant returns to scale technologies. Here the formulation constrains the weighted sum of inputs to unity and maximizes the outputs, which is output-based efficiency measurement. An alternative formulation constrains the sum of the weighted output to unity and minimizes the inputs given an input-based measurement of efficiency.

In the above formulation [equation (4.2)], the idea is to find values of u and v, such that the efficiency measure of the m^{th} firm is maximized, subject to the constraints. The formulation given in equation (4.2) can have infinite number of solutions. To avoid this problem, equation (4.2) may be reformulated as follows. By denoting the input weights of firm m by θ_m, and the input and output weights of other firms in the sample by λ_n, the dual form of the maximizing problem is formularized as follows:

$$
\begin{aligned}
&\text{Min } \theta_m \\
&\text{s.t} \sum_{n=1}^{N} \lambda_n y_{jn} - s_i^+ = y_{jm} \\
&\sum_{n=1}^{N} \lambda_n x_{in} - s_i^- = \theta_c x_{im} \\
&\lambda_n, s_i^+, s_i^- \geq 0; \\
&\text{n} = 1, 2, 3, \ldots, N
\end{aligned}
\qquad \ldots(4.3)
$$

The firm m is regarded as efficient if the θ_m, is equal to one and the slacks (s_i^+ and s_i^-) are zero. That is, if and only if,

$\theta_m^* = 1$ with $s_i^{+*} = s_i^{-*} = 0$ for all m and n ,

where asterisk denotes optimal values of the variables in the above problem. A firm is regarded as inefficient if θ_m, is less than one and/or slack variables being positive. For these inefficient firms, the optimal values of λ_n construct a hypothetical firm which is formed by the subset of the efficient firms. The above formulation can be transformed for the variable returns to scale (VRS), as Banker, Charnes and Cooper (1984) suggested, by including $\sum_{n=1}^{N} \lambda n$ as an extra constraint to the model (4.3).

4.2.2 Calculation of Scale Efficiencies

The DEA estimates of technical efficiency (TE) can be decomposed into two components, one due to scale inefficiency and one due to "pure" technical inefficiency. This is done by conducting both a CRS and VRS DEA upon the same data. If there is difference in the two TE scores for a particular firm, then this indicates that the firm has scale inefficiency, and that the scale inefficiency can be calculated from the difference between the VRS TE and the CRS TE score.

$$TE_{CRS} = TE_{VRS} \times SE$$

4.2.3 Data Source and Input-Output Specifications:

To analyse the efficiency of the pharmaceutical companies, the relevant data at firm level necessary for the computation has been collected from the financial balance sheets of the companies provided by the prowess data source of the Centre for Monitoring of Indian Economy (CMIE). The number of firms in the sample varies from 29 to 183 over the period of 1997-2011 and in total there is an unbalanced panel of 2069 firms for 15 years.

The first step to measure the efficiency using DEA is to specify inputs and outputs of firms. In the present study the inputs considered are raw material, labour, power and fuel, marketing and advertising cost, net fixed assets and capital. The outputs considered are total sales, foreign exchange earnings, and profit and total assets. Explanation of variables used in the DEA is given in the following table.

Table 4.1: Variable Description used in DEA

Variables as outputs	
Total sales	Gross sales for a period before making any deductions for discounts, returns transportation, and some other expenses
Foreign exchange earnings	Proceeds from the export of goods and services of a country, and the returns from its foreign investments
Profit	Net profit earned by the company after deducting all expenses like interest, depreciation and tax.
Total assets	The total value of all current and long-term assets owned by a company presented on the balance sheet
Variables as inputs	
Raw material	measured in terms of the companies' expenditure for raw material
Labour	measured in terms of wages and salaries for the workers
Power and fuel	measured is terms of the expenditure for power and fuel
Marketing and advertising cost	Measured in terms of expenditure for marketing and advertising
Net fixed assets	Total fixed assets minus accumulated depreciation
capital	The book value for plant and machinery, land and building

4.3 Classification of the Firms:

We have classified the firms into groups keeping in view the differences in the technology to analyze the relationship between the efficiency and different kinds of firms. There are firms which are spending on R&D activities and firms without spending on R&D. If the R&D group of firms become successful in their efforts they can realize the benefits in terms of turnover or profit and can perform better than non R&D group of firms. There are firms exploring the international market which produce their product according to the differences in population structure, the disease pattern and regulatory norms in the global context. There are possibilities for such firm to take advantages of technological transfer and collaboration with foreign big firms. The production possibilities that firms across these groups face are different from the firms which are not exposed to international market. Based on the origin, we have divided the firms between indigenous and MNCs. Based on the export performance, we have made two groups high exporting firms and low exporting firms. We have also classified the firms based on their size i.e. small firms (measured in terms of investment in plant and machinery) and big firms. Big firms are supposed to gain more from economies of scale or scope in its cost of production, R&D and marketing related activities and may have greater access to resources for technological expansion. Therefore big firms may perform better compared to small firms. Based on the product produced, we have classified firms in the industry into three groups i.e. firms producing only bulk drugs (raw material of medicines), firms producing final product and the firms engaged in the production of both bulk and formulation. Production of alternative varieties of drug is also closely related to the structure of the firms. Thus, firms producing bulk drug compete vertically in the intermediate good markets whereas firms producing formulation compete in the final market horizontally. Alternatively, firms producing both bulk and formulation are vertically linked with the input market and also compete in the final market and thus it may take the advantage of vertical integration in terms of higher efficiency gain.

4.4 Empirical Analysis:

4.4.1 Technical Efficiency Estimates: Firm Level Analysis

The DEA estimates of technical efficiency and scale efficiency at firm level are shown in Table 4.2 to Table 4.13 for the input-output combination mentioned as above. Though scores are generated for all the years in the sample period, the efficiency scores are reported in the tables for the selected years i.e. 1997, 1999, 2002, 2006, 2009 and 2011.

This has been done for two reasons namely- space constraint and the results being reflecting a similar trend for the intervening years. It may be noted that firms with efficiency score one are considered to be on frontier and regarded as technically efficient. Efficiency score less than one indicates technical inefficiency. A score being zero indicates that the firm is totally technically inefficient. As the score of a firm moves away from 1 it will be away from the frontier.

Table 4.2 shows the DEA estimate of technical efficiency scores for indigenous firms group. In the year 1997, under the assumption of variable returns to scale (VRS), out of 16 firms, 11 firms are on the frontier having efficiency score one. These firms regarded as technically efficient firms. However, the number of such firms is reduced to 10 when the scores are estimated on the assumption of constant returns to scale (CRS). This difference in the finding may be attributed to factors such as size of firms, branch locations and financial constraints, which are not considered in case of CRS. Caplin Point Laboratory with efficiency score 0.614 and 0.637 has been found to be the most technically inefficient firm when CRS and VRS are considered respectively. In the year 1999, number of firms with efficiency score one i.e. on the frontier are 12 in case of CRS and 23 in case of VRS out of total 43 firms. Raptakos Brett and Co. Ltd is most inefficient firm with efficiency score of 0.491 and 0.532 in terms of CRS and VRS respectively, while going by scale efficiency, Lyka Laboratories Ltd is found to be most inefficient firm with the score of 0.626. In the year 2002, Anglo French Drugs and Inds Ltd is most inefficient firm in the group with CRS and VRS technical efficiency score of 0.673 and 0.694 respectively and out of total 58 firms, 27 firms in terms of CRS and 36 firms in terms of VRS assumptions are on the frontier. In the year 2006, 22 firms and 35 firms out of 58 firms are at the frontier that is having technical efficiency score one in case of CRS and VRS assumption respectively. Bharat Serums and Vaccines Ltd is most inefficient firm with technical efficiency score of 0.585 and 0.593 in terms of CRS and VRS respectively) in the year 2009, the number of firms operating on the frontier in both cases that is VRS and CRS technical efficiency score are 15 and 34 out of 61 in case of CRS and VRS respectively and BDH Hindustan Ltd is the most inefficient firm in case of both CRS (0.549) and VRS (0.556). In the year 2011, out of 45 firms, 19 and 26 firms are on the frontier in case of CRS and VRS respectively and the most inefficient firm is Syncom Formulation (India) Ltd with technical efficiency score 0.566 and 0.674 in both case CRS as well as VRS respectively.

Table 4.3 shows the TE estimates of MNCs firms Group. In the year 1997, there are 6 firms out of 7 on the frontier with technical efficiency CRS and VRS TE score one. Intas Pharmaceuticals Ltd is the most inefficient firm with TE scores 0.622 and 0.778 in both CRS and VRS cases respectively. In the year 1999, 24 and 27 firms out of 38 firms are on frontier in terms of CRS and VRS technical efficiency and Intas Pharmaceutical Ltd is again the most inefficient in both CRS and VRS cases.

Table 4.2: DEA Estimates of Technical Efficiency for Indigenous Group

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**
Aarti Drugs Ltd.	-	-	-	0.831	1	0.831	0.793	1	0.793	0.992	1	0.992	0.894	1	0.894	0.893	1	0.893
Ahlcon Parenterals (India) Ltd.	-	-	-	0.985	1	0.985	1	1	1	1	1	1	0.852	0.87	0.979	0.846	0.898	0.943
Albert David Ltd.	-	-	-	0.677	0.892	0.759	0.758	1	0.758	0.777	0.857	0.907	0.737	0.765	0.964	0.737	0.841	0.876
Alembic Ltd.	-	-	-	0.781	1	0.781	0.729	1	0.729	0.644	1	0.644	0.626	1	0.626	0.776	1	0.776
Amrutanjan Health Care Ltd.	-	-	-	0.625	0.633	0.987	0.698	0.698	1	0.974	0.986	0.987	1	1	1	0.866	0.897	0.965
Anglo-French Drugs & Inds. Ltd.	-	-	-	0.551	0.56	0.985	0.673	0.694	0.969	0.856	0.857	0.998	0.7	0.701	0.999	0.698	0.706	0.989
Anuh Pharma Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Arvind Remedies Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Auro Laboratories Ltd.	-	-	-	0.679	0.812	0.836	1	1	1	0.597	0.782	0.763	1	1	1	1	1	1
B D H Industries Ltd.	1	1	1	0.556	0.556	0.999	1	1	1	0.567	0.597	0.949	0.549	0.556	0.986	0.638	0.681	0.936
Bal Pharma Ltd.	-	-	-	0.58	0.584	0.994	0.737	0.799	0.922	0.799	0.816	0.98	0.582	0.636	0.915	0.569	0.691	0.824
Bharat Serums & Vaccines Ltd.	-	-	-	-	-	-	0.737	1	0.737	0.585	0.593	0.986	0.809	0.853	0.949	-	-	-
Biological E. Ltd.	-	-	-	0.836	1	0.836	1	1	1	1	1	1	0.616	0.829	0.744	-	-	-
Caplin Point Laboratories Ltd.	0.614	0.637	0.964	1	1	1	-	-	-	0.76	0.883	0.861	1	1	1	1	1	1
Chemcaps Ltd.	-	-	-	0.789	1	0.789	0.889	0.97	0.916	-	-	-	0.843	1	0.843	-	-	-
Coral Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.613	0.632	0.97	0.832	0.958	0.869
East India Pharmaceutical Works Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.994	0.995	0.999	-	-	-
Enzal Chemicals (India) Ltd.	-	-	-	0.691	0.73	0.945	1	1	1	0.881	0.881	1	0.78	0.803	0.971	-	-	-
Everest Organics Ltd.	1	1	1	-	-	-	1	1	1	1	1	1	0.696	0.719	0.968	0.763	0.781	0.977
Fermenta Biotech Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fredun Pharmaceuticals Ltd.	-	-	-	0.65	0.924	0.704	0.838	1	0.838	1	1	1	0.788	1	0.788	-	-	-
Group Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.923	0.926	0.997	1	1	1	1	1	1
Harman Finochem Ltd.	-	-	-	0.763	0.815	0.936	0.921	0.931	0.99	0.958	1	0.958	0.939	0.985	0.953	-	-	-
Hester Biosciences Ltd.	-	-	-	-	-	-	0.862	0.966	0.892	0.971	0.978	0.994	0.818	0.822	0.995	1	1	1
Indoco Remedies Ltd.	1	1	1	0.966	1	0.966	0.875	0.962	0.91	0.885	1	0.885	0.752	0.983	0.765	0.638	0.92	0.693
Ishita Drugs & Inds. Ltd.	-	-	-	-	-	-	0.728	1	0.728	0.682	1	0.682	0.945	1	0.945	0.831	1	0.831
Jenburkt Pharmaceuticals Ltd.	-	-	-	-	-	-	0.703	0.786	0.894	1	1	1	1	1	1	1	1	1
K D L Biotech Ltd.	-	-	-	0.781	1	0.781	1	1	1	1	1	1	1	1	1	-	-	-
Karnataka Antibiotics & Pharmaceuticals Ltd.	-	-	-	-	-	-	0.98	1	0.98	1	1	1	1	1	1	0.954	0.994	0.96

Kilitch Drugs (India) Ltd.	-	-	-	-	-	-	0.911	0.914	0.996	1	1	1	0.886	0.892	0.993	0.831	0.839	0.99
Kopran Ltd.	1	1	1	0.881	1	0.881	1	1	1	0.75	0.865	0.868	0.539	0.828	0.652	0.593	0.694	0.854
Krebs Biochemicals & Inds. Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lincoln Pharmaceuticals Ltd.	-	-	-	0.676	0.677	0.999	0.768	0.805	0.955	0.984	0.988	0.996	1	1	1	1	1	1
Lyka Labs Ltd.	-	-	-	0.626	1	0.626	1	1	1	0.793	1	0.793	0.693	0.963	0.72	1	1	1
Macleods Pharmaceuticals Ltd.	-	-	-	1	1	1	0.806	1	0.806	0.888	1	0.888	0.613	1	0.613	-	-	-
Mangalam Drugs & Organics Ltd.	-	-	-	-	-	-	0.755	0.84	0.898	0.803	0.821	0.978	0.688	0.69	0.997	0.641	0.643	0.998
Marck Biosciences Ltd.	-	-	-	-	-	-	0.848	0.861	0.985	0.837	0.849	0.986	0.784	0.921	0.851	-	-	-
Medicamen Biotech Ltd.	-	-	-	0.869	0.874	0.994	1	1	1	1	1	1	0.934	0.973	0.96	0.898	0.949	0.947
Medley Pharmaceuticals Ltd.	1	1	1	0.989	0.989	1	1	1	1	-	-	-	0.923	1	0.923	-	-	-
Morepen Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.756	1	0.756	0.991	1	0.991
Natco Pharma Ltd.	-	-	-	-	-	-	0.939	1	0.939	0.824	1	0.824	0.759	1	0.759	1	1	1
Natural Capsules Ltd.	-	-	-	-	-	-	1	1	1	0.767	0.77	0.997	0.986	0.994	0.992	1	1	1
Nectar Lifesciences Ltd.	1	1	1	1	1	1	1	1	1	1	1	1	0.812	1	0.812	1	1	1
Parenteral Drugs (India) Ltd.	-	-	-	-	-	-	0.766	0.903	0.848	0.923	1	0.923	0.943	1	0.943	0.947	1	0.947
Raptakos, Brett & Co. Ltd.	-	-	-	0.491	0.532	0.922	-	-	-	1	1	1	0.917	1	0.917	-	-	-
Resonance Specialties Ltd.	-	-	-	0.756	0.756	1	1	1	1	-	-	-	1	1	1	1	1	1
S M S Pharmaceuticals Ltd.	1	1	1	1	1	1	-	-	-	0.788	0.92	0.857	0.83	1	0.83	1	1	1
Samrat Pharmachem Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Shilpa Medicare Ltd.	1	1	1	0.895	0.94	0.952	0.734	0.737	0.996	1	1	1	0.8	1	0.8	1	1	1
Smruthi Organics Ltd.	-	-	-	0.873	0.887	0.984	0.683	0.705	0.969	0.683	0.706	0.968	0.624	0.63	0.991	0.799	0.832	0.961
Span Diagnostics Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sri Krishna Drugs Ltd. [Merged]	-	-	-	0.996	1	0.996	0.903	0.916	0.986	0.868	0.873	0.995	0.751	0.76	0.989	-	-	-
Srini Pharmaceuticals Ltd.	-	-	-	1	1	1	0.985	1	0.985	1	1	1	0.73	1	0.73	-	-	-
Sunil Healthcare Ltd.	0.847	1	0.847	0.708	0.79	0.896	1	1	1	0.716	0.733	0.977	0.747	0.758	0.985	0.756	0.758	0.997
Syncom Formulations (India) Ltd.	-	-	-	0.555	0.558	0.994	0.762	0.857	0.889	1	1	1	0.564	0.566	0.997	0.566	0.574	0.988
Themis Medicare Ltd.	-	-	-	0.688	0.705	0.975	0.825	0.895	0.922	0.677	0.806	0.841	0.574	0.76	0.756	0.63	0.858	0.734
Tonira Pharma Ltd.	1	1	1	1	1	1	1	1	1	0.949	0.957	0.992	0.768	0.782	0.982	0.754	0.803	0.94
Twilight Litaka Pharma Ltd.	0.848	0.884	0.959	-	-	-	0.674	0.748	0.9	0.735	1	0.735	0.86	1	0.86	0.988	1	0.988
U S V Ltd.	1	1	1	0.765	1	0.765	1	1	1	1	1	1	0.992	1	0.992	-	-	-
Unimark Remedies Ltd.	-	-	-	0.714	0.774	0.922	0.684	0.907	0.754	0.852	1	0.852	0.756	1	0.756	-	-	-
Wanbury Ltd.	-	-	-	-	-	-	0.819	0.821	0.998	0.966	1	0.966	0.77	1	0.77	0.622	1	0.622
Mean	**0.936**	**0.962**	**0.972**	**0.839**	**0.898**	**0.935**	**0.911**	**0.953**	**0.955**	**0.898**	**0.941**	**0.954**	**0.852**	**0.922**	**0.925**	**0.881**	**0.929**	**0.948**

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency

Table 4.3: DEA Estimates of Technical Efficiency for MNCs Group

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	Scale
Abbott India Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Ajanta Pharma Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Alkem Laboratories Ltd.	-	-	-	1	1	1	1	1	1	0.586	0.676	0.866	0.438	0.499	0.877	-	-	-
Astrazeneca Pharma India Ltd.	-	-	-	0.925	0.933	0.991	0.847	0.913	0.927	0.698	0.726	0.961	0.851	0.862	0.987	0.906	0.974	0.93
Aurobindo Pharma Ltd.	-	-	-	1	1	1	1	1	1	0.748	1	0.748	0.737	1	0.737	0.926	1	0.926
Aventis Pharma Ltd.	-	-	-	0.715	0.797	0.896	0.771	0.81	0.952	-	-	-	0.652	0.735	0.887	0.79	0.889	0.889
Biocon Ltd.	-	-	-	-	-	-	0.793	0.801	0.991	0.931	1	0.931	0.725	0.834	0.869	0.886	1	0.886
Cadila Healthcare Ltd.	-	-	-	1	1	1	0.761	0.835	0.911	0.473	0.745	0.636	0.555	0.771	0.72	0.917	0.982	0.934
Cadila Pharmaceuticals Ltd.	-	-	-	0.726	0.973	0.746	0.582	0.628	0.926	-	-	-	0.451	0.535	0.844	0.56	0.567	0.988
Cipla Ltd.	-	-	-	1	1	1	1	1	1	0.855	1	0.855	0.967	1	0.967	0.955	1	0.955
Claris Lifesciences Ltd.	-	-	-	-	-	-	1	1	1	0.505	0.688	0.733	1	1	1	1	1	1
Divi'S Laboratories Ltd.	-	-	-	1	1	1	1	1	1	0.903	1	0.903	1	1	1	1	1	1
Dr. Reddy'S Laboratories Ltd.	-	-	-	0.913	0.917	0.995	1	1	1	0.802	1	0.802	0.86	1	0.86	1	1	1
Elder Pharmaceuticals Ltd.	1	1	1	1	1	1	1	1	1	0.795	0.906	0.878	0.707	0.761	0.928	0.889	0.897	0.99
F D C Ltd.	-	-	-	0.92	1	0.92	0.829	0.855	0.969	0.587	0.591	0.993	0.588	0.594	0.989	0.739	0.747	0.989
Gennex Laboratories Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.769	1	0.769	0.646	1	0.646
Glaxosmithkline Pharmaceuticals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Glenmark Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.822	0.877	0.937	1	1	1	1	1	1
Granules India Ltd.	-	-	-	1	1	1	0.909	0.943	0.964	0.482	0.873	0.552	0.759	0.872	0.87	0.88	0.906	0.971
Hetero Drugs Ltd.	-	-	-	1	1	1	1	1	1	-	-	-	0.948	1	0.948	-	-	-
Ind-Swift Laboratories Ltd.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Intas Pharmaceuticals Ltd.	0.622	0.778	0.8	0.691	0.72	0.959	0.697	0.699	0.997	0.667	1	0.667	1	1	1	-	-	-

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**
Ipca Laboratories Ltd.	-	-	-	0.958	0.962	0.996	0.914	0.939	0.974	0.34	0.77	0.441	0.441	0.697	0.633	0.76	0.772	0.985
J B Chemicals & Pharmaceuticals Ltd.	-	-	-	0.976	0.984	0.992	0.782	0.785	0.997	0.461	0.777	0.594	0.928	1	0.928	0.965	1	0.965
Jagsonpal Pharmaceuticals Ltd.	-	-	-	0.752	0.792	0.949	0.72	0.725	0.993	0.524	0.526	0.997	0.85	0.915	0.928	0.616	0.789	0.78
Lupin Ltd.	-	-	-	-	-	-	0.711	0.789	0.901	0.45	0.752	0.599	0.564	0.815	0.692	0.923	1	0.923
Matrix Laboratories Ltd.	-	-	-	1	1	1	1	1	1	0.794	1	0.794	0.884	1	0.884	1	1	1
Neuland Laboratories Ltd.	-	-	-	1	1	1	0.794	0.801	0.992	0.447	0.896	0.499	0.677	0.787	0.86	0.807	0.832	0.97
Novartis India Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Orchid Chemicals & Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.795	1	0.795	0.911	1	0.911	0.829	1	0.829
Organon (India) Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Panacea Biotec Ltd.	-	-	-	1	1	1	0.848	0.854	0.993	0.93	1	0.93	0.646	0.782	0.825	0.857	1	0.857
Pfizer Ltd.	-	-	-	-	-	-	1	1	1	0.593	0.736	0.807	1	1	1	1	1	1
Ranbaxy Laboratories Ltd.	1	1	1	1	1	1	1	1	1	0.769	1	0.769	0.998	1	0.998	1	1	1
Shasun Pharmaceuticals Ltd.	-	-	-	1	1	1	0.835	0.836	0.999	0.428	0.742	0.577	0.587	0.696	0.843	0.749	0.764	0.98
Strides Arcolab Ltd.	-	-	-	1	1	1	1	1	1	0.883	1	0.883	1	1	1	1	1	1
Sun Pharmaceutical Inds. Ltd.	-	-	-	0.785	0.785	0.999	1	1	1	1	1	1	1	1	1	1	1	1
Surya Pharmaceutical Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Suven Life Sciences Ltd.	1	1	1	1	1	1	1	1	1	0.664	0.673	0.987	0.613	0.688	0.892	0.904	1	0.904
Torrent Pharmaceuticals Ltd.	1	1	1	0.897	1	0.897	0.63	0.648	0.972	0.423	0.55	0.768	0.574	0.604	0.95	0.73	0.767	0.952
Unichem Laboratories Ltd.	-	-	-	0.661	0.664	0.996	0.593	0.604	0.981	0.537	0.58	0.925	0.573	0.594	0.964	0.684	0.693	0.986
Wockhardt Ltd.	1	1	1	0.871	1	0.871	0.988	1	0.988	0.762	0.922	0.826	0.803	1	0.803	0.889	0.954	0.932
Wyeth Ltd.	-	-	-	1	1	1	0.782	0.784	0.997	0.76	0.778	0.977	1	1	1	1	1	1
Mean	**0.953**	**0.972**	**0.975**	**0.946**	**0.964**	**0.981**	**0.915**	**0.928**	**0.985**	**0.761**	**0.891**	**0.849**	**0.839**	**0.895**	**0.931**	**0.904**	**0.942**	**0.96**

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

In the year 2002, the numbers of firms on the frontier are 24 and 25 out of 44 in case of CRS and VRS assumption respectively. Cadila Pharmaceutical Ltd and Unichem Laboratories Ltd are the most inefficient firms. In the year 2006, 9 and 20 firms out of 41 firms are on the frontier and Ipca Laboratories Ltd and Jagsonpal Pharmaceutical Ltd are most inefficient firms. In the year 2009, 15 and 25 firms out of 44 firms are on the frontier in both cases i.e. CRS and VRS and the most inefficient firm is Alkem Laboratories Ltd. In the year 2011, 16 and 26 out of 40 firms are on the frontier and Cadila Pharmaceutical Ltd is the most inefficient firm with technical efficiency score of 0.56 and 0.567 in terms of CRS and VRS assumption respectively. Cadila Pharmaceutical is least efficient in the group and Ind-Swift Laboratories Ltd is technically efficient in all the years in the group.

The above discussion clearly shows that the technical efficiency of the Indian pharmaceutical firms has varied over the years, and also across the CRS-VRS assumptions. More specifically, the firms in the indigenous group, such as Caplin Point Laboratories, Twilight Litaka Pharma Ltd etc which were technically inefficient in the year 1997, have progressively moved forward to achieve technical efficiency by the year 2011. There are firms which have performed very well throughout the period starting from 1997 to 2011 such as, Nector Lifesciences Ltd, Anuh Pharma, SMS Pharmaceutical Ltd, and Span Diagnostics Ltd. A few reversals in case of BDH Hindustan Ltd, Everest Organics Ltd, Indoco Remedies Ltd, Kopran Ltd, and Tonira Pharma Ltd are also noted.

The DEA estimates of the technical efficiency for big firms group are reported in table 4.4. Since the number of firms is less in the year 1997 due to data constrains, out of total 10 firms, 8 firms in case of CRS and 9 firms in case of VRS are on frontier regarded as technically efficient, and the least efficient firm in the year is Intas

Pharmaceutical Ltd in both CRS and VRS cases. In the year 1999, 21 and 35 out of 40 firms are on the frontier and the least efficient firm is Unichem Laboratories Ltd. In the year 2002, 29 and 34 out of 57 firms are on the frontier and the least efficient firm is Cadila Pharmaceutical Ltd with technical efficiency CRS score 0.582, while in case of VRS, Unichem Laboratories Ltd is the most inefficient firm. In the year 2006, 25 and 30 out of total 56 firms, are on the frontier and the least efficient firm is Alembic Ltd in both the cases CRS and VRS. In the year 2009, 22 and 27, out of 57 firms, are on the frontier and the least efficient firm is Albert David Ltd with TE scores 0.373 (CRS) and 0.388 (VRS). In the year 2011, 17 and 26 out of 52 firms, are on the frontier and Albert David Ltd is again the most inefficient firm with efficiency score of 0.497 in case of CRS and 0.5 in case of VRS. Overall, relatively best performing firms in the group over the period of 1997 to 2011, are Divi's Laboratories Ltd, Nector Lifescience Ltd, Surya pharmaceutical Ltd, Ind-Swift Laboratories Ltd, Glaxosmithkline Pharmaceutical Ltd and Cipla Ltd etc, and among the least technically efficient firms relative to other firms in the group, are Albert David Ltd, Cadila Pharmaceutical Ltd, Alembic Ltd and Unichem Laboratories Ltd.

Table 4.5 shows the technical efficiency score for the small firms group for the period of 1997 to 2011. In the year 1997, 3 out of 4 firms are on the frontier, and the least efficient firm is Caplin Point Laboratories Ltd (with 0.65 CRS and 0.656 VRS). In the year 1999, 7 and 9 out of 20 firms are on the frontier and the least efficient firm is Jagsonpal Pharmaceutical Ltd. In the year 2002, the number of firms on frontier has increased to 14 and 17 as the total number of firms also increased to 24 and the least efficient firm is Anglo-French Drugs & Inds Ltd with TE score 0.642 (CRS) and 0.711 (VRS).

Table 4.4: DEA Estimates of Technical Efficiency for Big Firms Group

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
Aarti Drugs Ltd.	-	-	-	0.927	0.935	0.991	0.776	0.777	1	0.95	0.954	0.996	0.94	0.94	1	0.972	0.99	0.982
Ahlcon Parenterals (India) Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.837	0.837	1	0.813	0.913	0.891
Ajanta Pharma Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Albert David Ltd.	-	-	-	-	-	-	0.808	1	0.808	0.639	0.759	0.842	0.373	0.388	0.96	0.497	0.5	0.994
Alembic Ltd.	-	-	-	1	1	1	0.637	0.67	0.95	0.534	0.619	0.862	0.536	0.587	0.912	0.614	0.627	0.979
Arch Pharmalabs Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.927	1	0.927	1	1	1
Arvind Remedies Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Astrazeneca Pharma India Ltd.	-	-	-	1	1	1	0.845	1	0.845	1	1	1	1	1	1	1	1	1
Aurobindo Pharma Ltd.	-	-	-	1	1	1	1	1	1	0.86	1	0.86	0.825	1	0.825	0.915	1	0.915
Aventis Pharma Ltd.	-	-	-	0.716	0.797	0.898	0.78	0.81	0.963	-	-	-	0.728	0.75	0.971	0.906	0.916	0.989
Biocon Ltd.	-	-	-	-	-	-	0.786	0.798	0.985	1	1	1	0.761	0.834	0.912	0.909	1	0.909
Cadila Healthcare Ltd.	-	-	-	0.974	1	0.974	0.694	0.829	0.838	0.645	0.791	0.814	0.586	0.769	0.762	0.928	1	0.928
Cadila Pharmaceuticals Ltd.	-	-	-	0.808	0.998	0.81	0.582	0.626	0.929	-	-	-	0.536	0.536	1	0.6	0.6	1
Capsugel Healthcare Ltd.	-	-	-	0.81	0.81	1	0.713	0.779	0.916	0.812	1	0.812	1	1	1	-	-	-
Cipla Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	-	-	-	0.966	1	0.966
Claris Lifesciences Ltd.	-	-	-	-	-	-	1	1	1	0.735	0.828	0.887	1	1	1	1	1	1
D S M Anti Infectives India Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Dishman Pharmaceuticals & Chemicals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Divi'S Laboratories Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dr. Reddy'S Laboratories Ltd.	-	-	-	0.903	0.922	0.98	1	1	1	0.948	1	0.948	1	1	1	1	1	1
Elder Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.774	0.783	0.989	0.917	0.92	0.996
Everest Organics Ltd.	1	1	1	-	-	-	1	1	1	1	1	1	0.827	1	0.827	0.832	1	0.832
F D C Ltd.	-	-	-	0.908	0.91	0.997	0.829	0.87	0.953	0.682	0.683	1	0.595	0.597	0.996	0.744	0.762	0.977
Glaxosmithkline Pharmaceuticals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Granules India Ltd.	-	-	-	-	-	-	0.907	1	0.907	0.766	0.777	0.987	0.875	0.877	0.997	0.88	0.894	0.984
Indoco Remedies Ltd.	0.974	1	0.974	1	1	1	0.675	0.753	0.897	0.737	0.751	0.982	0.52	0.526	0.988	0.57	0.57	1
Ind-Swift Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1

Intas Pharmaceuticals Ltd.	0.651	0.752	0.867	0.709	0.753	0.941	0.661	0.672	0.984	1	1	1	1	1	1	-	-	-
Ipca Laboratories Ltd.	-	-	-	0.957	0.958	0.999	0.879	0.939	0.936	0.667	0.799	0.835	0.602	0.697	0.863	0.766	0.772	0.993
J B Chemicals & Pharmaceuticals Ltd.	-	-	-	0.979	0.986	0.993	0.781	0.781	1	0.745	0.751	0.992	1	1	1	0.969	0.983	0.985
K D L Biotech Ltd.	-	-	-	0.869	0.93	0.934	1	1	1	1	1	1	1	1	1	-	-	-
Kopran Ltd.	1	1	1	1	1	1	1	1	1	0.691	0.72	0.96	0.554	0.596	0.929	0.684	0.71	0.963
Krebs Biochemicals & Inds. Ltd.	-	-	-	1	1	1	0.983	1	0.983	1	1	1	1	1	1	0.813	0.824	0.986
Lupin Ltd.	-	-	-	-	-	-	0.697	0.789	0.883	0.701	0.767	0.914	0.732	0.814	0.899	0.929	1	0.929
Matrix Laboratories Ltd.	-	-	-	1	1	1	1	1	1	0.874	1	0.874	1	1	1	1	1	1
Merck Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.71	0.746	0.951	0.802	0.845	0.949
Morepen Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.651	0.979	0.665	0.684	0.69	0.991
Natco Pharma Ltd.	-	-	-	-	-	-	1	1	1	0.797	0.8	0.997	0.647	0.649	0.997	0.878	0.912	0.963
Nectar Lifesciences Ltd.	1	1	1	1	1	1	1	1	1	1	1	1	0.855	0.978	0.874	0.968	1	0.968
Neuland Laboratories Ltd.	-	-	-	1	1	1	0.79	0.809	0.977	0.997	1	0.997	0.813	0.816	0.997	0.807	0.846	0.955
Orchid Chemicals & Pharmaceuticals Ltd.	-	-	-	1	1	1	0.969	1	0.969	0.929	1	0.929	0.968	1	0.968	0.823	1	0.823
Panacea Biotec Ltd.	-	-	-	1	1	1	0.815	0.823	0.99	1	1	1	0.643	0.768	0.837	0.854	1	0.854
Parenteral Drugs (India) Ltd.	-	-	-	-	-	-	0.685	0.752	0.911	0.856	0.87	0.984	0.801	0.816	0.982	0.919	0.924	0.995
Pfizer Ltd.	-	-	-	-	-	-	1	1	1	0.875	0.881	0.993	1	1	1	1	1	1
Ranbaxy Laboratories Ltd.	1	1	1	1	1	1	1	1	1	0.964	1	0.964	1	1	1	1	1	1
S M S Pharmaceuticals Ltd.	-	-	-	1	1	1	-	-	-	0.814	0.83	0.981	0.87	0.873	0.997	0.871	0.882	0.988
Shasun Pharmaceuticals Ltd.	-	-	-	0.933	0.935	0.998	0.833	0.836	0.997	0.73	0.762	0.957	0.761	0.761	1	0.749	0.754	0.994
Strides Arcolab Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sun Pharmaceutical Inds. Ltd.	-	-	-	0.796	0.805	0.989	1	1	1	1	1	1	1	1	1	1	1	1
Surya Pharmaceutical Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Suven Life Sciences Ltd.	1	1	1	0.978	1	0.978	1	1	1	0.957	0.993	0.964	0.894	0.894	0.999	0.895	0.919	0.974
Torrent Pharmaceuticals Ltd.	1	1	1	0.992	1	0.992	0.63	0.648	0.972	0.565	0.65	0.868	0.594	0.604	0.983	0.734	0.767	0.957
U S V Ltd.	1	1	1	1	1	1	1	1	1	0.936	0.955	0.98	0.789	0.792	0.996	-	-	-
Unichem Laboratories Ltd.	-	-	-	0.665	0.665	1	0.591	0.604	0.978	0.728	0.753	0.967	0.592	0.598	0.991	0.734	0.747	0.983
Unimark Remedies Ltd.	-	-	-	0.818	0.92	0.889	0.696	0.711	0.98	0.803	0.818	0.982	0.853	0.855	0.998	-	-	-
Wockhardt Ltd.	1	1	1	0.83	1	0.83	0.986	1	0.986	0.88	0.938	0.938	0.816	1	0.816	0.916	0.954	0.96
Wyeth Ltd.	-	-	-	1	1	1	0.782	0.787	0.993	1	1	1	1	1	1	-	-	-
Mean	0.969	0.979	0.987	0.937	0.958	0.977	0.903	0.934	0.965	0.884	0.921	0.957	0.839	0.881	0.951	0.875	0.917	0.956

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

Table 4.5: DEA Estimates of Technical Efficiency for Small Firms Group

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
Amrutanjan Health Care Ltd.	-	-	-	0.637	0.643	0.992	-	-	-	0.411	0.413	0.997	1	1	1	-	-	-
Anglo-French Drugs & Inds. Ltd.	-	-	-	-	-	-	0.641	0.711	0.901	0.328	0.336	0.977	0.467	0.479	0.977	0.51	0.544	0.938
Anuh Pharma Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Auro Laboratories Ltd.	-	-	-	0.685	0.812	0.843	1	1	1	0.563	0.792	0.71	1	1	1	1	1	1
B D H Industries Ltd.	1	1	1	0.644	0.786	0.82	1	1	1	0.466	0.484	0.964	0.47	0.471	0.997	0.638	0.699	0.913
Bal Pharma Ltd.	-	-	-	0.592	0.598	0.99	0.758	0.837	0.905	0.463	0.634	0.731	-	-	-	-	-	-
Bliss G V S Pharma Ltd.	-	-	-	0.834	0.858	0.972	-	-	-	0.732	1	0.732	1	1	1	1	1	1
Caplin Point Laboratories Ltd.	0.65	0.656	0.991	1	1	1	-	-	-	0.629	0.704	0.893	1	1	1	1	1	1
East India Pharmaceutical Works Ltd.	-	-	-	1	1	1	1	1	1	0.462	0.492	0.938	0.423	0.429	0.986	-	-	-
Enzal Chemicals (India) Ltd.	-	-	-	0.698	0.73	0.955	0.987	0.994	0.993	0.491	0.547	0.898	0.47	0.595	0.79	-	-	-
Fredun Pharmaceuticals Ltd.	-	-	-	0.688	0.925	0.744	0.962	1	0.962	1	1	1	0.682	1	0.682	-	-	-
Gennex Laboratories Ltd.	-	-	-	0.958	1	0.958	1	1	1	1	1	1	0.692	0.716	0.967	0.729	0.813	0.897
Group Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.602	0.631	0.954	0.656	0.683	0.961	1	1	1
Ishita Drugs & Inds. Ltd.	-	-	-	-	-	-	0.77	1	0.77	0.383	1	0.383	0.827	1	0.827	0.824	1	0.824
Jagsonpal Pharmaceuticals Ltd.	-	-	-	0.515	0.59	0.873	0.766	1	0.766	0.455	0.514	0.886	0.587	0.59	0.996	-	-	-
Jenburkt Pharmaceuticals Ltd.	-	-	-	-	-	-	0.703	0.758	0.926	0.427	0.537	0.795	0.817	1	0.817	0.693	1	0.693
Lincoln Pharmaceuticals Ltd.	-	-	-	0.684	0.704	0.972	0.745	0.774	0.963	0.542	0.552	0.982	0.83	0.854	0.973	0.916	0.928	0.987
Medicamen Biotech Ltd.	-	-	-	0.884	0.895	0.988	1	1	1	0.518	0.532	0.974	0.816	0.816	1	-	-	-
Medi-Caps Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.98	1	0.98	1	1	1
Medley Pharmaceuticals Ltd.	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-
Organon (India) Ltd.	-	-	-	0.913	1	0.913	1	1	1	1	1	1	1	1	1	-	-	-
Pan Drugs Ltd.	1	1	1	-	-	-	1	1	1	1	1	1	-	-	-	-	-	-
Panchsheel Organics Ltd.	-	-	-	-	-	-	1	1	1	0.594	0.669	0.889	0.757	0.805	0.941	1	1	1
Samrat Pharmachem Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Span Diagnostics Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.604	0.62	0.973	0.801	0.845	0.948
Sri Krishna Drugs Ltd. [Merged]	-	-	-	1	1	1	0.91	0.919	0.991	0.574	0.615	0.932	0.646	0.665	0.971	-	-	-
Mean	0.941	0.959	0.981	0.839	0.902	0.931	0.917	0.953	0.961	0.715	0.794	0.903	0.784	0.843	0.929	0.88	0.915	0.959

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

In the year 2006, 8 and 10 firms out of total 26 firms, are on the frontier and the least efficient firm is Anglo-French Drugs & Inds Ltd with TE score 0.328 (CRS) and 0.336 (VRS). In the year 2009, 7 and 11 firms out of total 24 firms, are on the frontier and the least efficient firm is again Anglo-French Drugs & Inds Ltd only in both the cases CRS and VRS. In the year 2011, 8 and 10 firms out of total 16 firms, are on the frontier and the least efficient is Anglo-french Drugs and Inds Ltd. Among the best performing firms in this group over the sample period, are Anuh Pharma Ltd, Samrat Pharmachem Ltd, Dedi-Caps Ltd and Organics Ltd. Whereas, among the least technically efficient firms of the group are Anglo-French Drugs & Inds Ltd Jagsonpal Pharmaceutical Ltd, Bal Pharma Ltd, Enzals Chemical (India) Ltd and Jenburkt Pharmaceuticals Ltd etc.

Table 4.6 reports the technical efficiency score for the high export intensive firm's group. In the year 1997, all firms are technically efficient with score one in case of CRS, VRS and SE. In the year 1990, 11 and 19 firms out of total 30 firms, are on the frontier and the least efficient firms are Fredun Pharmaceutical Ltd with 0.691 CRS and BDH Industries Ltd with 0.724 VRS. In the year 2002, 22 and 25 firms out of total 44 firms, are technically efficient with score one and the least efficient firm is Lupin Ltd. In the year 2006, 13 and 20 firms out of total 44 firms, are on the frontier and the least efficient firm is Neuland Laboratories Ltd in case of CRS and Tonira Pharma Ltd in case of VRS. In the year 2009, 17 and 20 firms out of total 44 firms, are on the frontier with efficiency score one while Tonira Pharma Ltd is found to the least efficient firm with TE score 0.53 CRS and 0.54 VRS. The numbers of technically efficient firms are 12 and 23 firms out of 37 firms in the year 2011, and the least efficient firm is Granules India Ltd with 0.58 CRS and Kopran Ltd with 0.63 VRS. Among the best performing firms in the group over the study period in term of technical efficiency scores are Ajanta Pharma Ltd, Anuh Pharma Ltd, Divi's Laboratories Ltd, Ind-Swift Laboratories Ltd, Ranbaxy Laboratories Ltd and Surya Pharmaceutical Ltd while, among the worst performing firms are Shasun Pharmaceutical Ltd, Themis Medicare Ltd, Granules India Ltd.

The technical efficiency scores for the low export intensive firm's group are shown in table 4.7 for the sample period. In the year 1997, 4 out of 6 firms are on the frontier with technical efficiency score one, and the least efficient firm is Intas pharmaceutical Ltd with 0.618 and 0.696 CRS and VRS technical efficiency respectively. The number of firma has increased in the year 1999 i.e. 13 and 15 firms out of total 25 firms, are technically efficient while Unichem Laboratories Ltd is the least efficient firm with efficiency scores 0.52 and 0.553 CRS and VRS respectively. In the year 2002, the total number of firms on frontier are 22 and 23 out of 41 which are considered as efficient and the least efficient firm is Amrutanjan Health Care Ltd with efficiency score 0.534 (CRS) and 0.535 (VRS).

In the year 2006, 14 and 15 firms out of the total 40 firms, are on the frontier with efficiency score one and the least efficient firm is East India Pharmaceutical works Ltd. In the year 2009, 11 and 12 out of total 38 firms, are on the frontier and the least efficient firm is East India Pharmaceutical Works Ltd with TE scores 0.427 in case of CRS and 0.43 in case of VRS. In the year 2011, 16 and 20 firms out of 31 firms, are on the frontier and the least efficient firm is Jagsonpal Pharmaceutical. The best performing firms in the group in terms of TE scores are Glaxosmithkline Pharmaceutical Ltd, Elder Pharmaceutical Ltd and Abbott India Ltd. The least performing firms in terms of TE scores are Anglo-French Drugs and Inds Ltd, East India Pharmaceutical Works Ltd, Jagsonpal Pharmaceutical Ltd etc.

Table 4.6: DEA Estimates of Technical Efficiency for Total High Export Group

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
Aarti Drugs Ltd.	-	-	-	0.893	1.000	0.893	0.81	0.83	0.98	0.76	0.93	0.82	0.88	0.93	0.94	0.95	1	0.95
Ajanta Pharma Ltd.	-	-	-	0.97	1	0.97	1	1	1	1	1	1	1	1	1	0.98	1	0.98
Anuh Pharma Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aurobindo Pharma Ltd.	-	-	-	0.97	1	0.97	1	1	1	0.68	1	0.68	0.73	1	0.73	0.86	1	0.86
B D H Industries Ltd.	1	1	1	0.71	0.72	0.97	1	1	1	0.49	0.49	0.99	0.53	0.58	0.91	0.64	0.82	0.78
Biocon Ltd.	-	-	-	-	-	-	0.83	0.96	0.86	1	1	1	0.82	0.88	0.93	0.85	1	0.85
Capsugel Healthcare Ltd.	-	-	-	-	-	-	0.84	0.84	1	0.99	1	0.99	1	1	1	-	-	-
Cipla Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	0.82	1	0.82
Claris Lifesciences Ltd.	-	-	-	-	-	-	1	1	1	0.68	0.98	0.69	1	1	1	1	1	1
D S M Anti Infectives India Ltd.	-	-	-	-	-	-	1	1	1	0.9	1	0.9	1	1	1	1	1	1
Dishman Pharmaceuticals & Chemicals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Divi'S Laboratories Ltd.	-	-	-	1	1	1	1	1	1	0.87	1	0.87	1	1	1	1	1	1
Dr. Reddy'S Laboratories Ltd.	-	-	-	1	1	1	1	1	1	0.73	1	0.73	1	1	1	1	1	1
Fermenta Biotech Ltd.	-	-	-	-	-	-	1	1	1	0.9	0.95	0.95	0.85	0.87	0.98	1	1	1
Fredun Pharmaceuticals Ltd.	-	-	-	0.69	1	0.69	0.9	1	0.9	1	1	1	0.8	1	0.8	-	-	-
Gennex Laboratories Ltd.	-	-	-	0.87	0.99	0.87	1	1	1	0.8	0.88	0.91	0.8	0.87	0.91	0.61	1	0.61
Granules India Ltd.	-	-	-	0.8	0.83	0.96	0.95	0.95	1	0.48	0.77	0.63	0.64	0.74	0.86	0.58	0.73	0.8
Harman Finochem Ltd.	-	-	-	0.87	0.93	0.94	0.92	0.93	0.98	1	1	1	0.82	0.83	0.99	-	-	-
Ind-Swift Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Ipca Laboratories Ltd.	-	-	-	0.87	1	0.87	0.84	0.95	0.88	0.53	0.85	0.62	0.63	0.85	0.74	0.81	0.87	0.93
J B Chemicals & Pharmaceuticals Ltd.	-	-	-	1	1	1	0.8	0.81	0.99	0.59	0.83	0.71	1	1	1	0.95	0.96	0.99
Kopran Ltd.	1	1	1	-	-	-	-	-	-	0.66	0.71	0.93	0.56	0.56	1	0.59	0.63	0.93

Lupin Ltd.	-	-	-	-	-	-	0.7	0.83	0.84	0.54	0.83	0.66	0.81	0.88	0.92	0.9	1	0.9
Malladi Drugs & Pharmaceuticals Ltd.	-	-	-	0.86	0.89	0.96	0.9	0.96	0.94	1	1	1	0.61	0.61	1	-	-	-
Matrix Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.72	1	0.72	0.76	1	0.76
Medicamen Biotech Ltd.	-	-	-	0.9	0.91	0.99	1	1	1	0.54	0.54	0.98	0.82	0.82	1	0.9	0.91	0.98
Natco Pharma Ltd.	-	-	-	-	-	-	0.98	1	0.98	0.68	0.86	0.79	0.72	0.77	0.93	0.97	1	0.97
Neuland Laboratories Ltd.	-	-	-	1	1	1	0.79	0.8	0.98	0.45	0.96	0.47	0.55	0.71	0.78	0.61	0.69	0.88
Orchid Chemicals & Pharmaceuticals Ltd.	-	-	-	0.87	1	0.87	1	1	1	0.64	1	0.64	1	1	1	0.82	1	0.82
Ranbaxy Laboratories Ltd.	1	1	1	1	1	1	1	1	1	0.77	1	0.77	1	1	1	1	1	1
S M S Pharmaceuticals Ltd.	1	1	1	1	1	1	-	-	-	0.56	0.72	0.78	0.91	0.91	1	0.88	0.89	0.98
Shasun Pharmaceuticals Ltd.	-	-	-	0.78	0.99	0.79	0.72	0.86	0.84	0.49	0.77	0.63	0.63	0.78	0.81	0.68	0.72	0.94
Shilpa Medicare Ltd.	-	-	-	0.95	1	0.95	0.7	0.77	0.9	0.79	0.8	0.98	0.79	0.81	0.98	1	1	1
Sri Krishna Drugs Ltd. [Merged]	-	-	-	1	1	1	1	1	1	0.57	0.58	0.99	0.68	0.7	0.97	-	-	-
Srini Pharmaceuticals Ltd.	-	-	-	1	1	1	0.92	1	0.92	0.92	1	0.92	0.67	0.7	0.97	-	-	-
Strides Arcolab Ltd.	-	-	-	0.91	1	0.91	1	1	1	1	1	1	1	1	1	1	1	1
Surya Pharmaceutical Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Suven Life Sciences Ltd.	1	1	1	0.96	0.96	1	1	1	1	0.63	0.69	0.91	0.64	0.76	0.84	0.84	0.89	0.95
Themis Medicare Ltd.	-	-	-	0.9	0.9	1	-	-	-	0.46	0.59	0.78	0.54	0.62	0.88	0.66	0.74	0.89
Tonira Pharma Ltd.	1	1	1	1	1	1	1	1	1	0.48	0.49	0.99	0.53	0.54	0.98	0.65	0.9	0.73
Unimark Remedies Ltd.	-	-	-	0.81	0.85	0.96	0.71	0.74	0.97	0.61	0.8	0.76	0.76	0.87	0.88	-	-	-
Wanbury Ltd.	-	-	-	-	-	-	0.8	0.8	1	0.74	0.88	0.83	1	1	1	0.65	0.66	0.98
Wockhardt Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	0.86	1	0.86
Mean	1	1	1	0.91	0.96	0.95	0.94	0.96	0.98	0.8	0.91	0.89	0.83	0.88	0.94	0.87	0.92	0.94

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

Table 4.7: DEA Estimates of Technical Efficiency for Low Export Intensive Group

Companies' name/Yeaar	1997			1999			2002			2006			2009			2011		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
Abbott India Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Ahlcon Parenterals (India) Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.609	0.613	0.994	0.857	1	0.857
Albert David Ltd.	-	-	-	0.696	0.712	0.979	0.976	0.978	0.998	0.566	0.577	0.982	0.434	0.453	0.958	0.67	0.672	0.997
Alembic Ltd.	-	-	-	1	1	1	0.744	0.795	0.936	0.653	0.684	0.955	-	-	-	0.802	1	0.802
Alkem Laboratories Ltd.	-	-	-	0.85	1	0.85	1	1	1	0.569	0.748	0.761	0.431	0.499	0.863	-	-	-
Amrutanjan Health Care Ltd.	-	-	-	0.703	0.724	0.97	0.534	0.535	0.998	0.519	0.52	0.998	1	1	1	0.689	0.702	0.981
Anglo-French Drugs & Inds. Ltd.	-	-	-	0.628	0.628	0.999	0.61	0.61	1	0.474	0.478	0.992	0.52	0.521	0.997	0.723	0.782	0.924
Astrazeneca Pharma India Ltd.	-	-	-	0.896	0.92	0.974	0.845	0.845	1	0.658	0.687	0.958	0.906	0.911	0.994	1	1	1
East India Pharmaceutical Works Ltd.	-	-	-	0.968	0.968	1	1	1	1	0.435	0.459	0.948	0.427	0.43	0.993	-	-	-
Elder Pharmaceuticals Ltd.	1	1	1	1	1	1	1	1	1	0.778	0.904	0.861	0.643	0.761	0.844	0.896	0.939	0.954
F D C Ltd.	-	-	-	1	1	1	0.851	0.856	0.995	0.617	0.644	0.959	0.586	0.601	0.974	0.966	1	0.966
Glaxosmithkline Pharmaceuticals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Glenmark Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Group Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.621	0.676	0.92	0.689	0.698	0.986	1	1	1
Hester Biosciences Ltd.	-	-	-	-	-	-	0.978	1	0.978	0.759	0.847	0.896	0.626	0.635	0.986	1	1	1
Indoco Remedies Ltd.	1	1	1	-	-	-	0.675	0.687	0.982	0.787	0.794	0.992	0.855	0.861	0.993	-	-	-
Intas Pharmaceuticals Ltd.	0.618	0.696	0.888	0.597	0.614	0.973	0.689	0.765	0.901	1	1	1	-	-	-	-	-	-
Jagsonpal Pharmaceuticals Ltd.	-	-	-	0.658	0.662	0.995	0.685	0.685	0.999	0.48	0.51	0.941	0.648	0.663	0.978	0.493	0.503	0.982
Jenburkt Pharmaceuticals Ltd.	-	-	-	-	-	-	0.657	0.664	0.99	0.492	0.556	0.885	1	1	1	1	1	1
Karnataka Antibiotics & Pharmaceuticals Ltd.	-	-	-	-	-	-	0.989	0.996	0.993	1	1	1	0.678	0.683	0.992	0.7	0.724	0.968
Kilitch Drugs (India) Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.91	0.91	0.999	0.848	0.848	1
Lincoln Pharmaceuticals Ltd.	-	-	-	1	1	1	0.827	0.832	0.994	1	1	1	1	1	1	1	1	1
Macleods Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.832	0.999	0.833	0.706	0.768	0.919	-	-	-

Mangalam Drugs & Organics Ltd.	-	-	-	-	-	-	1	1	1	0.846	0.846	0.999	0.634	0.65	0.975	0.68	0.681	0.999
Medi-Caps Ltd.	-	-	-	-	-	-	1	1	1	0.974	1	0.974	0.749	0.821	0.913	1	1	1
Medley Pharmaceuticals Ltd.	1	1	1	1	1	1	0.887	0.893	0.993	-	-	-	0.665	0.677	0.983	-	-	-
Merck Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.682	0.702	0.972	1	1	1
Natural Capsules Ltd.	-	-	-	-	-	-	1	1	1	0.867	0.948	0.915	1	1	1	1	1	1
Novartis India Ltd.	-	-	-	0.981	1	0.981	1	1	1	1	1	1	1	1	1	1	1	1
Organon (India) Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Panchsheel Organics Ltd.	-	-	-	-	-	-	1	1	1	0.62	0.797	0.778	0.7	0.823	0.85	1	1	1
Paras Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.928	0.937	0.99	-	-	-
Parenteral Drugs (India) Ltd.	-	-	-	-	-	-	0.701	0.757	0.925	0.612	0.615	0.996	0.82	0.826	0.993	0.968	1	0.968
Pfizer Ltd.	-	-	-	-	-	-	1	1	1	0.633	0.785	0.806	1	1	1	1	1	1
Span Diagnostics Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.915	0.984	0.93	0.813	0.867	0.938
Sun Pharmaceutical Inds. Ltd.	-	-	-	0.786	0.787	0.999	1	1	1	1	1	1	1	1	1	-	-	-
Sunil Healthcare Ltd.	1	1	1	-	-	-	1	1	1	0.743	0.833	0.892	-	-	-	0.924	1	0.924
Twilight Litaka Pharma Ltd.	0.847	0.899	0.942	-	-	-	0.605	0.631	0.959	0.792	0.994	0.796	0.977	1	0.977	1	1	1
Unichem Laboratories Ltd.	-	-	-	0.52	0.553	0.94	0.625	0.637	0.98	0.851	0.89	0.956	0.797	0.81	0.985	1	1	1
Wyeth Ltd.	-	-	-	1	1	1	0.795	0.804	0.99	0.753	0.757	0.994	0.845	0.846	0.999	1	1	1
Mean	0.92	0.948	0.968	0.904	0.924	0.978	0.894	0.913	0.979	0.784	0.835	0.935	0.816	0.847	0.96	0.918	0.94	0.976

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

Table 4.8 shows the TE score for the bulk and formulation firm's group. In the year 1997, all firms are technically efficient. In the year 1999, 27 and 30 firms out of 40 firms are on the frontier with TE score one and least efficient firm is Bal Pharma Ltd with TE score 0.696 (CRS) and Unichem Laboratories Ltd with TE score 0.721 (VRS). In the year 2002, 22 and 26 firms out of 44 firms, are on the frontier and the least efficient firm is Cadila Pharmaceutical Ltd. In the year 2006, 17 and 21 firms out of 44 firms are technically efficient and the least efficient firm is Alembic Ltd. In the year 2009, 18 and 26 firms out of 45 firms are on the frontier and the least efficient firm is Albert David Ltd. In the year 2011, 24 and 26 firms out of 41 firms are efficient and the least efficient firm is Cadila Pharmaceuticals Ltd. The best performing firms in the group in terms of TE scores are Ahlcon Parenterals (India) Ltd, Anuh Pharmaceuticals Ltd, Aurobindo Pharma Ltd, Cipla Ltd, Elder Pharmaceuticals Ltd, Ranbaxy Laboratories Ltd, Suven Life Sciences Ltd, Surya Pharmaceuticals Ltd etc. Among the worst performing are Jagsonpal Pharmaceuticals Ltd, Unichem Laboratories Ltd, Lupin Ltd Cadila Pharmaceutical Ltd etc.

Table 4.9 exhibits the TE scores for the only formulation firm's group for the period of 1997 to 2011. In the year 1997, all firms are technically efficient in all three cases i.e. TE at CRS, VRS and SE. In the year 1999, 10 and 14 firms out of 24 firms, are on the frontier with TE score one and the least efficient firm is Aventis Pharma Ltd in case of CRS, while in case of VRS, Anglo-French Drugs and Inds Ltd is the least technically efficient. In the year 2002, the performance of firms has improved as the number of firms with TE score one has increased to 22 and 24 out of 37. The least efficient firm is Amruntanjan Health Care Ltd. In the year 2006, 15 and 20 firms out of 36 firms, are at frontier i.e. technically efficient with TE score one, and the least efficient firm is Anglo-Frenc Drugs and Inds Ltd with TE scores 0.334 and 351 in case of CRS and VRS respectively. In the year 2009, 11 and 20 firms out of 38 firms, are at frontier, and Coral Laboratories Ltd is the most inefficient firm with TE CRS 0.372 and East India Pharmaceutical Works Ltd with TE VRS 0.38. In the year 2011, 16 and 21 firms out of 31 firms, are technically efficient and the least efficient firm is Anglo-French in case of CRS and Syncom Formulation (India) Ltd in case of VRS. The best performing firms in the group in terms of TE score are Kreb Biochemicals and Inds Ltd, Novartis, Abbott India Ltd etc. The least efficient firms of the group are Anglo-French, Jenburkt Pharma, Aventis Pharma Ltd etc.

The TE scores for the firms producing only bulk drugs are presented in table 4.10. In the year 1997, all are efficient with technical efficiency CRS and VRS score one. In the year 1999, 14 and 15 firms out of 18 firms are on the frontier with TE score one and the least efficient firm in the year is Resonance Specialities Ltd with the score 0.809 CRS and 0.838 VRS. In the year 2002, the number of firms on the frontier is 18 and 19 firms out of 23 in case of CRS and VRS respectively and the most inefficient firm is Smruthi Organics Ltd. In the year 2006, out of total 22 firms, 17 and 18 firms are on the frontier with score one and the least efficient firm is Smurthi Organics Ltd with TE scores of 0.727 in case of CRS and 0.742 in case of VRS. In the year 2009, 14 and 15 firms out of 23 firms are on frontier and Smurthi Organics Ltd with the score of 0.728 CRS and 0.732 VRS is regarded as the least efficient firm in that particular year. In the year 2011, 10 and 11 firms out of 16 firm are technically efficient and the least efficient firm is Gennex Laboratories Ltd with 0.653 CRS and Manglam Drugs And Organics Ltd with 0.723 VRS. Ind-Swift, Shilpa Medicare and Divi’s Lab are the firms which have shown impressive performance in the group. On the contrary there are firms such as Smurthi Organics, Manglam Drugs and Organics Ltd which exhibited very poor performance in the group in terms of TE scores.

Table 4.8: DEA Estimates of Technical Efficiency for Bulk and Formulation Group

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
Aarti Drugs Ltd.	-	-	-	0.949	0.961	0.988	0.806	0.952	0.847	0.971	0.999	0.972	1	1	1	1	1	1
Ahlcon Parenterals (India) Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Albert David Ltd.	-	-	-	1	1	1	1	1	1	0.656	0.685	0.958	0.648	0.65	0.998	0.683	0.895	0.763
Alembic Ltd.	-	-	-	1	1	1	0.74	0.741	1	0.534	0.62	0.861	0.685	0.715	0.958	1	1	1
Anuh Pharma Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Auro Laboratories Ltd.	-	-	-	0.757	1	0.757	1	1	1	0.547	1	0.547	1	1	1	1	1	1
Aurobindo Pharma Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B D H Industries Ltd.	1	1	1	1	1	1	1	1	1	0.656	0.669	0.981	0.736	0.757	0.972	0.939	1	0.939
Bal Pharma Ltd.	-	-	-	0.696	0.819	0.85	0.716	0.767	0.934	0.721	0.735	0.982	0.728	0.739	0.985	1	1	1
Cadila Healthcare Ltd.	-	-	-	1	1	1	0.788	0.865	0.911	0.645	0.791	0.814	0.793	0.844	0.939	-	-	-
Cadila Pharmaceuticals Ltd.	-	-	-	0.779	0.987	0.789	0.616	0.632	0.976	-	-	-	0.684	0.716	0.955	0.582	0.585	0.994
Cipla Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dr. Reddy'S Laboratories Ltd.	-	-	-	0.927	0.928	0.999	1	1	1	1	1	1	1	1	1	1	1	1
Elder Pharmaceuticals Ltd.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
F D C Ltd.	-	-	-	1	1	1	0.806	0.82	0.984	0.682	0.683	1	0.833	0.833	1	0.809	0.819	0.988
Glaxosmithkline Pharmaceuticals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Glenmark Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.908	0.963	0.943	1	1	1	1	1	1
Granules India Ltd.	-	-	-	1	1	1	0.968	0.985	0.983	1	1	1	1	1	1	1	1	1
Indoco Remedies Ltd.	1	1	1	0.988	0.989	0.999	0.964	0.966	0.998	0.737	0.755	0.976	0.75	0.784	0.957	0.644	0.646	0.997
Ipca Laboratories Ltd.	-	-	-	1	1	1	0.941	1	0.941	0.673	0.859	0.784	0.745	0.806	0.925	0.821	0.822	0.999
J B Chemicals & Pharmaceuticals Ltd.	-	-	-	1	1	1	0.815	0.819	0.995	0.854	0.872	0.98	1	1	1	0.981	0.997	0.984
Jagsonpal Pharmaceuticals Ltd.	-	-	-	0.709	0.785	0.904	0.854	0.892	0.957	0.688	0.69	0.998	0.852	0.902	0.945	0.734	0.876	0.838
K D L Biotech Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Kopran Ltd.	1	1	1	1	1	1	1	1	1	0.716	0.751	0.953	0.683	0.803	0.85	0.8	0.804	0.995
Lupin Ltd.	-	-	-	-	-	-	0.72	0.789	0.911	0.684	0.78	0.878	0.786	0.822	0.956	0.982	1	0.982

Lyka Labs Ltd.	-	-	-	1	1	1	1	1	1	0.972	1	0.972	0.908	1	0.908	1	1	1
Macleods Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.859	1	0.859	0.73	0.784	0.932	-	-	-
Morepen Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.681	1	0.681	0.973	0.976	0.998
Natco Pharma Ltd.	-	-	-	-	-	-	0.943	1	0.943	0.825	0.867	0.951	0.815	0.984	0.828	1	1	1
Nectar Lifesciences Ltd.	1	1	1	1	1	1	0.981	1	0.981	1	1	1	0.94	1	0.94	1	1	1
Orchid Chemicals & Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.936	1	0.936	1	1	1
Ranbaxy Laboratories Ltd.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
S M S Pharmaceuticals Ltd.	1	1	1	1	1	1	-	-	-	0.812	0.847	0.959	0.863	1	0.863	1	1	1
Shasun Pharmaceuticals Ltd.	-	-	-	1	1	1	0.952	1	0.952	0.842	1	0.842	0.933	0.978	0.955	0.957	0.978	0.979
Sun Pharmaceutical Inds. Ltd.	-	-	-	0.806	0.807	0.998	1	1	1	1	1	1	1	1	1	1	1	1
Surya Pharmaceutical Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Suven Life Sciences Ltd.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Themis Medicare Ltd.	-	-	-	0.997	1	0.997	0.793	0.797	0.995	0.668	0.67	0.997	0.682	0.762	0.895	0.84	0.841	0.999
Torrent Pharmaceuticals Ltd.	1	1	1	1	1	1	0.711	0.711	1	0.564	0.65	0.867	0.713	0.714	0.999	0.766	0.795	0.963
Unichem Laboratories Ltd.	-	-	-	0.719	0.721	0.998	0.83	0.83	1	0.728	0.76	0.958	0.81	0.81	1	0.707	0.711	0.995
Unimark Remedies Ltd.	-	-	-	0.835	0.835	1	0.686	0.821	0.836	0.879	0.97	0.906	0.878	1	0.878	-	-	-
Wanbury Ltd.	-	-	-	-	-	-	0.917	0.918	0.998	0.995	1	0.995	0.837	1	0.837	0.585	0.601	0.973
Wockhardt Ltd.	1	1	1	0.872	1	0.872	1	1	1	0.927	0.991	0.936	0.9	1	0.9	1	1	1
Wyeth Ltd.	-	-	-	1	1	1	0.785	0.793	0.99	1	1	1	1	1	1	1	1	1
Mean	**0.999**	**1**	**0.999**	**0.952**	**0.97**	**0.981**	**0.929**	**0.943**	**0.984**	**0.867**	**0.901**	**0.961**	**0.892**	**0.933**	**0.956**	**0.926**	**0.942**	**0.982**

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

Table 4.9: DEA Estimates of Technical Efficiency for Only Formulation Group

Companies' name/Years	**1997**			**1999**			**2002**			**2006**			**2009**			**2011**		
	crste	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**
Abbott India Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Ajanta Pharma Ltd.	-	-	-	0.99	1	0.99	1	1	1	1	1	1	0.856	1	0.856	0.824	1	0.824
Amrutanjan Health Care Ltd.	-	-	-	0.647	0.659	0.982	0.552	0.557	0.991	0.412	0.445	0.925	1	1	1	0.65	0.7	0.928
Anglo-French Drugs & Inds. Ltd.	-	-	-	0.571	0.572	0.999	0.636	0.648	0.981	0.334	0.351	0.95	0.455	0.493	0.923	0.509	0.691	0.736

Arvind Remedies Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Astrazeneca Pharma India Ltd.	-	-	-	0.841	0.875	0.962	0.944	0.945	0.999	0.764	0.766	0.998	0.728	0.728	1	0.617	0.628	0.982
Aventis Pharma Ltd.	-	-	-	0.555	1	0.555	0.786	1	0.786	-	-	-	0.548	1	0.548	0.602	1	0.602
Biocon Ltd.	-	-	-	-	-	-	0.899	1	0.899	1	1	1	0.739	1	0.739	1	1	1
Caplin Point Laboratories Ltd.	1	1	1	1	1	1	-	-	-	0.708	0.722	0.981	1	1	1	1	1	1
Capsugel Healthcare Ltd.	-	-	-	0.757	0.791	0.957	0.871	0.926	0.94	0.798	0.86	0.928	1	1	1	-	-	-
Claris Lifesciences Ltd.	-	-	-	-	-	-	1	1	1	0.519	0.701	0.74	1	1	1	1	1	1
Coral Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.417	0.479	0.871	0.675	1	0.675
East India Pharmaceutical Works Ltd.	-	-	-	1	1	1	1	1	1	0.589	0.629	0.936	0.431	0.46	0.936	-	-	-
Fermenta Biotech Ltd.	-	-	-	1	1	1	1	1	1	0.952	1	0.952	0.807	0.865	0.933	1	1	1
Fredun Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.611	1	0.611	-	-	-
Group Pharmaceuticals Ltd.	-	-	-	1	1	1	0.898	0.992	0.906	0.62	0.673	0.921	0.649	0.76	0.854	1	1	1
Hester Biosciences Ltd.	-	-	-	-	-	-	1	1	1	0.897	1	0.897	0.704	0.742	0.948	1	1	1
Intas Pharmaceuticals Ltd.	1	1	1	0.607	0.676	0.898	0.641	0.696	0.92	0.639	1	0.639	0.806	1	0.806	-	-	-
Jenburkt Pharmaceuticals Ltd.	-	-	-	-	-	-	0.708	0.713	0.993	0.434	0.556	0.781	0.739	0.988	0.748	0.688	1	0.688
Karnataka Antibiotics & Pharmaceuticals Ltd.	-	-	-	-	-	-	0.88	0.882	0.998	0.603	0.62	0.972	0.636	0.645	0.986	0.573	0.599	0.956
Kilitch Drugs (India) Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.973	0.986	0.987	1	1	1
Krebs Biochemicals & Inds. Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lincoln Pharmaceuticals Ltd.	-	-	-	0.701	0.708	0.989	0.789	0.825	0.957	0.595	0.612	0.972	0.79	0.819	0.964	0.899	0.911	0.986
Medi-Caps Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.997	1	0.997	1	1	1
Medley Pharmaceuticals Ltd.	1	1	1	0.989	0.989	1	1	1	1	-	-	-	0.532	0.538	0.989	-	-	-
Natural Capsules Ltd.	-	-	-	-	-	-	1	1	1	0.878	0.933	0.94	0.969	1	0.969	1	1	1
Novartis India Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Organon (India) Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Panacea Biotec Ltd.	-	-	-	0.752	1	0.752	1	1	1	1	1	1	0.625	1	0.625	0.641	1	0.641
Paras Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.814	0.815	0.999	-	-	-
Parenteral Drugs (India) Ltd.	-	-	-	-	-	-	0.819	0.836	0.98	0.555	0.672	0.826	0.85	0.91	0.935	0.842	0.916	0.92
Pfizer Ltd.	-	-	-	-	-	-	1	1	1	0.632	1	0.632	1	1	1	1	1	1
Span Diagnostics Ltd.	-	-	-	1	1	1	1	1	1	0.971	0.992	0.979	0.606	0.645	0.939	0.709	0.854	0.83
Strides Arcolab Ltd.	-	-	-	0.86	1	0.86	1	1	1	1	1	1	1	1	1	1	1	1
Sunil Healthcare Ltd.	1	1	1	0.771	0.86	0.897	1	1	1	0.544	0.575	0.946	0.494	0.564	0.877	0.828	1	0.828
Syncom Formulations (India) Ltd.	-	-	-	0.593	0.603	0.983	0.925	0.965	0.958	1	1	1	0.521	0.529	0.985	0.52	0.576	0.903
Twilight Litaka Pharma Ltd.	1	1	1	-	-	-	0.717	0.736	0.975	0.733	1	0.733	0.948	1	0.948	1	1	1
Mean	**1**	**1**	**1**	**0.886**	**0.928**	**0.956**	**0.909**	**0.938**	**0.969**	**0.771**	**0.859**	**0.896**	**0.787**	**0.867**	**0.909**	**0.857**	**0.933**	**0.918**

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

Table 4.10: DEA Estimates of Technical Efficiency for Only Bulk group

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**
Alkem Laboratories Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.821	1	0.821	-	-	-
Arch Pharmalabs Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
D S M Anti Infectives India Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Divi'S Laboratories Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Enzal Chemicals (India) Ltd.	-	-	-	0.948	1	0.948	1	1	1	0.923	0.943	0.979	0.795	0.847	0.938	-	-	-
Everest Organics Ltd.	1	1	1	-	-	-	1	1	1	1	1	1	0.828	0.844	0.982	0.835	0.838	0.997
Gennex Laboratories Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.943	0.982	0.96	0.653	0.839	0.778
Harman Finochem Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Ind-Swift Laboratories Ltd.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ishita Drugs & Inds. Ltd.	-	-	-	-	-	-	0.835	1	0.835	0.865	1	0.865	1	1	1	1	1	1
Malladi Drugs & Pharmaceuticals Ltd.	-	-	-	0.896	0.989	0.906	1	1	1	1	1	1	0.839	0.841	0.998	-	-	-
Mangalam Drugs & Organics Ltd.	-	-	-	-	-	-	0.779	0.808	0.964	0.781	0.783	0.998	0.77	0.771	0.998	0.719	0.723	0.994
Matrix Laboratories Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Medicamen Biotech Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Neuland Laboratories Ltd.	-	-	-	1	1	1	0.896	0.96	0.933	1	1	1	0.84	0.841	0.999	0.811	0.82	0.988
Resonance Specialties Ltd.	-	-	-	0.809	0.838	0.965	1	1	1	-	-	-	1	1	1	1	1	1
Samrat Pharmachem Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Shilpa Medicare Ltd.	1	1	1	1	1	1	0.836	0.878	0.952	1	1	1	1	1	1	1	1	1
Smruthi Organics Ltd.	-	-	-	1	1	1	0.755	0.762	0.991	0.727	0.742	0.981	0.728	0.732	0.995	0.862	1	0.862
Sri Krishna Drugs Ltd. [Merged]	-	-	-	1	1	1	1	1	1	0.923	0.949	0.973	0.922	0.945	0.976	-	-	-
Srini Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Tonira Pharma Ltd.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.694	1	0.694
U S V Ltd.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Mean	**1**	**1**	**1**	**0.969**	**0.992**	**0.976**	**0.963**	**0.978**	**0.985**	**0.971**	**0.986**	**0.985**	**0.936**	**0.95**	**0.986**	**0.919**	**0.961**	**0.957**

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

The DEA technical efficiency scores for the R&D group of firms have been depicted in the table 4.11. In the year 1997, 14 and 15 firms out of 17 firms are on frontier with score one and the most inefficient firm is Intas Pharmaceutical Ltd with the TE score of 0.592 CRS and 0.593 VRS. In the year 1999, 33 and 41 firms out of 68 firms are efficient and the least efficient firm is Bharat Serums and Vaccines Ltd and Unichem Laboratories Ltd. In the year 2002, 43 and 47 firms out of 92 firms are on the frontier and Anglo-French with efficiency is the most inefficient firm with TE scores of 0.568 CRS and 0.57 VRS. In the year 2006, 21 and 33 firms out of 89 firms are on the frontier and the least efficient firm is Albert David Ltd. In the year 2009, 18 and 33 firms out of 93 firms are on the frontier i.e. technically efficient with RE score one and the least efficient is again Albert David Ltd again with efficiency score of 0.346 CRS and 0.347 VRS. In the year 2011, 27 and 38 firms out of 73 firms are on the frontier having efficiency score one and Albert David Ltd is the most inefficient firm in this year also. There are firms such as Novatis, Surya, Divi's and Ind-Swift Lab etc which are relatively best performer in the group. On the other hand, there are firms such as Albert David, Alembic Pharma, Anglo-French, Jagsonpal, Manglam and Unichem Laboratories Ltd. etc which are among the poor performers in the group.

Table 4.12 depicts the TE scores for the firms not engaged in R&D related work for the period of 1997 to 2011. In the year 1997, all firms are found to be on the frontier with TE score one in all case i.e. TE CRS, VRS and scale efficiency. In the year 1999, 5 and 9 firms out of 11 firms are technically efficient and the most inefficient firm is Auro Laboratories Ltd and Amrutanjan Health Care Ltd. In the year 2002, the TE estimates depict an interesting scenario in which 14 and 15 firms out of 16 firms are technically efficient and Smurthi Organics Ltd is found to be the least efficient firm in the group with TE scores 0.826 CRS and 0.865 VRS.

Table 4.11: DEA Estimates of Technical Efficiency for R&D Related Outlays Group

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
Aarti Drugs Ltd.	-	-	-	0.955	0.971	0.984	0.756	0.777	0.974	0.752	0.912	0.824	0.769	0.867	0.888	0.916	0.98	0.934
Abbott India Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Ahlcon Parenterals (India) Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.584	0.586	0.995	0.848	0.873	0.971
Ajanta Pharma Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.927	1	0.927	1	1	1
Albert David Ltd.	-	-	-	0.818	0.825	0.992	0.725	0.78	0.93	0.31	0.317	0.98	0.346	0.347	0.999	0.478	0.495	0.966
Alembic Ltd.	-	-	-	0.871	0.974	0.894	0.633	0.67	0.944	0.365	0.468	0.78	0.394	0.587	0.67	0.611	0.627	0.973
Alkem Laboratories Ltd.	-	-	-	1	1	1	1	1	1	0.561	0.676	0.829	0.411	0.499	0.823	-	-	-
Anglo-French Drugs & Inds. Ltd.	-	-	-	0.674	0.677	0.996	0.568	0.57	0.997	0.328	0.337	0.974	0.452	0.468	0.966	0.492	0.681	0.724
Anuh Pharma Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Arch Pharmalabs Ltd.	-	-	-	-	-	-	0.837	0.839	0.998	0.998	1	0.998	0.868	1	0.868	1	1	1
Arvind Remedies Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Astrazeneca Pharma India Ltd.	-	-	-	0.923	0.931	0.991	0.837	0.838	0.999	0.651	0.687	0.947	0.79	0.795	0.994	0.64	0.652	0.981
Aurobindo Pharma Ltd.	-	-	-	1	1	1	1	1	1	0.629	1	0.629	0.682	1	0.682	0.891	1	0.891
Aventis Pharma Ltd.	-	-	-	-	-	-	0.734	0.81	0.906	-	-	-	0.534	0.735	0.727	0.537	0.832	0.646
B D H Industries Ltd.	1	1	1	0.699	0.797	0.877	1	1	1	0.438	0.441	0.993	0.464	0.501	0.925	0.789	0.922	0.856
Bal Pharma Ltd.	-	-	-	0.832	0.876	0.95	0.699	0.701	0.996	0.478	0.496	0.965	0.45	0.458	0.981	0.695	0.696	0.999
Bharat Serums & Vaccines Ltd.	-	-	-	0.651	0.693	0.939	0.708	0.808	0.876	0.341	0.346	0.984	0.572	0.596	0.96	-	-	-
Biocon Ltd.	-	-	-	-	-	-	0.751	0.798	0.941	0.862	1	0.862	0.717	0.834	0.86	0.851	1	0.851
Biological E. Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.478	0.676	0.707	-	-	-
Cadila Healthcare Ltd.	-	-	-	0.947	1	0.947	0.666	0.835	0.798	0.442	0.745	0.593	0.53	0.769	0.689	0.917	0.982	0.934
Cadila Pharmaceuticals Ltd.	-	-	-	0.685	0.973	0.704	0.578	0.627	0.922	-	-	-	0.434	0.535	0.811	0.538	0.563	0.957
Capsugel Healthcare Ltd.	-	-	-	0.852	0.889	0.958	0.689	0.689	0.999	0.69	0.755	0.914	1	1	1	-	-	-
Cipla Ltd.	-	-	-	1	1	1	1	1	1	0.854	1	0.854	0.886	1	0.886	0.805	1	0.805
Claris Lifesciences Ltd.	-	-	-	-	-	-	1	1	1	0.472	0.688	0.686	0.983	1	0.983	1	1	1
D S M Anti Infectives India Ltd.	-	-	-	-	-	-	1	1	1	0.87	1	0.87	0.95	1	0.95	1	1	1
Dishman Pharmaceuticals & Chemicals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Divi'S Laboratories Ltd.	-	-	-	1	1	1	1	1	1	0.9	1	0.9	1	1	1	1	1	1
Dr. Reddy'S Laboratories Ltd.	-	-	-	0.895	0.915	0.978	1	1	1	0.802	1	0.802	0.855	1	0.855	1	1	1
East India Pharmaceutical Works Ltd.	-	-	-	1	1	1	1	1	1	0.435	0.485	0.896	0.423	0.431	0.982	-	-	-

Elder Pharmaceuticals Ltd.	1	1	1	1	1	1	1	1	1	0.778	0.852	0.913	0.637	0.761	0.836	0.889	0.892	0.996
Emcure Pharmaceuticals Ltd.	-	-	-	-	-	-	0.597	0.696	0.857	0.351	0.422	0.832	0.585	0.656	0.891	-	-	-
Enzal Chemicals (India) Ltd.	-	-	-	0.72	0.873	0.824	0.948	0.955	0.994	0.491	0.547	0.898	0.47	0.595	0.789	-	-	-
F D C Ltd.	-	-	-	0.828	0.918	0.902	0.763	0.806	0.946	0.571	0.574	0.995	0.534	0.575	0.928	0.73	0.743	0.982
Fermenta Biotech Ltd.	-	-	-	1	1	1	1	1	1	0.757	0.833	0.91	0.802	0.815	0.984	1	1	1
Fredun Pharmaceuticals Ltd.	-	-	-	0.71	1	0.71	0.934	1	0.934	1	1	1	0.548	1	0.548	-	-	-
Glaxosmithkline Pharmaceuticals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Glenmark Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.822	0.877	0.937	1	1	1	1	1	1
Granules India Ltd.	-	-	-	1	1	1	0.906	0.912	0.993	0.481	0.873	0.55	0.645	0.737	0.874	0.709	0.711	0.998
Group Pharmaceuticals Ltd.	-	-	-	1	1	1	0.898	0.94	0.955	0.57	0.624	0.913	0.667	0.687	0.97	1	1	1
Harman Finochem Ltd.	-	-	-	0.918	1	0.918	0.927	0.94	0.986	0.786	0.787	0.999	0.816	0.816	1	-	-	-
Hetero Drugs Ltd.	-	-	-	1	1	1	1	1	1	-	-	-	0.58	1	0.58	-	-	-
Indoco Remedies Ltd.	1	1	1	0.898	0.983	0.914	0.667	0.67	0.996	0.506	0.507	0.999	0.427	0.483	0.884	0.544	0.544	1
Ind-Swift Laboratories Ltd.	0.979	1	0.979	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Intas Pharmaceuticals Ltd.	0.592	0.593	0.998	0.655	0.66	0.993	0.657	0.672	0.978	0.62	1	0.62	0.828	1	0.828	-	-	-
Ipca Laboratories Ltd.	-	-	-	0.834	0.958	0.87	0.809	0.939	0.861	0.326	0.77	0.423	0.434	0.697	0.623	0.712	0.771	0.923
J B Chemicals & Pharmaceuticals Ltd.	-	-	-	0.82	0.956	0.858	0.757	0.779	0.973	0.442	0.702	0.63	0.813	1	0.813	0.916	0.925	0.991
Jagsonpal Pharmaceuticals Ltd.	-	-	-	0.691	0.713	0.969	0.672	0.673	0.998	0.467	0.497	0.941	0.581	0.584	0.994	0.486	0.514	0.945
Kilitch Drugs (India) Ltd.	-	-	-	-	-	-	0.899	0.903	0.996	1	1	1	0.874	0.893	0.979	0.84	0.844	0.996
Kopran Ltd.	1	1	1	0.98	1	0.98	1	1	1	0.66	0.665	0.992	0.485	0.511	0.949	0.637	0.638	1
Lincoln Pharmaceuticals Ltd.	-	-	-	0.871	0.913	0.953	0.728	0.728	1	0.566	0.576	0.983	0.79	0.819	0.964	0.893	0.984	0.908
Lupin Ltd.	-	-	-	-	-	-	0.679	0.789	0.861	0.446	0.752	0.592	0.564	0.814	0.693	0.902	1	0.902
Lyka Labs Ltd.	-	-	-	1	1	1	1	1	1	0.76	0.979	0.777	0.665	0.717	0.928	1	1	1
Macleods Pharmaceuticals Ltd.	-	-	-	1	1	1	0.806	1	0.806	0.563	0.664	0.848	0.452	0.75	0.602	-	-	-
Malladi Drugs & Pharmaceuticals Ltd.	-	-	-	0.978	0.984	0.994	0.902	0.958	0.942	0.807	0.809	0.998	0.525	0.534	0.983	-	-	-
Mangalam Drugs & Organics Ltd.	-	-	-	-	-	-	0.724	0.747	0.968	0.613	0.616	0.994	0.596	0.6	0.993	0.672	0.672	0.999
Marksans Pharma Ltd.	-	-	-	-	-	-	1	1	1	0.889	0.985	0.903	1	1	1	1	1	1
Matrix Laboratories Ltd.	-	-	-	0.783	0.848	0.923	1	1	1	0.774	1	0.774	0.713	1	0.713	0.813	1	0.813
Medi-Caps Ltd.	1	1	1	-	-	-	1	1	1	0.996	1	0.996	0.75	0.801	0.936	0.969	1	0.969
Medley Pharmaceuticals Ltd.	1	1	1	1	1	1	0.846	0.851	0.995	-	-	-	0.546	0.55	0.994	-	-	-
Merck Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.66	0.69	0.956	0.673	0.675	0.997
Morepen Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.65	0.979	0.663	0.67	0.678	0.988
Natco Pharma Ltd.	-	-	-	-	-	-	0.925	1	0.925	0.555	0.669	0.829	0.533	0.635	0.84	0.9	0.915	0.984

Natural Capsules Ltd.	-	-	-	-	-	-	1	1	1	0.721	0.781	0.923	0.754	0.863	0.874	0.805	0.895	0.9
Nectar Lifesciences Ltd.	1	1	1	1	1	1	0.946	1	0.946	1	1	1	0.799	0.978	0.817	0.951	1	0.951
Neuland Laboratories Ltd.	-	-	-	1	1	1	0.768	0.776	0.989	0.433	0.875	0.495	0.545	0.709	0.769	0.681	0.689	0.989
Novartis India Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Orchid Chemicals & Pharmaceuticals Ltd.	-	-	-	1	1	1	0.96	1	0.96	0.642	1	0.642	0.907	1	0.907	0.817	1	0.817
Organon (India) Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-
Panacea Biotec Ltd.	-	-	-	1	1	1	0.756	0.798	0.947	0.876	1	0.876	0.531	0.768	0.691	0.716	1	0.716
Panchsheel Organics Ltd.	-	-	-	-	-	-	1	1	1	0.576	0.665	0.866	0.688	0.822	0.837	1	1	1
Paras Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.843	0.848	0.995	-	-	-
Pfizer Ltd.	-	-	-	-	-	-	1	1	1	0.592	0.736	0.805	1	1	1	0.999	1	0.999
Ranbaxy Laboratories Ltd.	1	1	1	1	1	1	1	1	1	0.708	1	0.708	0.955	1	0.955	1	1	1
S M S Pharmaceuticals Ltd.	1	1	1	1	1	1	-	-	-	0.544	0.69	0.788	0.823	0.852	0.965	0.846	0.853	0.992
Samrat Pharmachem Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Shasun Pharmaceuticals Ltd.	-	-	-	0.855	0.934	0.915	0.716	0.835	0.857	0.428	0.742	0.577	0.531	0.696	0.763	0.722	0.725	0.996
Shilpa Medicare Ltd.	1	1	1	0.954	1	0.954	0.673	0.688	0.978	0.786	0.802	0.981	0.812	0.812	1	1	1	1
Span Diagnostics Ltd.	-	-	-	1	1	1	1	1	1	0.989	1	0.989	0.575	0.584	0.984	0.741	0.914	0.81
Sri Krishna Drugs Ltd. [Merged]	-	-	-	1	1	1	0.969	0.98	0.989	0.565	0.577	0.979	0.588	0.628	0.937	-	-	-
Strides Arcolab Ltd.	-	-	-	0.936	1	0.936	1	1	1	0.881	1	0.881	1	1	1	1	1	1
Sun Pharmaceutical Inds. Ltd.	-	-	-	0.781	0.782	0.999	1	1	1	1	1	1	1	1	1	1	1	1
Surya Pharmaceutical Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Syncom Formulations (India) Ltd.	-	-	-	0.699	0.709	0.986	0.756	0.763	0.99	1	1	1	0.596	0.606	0.983	0.615	0.827	0.744
Themis Medicare Ltd.	-	-	-	0.94	0.942	0.998	0.77	0.77	0.999	0.492	0.515	0.956	0.444	0.458	0.969	0.733	0.734	0.999
Tonira Pharma Ltd.	1	1	1	1	1	1	1	1	1	0.488	0.488	1	0.514	0.522	0.984	0.694	1	0.694
Torrent Pharmaceuticals Ltd.	1	1	1	0.891	1	0.891	0.608	0.648	0.938	0.404	0.55	0.734	0.55	0.604	0.91	0.66	0.767	0.861
Twilight Litaka Pharma Ltd.	0.893	0.897	0.996	-	-	-	0.605	0.608	0.995	0.611	0.966	0.632	0.854	0.991	0.862	1	1	1
U S V Ltd.	1	1	1	1	1	1	1	1	1	0.788	0.838	0.941	0.698	0.765	0.913	-	-	-
Unichem Laboratories Ltd.	-	-	-	0.656	0.657	0.999	0.59	0.604	0.976	0.537	0.571	0.94	0.559	0.58	0.964	0.678	0.692	0.98
Unimark Remedies Ltd.	-	-	-	0.822	0.823	0.999	0.673	0.691	0.974	0.577	0.799	0.723	0.681	0.847	0.804	-	-	-
Wanbury Ltd.	-	-	-	-	-	-	0.789	0.797	0.991	0.714	0.758	0.941	0.705	0.87	0.81	0.531	0.539	0.985
Wockhardt Ltd.	1	1	1	0.817	1	0.817	0.931	1	0.931	0.751	0.922	0.814	0.703	1	0.703	0.859	0.954	0.9
Wyeth Ltd.	-	-	-	1	1	1	0.777	0.78	0.996	0.76	0.765	0.993	1	1	1	1	1	1
Mean	**0.974**	**0.976**	**0.998**	**0.915**	**0.947**	**0.965**	**0.883**	**0.904**	**0.976**	**0.714**	**0.804**	**0.89**	**0.736**	**0.804**	**0.914**	**0.841**	**0.889**	**0.947**

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

Table 4.12: DEA Estimates of Technical Efficiency for Without R&D Related Outlays Group

Companies' name/Year	**1997**			**1999**			**2002**			**2006**			**2009**			**2011**		
	crste	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**	**crste**	**vrste**	**scale**
Amrutanjan Health Care Ltd.	-	-	-	0.81	0.814	0.994	1	1	1	1	1	1	1	1	1	0.923	0.926	0.997
Auro Laboratories Ltd.	-	-	-	0.74	1	0.74	1	1	1	0.719	0.958	0.75	1	1	1	1	1	1
Caplin Point Laboratories Ltd.	1	1	1	1	1	1	-	-	-	0.974	1	0.974	1	1	1	1	1	1
Coral Laboratories Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	0.743	0.747	0.995	0.917	1	0.917
Everest Organics Ltd.	1	1	1	-	-	-	1	1	1	1	1	1	0.758	0.76	0.998	1	1	1
Gennex Laboratories Ltd.	-	-	-	1	1	1	1	1	1	0.923	1	0.923	1	1	1	0.772	0.873	0.885
Hester Biosciences Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Ishita Drugs & Inds. Ltd.	-	-	-	-	-	-	0.985	1	0.985	0.842	1	0.842	1	1	1	1	1	1
Jenburkt Pharmaceuticals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
K D L Biotech Ltd.	-	-	-	0.921	1	0.921	1	1	1	1	1	1	1	1	1	-	-	-
Karnataka Antibiotics & Pharmaceuticals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Krebs Biochemicals & Inds. Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Medicamen Biotech Ltd.	-	-	-	0.984	1	0.984	1	1	1	1	1	1	1	1	1	1	1	1
Smruthi Organics Ltd.	-	-	-	1	1	1	0.826	0.865	0.955	0.751	0.827	0.908	0.692	0.704	0.983	1	1	1
Srini Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.775	1	0.775	-	-	-
Sunil Healthcare Ltd.	1	1	1	0.811	0.865	0.938	1	1	1	0.903	0.906	0.996	0.901	0.905	0.996	0.831	0.912	0.911
Suven Life Sciences Ltd.	1	1	1	0.896	1	0.896	1	1	1	1	1	1	0.838	1	0.838	1	1	1
Mean	**0.996**	**1**	**0.996**	**0.893**	**0.955**	**0.937**	**0.986**	**0.993**	**0.993**	**0.947**	**0.969**	**0.976**	**0.929**	**0.952**	**0.975**	**0.97**	**0.983**	**0.986**

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

In the year 2006, 11 and 14 firms out of 17 firms are efficient with TE score one and the least efficient firm is Auro Laboratories Ltd and Smurthi Organics Ltd. In the year 2009, 11 and 13 firms out of 17 firms are on frontier and is regarded as efficient while the least efficient firm is Smurthi Organics Ltd. In the year 2011, 11 and 12 firms out of 15 firms are technically efficient and the most inefficient firm in the group for that particular year is Gennex Laboratories Ltd. Among the best performing firms of the group are, Krebs Biochemicals and Inds Ltd, Medicamen Biotech Ltd, Suven Life Sciences Ltd etc which are having efficiency scores scores one or near to one throughout the sample period, while on the other side, Smurthi Organic Ltd and Sunil Healthcare Ltd are the firms in the group which have shown poor performance.

The DEA estimates of the technical efficiency for all firms group have been depicted in the table 4.13. In the year 1997, under the assumptions of CRS, out of total 20 firms, 12 firms are on the frontier having technical efficiency score one. These firms are regarded as technically efficient firms. But the number of such firms has increased to 15 when estimated in case of VRS. Caplin Point Lab is found the most inefficient firms with TE score 0.588 in case of CRS where as in case of VRS Intas Pharma is the most inefficient with the score of 0.593. In the year 1999, the number of firms with efficiency score one are 17 in case of CRS and 33 in case of VRS out of total 79 firms. Raptakos Brett and Co. Ltd is found to be the most inefficient firm in case of CRS and VRS respectively, going by scale efficiency Cadila Pharma is the most inefficient firm. In the year 2002, 44 and 51 out of the total 103 firms are found to be on frontier with TE score one in case of CRS and VRS respectively. The most inefficient firm is Amrutanjan Health Care Ltd with the score 0.532 in case of CRS and 0.533 in case of VRS. The year 2006 presents an interesting scenario in which only 18 and 32 firms out of 103 firms are on frontier with TE score one and the least efficient firm is Bharat Serums and Vaccines Ltd. In the year 2009, out of total 106 firms 18 and 34 firms are on frontier and the least efficient firm is Albert David Ltd. In the year 2011, Jagsonpal Pharmaceutical Ltd has been identified as the most inefficient firm with TE scores 0.446 and 0.447 in case of CRS and VRS respectively. The numbers of the firms on the frontier are 21 and 39 out of total 88 firms in case of CRS and VRS respectively. There are some firms which are among the least technical efficient firms in all the selected years such as Jagsonpal, Anglo-Frech, Bal Pharma, Albert David Ltd, Intas Pharmaceutical Ltd, Unichem Laboratories Ltd etc. On the other hand, there are firms which are among the most technical efficient relative to other firms in the group having technical efficiency score one and close to one in most of the reported years like Surya Pharmaceutical Ltd., Anuh Pharma Ltd, Sun Pharmaceutical Ltd, Novartis India Ltd, Ind-Swift Laboratories Ltd etc.

Summary

From the above discussion it is clear that the technical efficiency scores have varied over the years and also across the CRS-VRS assumptions. More specifically, firms such as Caplin Point Labs, Lyka Labs, Twilight Litaka Pharma which were technically inefficient in the year 1997 and 1999 have progressively moved forward to achieve technical efficiency by the year 2009 and 2011. A few reversals in case of Sunil Healthcare, Tonira Pharma Ltd, Kopran Ltd, Indoco Remedies Ltd firm are also noted. Firms such as Jagsonpal pharma, Ipca Laboratories Ltd, FDC Ltd, Cdila and Unimark Remedies Ltd which were in existence from 1999 either never improved their performance or showed a decline as reflected in their scores. Quite a few firms such as Abbott India Ltd, Anuh Pharma, Glaxosmithkline, Ind-Swift, and Surya Pharmaceutical Ltd etc have consistently high level of technical efficiency. Thus the evidences are quite mixed, restraining us to draw any general conclusion.

Table 4.13: DEA Estimates of All Firms Group

Companies' name/Year	1997			1999			2002			2006			2009			2011		
	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
Aarti Drugs Ltd.	-	-	-	0.831	0.891	0.933	0.756	0.777	0.974	0.752	0.912	0.824	0.767	0.867	0.885	0.893	0.98	0.912
Abbott India Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Ahlcon Parenterals (India) Ltd.	-	-	-	0.985	1	0.985	1	1	1	1	1	1	0.575	0.585	0.983	0.809	0.871	0.929
Ajanta Pharma Ltd.	-	-	-	0.901	1	0.901	1	1	1	1	1	1	0.833	1	0.833	0.822	1	0.822
Albert David Ltd.	-	-	-	0.644	0.668	0.964	0.725	0.78	0.93	0.292	0.294	0.994	0.346	0.347	0.999	0.465	0.478	0.973
Alembic Ltd.	-	-	-	0.76	0.974	0.78	0.633	0.67	0.944	0.363	0.468	0.776	0.393	0.587	0.668	0.58	0.607	0.955
Alkem Laboratories Ltd.	-	-	-	0.6	1	0.6	1	1	1	0.561	0.676	0.829	0.41	0.499	0.821	-	-	-
Amrutanjan Health Care Ltd.	-	-	-	0.601	0.613	0.981	0.532	0.533	0.998	0.411	0.411	1	1	1	1	0.65	0.666	0.976
Anglo-French Drugs & Inds. Ltd.	-	-	-	0.551	0.56	0.985	0.568	0.57	0.997	0.328	0.336	0.977	0.449	0.462	0.971	0.476	0.511	0.931
Anuh Pharma Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Arch Pharmalabs Ltd.	-	-	-	-	-	-	0.837	0.837	1	0.922	1	0.922	0.868	1	0.868	1	1	1
Arvind Remedies Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Astrazeneca Pharma India Ltd.	-	-	-	0.828	0.836	0.99	0.837	0.837	0.999	0.651	0.687	0.947	0.728	0.728	1	0.617	0.628	0.982
Auro Laboratories Ltd.	-	-	-	0.676	0.812	0.833	1	1	1	0.502	0.782	0.642	0.973	1	0.973	0.96	1	0.96
Aurobindo Pharma Ltd.	-	-	-	0.955	1	0.955	1	1	1	0.629	1	0.629	0.682	1	0.682	0.849	1	0.849
Aventis Pharma Ltd.	-	-	-	0.544	0.797	0.683	0.73	0.81	0.901	-	-	-	0.534	0.735	0.726	0.53	0.832	0.637
B D H Industries Ltd.	1	1	1	0.556	0.556	0.999	0.994	1	0.994	0.421	0.425	0.992	0.464	0.471	0.985	0.638	0.681	0.936
Bal Pharma Ltd.	-	-	-	0.561	0.572	0.981	0.665	0.675	0.985	0.457	0.487	0.938	0.412	0.436	0.944	0.568	0.594	0.957
Bharat Serums & Vaccines Ltd.	-	-	-	-	-	-	0.708	0.808	0.876	0.296	0.319	0.926	0.572	0.596	0.96	-	-	-
Biocon Ltd.	-	-	-	-	-	-	0.751	0.798	0.941	0.857	1	0.857	0.717	0.834	0.86	0.816	1	0.816
Biological E. Ltd.	-	-	-	0.799	0.904	0.884	1	1	1	0.676	0.951	0.712	0.478	0.676	0.707	-	-	-
Cadila Healthcare Ltd.	-	-	-	0.905	1	0.905	0.666	0.829	0.804	0.425	0.745	0.571	0.53	0.769	0.689	0.908	0.982	0.925
Cadila Pharmaceuticals Ltd.	-	-	-	0.545	0.968	0.563	0.578	0.626	0.924	-	-	-	0.434	0.535	0.811	0.508	0.563	0.903
Caplin Point Laboratories Ltd.	0.588	0.624	0.943	0.968	1	0.968	-	-	-	0.624	0.631	0.989	1	1	1	1	1	1
Capsugel Healthcare Ltd.	-	-	-	0.757	0.773	0.979	0.689	0.689	0.999	0.681	0.708	0.962	1	1	1	-	-	-

Cipla Ltd.	-	-	-	1	1	1	1	1	1	0.836	1	0.836	0.886	1	0.886	0.791	1	0.791
Claris Lifesciences Ltd.	-	-	-	-	-	-	1	1	1	0.472	0.688	0.686	0.983	1	0.983	1	1	1
Coral Laboratories Ltd.	-	-	-	-	-	-	1	1	1	0.915	0.927	0.987	0.416	0.441	0.942	0.606	0.727	0.833
D S M Anti Infectives India Ltd.	-	-	-	-	-	-	1	1	1	0.822	1	0.822	0.95	1	0.95	0.973	1	0.973
Dishman Pharmaceuticals & Chemicals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Dr. Reddy'S Laboratories Ltd.	-	-	-	0.815	0.914	0.892	1	1	1	0.62	1	0.62	0.855	1	0.855	0.948	1	0.948
East India Pharmaceutical Works Ltd.	-	-	-	0.968	0.968	1	1	1	1	0.435	0.451	0.964	0.423	0.429	0.986	-	-	-
Elder Pharmaceuticals Ltd.	1	1	1	1	1	1	1	1	1	0.751	0.852	0.881	0.637	0.761	0.836	0.854	0.885	0.965
Enzal Chemicals (India) Ltd.	-	-	-	0.691	0.73	0.945	0.948	0.955	0.994	0.491	0.547	0.898	0.47	0.595	0.789	-	-	-
Everest Organics Ltd.	0.985	1	0.985	-	-	-	1	1	1	1	1	1	0.61	0.625	0.976	0.763	0.781	0.977
F D C Ltd.	-	-	-	0.729	0.844	0.864	0.763	0.806	0.946	0.571	0.574	0.995	0.528	0.575	0.918	0.667	0.743	0.897
Fermenta Biotech Ltd.	-	-	-	1	1	1	1	1	1	0.757	0.807	0.939	0.794	0.813	0.976	1	1	1
Fredun Pharmaceuticals Ltd.	-	-	-	0.65	0.924	0.704	0.835	1	0.835	1	1	1	0.548	1	0.548	-	-	-
Gennex Laboratories Ltd.	-	-	-	0.859	0.958	0.896	1	1	1	0.765	0.859	0.891	0.679	0.712	0.954	0.606	0.743	0.816
Glaxosmithkline Pharmaceuticals Ltd.	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1
Glenmark Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	0.71	0.877	0.809	1	1	1	1	1	1
Granules India Ltd.	-	-	-	0.787	0.806	0.976	0.906	0.909	0.996	0.481	0.767	0.627	0.635	0.737	0.862	0.576	0.711	0.81
Group Pharmaceuticals Ltd.	-	-	-	1	1	1	0.898	0.94	0.955	0.566	0.622	0.91	0.649	0.679	0.956	1	1	1
Harman Finochem Ltd.	-	-	-	0.758	0.808	0.938	0.916	0.928	0.988	0.778	0.785	0.99	0.805	0.81	0.995	-	-	-
Hester Biosciences Ltd.	-	-	-	-	-	-	0.84	0.966	0.87	0.757	0.843	0.898	0.623	0.633	0.984	0.861	0.893	0.964
Indoco Remedies Ltd.	0.831	0.941	0.882	0.895	0.919	0.973	0.667	0.67	0.996	0.463	0.506	0.914	0.427	0.483	0.884	0.491	0.537	0.915
Ind-Swift Laboratories Ltd.	0.979	1	0.979	0.902	0.999	0.902	1	1	1	1	1	1	1	1	1	1	1	1
Intas Pharmaceuticals Ltd.	0.592	0.593	0.999	0.588	0.588	1	0.602	0.672	0.896	0.62	1	0.62	0.803	1	0.803	-	-	-
Ipca Laboratories Ltd.	-	-	-	0.676	0.954	0.709	0.796	0.939	0.848	0.319	0.77	0.414	0.433	0.697	0.621	0.588	0.771	0.763
Ishita Drugs & Inds. Ltd.	-	-	-	-	-	-	0.711	1	0.711	0.364	1	0.364	0.781	1	0.781	0.821	1	0.821
J B Chemicals & Pharmaceuticals Ltd.	-	-	-	0.743	0.928	0.8	0.752	0.779	0.966	0.442	0.702	0.629	0.813	1	0.813	0.828	0.908	0.912
Jagsonpal Pharmaceuticals Ltd.	-	-	-	0.506	0.567	0.893	0.672	0.673	0.998	0.455	0.493	0.923	0.581	0.584	0.995	0.446	0.447	0.997
Jenburkt Pharmaceuticals Ltd.	-	-	-	-	-	-	0.644	0.652	0.989	0.427	0.537	0.795	0.739	0.968	0.763	0.688	1	0.688
Karnataka Antibiotics & Pharma Ltd.	-	-	-	-	-	-	0.867	0.873	0.993	0.532	0.538	0.99	0.633	0.633	0.999	0.548	0.553	0.992

Kilitch Drugs (India) Ltd.	-	-	-	-	-	-	0.899	0.903	0.996	1	1	1	0.874	0.885	0.988	0.825	0.833	0.99
Kopran Ltd.	0.978	1	0.978	0.88	1	0.88	1	1	1	0.648	0.665	0.975	0.485	0.511	0.949	0.585	0.602	0.973
Krebs Biochemicals & Inds. Ltd.	-	-	-	1	1	1	0.954	1	0.954	1	1	1	1	1	1	0.813	0.818	0.994
Lincoln Pharmaceuticals Ltd.	-	-	-	0.676	0.677	1	0.728	0.728	1	0.542	0.549	0.987	0.79	0.819	0.964	0.891	0.904	0.986
Lupin Ltd.	-	-	-	-	-	-	0.679	0.789	0.861	0.434	0.752	0.577	0.549	0.814	0.674	0.777	1	0.777
Lyka Labs Ltd.	-	-	-	0.626	1	0.626	1	1	1	0.744	0.979	0.76	0.614	0.717	0.856	0.894	0.894	1
Macleods Pharmaceuticals Ltd.	-	-	-	1	1	1	0.806	1	0.806	0.563	0.664	0.848	0.451	0.737	0.612	-	-	-
Malladi Drugs & Pharmaceuticals Ltd.	-	-	-	0.778	0.876	0.888	0.902	0.958	0.942	0.806	0.806	1	0.525	0.534	0.983	-	-	-
Mangalam Drugs & Organics Ltd.	-	-	-	-	-	-	0.724	0.747	0.968	0.613	0.616	0.994	0.596	0.597	0.998	0.641	0.643	0.998
Marksans Pharma Ltd.	-	-	-	-	-	-	1	1	1	0.843	0.985	0.856	1	1	1	1	1	1
Matrix Laboratories Ltd.	-	-	-	0.758	0.848	0.893	1	1	1	0.736	1	0.736	0.713	1	0.713	0.749	1	0.749
Medicamen Biotech Ltd.	-	-	-	0.858	0.861	0.997	1	1	1	0.518	0.532	0.974	0.816	0.816	1	0.898	0.913	0.984
Medi-Caps Ltd.	-	-	-	-	-	-	1	1	1	0.959	0.983	0.976	0.746	0.801	0.932	0.936	1	0.936
Medley Pharmaceuticals Ltd.	1	1	1	0.962	0.973	0.989	0.846	0.851	0.995	-	-	-	0.529	0.529	1	-	-	-
Natco Pharma Ltd.	-	-	-	-	-	-	0.923	1	0.923	0.547	0.669	0.817	0.533	0.635	0.84	0.858	0.912	0.941
Natural Capsules Ltd.	-	-	-	-	-	-	1	1	1	0.643	0.695	0.925	0.754	0.803	0.939	0.772	0.824	0.937
Nectar Lifesciences Ltd.	1	1	1	1	1	1	0.946	1	0.946	1	1	1	0.799	0.978	0.817	0.951	1	0.951
Neuland Laboratories Ltd.	-	-	-	1	1	1	0.768	0.776	0.989	0.415	0.875	0.474	0.545	0.709	0.769	0.605	0.689	0.879
Novartis India Ltd.	-	-	-	0.906	1	0.906	1	1	1	1	1	1	1	1	1	1	1	1
Orchid Chemicals & Pharmaceuticals Ltd.	-	-	-	0.867	1	0.867	0.768	0.776	0.989	0.613	1	0.613	0.907	1	0.907	0.817	1	0.817
Panacea Biotec Ltd.	-	-	-	0.728	1	0.728	0.756	0.798	0.947	0.728	1	0.728	0.525	0.768	0.684	0.605	1	0.605
Panchsheel Organics Ltd.	-	-	-	-	-	-	1	1	1	0.574	0.665	0.863	0.687	0.786	0.874	1	1	1
Paras Pharmaceuticals Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	0.813	0.814	1	-	-	-
Parenteral Drugs (India) Ltd.	-	-	-	-	-	-	0.675	0.678	0.995	0.527	0.585	0.9	0.796	0.797	1	0.842	0.866	0.972
Pfizer Ltd.	-	-	-	-	-	-	1	1	1	0.575	0.736	0.781	1	1	1	0.999	1	0.999
Ranbaxy Laboratories Ltd.	1	1	1	0.901	1	0.901	1	1	1	0.697	1	0.697	0.955	1	0.955	1	1	1
Raptakos, Brett & Co. Ltd.	-	-	-	0.491	0.515	0.954	-	-	-	0.508	0.509	0.997	0.506	0.548	0.923	-	-	-
Resonance Specialties Ltd.	-	-	-	0.756	0.756	1	1	1	1	-	-	-	1	1	1	1	1	1
S M S Pharmaceuticals Ltd.	1	1	1	1	1	1	-	-	-	0.544	0.69	0.788	0.821	0.852	0.963	0.846	0.853	0.992

Shasun Pharmaceuticals Ltd.	-	-	-	0.737	0.923	0.798	0.716	0.835	0.858	0.413	0.742	0.557	0.531	0.696	0.763	0.669	0.724	0.924
Shilpa Medicare Ltd.	1	1	1	0.833	0.931	0.894	0.664	0.677	0.98	0.786	0.799	0.984	0.79	0.81	0.975	0.954	1	0.954
Smruthi Organics Ltd.	-	-	-	0.873	0.876	0.996	0.669	0.669	1	0.426	0.426	1	0.545	0.545	1	0.793	0.832	0.953
Span Diagnostics Ltd.	-	-	-	1	1	1	1	1	1	0.971	0.991	0.979	0.558	0.571	0.976	0.707	0.752	0.94
Sri Krishna Drugs Ltd. [Merged]	-	-	-	0.996	1	0.996	0.903	0.916	0.986	0.565	0.567	0.995	0.588	0.611	0.964	-	-	-
Srini Pharmaceuticals Ltd.	-	-	-	1	1	1	0.923	0.953	0.969	0.921	1	0.921	0.674	0.698	0.966	-	-	-
Strides Arcolab Ltd.	-	-	-	0.799	1	0.799	1	1	1	0.858	1	0.858	1	1	1	1	1	1
Sun Pharmaceutical Inds. Ltd.	-	-	-	0.762	0.768	0.993	1	1	1	1	1	1	1	1	1	1	1	1
Sunil Healthcare Ltd.	0.843	1	0.843	0.708	0.79	0.896	1	1	1	0.474	0.514	0.921	0.493	0.502	0.981	0.747	0.752	0.994
Surya Pharmaceutical Ltd.	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Suven Life Sciences Ltd.	1	1	1	0.874	0.903	0.968	1	1	1	0.576	0.617	0.933	0.539	0.688	0.783	0.833	0.856	0.974
Syncom Formulations (India) Ltd.	-	-	-	0.543	0.546	0.995	0.752	0.758	0.991	1	1	1	0.52	0.524	0.993	0.52	0.532	0.978
Themis Medicare Ltd.	-	-	-	0.687	0.698	0.984	0.77	0.77	0.999	0.45	0.515	0.873	0.44	0.458	0.961	0.625	0.692	0.904
Tonira Pharma Ltd.	1	1	1	1	1	1	1	1	1	0.481	0.487	0.986	0.514	0.522	0.984	0.65	0.8	0.812
Torrent Pharmaceuticals Ltd.	1	1	1	0.722	1	0.722	0.608	0.648	0.938	0.399	0.55	0.725	0.546	0.604	0.904	0.613	0.767	0.8
Twilight Litaka Pharma Ltd.	0.837	0.841	0.995	-	-	-	0.605	0.608	0.995	0.611	0.966	0.632	0.845	0.991	0.852	0.985	1	0.985
U S V Ltd.	1	1	1	0.758	0.935	0.811	1	1	1	0.788	0.838	0.941	0.695	0.765	0.909	-	-	-
Unichem Laboratories Ltd.	-	-	-	0.499	0.553	0.902	0.59	0.604	0.976	0.535	0.571	0.937	0.558	0.58	0.964	0.654	0.692	0.945
Unimark Remedies Ltd.	-	-	-	0.714	0.753	0.948	0.673	0.691	0.974	0.56	0.794	0.705	0.675	0.847	0.797	-	-	-
Wanbury Ltd.	-	-	-	-	-	-	0.779	0.779	1	0.534	0.758	0.705	0.705	0.87	0.81	0.515	0.515	1
Wockhardt Ltd.	1	1	1	0.702	1	0.702	0.931	1	0.931	0.731	0.922	0.793	0.703	1	0.703	0.791	0.954	0.829
Wyeth Ltd.	-	-	-	1	1	1	0.777	0.78	0.996	0.753	0.757	0.994	0.845	0.846	0.999	1	1	1
Mean	0.929	0.955	0.973	0.826	0.893	0.928	0.881	0.905	0.973	0.689	0.788	0.878	0.734	0.8	0.918	0.81	0.864	0.937

Note: crste and vrste refer to constant return to scale and variable return to scale technical efficiency, and scale is for scale efficiency.

4.4.2 Mean Technical Efficiency: Group Wise Analysis

The estimated results of mean technical efficiency are shown in the tables 4.14 to 4.19 for all the groups as well as all the selected firms together for the period of 1997 to 2011. Table 4.14 shows the mean technical efficiency scores for the big firms and small firms group. The big and small firms have been defined according to the Ministry of Medium, Small and Micro Enterprises, Development Act 2006 i.e. the firms having investment of more than Rs. 100 million in their plan and machinery, are considered as big firms and the firms having investment less than Rs. 100 million are considered as small firms. Column 2 shows the mean (geometric mean) technical efficiency scores of big firms measured in case of constant return to scale and variable return to scale in the next column and then scale efficiency scores.

Table 4.14: Mean Efficiency Scores for Big Firms and Small firms Group

	Big			Small		
Year	crste	vrste	scale	crste	vrste	scale
1997	0.969	0.979	0.987	0.941	0.959	0.981
1998	1	1	1	0.984	0.998	0.986
1999	0.937	0.958	0.977	0.839	0.902	0.931
2000	0.926	0.96	0.964	0.877	0.924	0.949
2001	0.917	0.95	0.966	0.897	0.932	0.962
2002	0.903	0.934	0.965	0.917	0.953	0.961
2003	0.898	0.934	0.959	0.895	0.923	0.97
2004	0.872	0.925	0.943	0.875	0.917	0.955
2005	0.878	0.918	0.954	0.776	0.837	0.927
2006	0.884	0.921	0.957	0.715	0.794	0.903
2007	0.894	0.92	0.97	0.733	0.8	0.915
2008	0.832	0.878	0.947	0.757	0.818	0.923
2009	0.839	0.881	0.951	0.784	0.843	0.929
2010	0.849	0.896	0.947	0.839	0.847	0.99
2011	0.875	0.917	0.956	0.88	0.915	0.959

A value of 0.969 in 1997 computed in case of CRS implies that big firms can further maximize its level of production by another 4 percent without employing any additional inputs. Whereas computed in case of VRS the value is 0.979 (see column 3) which implies that on an average big firms cannot increase their level of production by more than 3 percent. We also notice that there has been a drastic fall in the efficiency level of big firms from 0.969 and 0.797 in 1997 to 0.875 and 0.917 in 2011 when estimated in case of CRS and VRS respectively. The value of mean scale efficiency also came down around by 3 percent during the study period. Let us now consider the case of small firms group. Column 5 and 6 show the mean (geometric mean) technical efficiency scores of small firms measured in case of CRS and VRS respectively. The efficiency figures of 0.941 and 0.959 estimated in terms of CRS and VRS respectively in 1997 implies that the small firms have been able to maintain an efficiency level of around 94percent and 95 percent in 1997. This implies that on average small firms can further increase its level of production by another 6 percent in case of CRS and 5 percent in case of VRS without any additional employment in the factors of production. We find that the magnitude and trend in the efficiency level of small firms have shown a declining pattern over a period of time.

Table 4.15 shows the mean efficiency scores for firms from different product groups. The figures in the table 2 depicts that there is no noticeable difference in the technical efficiency scores until 1998 for all the three groups of firms estimated in terms of CRS and VRS. Thus, for example in 1999 in case of bulk and formulation group, we notice that the efficiency score computed in terms of CRS is 0.952. This implies that compared to all the firms in the industry firms producing both bulk drug and formulation can further increase its level of production by another 5 percent without employing any additional inputs. Similarly, TE score in case of VRS for the same year is 0.97. Thus, there has been a marginal improvement in its efficiency performance when estimated considering VRS assumptions.

Table 4.15: Mean Efficiency Scores for Firms from Different Product Groups

	Bulk and Formulation			Only Formulation			Only Bulk		
Year	crste	vrste	scale	crste	vrste	scale	crste	vrste	scale
1997	0.999	1	0.999	1	1	1	1	1	1
1998	1	1	1	0.995	1	0.995	0.989	1	0.989
1999	0.952	0.97	0.981	0.886	0.928	0.956	0.969	0.992	0.976
2000	0.934	0.954	0.977	0.881	0.935	0.942	0.982	0.99	0.992
2001	0.916	0.942	0.97	0.913	0.944	0.967	0.986	0.992	0.994
2002	0.929	0.943	0.984	0.909	0.938	0.969	0.963	0.978	0.985
2003	0.887	0.921	0.962	0.914	0.942	0.97	0.953	0.971	0.981
2004	0.867	0.929	0.935	0.899	0.937	0.959	0.969	0.98	0.989
2005	0.865	0.902	0.957	0.816	0.878	0.925	0.969	0.985	0.985
2006	0.867	0.901	0.961	0.771	0.859	0.896	0.971	0.986	0.985
2007	0.897	0.916	0.978	0.734	0.844	0.875	0.949	0.966	0.982
2008	0.9	0.924	0.973	0.752	0.828	0.909	0.935	0.949	0.985
2009	0.892	0.933	0.956	0.787	0.867	0.909	0.936	0.95	0.986
2010	0.929	0.939	0.989	0.819	0.876	0.933	0.91	0.919	0.988
2011	0.926	0.942	0.982	0.857	0.933	0.918	0.919	0.961	0.957

The trend in the efficiency scores of the firms estimated in terms of CRS and VRS indicates a gradual fall in its value from 0.999 in 1997 to 0.926 in 2011 in case of CRS and from 1 in 1997 to 0.942 in 2011 in case of VRS. We find a similar trend in the efficiency scores for firms producing only formulation and only bulk. More precisely, we notice that firms producing formulation are moderately efficient when they are compared amongst themselves. A cross comparison of the technical efficiency estimated in terms of CRS and VRS and scale efficiency for all these three group indicates that firms producing only bulk drug are the most efficient ones followed by the firms producing both bulk drugs and formulation and firms producing only formulation. Among the firms producing only formulation or both bulk and formulation we find that, firms producing both bulk drugs and formulation are the most efficient ones when they are compared amongst themselves.

Table 4.16 presents the mean TE scores for MNCs and indigenous firm groups estimated in case of CRS and VRS. Column 2 and 3 of the table depict the TE score of MNCs group of firms. The value 0.953 in the year 1997 in case of CRS and 0.972 in case of VRS imply that firms can improve further their efficiency level by 5 percent and 3 percent respectively without employing additional inputs. The trend in efficiency for this group shows a declining pattern up to 2007 in case of TE CRS, VRS and SE. After that in the recent period the firm's efficiency level is showing an improvement.

Table 4.12: Mean Efficiency Scores for MNCs and Indigenous Group of Firms

	MNCs			Indigenous		
Year	crste	vrste	scale	crste	vrste	scale
1997	0.953	0.972	0.975	0.936	0.962	0.972
1998	0.989	0.993	0.996	0.977	0.997	0.979
1999	0.946	0.964	0.981	0.839	0.898	0.935
2000	0.912	0.951	0.958	0.878	0.922	0.951
2001	0.922	0.937	0.983	0.884	0.929	0.951
2002	0.915	0.928	0.985	0.911	0.953	0.955
2003	0.904	0.93	0.97	0.897	0.935	0.96
2004	0.864	0.912	0.946	0.91	0.942	0.966
2005	0.853	0.906	0.938	0.896	0.941	0.952
2006	0.761	0.891	0.849	0.898	0.941	0.954
2007	0.754	0.876	0.854	0.92	0.955	0.963
2008	0.815	0.882	0.917	0.845	0.915	0.923
2009	0.839	0.895	0.931	0.852	0.922	0.925
2010	0.895	0.923	0.968	0.81	0.887	0.916
2011	0.904	0.942	0.96	0.881	0.929	0.948

There are several factors that can be attributed to this growth like the firms in the recent past has benefited from the product patent being more competitive in the international market, spending more on R&D activities etc. Column 5 and 6 show the mean technical efficiency scores for indigenous firms groups. Thus the value 0.936 in the year 1997 estimated in case of CRS implies that there is possibility to increase the efficiency level by 7 percent without employing additional inputs. The mean technical efficiency of this group has declined over a period of time. The cross comparison of both the groups shows that MNCs have performed better than the indigenous firms group in all cases.

In the table 4.17 we have reported the mean TE scores for the firms with and without any R&D related outlays. Let us first consider the case of firms with R&D related outlays.

Table 4.13: Mean Efficiency Scores for Firms With and Without R&D Related Outlays

	Engaged in R&D			Not Engaged in R&D		
Year	Crste	vrste	scale	crste	vrste	scale
1997	0.974	0.976	0.998	0.996	1	0.996
1998	0.986	0.991	0.995	0.999	1	0.999
1999	0.915	0.947	0.965	0.893	0.955	0.937
2000	0.885	0.933	0.95	0.934	0.972	0.961
2001	0.887	0.923	0.958	0.959	0.975	0.985
2002	0.883	0.904	0.976	0.986	0.993	0.993
2003	0.873	0.898	0.971	0.943	0.968	0.974
2004	0.825	0.866	0.953	0.963	0.974	0.988
2005	0.793	0.835	0.947	0.966	0.979	0.987
2006	0.714	0.804	0.89	0.947	0.969	0.976
2007	0.711	0.802	0.887	0.975	0.985	0.989
2008	0.713	0.788	0.904	0.916	0.955	0.957
2009	0.736	0.804	0.914	0.929	0.952	0.975
2010	0.771	0.829	0.931	0.923	0.976	0.943
2011	0.841	0.889	0.947	0.97	0.983	0.986

The values of technical efficiency at 0.974 and 0.976 in 1997 estimated in case of CRS and VRS respectively imply that when all firms are taken into consideration firms engaged in R&D activity can further increase their level of production by another 3 percent. However, the scale efficiency figure takes a value of 0.998, implying that the firms are close to frontier and no further improvement is possible. The values of technical efficiency at 0.974 and 0.976 in 1997 estimated in case of CRS and VRS respectively imply that when all firms are taken into consideration firms engaged in R&D activity can further increase their level of production by another 3 percent. However, the scale efficiency figure takes a value of 0.998, implying that the firms are close to frontier and no further improvement is possible.

The trend in the efficiency score for this group of firms also indicates a gradual fall in its values. We next consider the case of firms without any R&D related outlays. We notice that the trend in the efficiency score indicates that there has been a gradual fall in the efficiency of the firms from this group whether estimated in case of CRS or VRS and the value of SE also has declined slightly over the period of 1997 to 2011. Table 4 indicate that the technical efficiency level for both R&D and without R&D firms has declined over the period of time. R&D has then played a negligible role in enhancing the production capability of firms to catch up with the rest of the firms in the group.

Table 4.18 depicts the efficiency scores for the high exporting firms (for the firms earning more than 25% of their total income in the international market) and the low-exporting firms (for the firms with an export earning less than or equal to 25% of their total income). Let us first consider the case of high exporting firms. We find that in 1997 the firms from this group have an efficiency level of 1 in case of CRS, VRS and SE.

This implies that firms from this group are on frontier that is all are efficient and further improvement is not possible.

Table 4.14: Mean Efficiency Scores for High and Low Export Intensive Group of Firms

	High Export			Low Export		
Year	crste	vrste	scale	crste	vrste	scale
1997	1	1	1	0.92	0.948	0.968
1998	0.993	1	0.993	0.988	0.993	0.995
1999	0.909	0.956	0.952	0.904	0.924	0.978
2000	0.885	0.958	0.925	0.928	0.938	0.988
2001	0.902	0.937	0.962	0.924	0.953	0.969
2002	0.936	0.955	0.98	0.894	0.913	0.979
2003	0.906	0.938	0.964	0.875	0.905	0.966
2004	0.906	0.932	0.971	0.854	0.88	0.97
2005	0.919	0.948	0.969	0.784	0.835	0.935
2006	0.804	0.907	0.886	0.784	0.835	0.935
2007	0.798	0.891	0.894	0.805	0.84	0.953
2008	0.826	0.897	0.921	0.772	0.807	0.951
2009	0.828	0.879	0.941	0.816	0.847	0.96
2010	0.817	0.881	0.929	0.87	0.914	0.951
2011	0.866	0.923	0.936	0.918	0.94	0.976

However after 1998 all firms in this group exhibited a declining trend in the efficiency component computed in all cases i.e. CRS, VRS and SE. In the next step, we have reported the efficiency scores for the low exporting firms. We find that the efficiency level is around 0.92 in 1997 estimated in terms of CRS for low exporting firms. This improves to 0.94 in 1997 when estimated in terms of VRS implying that further improve of 8 percent in case of CRS and 6 percent in case of VRS is possible without employing additional inputs. However, in the subsequent years, the magnitude of efficiency level has shown a mixed trend. Cross comparison of the efficiency scores reveals that the average efficiency scores for the firms from high export intensive group, was higher than the firms from the low export intensive group. There might be a possibility of technological transfer and collaboration with foreign firms (see Clerides et al 1998, World Bank Report, 1993, 1997) for high exporting firms exposed in the international market that might have facilitated to gain higher efficiency compared to low exporting firms.

The mean technical efficiency for the all firms group is depicted in table 4.19. The columns of the table depict the value of TE score estimated in case of CRS and VRS assumptions and scale efficiency. More precisely in 1997, the average technical efficiency attained by the firms was around 93 percent computed in case of CRS and 95 percent in case of VRS. This implies that there is possibility for the firms to expand their output by about 7 percent in case of CRS and 5 percent in case of VRS without employing any additional inputs. The results in the above table suggest that there is a persistent fall in the mean efficiency level of the firms for the sector from 0.929 in 1997 to 0.81 in 2011 in case of CRS and from 0.955 in 1997 to 0.864 in 2011 in case of VRS. The value of scale efficiency also has shown a declining trend from 0.973 in 1997 to 0.937 in 2011.

Consistent fall in mean efficiency for the sector also implies that compared to the output produced by frontier firms the production level of inefficient firms are falling over the years. There is possibility that due to technological progress there is an outward shift in the production frontier which may result in the distance to increase from the frontier for an inefficient firm. However, its performance may not decline in the absolute sense of the term.

Table 4.15: Mean Efficiency Scores for All Firms Group

Year	crste	vrste	scale
1997	0.929	0.955	0.973
1998	0.968	0.987	0.981
1999	0.826	0.893	0.928
2000	0.842	0.909	0.927
2001	0.861	0.904	0.95
2002	0.881	0.905	0.973
2003	0.842	0.879	0.957
2004	0.815	0.855	0.954
2005	0.77	0.827	0.93
2006	0.689	0.788	0.878
2007	0.699	0.789	0.887
2008	0.714	0.786	0.908
2009	0.734	0.8	0.918
2010	0.761	0.808	0.944
2011	0.81	0.864	0.937

4.5 Concluding Remarks:

In this study we have analyzed the technical efficiency of Indian pharmaceutical firms over the period 1997 to 2011. The soft patent regime, prior to 2005, provided opportunities for this industry to witness significant growth, particularly in generics production and exports, however results of the study reveal that prior to 2005 (during 1997 to 2005) the sector has witnessed a gradual fall in its efficiency values and after 2005 i.e. the post product patent regime, the industry has witnessed an increasing trend in the level of efficiency in almost all groups of firms and all firms put together. Our study also indicates that the industry has experienced rapid pace of technical progress opening up new production possibilities. However, most of the firms have failed to appropriate the benefits of such technological change. Further, the study categorised the firms on the basis of size, its expenditure on R&D and other characteristics. The results of the group wise analysis indicate that there is a positive association between the size of firms and their technical efficiencies. In turn we may conclude that scale of economies is prevailed in the pharmaceutical industry of India. The results of the study also reveal that inefficient firms investing in R&D related activities have not benefited much to achieve higher efficiency. However, such firms have benefited from technological innovation. The results indicate that the overall average technical efficiency of MNCs group of firms is higher than that of indigenous firms. The study also reveals that high exporting firms have experienced more efficiency gain than low exporting firms group. The study also finds that vertically integrated firms have benefited much from efficiency change whereas the firms producing only bulk performed well in overall average technical efficiency. The study also indicates that adopting capital-intensive techniques, importing advanced technology and R&D can ensure technological growth of the frontier firms across all possible groups of firms considered for the study.

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5. CHAPTER

EMPIRICAL ANALYSIS OF TECHNICAL EFFICIENCY OF INDIAN PHARMACEUTICAL FIRMS: SFA APPROACH

5.1 Stochastic Frontier Analysis:

The study has utilised the parametric technique; stochastic frontier analysis (SFA) to estimate a production frontier which will serve as a benchmark to estimate the technical efficiencies of the Indian pharmaceutical industry. SFA, developed by Anger, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), is a parametric technique that generates an efficiency frontier for the sample firms. The efficiency of each decision making unit (in the present case a firm) is then measured as the distance of its output to the frontier. This involves estimation of stochastic frontier production function where the output of a firm is expressed as a function of a set of inputs, inefficiency and random error. The SFA treats the observed inefficiency of a firm as a combination of the inefficiency specific to the firm and a random error and tries to disentangle the two components by making explicit assumptions about the underlying inefficiency process.

The original specification of SFA involved estimation of production function for cross-sectional data which had an error term having two components, one accounting for random factors and another for technical [in]efficiency.

Formally, the model may be specified as,

$$Y_i = x_i\beta + (v_i - u_i), \quad i = 1, 2, 3, \ldots, n \qquad \ldots (5.1)$$

Where Y_i represents the actual output for the sample firm i ;

x_i is a $k \times 1$vector of inputs of the i-th firm;

β is a vector of unknown parameters that describe the transformation process;

v_i are random variables which are assumed to be $iid\ N(0,\sigma^2)$, and independent of the u_i which are one-sided (non-negative) random variables assumed to account for technical efficiency in production and generally assumed to be iid $N(0,\sigma_u{}^2)$. If the operation of a firm is inefficient (efficient), its actual output is less than (equal to) the potential output. Therefore, one can treat the ratio of the actual output to potential output as a measure of TE of a firm during the time period. The residual term u_i is zero when the firm produces the potential output (full TE) and is greater than zero when production is below the frontier (less than full TE).

The original specification has been modified later on to incorporate more general distribution assumptions for the u_i, such as truncated normal or two-parameter gamma distributions' for the consideration of panel data and time-varying technical efficiencies. It is also extended to estimate the cost function and of system of equations.

In the present study, we have employed the specification of stochastic frontier production developed by Battese and Coelli (1992) for panel data which has firm effects and assumed to be distributed as truncated normal random variables, which may also vary systematically with time i.e. it capture time varying technical efficiency (TE). This may be expressed as,

$$Y_{it} = x_{it}\beta + (v_{it} - u_{it}) \quad i = 1,2,3,\ldots,n; \quad t = 1,2,3,..T; \qquad \ldots (5.2)$$

Where Y_{it} represents the actual output for the sample firm i in period t;

x_{it} is a $k \times 1$ vector of inputs of the sample firm i in period t ;

β is a vector of unknown parameters that describe the transformation process;

v_{it} are random variables which are assumed to be $N(0,\sigma^2)$, and independent of the u_{it}. Following, Battese and Coelli (1992), we can write:

$$u_{it} = u_i \exp\{-\eta(t - T_i)\}; \quad i = 1,\ldots\ldots,n, t \in g(i) \qquad \ldots (5.3)$$

where u_i's are non-negative random variables, assumed to be iid $N(0,\sigma_u{}^2)$, η is an unknown parameter to be estimated and $g(i)$ is the set of T_i time periods for which observations for firm i are available. Hence, the TE effect of firm i in period t(*i.e.* u_{it}) depends on η and number of remaining periods $(t - T_i)$. When $t = T_i$, u_{it} equals u_i which can be treated as the TE effect of firm *i* in the last period T_i. From Equation (3), it is clear that as t increases, u_{it} decreases, remains constant, or increases, depending on whether η is greater than, equal to, or less than zero. Therefore, a firm's TE increases, remains the same, or decreases over time, according to weather η is positive, zero, or negative. Following the model specified in Equations (2) and (3), the conditional expectation of $\exp(-u_{it})$, given the composite error term $\varepsilon_{it}(= v_{it} - u_{it})$, that is $E[\exp(-\eta_{it}u_{it})/\varepsilon_{it}]$ would provide the measure of TE of firm *i* in period *t.*

The model given in equations (2) and (3) can be estimated by the maximum likelihood (ML) method. Various parametric restrictions in the model would lead to a number of interesting cases. For example setting μ=0 reduces the model to the traditional half-normal distribution model. If $\eta = 0$, then TE is time-invariant (i.e. firms never improve their TE). The value of $\gamma = \sigma_u^2 / \sigma^2$ $(where\ \sigma^2 = \sigma_u^2 + \sigma_v^2)$ will lie between 0 and 1. In the event that $u_i = 0$ i.e., firms are fully efficient, then γ equals to zero and deviations from the frontier are entirely due to noise v_{it}. In this case, the Ordinary Least Squares (OLS) estimates of the remaining parameters are also ML estimates. When $\gamma = 1$, all deviations from the frontier are entirely due to technical inefficiency (in this case $\sigma_v^2 = 0$). One can test the null hypothesis that $\gamma = \eta = \mu = 0$ using the generalized likelihood-ratio test statistic, which equals twice the difference between the logarithmic likelihood values of the unrestricted and restricted $(\gamma = \eta = \mu = 0)$ ML estimates. The test statistic is a mixed χ^2 (with degrees of freedom equal to 3). If the null is not rejected, it implies that the firms are fully technically efficient; do not exhibit changes in technical efficiency over time, and the error associated with the frontier being half normal distribution.

5.1.1 Model Specifications:

The study has conceptualised a 4-output, 4-input production technology. Considering the goals of Indian pharmaceutical industry and previous studies, the outputs considered in the model are (i) total sales (Y_1) (ii) total foreign exchange (forex) earnings (Y_2), (iii) profit after tax (Y_3) and (iv) total assets (Y_4). The inputs in the model are (i) labour (L) (measured in terms of wages and salaries for the workers) (ii) material inputs (R) (measured in terms of the companies' expenditure for raw material), (iii) marketing and advertising cost (M) measured in terms of expenditure for marketing and advertising, and (iv) capital (K) is the book value for plant, machinery and building. For the estimation of stochastic frontier production function, functional form should be specified. In the present study we have employed the Cobb–Douglas functional form (as it is known to provides the best fit and the same having been applied in the literature extensively). More specifically the production frontier is specified as

$$\ln Y_{it} = \beta_{0t} + \beta_{1t} \ln R_{it} + \beta_{2t} \ln M_{it} + \beta_{3t} \ln L_{it} + \beta_{4t} \ln K_{it} + v_{it} - \eta_{it} u_i \qquad \ldots(5.4)$$

5.1: Descriptive Statistics of Variables Considered for SFA

Firms Group	Indigenous		MNCs		Big		Small		Bulk and Formulation		Only formulation		Only Bulk		Total High Export		Total Low Export		R&D Related Outlays		Without R&D Related Outlays		All	
Variables	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Total Sales	6.1	1.3	8.1	1.4	7.7	1.3	5.6	1.1	7.5	1.5	6.5	1.4	6.2	1.5	6.8	1.6	6.5	1.5	6.9	1.4	5.6	1.2	6.8	1.6
Forex Earning	4.0	2.1	6.4	2.2	6.1	2.0	3.1	1.9	5.7	2.4	4.0	2.2	4.9	2.2	6.1	1.7	3.4	2.2	4.8	2.2	3.4	2.2	4.9	2.4
Profit After Tax	3.1	1.9	5.6	1.9	5.2	1.8	2.4	1.7	4.8	2.2	3.6	2.2	3.5	2.1	4.1	2.2	3.5	2.2	4.1	2.1	2.5	1.9	4.1	2.2
Total Assets	6.2	1.3	8.3	1.4	8.0	1.3	5.6	1.0	7.7	1.6	6.6	1.4	6.4	1.6	7.1	1.7	6.5	1.5	6.9	1.5	5.8	1.2	7.0	1.6
Raw Material	5.1	1.3	6.8	1.4	6.6	1.3	4.5	1.1	6.4	1.5	5.2	1.5	5.5	1.5	6.0	1.6	5.2	1.4	5.8	1.5	4.6	1.2	5.8	1.6
Labour	3.4	1.4	5.3	1.5	5.0	1.4	2.9	1.3	4.8	1.7	3.9	1.5	3.3	1.5	3.9	1.7	3.8	1.6	4.1	1.6	2.9	1.2	4.1	1.7
Marketing and Advertising Cost	2.3	1.9	4.7	2.0	4.1	2.0	1.8	1.9	4.0	2.1	3.1	2.1	1.8	2.0	2.8	2.2	3.1	2.2	3.4	2.1	1.5	1.8	3.2	2.3
Power and Fuel	2.5	1.4	4.2	1.4	4.2	1.2	1.8	1.1	3.8	1.6	2.6	1.5	3.0	1.5	3.4	1.6	2.6	1.5	3.2	1.5	2.2	1.4	3.2	1.6
Capital	4.9	1.4	6.7	1.4	6.7	1.1	4.0	0.9	6.3	1.7	5.1	1.4	5.2	1.6	5.8	1.7	5.0	1.5	5.6	1.5	4.5	1.4	5.6	1.7

Units of Measurement of all variables in Rs. million, Sd Refers to standard deviation

5.2 Empirical Analysis:

In the following tables, the first column shows input variables and parameters of stochastic frontier function, whereas first row shows the different outputs. In the tables, σ^2, γ, μ and η are parameters of stochastic frontier function. Where σ^2 is variance of composite error term i.e. u_{it} and v_{it}, if it is significant, then one can infer that the difference between actual output and frontier output is because of the factors which are in control of firms. u_{it} measures the technical effect of the firms and v_{it} (iid normal with mean 0 and variance $\sigma^2 v$) captures the effects of omitted variables/ measurement errors. The term γ is ratio of $\sigma^2 u$ and σ^2, which measures that how much of the difference between actual output and frontier output is because of technical inefficiency. μ is the mean of the distribution of the u_{it}, assuming that error term follow truncated normal distribution. If the μ is not significant then error term will follow half normal distribution. The parameter η show whether the technical efficiency is time varying or not. If it is significant, technical efficiency of the firm will be time varying otherwise it will time invariant. Log likelihood and χ^2 are the test statistic of the assumption that γ, μ and η are equal to zero.

Tables 5.2 to 5.7 present the ML estimates of stochastic frontier function of the firms, group-wise as well as all the firms taken together. The estimates refer to the panel frontier. First we have estimated the model with μ and η unrestricted. Since the asymptotic t value of the estimated value of μ is not statistically significant at 5% level, it indicates that the error term of the frontier does not follow truncated normal distribution rather it follows half normal distribution. Subsequently, we have imposed a restriction μ=0 then re-estimated the equations.

The ML Estimates of stochastic frontier function for indigenous and MNCs groups have been presented in table 5.2. In case of total sales all the inputs have positive effect and significant at 5% level. But capital has a very insignificant effect. The variable raw material is the dominant factor in determining the total sales, as its coefficient is the largest (0.56) and (0.44) in case of indigenous and MNCs respectively. The significant σ^2 and γ terms are positive and statistically significant at 5% level, indicating that the observed level of total sales significantly differ from frontier level due to factors, which are within the control of the firms.

Table 5.2: ML Estimates of Stochastic Frontier Function for Indigenous and MNCs Group Firms

	Indigenous				**MNCs**			
	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax (Y3)	Total Assets (Y4)	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax (Y3)	Total Assets (Y4)
	1.92	-1.03	-1.45	2.10	3.13	-1.87	-0.86	2.50
Constant	(-62.09)	(-4.65)	(-8.74)	(-35.66)	(-20.65)	(-7.55)	(-4.40)	(-28.00)
	0.56	0.68	0.28	0.25	0.44	0.89	0.15	0.26
Log R	(-69.03)	(-14.17)	(-7.49)	(-22.91)	(-22.69)	(-14.85)	(-2.85)	(-11.6)
	0.30	-0.03	0.26	0.16	0.35	-0.06	0.70	0.38
Log L	(-27.35)	(-0.40)	(-5.01)	(-10.24)	(-13.9)	(-0.92)	(-11.41)	(-15.39)
	0.12	0.04	0.14	0.08	0.16	-0.06	0.12	0.05
Log M	(-18.31)	(-0.88)	(-4.7)	(-9.07)	(-10.95)	(-1.52)	(-3.18)	(-3.07)
	0.01	0.38	0.46	0.47	-0.01	0.48	0.24	0.29
Log K	(-1.04)	(-7.37)	(-11.52)	(-39.39)	(-0.64)	(-8.27)	(-4.45)	(-13.45)
	0.07	2.44	1.62	0.13	0.18	1.83	1.34	0.17
σ^2	(-25.02)	(-22.95)	(-16.61)	(-22.96)	(-6.97)	(-6.50)	(-8.30)	(-13.07)
	0.00	0.00	0.11	0.04	0.54	0.44	0.32	0.08
γ	(-0.00)	(-0.17)	(-2.20)	(-2.14)	(-8.74)	(-4.28)	(-3.82)	(-1.25)
		0.19		0.14	0.63	-1.79		
μ		(-2.17)		(-3)	(-2.14)	(-2.72)		
	-0.07	0.07	-0.01	0.04	-0.01	0.12	-0.07	0.09
η	(-1.68)	(-6.93)	(-0.19)	(-2.62)	(-0.66)	(-6.98)	(-2.29)	(-2.84)
Log Likelihood	-133.31	-2509.32	-2181.39	-516.15	-235.95	-1081.87	-1015.51	-372.51
χ^2		4.97	10.86	28.56	92.66	109.70	27.44	41.49
Iterations	17	14	10	15	13.00	15.00	14.00	17.00

Note: Values inside parentheses are t-statistics; σ^2 is error variance of frontier function; μ-is decision parameter concerning distribution of error term. Variables are in logarithm form.

The ML estimates of forex earning (log Y2), profit after tax (log Y3) and total assets (log Y4) are also given in the relevant columns of the table. In all cases, coefficients of all inputs are positive except labour in case of forex earning of both the group, capital in case of total assets of MNCs and marketing and advertising cost in case of forex earning of MNCs. Notably, in all equations raw material plays a dominant role. The likelihood ratio test rejects the null hypothesis of $\gamma = \mu = \eta = 0$ in all cases. Interestingly, σ^2 and γ are positive and statistically significant at 5% - 10% level in all cases, revealing inefficient performance of the firms in producing these outputs. The η term statistically significant at 5% level in almost all cases, indicating that the firm specific effects associated with technical efficiency is time varying. μ is not significant in case of total sales and profit of indigenous firms group indicating that error term follows the half normal distribution. Similarly for MNCs group in case of profit and total assets μ is not significant and the u follows half normal distribution.

In table 5.3, ML estimates for the big and small firms group are reported. The results suggest that the previous (as in indigenous and MNCs group) trend is repeated in case of raw material across all the output measures, and is significant at 5% level and has retained a positive and dominant effect except profit where labour is dominant. In case of total sales of both the groups capital has negative effect and is insignificant at 5% level. The likelihood ratio test rejects the null hypothesis of $\gamma = \mu = \eta = 0$ in all cases. Interestingly, σ^2 and γ are positive and statistically significant at 5%-10% level in all cases, revealing inefficient performance of firms in producing these outputs. The μ is statistically insignificant at 5% level in all cases except total assets of big firms group and foreign exchange earnings and profit of small firms group where the error term follows half normal distribution. The term η is statistically insignificant at 5% level in all cases, indicating that the firm specific effects associated with technical efficiency (TE) are time varying in all.

Table 5.3: ML Estimates of Stochastic Frontier Function for Big Firms and Small Firms Group

	Big				Small			
	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax (Y3)	Total Assets (Y4)	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax (Y3)	Total Assets (Y4)
Constant	2.23 (-40.55)	-2.36 (-9.34)	-1.70 (-9.21)	1.64 (-18.69)	2.09 (-2.13)	-0.83 (-2.55)	-0.87 (-3.18)	2.39 (-28.55)
Log R	0.53 (-56.07)	0.85 (-19.61)	0.27 (-7.56)	0.23 (-18.32)	0.55 (-10.54)	0.76 (-11.79)	0.23 (-4.42)	0.26 (-17.30)
Log L	0.34 (-24.19)	0.32 (-5.48)	0.62 (-12.64)	0.30 (-16.90)	0.34 (-16.37)	-0.28 (-3.40)	0.28 (-4.03)	0.23 (-10.36)
Log M	0.12 (-14.99)	-0.07 (-1.91)	0.05 (-1.58)	0.05 (-4.37)	0.14 (-4.52)	0.02 (-0.32)	0.23 (-5.66)	0.12 (-13.92)
Log K	-0.01 (-0.86)	0.28 (-5.27)	0.31 (-6.93)	0.48 (-29.84)	-0.03 (-0.18)	0.44 (-5.13)	0.32 (-4.24)	0.31 (-13.41)
σ^2	0.08 (-18.85)	3.37 (-6.24)	1.00 (-11.28)	0.13 (-24.41)	0.13 (-10.40)	2.60 (-16.05)	1.92 (-16.37)	0.18 (-19.18)
γ	0.09 (-2.27)	0.58 (-7.99)	0.05 (-0.79)	0.00 (-0.52)	0.00 (-0.06)	0.05 (-1.04)	0.04 (-1.02)	0.00 (-1.18)
μ	0.17 (-4.20)	-2.79 (-3.56)	0.47 (-4.56)		0.05 (-3.16)			0.05 (-2.94)
η	-0.07 (-4.88)	-0.06 (-3.72)	-0.25 (-2.87)	0.12 (-0.79)	0.07 (-0.72)	0.06 (-1.45)	0.02 (-0.43)	0.10 (-4.56)
Log Likelihood	-0.14	-0.20	-0.17	-497.31	-336.65	- 1635.96	- 1493.41	-482.89
χ^2	25.70	58.26	20.88	2.47	2.48	9.05	2.73	9.15
Iterations	14	17	15	26	9	15	12	12

Note: Values inside parentheses are t-statistics; σ^2 is error variance of frontier function; μ-is decision parameter concerning distribution of error term. Variables are in logarithm form.

The estimated results of various product groups of firms namely; bulk & formulation, only formulation and only bulk drug, are reported in table 5.4. Let us first take the group of bulk & formulations where in case of total sales all the input variables are significant at 5% level and have positive effect except capital which is not significant and having zero coefficients. Raw material is the determining factor for total sales, as its parameter is largest (0.59) among all other inputs. The significant σ^2 and γ terms are positive and statistically significant at 5% level, indicating that the observed level of total sales significantly differ from frontier level due to factors, which are within the control of the firms. The ML estimates of foreign exchange income (log Y2), profit after tax (log Y3) and total assets (log Y4) are also reported in the relevant columns of the table. In all cases, the coefficients of all inputs are positive except labour in case of foreign exchange earnings. In all equation raw materials plays crucial role except total assets where capital is dominant factor in determining the total assts. The likelihood ratio test rejects the null hypothesis of $\gamma = \mu = \eta = 0$ in all cases. Interestingly, σ^2 and γ are positive and statistically significant at 5% level in all cases, revealing inefficient performance of the firms in producing these outputs. The μ is statistically significant at 5% level in case of total sales and total assets indicating that u follows a truncated normal distribution, while in case of foreign exchange earnings and profit it follows half normal distribution.

Now consider the case of only formulation group where in case of total sales, raw material is dominant factor followed by the labour input. All input variables are positive and significant except capital which has negative impact on total sales. Interestingly, capital is shown to be the determining factor in case of foreign exchange earnings, profit and total assets; and marketing and advertising cost seems to be least influential factor in determining the output of the firms from this group. Considering the case of only bulk group, raw material is most determining factor in case of total sales and foreign exchange earnings while capital is least determining factor for these outputs. On the other hand, in case of profit and total assets the results show that capital is most important factor in determining the these outputs of firms while the raw material is least important factor after marketing and advertising cost in these cases. The μ is statistically significant in case of total sales and profit indicating that error term u follows truncated normal distribution and for other output variables it follows half normal distribution.

Table 5.4: ML Estimates of Stochastic Frontier Function for Bulk & Formulation, Only Formulations and Only Bulk Firms Group

	Bulk & Formulation				**Only Formulation**				**Only Bulk**			
	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax(Y3)	Total Assets (Y4)	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax(Y3)	Total Assets (Y4)	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax(Y3)	Total Assets (Y4)
Constant	2.06	-2.56	-1.79	2.11	2.38	-1.05	-1.70	1.98	1.65	-0.12	-1.68	1.85
	(-33.44)	(-10.80)	(-8.63)	(-26.02)	(-30.28)	(-3.76)	(-7.71)	(-22.14)	(-25.04)	(-0.38)	(-7.19)	(-23.8)
Log R	0.59	1.02	0.46	0.30	0.46	0.50	0.17	0.28	0.63	0.61	0.14	0.18
	(-52.15)	(-17.65)	(-9.02)	(-16.42)	(-29.14)	(-7.55)	(-3.46)	(-14.28)	(-47.55)	(-8.83)	(-2.17)	(-9.80)
Log L	0.24	-0.08	0.51	0.25	0.41	-0.06	0.46	0.31	0.30	0.49	0.38	0.22
	(-16.63)	(-1.18)	(-7.83)	(-10.45)	(-18.88)	(-0.68)	(-6.78)	(-12.16)	(-16.88)	(-5.07)	(-4.49)	(-8.80)
Log M	0.16	0.04	0.08	0.07	0.13	0.16	0.21	0.07	0.08	0.02	0.12	0.07
	(-15.94)	(-0.94)	(-1.71)	(-3.88)	(-10.64)	(-3.18)	(-5.34)	(-4.87)	(-8.64)	(-0.30)	(-2.59)	(-5.72)
Log K	0.00	0.40	0.19	0.38	-0.01	0.55	0.48	0.38	0.02	0.03	0.61	0.55
	(-0.12)	(-7.14)	(-3.85)	(-19.39)	(-0.56)	(-7.38)	(-8.43)	(-16.66)	(-1.15)	(-0.41)	(-9.36)	(-30.8)
σ^2	0.06	1.85	1.50	0.15	0.15	2.50	1.72	0.18	0.06	1.58	1.31	0.10
	(-14.09)	(-9.64)	(-9.53)	(-16.03)	(-19.94)	(-11.49)	(-10.43)	(-15)	(-9.31)	(-15.7)	(-11.61)	(-8.05)
γ	0.08	0.24	0.24	0.01	0.07	0.16	0.19	0.02	0.10	0.01	0.08	0.10
	(-1.37)	(-3.21)	(-3)	(-0.38)	(-1.94)	(-2.37)	(-2.51)	(-0.50)	(-1.21)	(-.33)	(-1.89)	(-0.85)
μ	0.14			0.08	0.20			0.12	0.15		0.65	
	(-2.27)			(-4.65)	(-3.16)			(-3.11)	(-2.22)		(-2.33)	
η	-0.02	0.03	-0.09	0.08	0.00	0.03	-0.02	0.06	-0.09	0.22	-0.25	-0.05
	(-0.69)	(-1.825)	(-1.86)	(-3.07)	(-0.08)	(-1.48)	(-0.81)	(-2.29)	(-1.83)	(-1.88)	(-4.61)	(-0.55)
Log Likelihood	0.22	-1368	-1266	-0.40	-0.33	-1364	-1172	-0.42	0.14	-827	-0.76	-129
χ^2	13.14	49.12	14.39	17.10	21.20	32.42	12.54	18.01	9.86	9.31	16.50	1.38
Iterations	17	11	14	15	15	12	12	11	15	30	11	14

Note: Values inside parentheses are t-statistics; σ^2 is error variance of frontier function; μ-is decision parameter concerning distribution of error term. Variables are in logarithm form.

In all the three groups, all inputs are positive and significant at 5% level except labour in case of foreign exchange earnings of bulk & formulation and only formulation and capital in case of total sales of only formulation group. The coefficient of constant term has negative effect in case of foreign exchange earnings and profit for all the three groups. Raw material is found to be a determining factor in all outputs except profit followed by labour for all the three groups. Labour is most influential factor in determining the profit of firms in all the three groups. In these three groups the error term follows truncated normal distribution except in case of foreign exchange earnings and profit of bulk & formulation and only formulation and foreign exchange earnings and total assets in case of only bulk group. The likelihood ratio test rejects the null hypothesis of $\gamma = \mu = \eta = 0$ in all the three groups and σ^2 and γ are positive and statistically significant, revealing inefficient performance of firms in producing these outputs. The η term is statistically insignificant at 5% level in all cases, indicating that the firm specific effects associated with technical efficiency (TE) are time varying in all the three groups of firms producing various products.

The results of the high export and low export intensive firms group are provided in table 5.5. All inputs have positive effects and significant at 5% level in both the groups. The raw material is the dominant factor in determining the total sales and foreign exchange earnings while labour and capital play important role in case of profit and total assets respectively.

The likelihood ratio test rejects the null hypothesis of $\gamma = \mu = \eta = 0$ in all cases. Interestingly, σ^2 and γ are positive and statistically significant at 5% - 10% level in all cases, revealing inefficient performance of firms in producing these outputs. The μ is statistically insignificant at 5% level in all cases except total sales of total high export group, indicating that u follows a half normal distribution(if insignificant) otherwise truncated normal distribution is more relevant. On the other hand in case of low export intensive firms group the μ is significant in case of total sales and total assets whereas it is insignificant in case of forex earning and profit following half normal distribution. The η term is statistically insignificant at 5% level in all cases, indicating that the firm specific effects associated with technical efficiency (TE) are time varying.

Table 5.5: ML Estimates of Stochastic Frontier Function for High and Low Export Intensive Firms Group

	High Export				**Low Export**			
	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax (Y3)	Total Assets (Y4)	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax (Y3)	Total Assets (Y4)
Constant	1.80 (-32.72)	1.08 (-13.22)	-1.75 (-8.64)	1.96 (-28.51)	2.25 (-41.33)	-1.57 (-7.94)	-1.72 (-9.91)	2.04 (-30.72)
Log R	0.60 (-56.74)	0.58 (-32.64)	0.33 (-7.10)	0.27 (-17.52)	0.51 (-42.67)	0.59 (-12.33)	0.22 (-5.23)	0.24 (-16.17)
Log L	0.27 (-17.04)	0.36 (-14.01)	0.45 (-6.47)	0.23 (-10.66)	0.35 (-22.14)	0.14 (-2.25)	0.41 (-7.53)	0.27 (-13.96)
Log M	0.11 (-13.56)	0.06 (-4.44)	0.08 (-2.30)	0.09 (-7.40)	0.13 (-13.59)	0.14 (-3.71)	0.19 (-6.28)	0.08 (-6.78)
Log K	0.03 (-2.09)	0.01 (-0.52)	0.35 (-6.25)	0.42 (-23.12)	0.00 (-0.07)	0.29 (-5.71)	0.45 (-10.31)	0.42 (-26.42)
σ^2	0.06 (-17.42)	0.22 (-10.07)	1.63 (-9.25)	0.13 (-21.41)	0.12 (-12.78)	1.98 (-17.94)	1.44 (-20.67)	0.18 (-20.57)
γ	0.05 (-1.59)	0.17 (-1.38)	0.21 (-2.41)	0.00 (-0.41)	0.07 (-1.30)	0.08 (-2.07)	0.03 (-1.08)	0.01 (-0.74)
μ	0.12 (-2.11)				0.19 (-5.36)			0.10 (-5.43)
η	-0.03 (-0.75)	-0.13 (-1.38)	-0.24 (-2.24)	0.15 (-1.60)	0.00 (-0.13)	0.06 (-2.79)	0.03 (-0.73)	0.07 (-5.18)
Log Likelihood	-33.66	-546.61	-1477.85	-366.32	-387.05	-1949.60	-1788.96	-631.63
χ^2	9.92	6.60	12.73	3.00	26.81	33.90	4.49	28.17
Iterations	17	18	18	22	14	14	13	16

Note: Values inside parentheses are t-statistics; σ^2 is error variance of frontier function; μ-is decision parameter concerning distribution of error term. Variables are in logarithm form.

Table 5.6 depicts the ML estimates of stochastic frontier function for the firms engaged in R&D and not engaged in R&D. In case of total sales all inputs have positive effect and significant at 5% level in both the groups except capital in R&D firms group. The raw material has been the dominant factor in determining the total sales, as its coefficient retained the largest (0.53) in case of R&D and (0.92) in case of non R&D group of firms. The σ^2 and γ terms are positive and statistically significant at 5% level, indicating that the observed level of total sales significantly differ from frontier level due to factors, which are within the control of the firms.

Table 5.6: ML Estimates of Stochastic Frontier Function for R&D and Without R&D Related Outlays Firms Group

	With R&D				Without R&D			
	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax (Y3)	Total Assets (Y4)	Total Sales (Y1)	Forex Earning (Y2)	Profit After Tax (Y3)	Total Assets (Y4)
Constant	2.29 (-51.24)	-1.71 (-10.51)	-1.34 (-9.09)	1.96 (-36.74)	1.92 (-31.65)	-1.33 (-3.92)	-1.76 (-6.63)	2.02 (-23.10)
Log R	0.53 (-54.15)	0.77 (-18.11)	0.32 (-9.95)	0.24 (-21.64)	0.55 (-37.25)	0.92 (-10.73)	0.11 (-1.57)	0.27 (-12.63)
Log L	0.33 (-24.80)	0.04 (-0.75)	0.48 (-10.98)	0.28 (-17.13)	0.31 (-16.68)	-0.11 (-0.97)	0.25 (-2.85)	0.16 (-5.79)
Log M	0.14 (-17.63)	0.01 (-0.21)	0.17 (-6.63)	0.09 (-7.78)	0.13 (-11.24)	-0.07 (-1.07)	0.09 (-1.93)	0.08 (-5.39)
Log K	-0.02 (-1.74	0.43 (-9.53)	0.22 (-5.95)	0.41 (-29.96)	0.02 (-1.15)	0.33 (-3.94)	0.73 (-11.16)	0.46 (-22.72)
σ^2	0.10 (-17.64)	1.96 (-19.56)	1.33 (-20.43)	0.16 (-28.15)	0.07 (-14.55)	2.87 (-10.82)	1.98 (-8.89)	0.15 (-11.02)
γ	0.05 (-1.19)	0.07 (-1.74)	0.05 (-1.21)	0.00 (-0.51)	0.03 (-0.52)	0.10 (-1.66)	0.18 (-1.90)	0.06 (-1.34)
μ	0.15 (-6.03)							
η	-0.01 9-0.62)	0.03 (-1.33)	0.02 (-0.04)	0.16 (-2.54)	0.16 (-1.60)	0.03 (-1.13)	-0.05 (-1.37)	0.04 (-1.15)
Log Likelihood	-436.78	-2784.32	-2416.89	-786.64	-61.64	-889.47	-778.71	-222.52
χ^2	24.23	22.64	2.86	16.54	5.71	9.95	6.07	8.40
Iterations	15	13	10	23	19	12	13	13

Note: Values inside parentheses are t-statistics; σ^2 is error variance of frontier function; μ-is decision parameter concerning distribution of error term. Variables are in logarithm form.

The ML estimates of forex earning (log Y2), profit (log Y3) and total assets (log Y4) are also shown in the relevant columns of the table. In all these cases, coefficients of all inputs are positive. Notably, as in the previous cases, in all equations raw material plays a dominant role. The likelihood ratio test rejects the null hypothesis of $\gamma = \mu = \eta = 0$ in all cases. Interestingly, σ^2 and γ are positive and statistically significant at 5% - 10% level in all cases, revealing inefficient performance of firms in producing these outputs. The μ is statistically insignificant at 5% level in all cases except total sales of R&D group indicating that u follows a half normal distribution except total sales where the error term follows truncated normal distribution and η term is statistically insignificant at 5% level in all cases, indicating that the firm specific effects associated with technical efficiency are time varying.

The ML Estimates of Stochastic Frontier Function for all firms group is reported in table 5.7. In case of total sales, all input variables are positive and significant except capital which is having negative impact on the total sales. In case of foreign exchange earnings all inputs have positive effect and significant at 5% level except labour as its coefficient is negative. Raw material is dominant input in determining the total sales and foreign exchange earnings while labour has most determining effect on the profit output. In case of total assets all inputs are positive and significant at 5% level and capital is a dominant factor. The likelihood ratio test rejects the null hypothesis of $\gamma = \mu = \eta = 0$ in all cases. Interestingly, σ^2 and γ are positive and statistically significant at 5% - 10% level in all cases, revealing inefficient performance of the firms in producing these outputs. The μ is statistically significant at 5% level in case of total sales and profit, indicating that u follows a truncated normal distribution and insignificant in case of foreign exchange earnings and total assets following half normal distribution.

Table 5.7: ML Estimates of Stochastic Frontier Function for All Firms Group

	Total Sales(Y1)	Forex Earning(Y2)	Profit After Tax(Y3)	Total Assets(Y4)
Constant	2.11 (-55.30)	-1.98 (-12.69)	-1.65 (-12.36)	1.98 (-44.04)
Log R	0.54 (-64.41)	0.80 (-21.01)	0.26 (-8.77)	0.26 (-24.43)
Log L	0.33 (-29.92)	-0.02 (-0.39)	0.44 (-10.85)	0.25 (-18.37)
Log M	0.14 (-22.52)	0.02 (-0.57)	0.14 (-5.72)	0.09 (-9.30)
Log K	-0.01 (-1.36)	0.43 (-10.32)	0.38 (-12.19)	0.42 (-37.88)
σ^2	0.10 (-25.35)	2.14 (-31.60)	1.35 (-18.49)	0.16 (-31.94)
γ	0.03 (-1.03)	0.02 (-0.31)	0.01 (-0.25)	0.01 (-0.79)
μ	0.10 (-3.62)		0.28 (-2.33)	
η	-0.02 (-0.53)	0.34 (-1.58)	-0.10 (-1.95)	0.12 (-2.59)
Log Likelihood	-0.53	-3706.90	-0.32	-1026.1
χ^2	8.55	13.49	5.37	20.20
Iterations	16	64	21	20

Note: Values inside parentheses are t-statistics; σ^2 is error variance of frontier function; μ-is decision parameter concerning distribution of error term. Variables are in logarithm form.

The η term is statistically insignificant at 5% level in all cases indicates that the firm specific effects associated with TE are time varying. Over all, it is observed that in all firm groups, raw material is the most important determining factor (followed by labour and capital) which positively influences the output. The marketing and advertising cost input seems to have almost a negligible effect. Firm specific effects associated with technical efficiency (TE) are found to be time varying.

From the above analysis of the frontier, the following findings emerge:

1. In all the firm groups, the raw material has been the most significant input variable influencing the total sales and forex earning in all groups of firms. This finding is consistent across all the groups and all firms together.
2. Whereas labour as an input variable has emerged as the most significant variable influencing the profit of the firms for all the groups and in case of total assets capital has been dominant input variable.
3. On the other hand, the marketing and advertising cost has been found to have marginal influence on firm's output.
4. In case of total sales capital has been almost negligible effect in all groups as well all firms put together, and in case of forex earning, labour has been found to have marginal influence on firm's output.
5. The firm specific effects associated with technical efficiencies are found to be time varying.

5.3 Mean Technical Efficiency Firms: Group wise Analysis

In this section we have shown the TE scores for each firm group with reference to all outputs. The mean TE of indigenous and MNCs group of firms has been depicted in table 5.8. The mean TE for raising some outputs has increased, for some other outputs decreased over the period of 1997 to 2011. Mean TE for raising total sales has been almost same for all the years from 1997 to 2011 in case of indigenous group while in case of MNCs group it has decreased over the period of time from 62.92% in 1997 to 53.35% in 2011. In case of forex earning and total assets the mean TE has shown an increasing trend and this tendency of increasing the TE (of both forex and total assets) is more in MNCs compared to indigenous firms group. The TE for raising the profit output in case of indigenous firms group has been more or less same over the period of time while in case of MNCs it has shown a consistently decreasing trend from

86.49% in 1997 to 69.35% in 2011. In case of indigenous firms group, the highest TE scores has been registered for raising total sales in all the years from 1997 to 2011.

Table 5.8: Mean Efficiency of Indigenous and MNCs Group of Firms

	Indigenous				MNCs			
Year	Total Sales	Forex Earning	Profit After Tax	Total Assets	Total Sales	Forex Earning	Profit After Tax	Total Assets
1997	99.68	59.62	76.35	79.61	62.92	38.92	86.49	64.91
1998	99.68	61.45	76.63	80.33	60.93	43.77	83.54	65.68
1999	99.69	62.98	77.60	79.86	57.98	53.14	84.07	68.39
2000	99.69	65.03	77.62	80.80	57.75	56.02	83.23	70.50
2001	99.69	67.10	78.12	81.30	57.30	59.90	82.22	73.08
2002	99.69	69.40	78.66	81.91	56.34	61.07	81.05	74.87
2003	99.69	71.33	78.57	82.40	55.95	64.06	79.92	76.75
2004	99.69	73.09	78.65	83.02	56.34	64.62	78.90	78.79
2005	99.70	74.72	78.73	83.74	55.60	66.66	77.43	80.41
2006	99.70	76.16	78.63	84.23	55.21	69.27	76.15	81.93
2007	99.70	77.61	78.63	84.90	55.06	70.28	74.47	83.40
2008	99.70	78.94	78.55	85.43	54.12	70.91	73.69	84.88
2009	99.70	80.26	78.58	86.00	53.72	73.25	72.27	86.09
2010	99.70	81.40	78.20	86.39	53.88	77.08	70.14	87.08
2011	99.70	81.92	77.03	87.20	53.35	84.34	69.35	88.06

Note: Mean efficiencies are in percentage term.

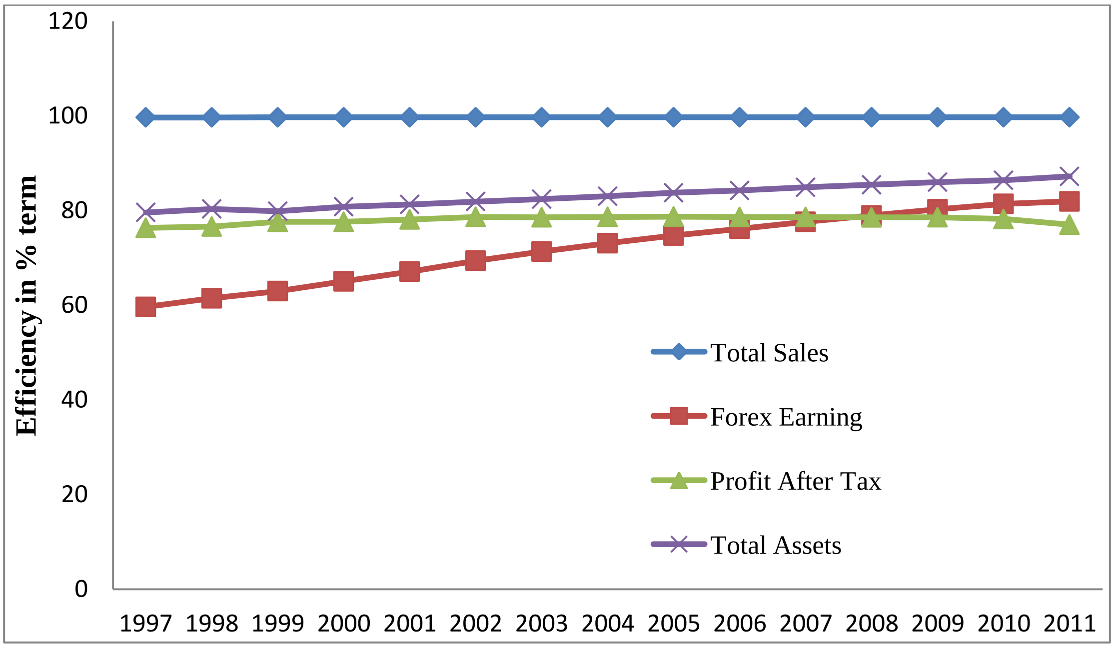

Figure 5.1: Mean Efficiency of Indigenous Firms Group

All firms have been close to the frontier that is technically fully efficient whereas the lowest TE scores in case of indigenous firms have for raising forex earning that is 59.62% in 1997 however it has improved drastically up to 81.92% in 2011. In case of MNCs group the TE of profit has shown highest Te score of 86.49% in 1997 and lowest is of forex earning 38.92% but in 2011 TE of total assets is highest i.e. 88.06% and total sales is lowest with TE score 53.53%.

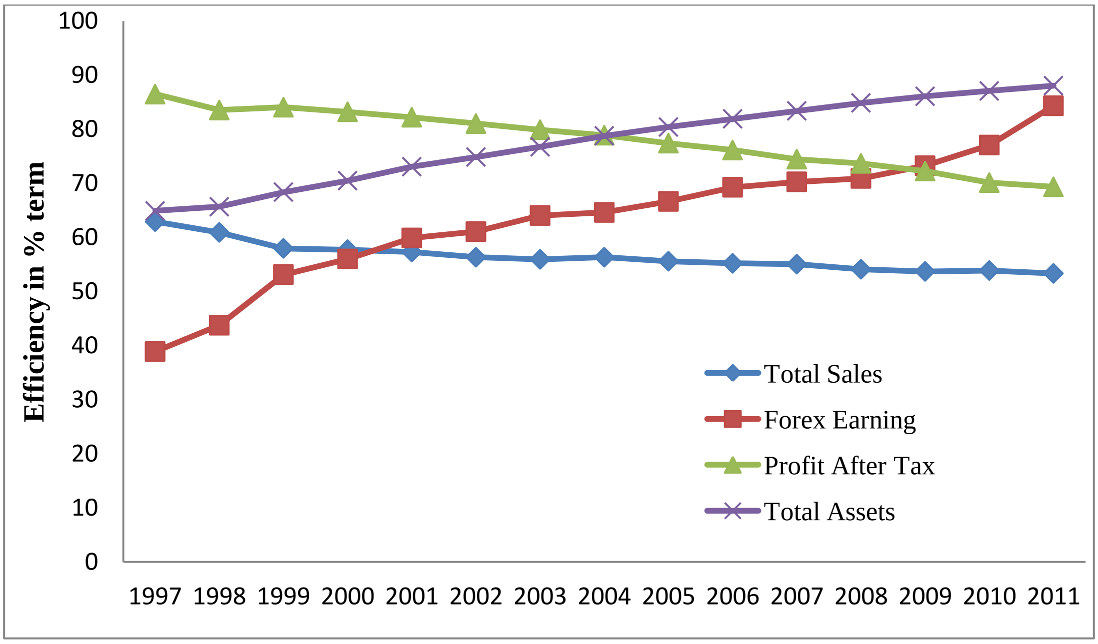

Figure 5.2: Mean Efficiency of MNCs Group of Firms

The mean TE for big and small firms group is given in the table 5.9. In the case of big firms the mean TE scores for raising total sales decreased from 94.35% in 1997 to 84.25% in 2011. Similar trend was observed in the case of profit where the TE declined consistently from 98.48% in 1997 to 63.25% in 2011. With reference to the total assets, the TE has shown an increasing trend from 89.96% in 1997 to 96.92% in 2011. As regards forex earning TE declined in first two years and then increased in 1999 after that it has declined continuously from 80.27% in 1999 to 66.45% in 2011.

In case of small firms group the TE for raising all four output variables i.e. total sales, forex earning, profit and total assets has increased from 87.73%, 46.87%, 71.35% and 81.14% in 1997 to 95.06%, 60.10%, 75.56% and 94.98% in 2011 respectively.

Table 5.9: Mean Efficiency of Big Firms and Small Firms Group

	Big				**Small**			
Year	Total Sales	Forex Earning	Profit After Tax	Total Assets	Total Sales	Forex Earning	Profit After Tax	Total Assets
1997	94.35	68.74	98.48	89.96	87.73	46.87	71.35	81.14
1998	94.11	67.56	98.10	90.85	88.49	47.04	71.90	82.56
1999	92.84	80.27	97.62	91.74	89.89	46.10	73.12	84.09
2000	92.41	79.37	97.00	92.35	90.50	46.93	73.22	85.52
2001	91.76	78.04	96.08	92.96	91.09	48.57	73.92	86.82
2002	91.12	77.61	94.98	93.53	91.66	49.97	74.49	88.04
2003	90.44	76.69	93.61	94.04	92.16	51.35	74.95	89.15
2004	89.79	75.78	91.91	94.52	92.67	52.72	75.32	90.18
2005	89.13	74.56	89.78	94.95	93.10	53.96	75.79	91.13
2006	88.41	73.31	87.11	95.34	93.54	55.13	76.09	91.94
2007	87.64	72.63	83.84	95.71	93.94	56.01	76.23	92.66
2008	86.81	71.34	79.88	96.05	94.33	57.26	76.35	93.37
2009	85.89	69.30	75.25	96.37	94.65	57.67	76.53	93.98
2010	85.06	68.37	69.62	96.65	94.85	58.19	76.36	94.48
2011	84.25	66.45	63.24	96.92	95.06	60.10	75.56	94.98

Note: Mean efficiencies are in percentage term.

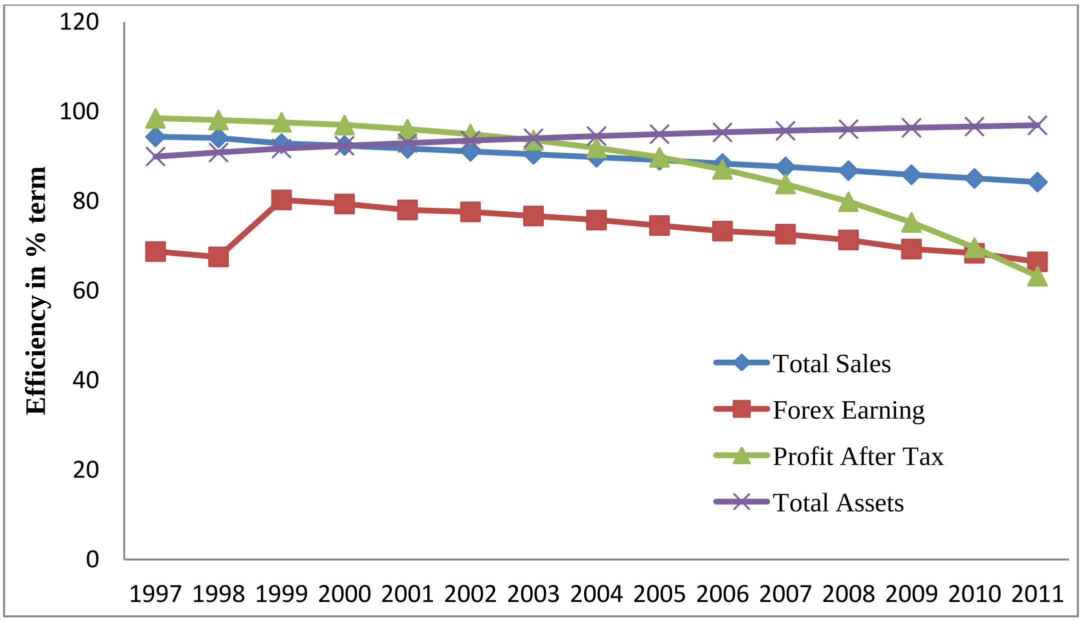

Figure 5.3: Mean Efficiency of Big Firms Group

The cross comparison between big firms group and small firm group shows that the TE score for big firm has been higher when compared to the small firms group in absolute term. With reference to total sales, forex earnings and profit, the small firms has shown an increasing trend in its TE levels whereas in case of big firms the TE score has declined for the firm's output over the period of 1997 to 2011. Overall it can be concluded that the small firms have performed better than that of big firms during the study period.

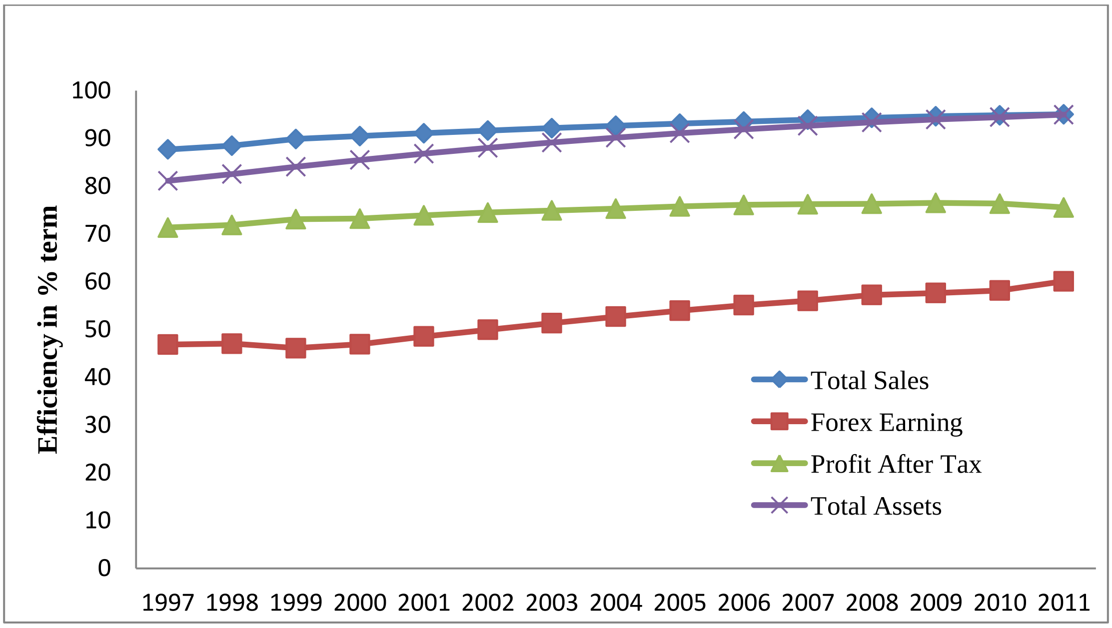

Figure 5.4: Mean Efficiency of Small Firms Group

The TE for the outputs of various product groups of firm has been reported in table 5.10. Regarding the firms producing bulk & formulation, the TE scores for raising total sales declined slightly from 89.81% in 1997 to 87.22% in 2011. A marginal increase was observed in 1998 and thereafter TE started diminishing up to 2011. With reference to forex earning, the overall TE has declined marginally from 70.68% in 1997 to 68.97% in 2011. An increase was observed in TE in the year 2000 (61.08%)

and continued to rise up to 2010 (70.13%) and then again declined. With regard to profit, the TE declined from 84.42% in 1997 to 66.19% in 2011. For total assets, the TE score has shown an increasing trend from 78.59% in 1997 to 91.63% in 2011.

Table 5.10: Mean Efficiency of Various Product Group of Firms

	Bulk & formulation				Only formulation				Only bulk			
Year	Total Sales	Forex Earning	Profit After Tax	Total Assets	Total Sales	Forex Earning	Profit After Tax	Total Assets	Total Sales	Forex Earning	Profit After Tax	Total Assets
1997	89.81	70.68	84.42	78.59	81.51	22.22	50.88	73.55	95.82	56.41	98.19	91.6
1998	90.25	67.09	85.68	78.71	80.8	23.7	53.08	74.38	95.43	61.34	97.64	90.9
1999	89.33	58.77	85.47	80.1	79.87	31.23	53.96	77.81	94.75	63.97	96.88	90.65
2000	89.23	61.08	84.56	81.35	79.75	32.4	53.73	78.72	94.42	68.18	95.93	90.85
2001	89.05	62.76	83.71	82.5	80.49	32.35	54.46	80.44	93.88	72.17	94.84	90.63
2002	88.87	64.04	82.67	83.75	80.85	34.28	53.83	81.98	93.25	76.69	93.43	90.42
2003	88.72	65.13	81.47	84.93	81.04	35.37	53.24	82.85	92.64	79.41	91.64	90.24
2004	88.51	65.8	80.29	85.99	81.41	36.55	52.99	83.58	91.91	82.4	89.37	89.99
2005	88.27	65.98	79.68	87.27	81.13	37.25	52.51	84.4	91.17	84.79	86.4	89.8
2006	88.14	66.79	78.12	88.13	81.1	38	52.3	85.27	90.47	87.11	82.94	89.71
2007	87.9	67.45	76.6	89	81.44	39.25	51.94	85.92	89.64	89.18	78.63	89.54
2008	87.76	68.25	74.87	89.75	81.48	40.15	51.6	86.62	88.74	90.92	73.51	89.48
2009	87.5	68.53	73.43	90.54	81.5	40.99	51.23	87.28	87.74	92.32	67.43	89.36
2010	87.27	70.13	70.78	91.05	81.54	41.88	50.66	87.92	86.79	93.66	60.83	89.28
2011	87.22	68.97	66.19	91.63	80.72	41.57	50.96	88.04	86.33	94.85	53.03	89.77

Note: Mean efficiencies are in percentage term.

In case of only formulation group TE for rising total sales has been more or less same. The TE score for rising forex earning has mounted to 41.57% in 2011 from 22.22% in 1997. With respect to profit, the TE has shown fluctuating trend initially increased up to 2001 and then started diminishing gradually from 2002 to 2011. Figure 5.5

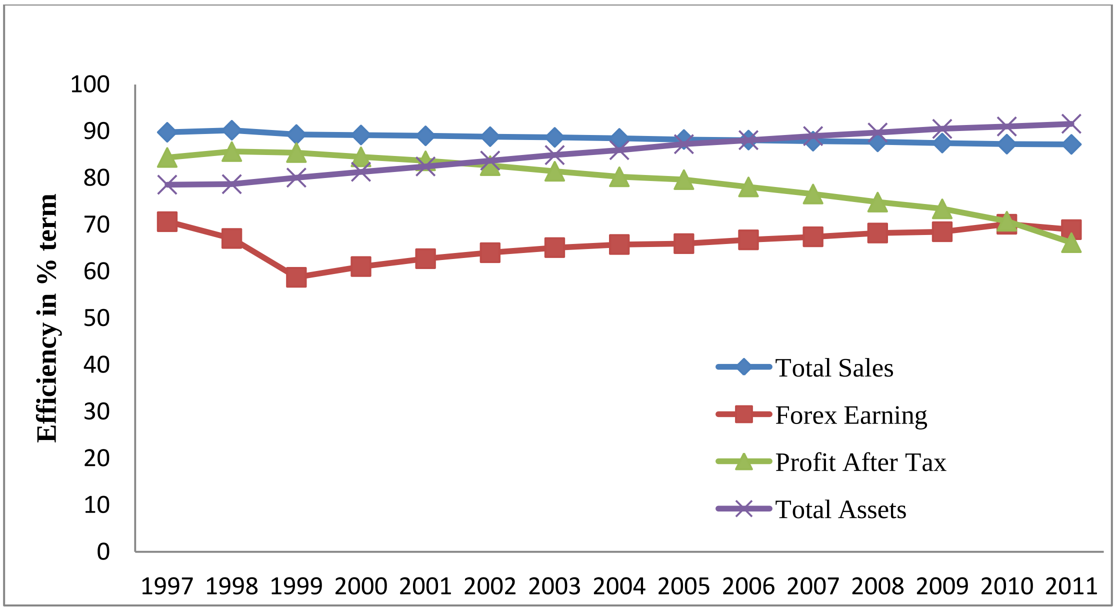

Figure 5.5: Mean Efficiency of Bulk & Formulation Group

The TE for raising total assets has exhibited an increasing trend from 73.55% in 1997 to 88.04% in 2011. In case of only bulk, the TE for raising total sales has shown a diminishing trend from 95.82% in 1997 to 86.33% in 2011.

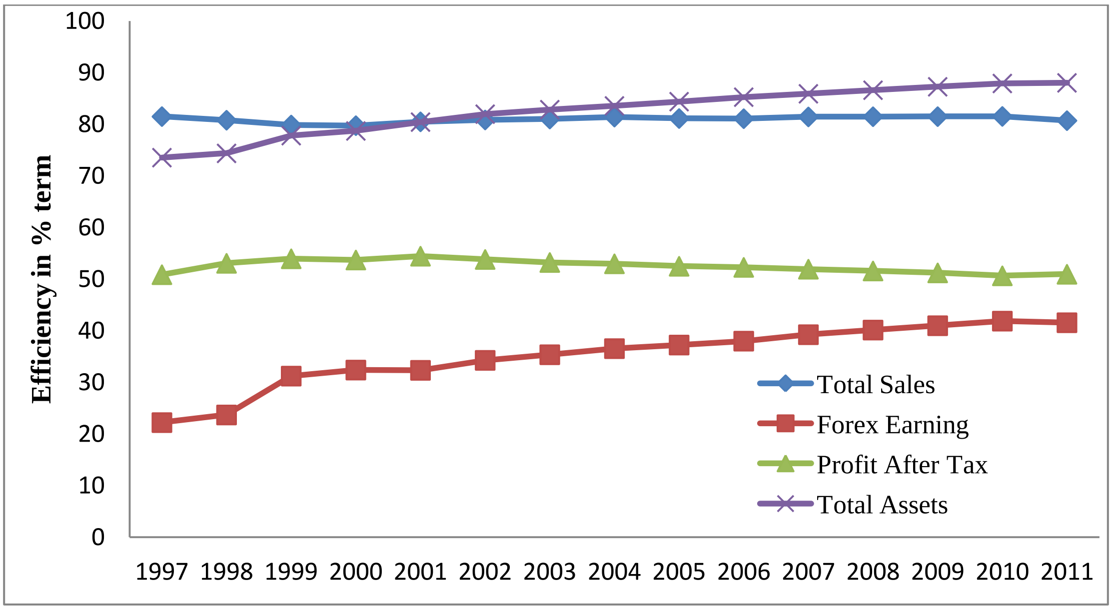

Figure 5.6: Mean Efficiency of Only Formulation

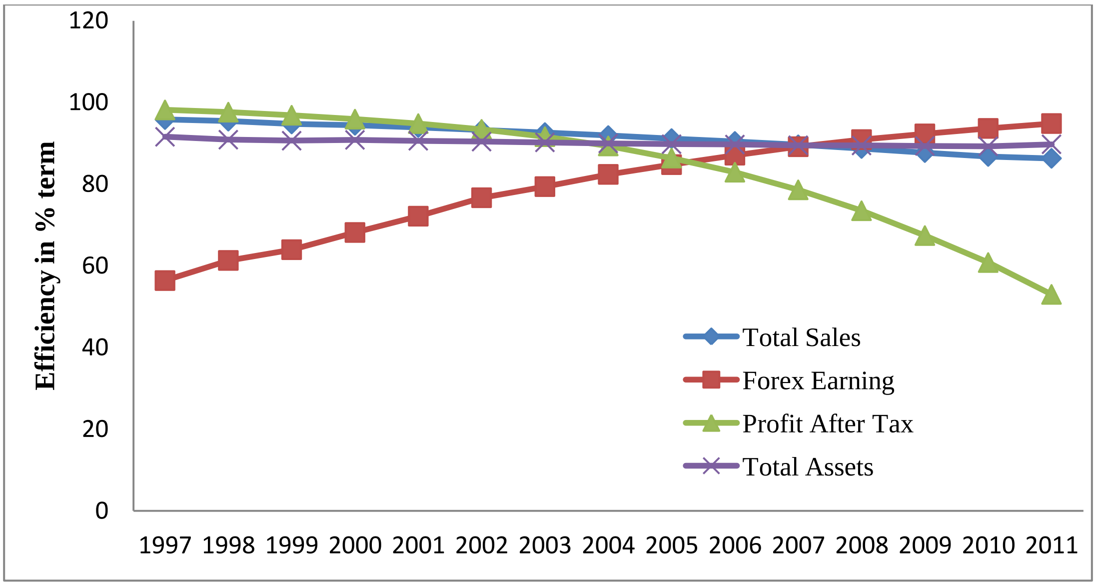

Figure 5.7: Mean Efficiency of Only Bulk Group

With respect to forex earning, the TE has escalated to 94.84% in 2011 from 56.41% in 1997. TE for profit and total assets has declined from 98.19% and 91.60% in 1997 to 53.03% and 89.77% in 2011. A cross comparison of average TE of these three group shows that the firms group producing only bulk performed better followed by bulk & formulation and only formulation group of firms.

The mean technical efficiency of total high and total low export firms groups is reported in the table 5.11. In the case of total high export firms, the TE for rising total sales has diminished from 92.49% in 1997 to 88.90% in '11. With regard to forex earning and profit also, the TE scores gradually tapered off from 98.40% and 93.80% in 1997 to 87.62% and 58.71% in 2011. With respect to total assets, the TE scores continuously increased over the period from 90.48% in 1997 to 98.05% in 2011. In case of total low export firms the TE scores for raising total sales has been fluctuating with 1 - 2% margin from the year 1997 to 2011. The TE for rising forex earning, profit and total assets has shown an increasing trend during the study period.

Table 5.11: Mean Efficiency of High and Low Export Intensive Firms Group

	High Export				Low Export			
Year	Total Sales	Forex Earning	Profit After Tax	Total Assets	Total Sales	Forex Earning	Profit After Tax	Total Assets
1997	92.49	98.40	93.80	90.84	82.57	63.25	62.72	75.08
1998	92.86	98.07	92.96	91.57	82.53	64.68	63.01	76.52
1999	92.26	98.13	92.21	91.93	83.27	64.18	64.85	78.65
2000	92.09	97.76	90.97	92.82	83.09	65.16	64.89	79.86
2001	91.85	97.39	89.51	93.60	83.17	66.71	65.70	81.17
2002	91.49	97.02	87.69	94.26	83.11	68.25	65.92	82.30
2003	91.24	96.55	85.75	94.90	83.07	69.63	66.10	83.41
2004	90.99	95.96	83.57	95.47	83.01	70.94	66.64	84.53
2005	90.74	95.16	81.04	95.97	82.91	71.96	66.98	85.58
2006	90.45	94.39	78.21	96.42	82.90	73.33	67.26	86.45
2007	90.14	93.37	75.03	96.83	82.87	74.47	67.53	87.32
2008	89.80	92.08	71.52	97.19	82.86	75.93	67.71	88.07
2009	89.48	90.68	67.68	97.50	82.88	77.19	67.80	88.77
2010	89.19	89.16	63.44	97.79	83.00	78.29	68.04	89.43
2011	88.90	87.62	58.71	98.05	81.97	77.66	67.50	89.86

Note: Mean efficiencies are in percentage term.

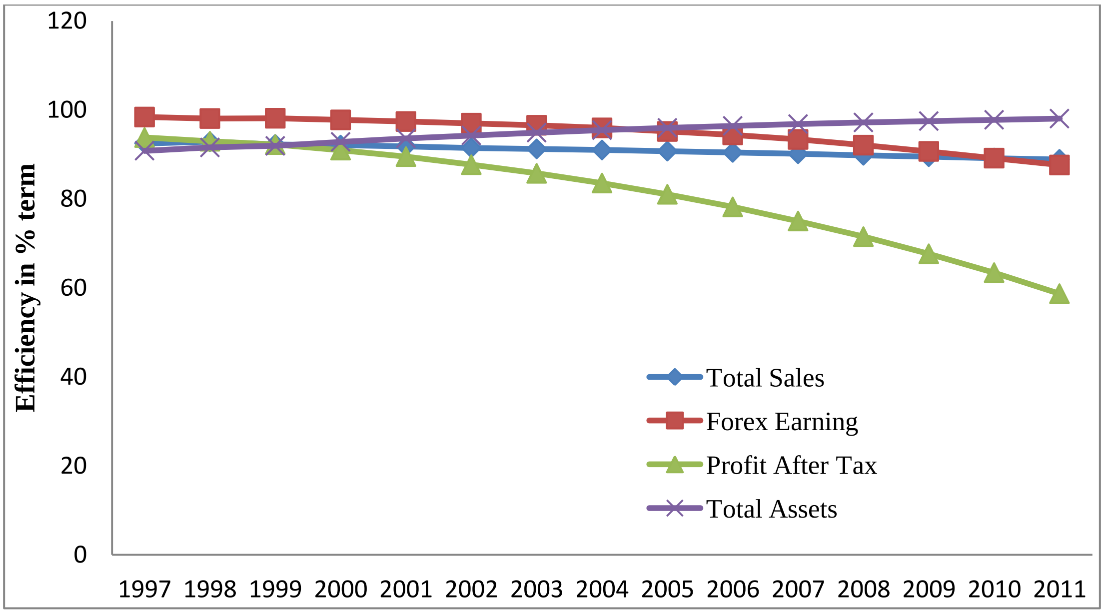

Figure 5.8: Mean Efficiency of High Exporting Firms Group

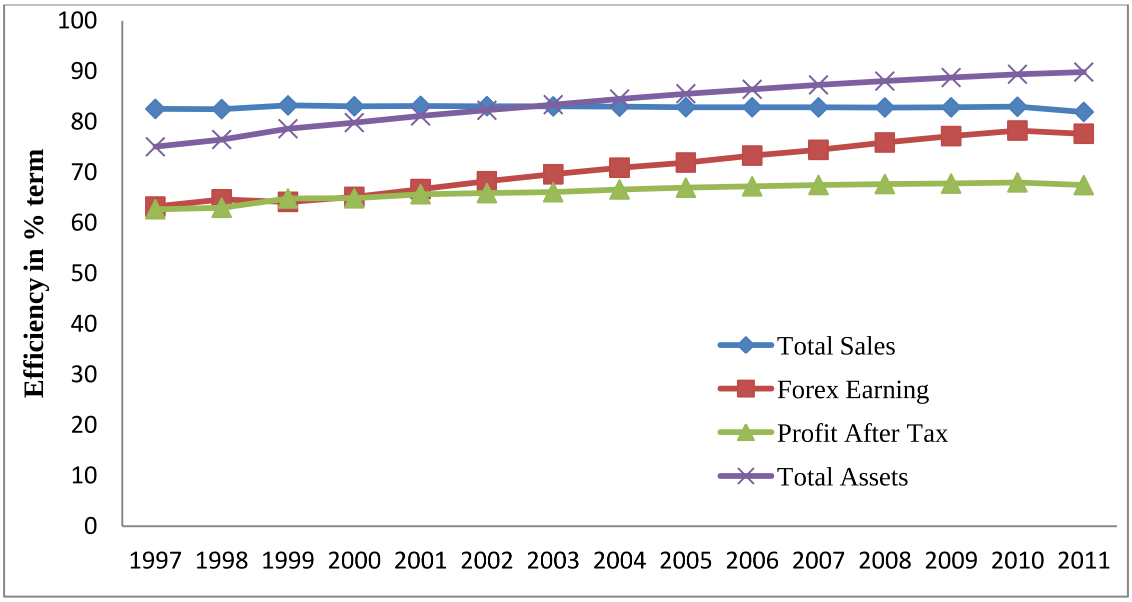

Figure 5.9: Mean Efficiency of Low Exporting Firms Group

Table 5.12 shows the average TE scores for the firms with and without R&D groups.

Table 5.12: Mean Efficiency of Firms With and Without R&D Related Outlays

	Firms with R&D outlays				Firms without R&D outlays			
Year	Total Sales	Forex Earning	Profit After Tax	Total Assets	Total Sales	Forex Earning	Profit After Tax	Total Assets
1997	88.58	66.56	80.85	81.72	83.62	54.04	79.90	70.91
1998	88.43	67.24	81.10	83.26	87.03	55.02	79.97	72.61
1999	88.13	71.45	83.70	84.12	90.08	64.33	82.43	77.42
2000	87.97	72.10	83.92	85.48	91.46	63.53	81.13	77.54
2001	87.89	72.94	84.29	86.79	92.65	64.61	80.35	78.02
2002	87.72	74.28	84.83	87.93	93.66	65.06	79.77	78.29
2003	87.54	75.06	85.07	89.01	94.64	67.16	78.79	78.86
2004	87.46	75.78	85.33	89.97	95.26	67.98	78.16	79.76
2005	87.31	76.30	85.57	90.89	95.86	68.72	77.54	80.32
2006	87.14	76.94	85.76	91.69	96.49	69.38	76.43	80.70
2007	86.91	77.43	86.00	92.46	97.02	70.12	75.20	80.92
2008	86.76	77.98	86.17	93.15	97.49	70.88	74.07	81.07
2009	86.54	78.31	86.37	93.78	97.87	70.60	72.97	81.16
2010	86.39	79.07	86.58	94.33	98.17	71.15	71.32	81.58
2011	86.25	78.48	86.36	94.85	98.31	68.91	70.66	81.37

Note: Mean efficiencies are in percentage term.

In the case of R&D group of firms, the TE scores for raising total sales have shown a continuously declining trend from 88.58% in ’97 to 86.25% in ’11. With regard to forex earning, profit and total assets, there has been a continuous escalation in the TE scores from 66.56%, 80.85% and 81.72% in 1997 to 78.48%, 86.36% and 94.85% in the year 2011 respectively. In case of non R&D firms group, the TE scores for raising total sales and forex earning have increased over the study period from 83.62% in 1997 to 98.31% in 2011 in case of total sales and from 54.04% in 1997 to 68.91% in 2011 in case of forex earnings. With reference to the profit, the TE scores have declined from 79.90% in 1997 to 70.66% in 2011. The study observed a rise in TE with regard to total assets from 70.91% in 1997 to 81.37% in 2011.

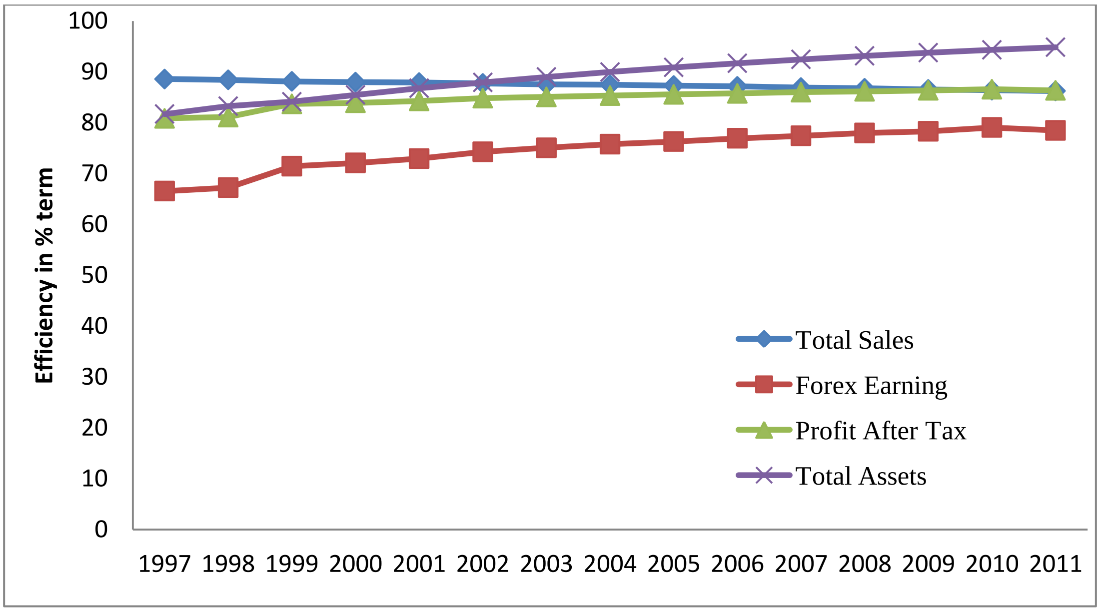

Figure 5.10: Mean Efficiency of R&D Firms Group

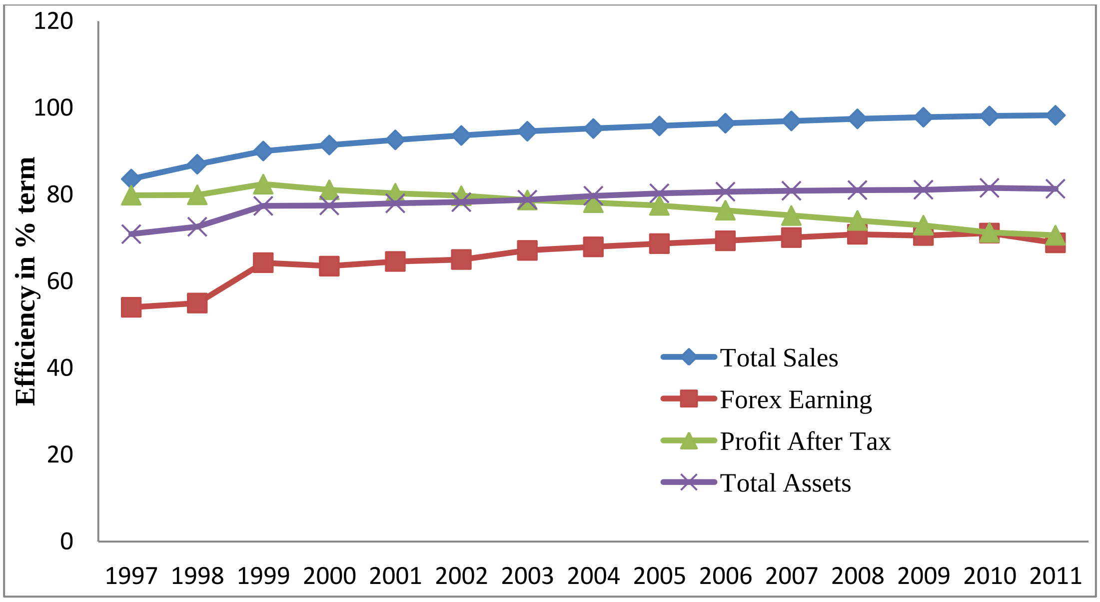

Figure 5.11: Mean Efficiency of Without R&D Firms Group

Table 5.13 shows the mean TE for all firms together. The TE score in raising total sales has declined marginally from 91.8% in 1997 to 90.1% in 2011. With reference to the forex earning, the study found a boost in TE from 65.48% in 1997 to 92.16% in 2011.

Table 5.13: Mean Efficiency of All Firms Group

Year	Total Sales	Forex Earning	Profit After Tax	Total Assets
1997	91.82	65.48	93.36	82.54
1998	91.77	68.89	92.73	83.72
1999	91.73	71.74	92.04	84.69
2000	91.61	74.18	91.22	85.80
2001	91.48	76.98	90.37	86.82
2002	91.36	79.48	89.44	87.73
2003	91.23	81.57	88.36	88.63
2004	91.12	83.37	87.22	89.44
2005	90.97	85.02	85.98	90.25
2006	90.84	86.60	84.60	90.93
2007	90.70	88.00	83.12	91.63
2008	90.56	89.27	81.52	92.25
2009	90.41	90.42	79.80	92.83
2010	90.32	91.49	77.88	93.32
2011	90.17	92.16	75.68	93.81

Note: Mean efficiencies are in percentage term.

TE for raising profit gradually tapered off from 93.3% to 77.6% in 2011. With regard to total assets, the TE escalated from 82.54% in ’97 to 93.81% in ’11. On the whole it may be observed that in the entire pharmaceutical sector, TE registered an increasing trend in rising two outputs i.e. forex earning and total assets while in case of total sales and profit TE shows fluctuating trends, in some groups it is increasing and in some other groups it has declined over the study years 1997 to 2011.

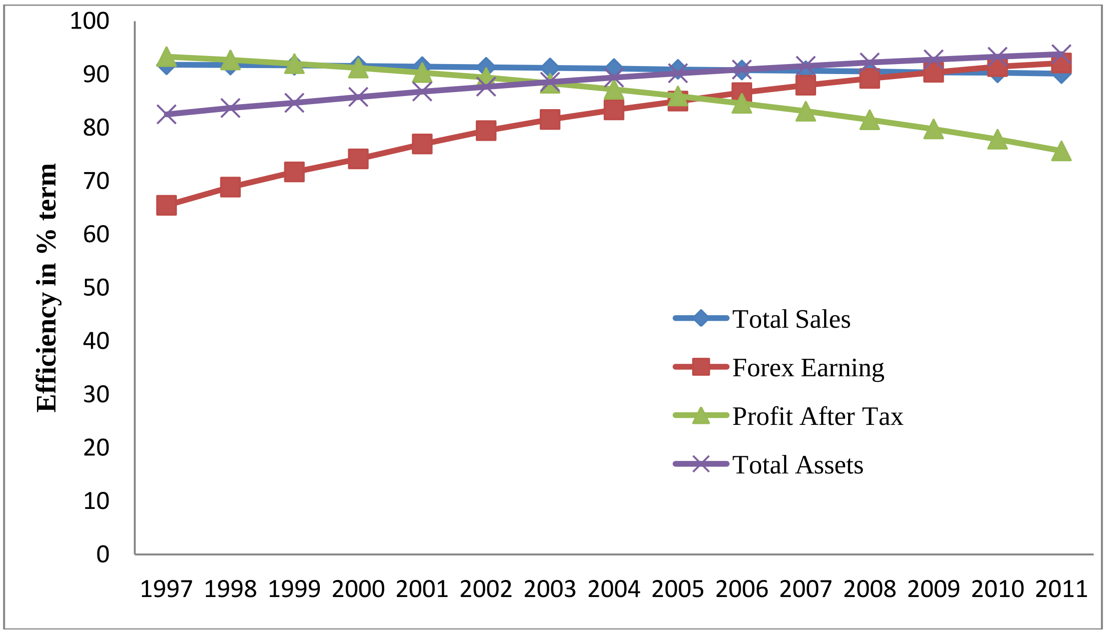

Figure 5.12: Mean Efficiency of All Firms Group

5.4 Mean Technical Efficiency: Output Wise for All Groups

The mean TE estimates over the study period are provided in the following tables. These measures are provided output-wise for all the firm groups which help to assess the average behaviour of the member firms together in a firm group, over a period of time, in respect of alternative output measures. The table 5.14 depicts the time varying TE values of total sales for all the group of firms over the sample period. The TE in raising the total sales for all firms group has declined slightly from 91.8% in 1997 to

90.2% in 2011. It has increased in case of small firms group and the firms not engaged in R&D activities. In the other groups the TE for raising the firms' output has shown a declining trend. In the year 1997, the highest TE score in raising total sales is realized in indigenous group with TE score 99.68% followed by only bulk group (95.82%), in 1997. However, in the year 2011, the highest TE scores are observed in case of indigenous firms followed by without R&D group and small firms group.

Similarly efficiency measures for each firm group of raising foreign exchange earnings are shown in table 5.15. It is observed that TE of all groups has gone up over the sample period except the big firms, bulk & formulation and high export groups. In case of big firms TE has declined from 68.7% in 1997 to 66.5% in 2011, whereas in case of bulk & formulation and high export group, it has came down from 70.6% and 98.4% in 1997 to 68.9% and 87.6% in 2011 respectively. The highest increase in TE score has been observed for of MNCs group where it has escalated from 38.9% in 1997 to 84.34% in 2011. In 1997 the high export group was at the top with 98.4% and only formulation group was at the bottom with 22.2%. In 2011 all firms group has been the second highest. Only bulk group with 94.85% is ranked first in 2011, while, the only formulation group is at the bottom in 2011 with TE score 41.5%.

Table 5.14: Mean Efficiency of Total Sales -Aggregate Industry

Year	Indigenous	MNCs	Big	Small	Bulk and Formulation	Only formulation	Only Bulk	Total High Export	Total Low Export	R&D Related Outlays	Without R&D outlays	All Firms
1997	99.68	62.92	94.4	87.7	89.81	81.51	95.82	92.49	82.57	88.58	83.62	91.82
1998	99.68	60.93	94.1	88.5	90.25	80.8	95.43	92.86	82.53	88.43	87.03	91.77
1999	99.69	57.98	92.8	89.9	89.33	79.87	94.75	92.26	83.27	88.13	90.08	91.73
2000	99.69	57.75	92.4	90.5	89.23	79.75	94.42	92.09	83.09	87.97	91.46	91.61
2001	99.69	57.3	91.8	91.1	89.05	80.49	93.88	91.85	83.17	87.89	92.65	91.48
2002	99.69	56.34	91.1	91.7	88.87	80.85	93.25	91.49	83.11	87.72	93.66	91.36
2003	99.69	55.95	90.4	92.2	88.72	81.04	92.64	91.24	83.07	87.54	94.64	91.23
2004	99.69	56.34	89.8	92.7	88.51	81.41	91.91	90.99	83.01	87.46	95.26	91.12
2005	99.7	55.6	89.1	93.1	88.27	81.13	91.17	90.74	82.91	87.31	95.86	90.97
2006	99.7	55.21	88.4	93.5	88.14	81.1	90.47	90.45	82.9	87.14	96.49	90.84
2007	99.7	55.06	87.6	93.9	87.9	81.44	89.64	90.14	82.87	86.91	97.02	90.7
2008	99.7	54.12	86.8	94.3	87.76	81.48	88.74	89.8	82.86	86.76	97.49	90.56
2009	99.7	53.72	85.9	94.7	87.5	81.5	87.74	89.48	82.88	86.54	97.87	90.41
2010	99.7	53.88	85.1	94.9	87.27	81.54	86.79	89.19	83	86.39	98.17	90.32
2011	99.7	53.35	84.3	95.1	87.22	80.72	86.33	88.9	81.97	86.25	98.31	90.17

Note: Mean efficiencies are in percentage term.

Table 5.15: Mean Efficiency of Foreign Exchange Earning -Aggregate Industry

Year	Indigenous	MNCs	Big	Small	Bulk and Formulation	Only formulation	Only Bulk	Total High Export	Total Low Export	R n D Related Outlays	Without R&D outlays	All Firms
1997	59.62	38.92	68.7	46.9	70.68	22.22	56.41	98.4	63.25	66.56	54.04	65.48
1998	61.45	43.77	67.6	47	67.09	23.7	61.34	98.07	64.68	67.24	55.02	68.89
1999	62.98	53.14	80.3	46.1	58.77	31.23	63.97	98.13	64.18	71.45	64.33	71.74
2000	65.03	56.02	79.4	46.9	61.08	32.4	68.18	97.76	65.16	72.1	63.53	74.18
2001	67.1	59.9	78	48.6	62.76	32.35	72.17	97.39	66.71	72.94	64.61	76.98
2002	69.4	61.07	77.6	50	64.04	34.28	76.69	97.02	68.25	74.28	65.06	79.48
2003	71.33	64.06	76.7	51.4	65.13	35.37	79.41	96.55	69.63	75.06	67.16	81.57
2004	73.09	64.62	75.8	52.7	65.8	36.55	82.4	95.96	70.94	75.78	67.98	83.37
2005	74.72	66.66	74.6	54	65.98	37.25	84.79	95.16	71.96	76.3	68.72	85.02
2006	76.16	69.27	73.3	55.1	66.79	38	87.11	94.39	73.33	76.94	69.38	86.6
2007	77.61	70.28	72.6	56	67.45	39.25	89.18	93.37	74.47	77.43	70.12	88
2008	78.94	70.91	71.3	57.3	68.25	40.15	90.92	92.08	75.93	77.98	70.88	89.27
2009	80.26	73.25	69.3	57.7	68.53	40.99	92.32	90.68	77.19	78.31	70.6	90.42
2010	81.4	77.08	68.4	58.2	70.13	41.88	93.66	89.16	78.29	79.07	71.15	91.49
2011	81.92	84.34	66.5	60.1	68.97	41.57	94.85	87.62	77.66	78.48	68.91	92.16

Note: Mean efficiencies are in percentage term.

The mean technical efficiency value in raising the profit has been reported in table 5.16 for all groups of firm. In case of TE for all firms group and also for each firm group has gone down over the period 1997 to 2011 except four groups i.e. indigenous, small, high export and R&D. The technical efficiency in raising profit for indigenous firms group has increased by 1%, for small firms group, it has gone up by 4%, while in case of high export firms group and R&D group of firms it has increased by 5% and 6% respectively from 1997 to 2011. In case of only formulation group of firms the TE has been more or less same over the same period of time. In 1997, the big firms group was at the top with 98.5% TE value followed by the only bulk group with 98.19% and high export intensive firms group with 93.8%, while the only formulation group was at the bottom with 50.88%. In 2011, the firms with R&D related outlays are at the top with 86.36% followed by the indigenous firms group with 77.03%.

The mean technical efficiency value in raising total assets of all firms and each firm group is shown in table 5.17. The value of mean TE in raising total assets for all firms as well as for each firm group has increased over the period of 1997 to 2011 except the only bulk group of firms where it has declined by 2% from 91.6% in 1997 to 89.77% in 2011. In 1997 with 91.6% the only bulk group of firms was at the top, followed by the high export firms group with 90.84% and big firms group with 90%. On the other hand with 64.91% the MNCs group of firms was at the bottom, followed by the firms not engaged in R&D activities70.91%. In 2011, the big firms group with 96.9% is ranked first followed by small firms group with 95% and the firms involved in R&D activities with efficiency value 94.85%. For all firms the TE of raising total assets went up from 82.54% in 1997 to 93.81% in 2011. The MNCs group of firms has shown excellent performance in terms of the technical efficiency which has shown highest (24%) increase from 64.91% in 1997 to 88.06% in 2011.

Table 5.16: Mean Efficiency of Profit after Tax -Aggregate Industry

Year	Indigenous	MNCs	Big	Small	Bulk and Formulation	Only formulation	Only Bulk	Total High Export	Total Low Export	RnD Related Outlays	Without RnD outlays	All Firms
1997	76.35	86.49	98.5	71.4	84.42	50.88	98.19	93.8	62.72	80.85	79.9	93.36
1998	76.63	83.54	98.1	71.9	85.68	53.08	97.64	92.96	63.01	81.1	79.97	92.73
1999	77.6	84.07	97.6	73.1	85.47	53.96	96.88	92.21	64.85	83.7	82.43	92.04
2000	77.62	83.23	97	73.2	84.56	53.73	95.93	90.97	64.89	83.92	81.13	91.22
2001	78.12	82.22	96.1	73.9	83.71	54.46	94.84	89.51	65.7	84.29	80.35	90.37
2002	78.66	81.05	95	74.5	82.67	53.83	93.43	87.69	65.92	84.83	79.77	89.44
2003	78.57	79.92	93.6	75	81.47	53.24	91.64	85.75	66.1	85.07	78.79	88.36
2004	78.65	78.9	91.9	75.3	80.29	52.99	89.37	83.57	66.64	85.33	78.16	87.22
2005	78.73	77.43	89.8	75.8	79.68	52.51	86.4	81.04	66.98	85.57	77.54	85.98
2006	78.63	76.15	87.1	76.1	78.12	52.3	82.94	78.21	67.26	85.76	76.43	84.6
2007	78.63	74.47	83.8	76.2	76.6	51.94	78.63	75.03	67.53	86	75.2	83.12
2008	78.55	73.69	79.9	76.4	74.87	51.6	73.51	71.52	67.71	86.17	74.07	81.52
2009	78.58	72.27	75.3	76.5	73.43	51.23	67.43	67.68	67.8	86.37	72.97	79.8
2010	78.2	70.14	69.6	76.4	70.78	50.66	60.83	63.44	68.04	86.58	71.32	77.88
2011	77.03	69.35	63.2	75.6	66.19	50.96	53.03	58.71	67.5	86.36	70.66	75.68

Note: Mean efficiencies are in percentage term.

Table 5.17: Mean Efficiency of Total Assets -Aggregate Industry

Year	Indigenous	MNCs	Big	Small	Bulk and Formulation	Only formulation	Only Bulk	Total High Export	Total Low Export	R&D Related Outlays	Without R&D outlays	All Firms
1997	79.61	64.91	90	81.1	78.59	73.55	91.6	90.84	75.08	81.72	70.91	82.54
1998	80.33	65.68	90.9	82.6	78.71	74.38	90.9	91.57	76.52	83.26	72.61	83.72
1999	79.86	68.39	91.7	84.1	80.1	77.81	90.65	91.93	78.65	84.12	77.42	84.69
2000	80.8	70.5	92.4	85.5	81.35	78.72	90.85	92.82	79.86	85.48	77.54	85.8
2001	81.3	73.08	93	86.8	82.5	80.44	90.63	93.6	81.17	86.79	78.02	86.82
2002	81.91	74.87	93.5	88	83.75	81.98	90.42	94.26	82.3	87.93	78.29	87.73
2003	82.4	76.75	94	89.2	84.93	82.85	90.24	94.9	83.41	89.01	78.86	88.63
2004	83.02	78.79	94.5	90.2	85.99	83.58	89.99	95.47	84.53	89.97	79.76	89.44
2005	83.74	80.41	95	91.1	87.27	84.4	89.8	95.97	85.58	90.89	80.32	90.25
2006	84.23	81.93	95.3	91.9	88.13	85.27	89.71	96.42	86.45	91.69	80.7	90.93
2007	84.9	83.4	95.7	92.7	89	85.92	89.54	96.83	87.32	92.46	80.92	91.63
2008	85.43	84.88	96.1	93.4	89.75	86.62	89.48	97.19	88.07	93.15	81.07	92.25
2009	86	86.09	96.4	94	90.54	87.28	89.36	97.5	88.77	93.78	81.16	92.83
2010	86.39	87.08	96.7	94.5	91.05	87.92	89.28	97.79	89.43	94.33	81.58	93.32
2011	87.2	88.06	96.9	95	91.63	88.04	89.77	98.05	89.86	94.85	81.37	93.81

Note: Mean efficiencies are in percentage term.

5.5 Concluding Remarks:

The study has attempted to analyse the relative technical efficiency of the Indian pharmaceutical companies using SFA for the period 1997 to 2011. The study finds that the raw material as an input has emerged as the most significant variable influencing total sales and foreign exchange earnings among all group of firms. Labour has been found to be the most significant input variable influencing the profit of firms, and capital has played dominant role in enhancing the total assets of the firms across all the groups. On the other hand, the marketing and advertising cost has been found to have marginal influence on firm's output. The technical efficiency has been found to be time varying in almost all the firms' groups.

The study further reveals that overall average TE has shown an increasing trend in raising foreign exchange earnings and total assets while in case of total sales the trend has been fluctuating across the groups. The profit has shown a declining trend across the groups except total low export and R&D firms group. Taking into consideration the TE for raising total sales and profit, indigenous firms performed more efficiently compared to MNCs. Only formulation group has performed well compared to bulk & formulation and only bulk group. Low exporting firms have performed more efficiently relative to high exporting firms and R&D group has performed better than the non R&D group in case of all outputs except total sales. Small firms have performed relatively more efficiently than the big firms in all outputs. There are considerable evidences that the observed outputs are less than their respective potential outputs due to technical inefficiency of firms.

6. CHAPTER

PRODUCTIVITY ANALYSIS OF INDIAN PHARMACEUTICAL INDUSTRY

6.1 Introduction:

The analysis of productivity and efficiency has attracted considerable attention during the last few decades in economic literature as well as by policy makers in both developed and developing countries (Battese and Coelli, 1995; O'Donnell, 2012). The productivity growth is very important for firms to survive and face competition from newly emerging domestic as well as foreign MNCs of the developed world. By enhancing the productivity the firm as well as the industry can maintain their competitiveness and market share. It is very difficult for a nation to move forward towards economic growth and prosperity without attaining a considerable progress in productivity. In case of India, since the initiation of economic reforms in 1991, it has become imperative to achieve the high growth for industrial sector by improving productivity and efficiency of firms as the removal of barriers to entry and several other measures during deregulation period has opened up the economy to international market forces especially in the industrial sector. The productivity growth in the industrial sector is among the most important factors for successful economic reforms to strengthen the Indian industrial sector. The productivity plays crucial role in firm's profitability, reduction of cost and price, which ultimately strengthens the competitiveness of firms and industries in the global competitive world.

There are several productivity indices in the literature for computing the total factor productivity (TFP) such as Tronqvist index, the Fisher index, and Malmquist index etc which have been extensively used in empirical research. However both Tronqvist and Fisher indices follow neither transitive nor identity axioms which make them inappropriate to be used to make multi-lateral or multi-temporal comparisons (O'Donnell, 2012). On the other hand, Malmquist productivity index is one of the standard approaches in productivity literature that can be decomposed exhaustively especially in nonparametric specifications (Bjurek, 1996). Recently, two other indexes namely Hicks-Moorsteen TFP index proposed by Bjurek (1996) and Fare-Primont index proposed by O'Donnell (2011) are used in constructing productivity indices. They are more reliable and can be broken into several components without requiring data on prices and any restrictive assumptions concerning statistical noise. Therefore, in the present study we have utilized the Malmquist index, Fare-Primont index and Hicks-Moorsteen index for computing the TFP change and to decompose these changes into measures of technical change, technical efficiency change and scale efficiency change for Indian pharmaceutical industry over the period 2001 to 2011.

6.2 Productivity Indices and Measurement of Productivity of Firms:

The TFP change can be measured as changes in the ratio of aggregate outputs index to the aggregate inputs index. For constructing a ratio of an index of all outputs over all inputs, first we need to aggregate the inputs together and the outputs together. Suppose there is a dataset on N firms over T time periods and let

$x_{it} = (x_{1it}, \ldots, x_{kit})'$ and $y_{it} = (y_{1it}, \ldots, y_{kit})'$ denote the input and output quantity vectors of firm i in period t. Then the TFP of the firm is,

$$TFP_{it} = \frac{Y_{it}}{X_{it}} \qquad ...(6.1)$$

Where, $Y_{it} = Y(y_{it})$ is an aggregate output, $X_{it} = X(x_{it})$ is an aggregate input and (.)Y and (.) X are non-negative, non-decreasing and linearly homogeneous aggregator functions. The associated index number that measures the TFP of firm i in period t relative to the TFP of firm j in period m is (O'Donnell, 2011),

$$TFP_{jm,it} = \frac{TFP_{it}}{TFP_{jm}} = \frac{Y_{it} / X_{it}}{Y_{jm} / X_{it}} = \frac{Y_{jm,it}}{X_{jm,it}} \qquad ...(6.2)$$

Where $Y_{jm,it} = Y_{it} / Y_{jm}$ and $X_{jm,it} = X_{it} / X_{jm}$ are output quantity index and input quantity index respectively. Thus, this equation shows that TFP growth can be expressed as a measure of output growth divided by a measure of input growth. This measure of relative productivity (Jorgenson and Griliches, 1967) is said to be multiplicatively complete (O'Donnell, 2012).

6.2.1 Fare-Primont Productivity Index:

The Fare-Primont index, recently proposed by O'Donnell (2012), is the only total factor productivity index that can be constructed from distance functions without violating important transitivity and identity axioms from index theory. It also has the important property that it can be exhaustively decomposed into various measures of technical change and efficiency change without having any residual effects. It can be used to compute quantity data only i.e. price data are not required to compute the indexes. The present study uses the Fare-Primont index to compute and decompose total factor productivity into a measure of technical change and several measures of efficiency. The Fare-Primont index is a member of a class of "multiplicatively complete" productivity indexes that uses following non-negative, non-decreasing and linearly homogenous aggregator function:

$$Y(y) = D_0(x_{it}, y, t_0)$$
$$X(x) = D_1(x, y_0, t_0)$$

Where $D_0(x_{it}, y, t_0)\, and\, D_1(x, y_0, t_0)$ are Shephard (1953) outputs and input distance functions representing the production technology available in period t, respectively. Then the Fare-Primont index takes the following form (O'Donnell, 2011):

$$TFP_{jm,it} = \frac{D_0(x_0, y_{it}, t_0)}{D_0(x_0, y_{jm}, t_0)} \frac{D_1(x_{jm}, y_0, t_0)}{D_1(x_{it}, y_0, t_0)} \qquad \text{... (6.3)}$$

Productivity growth (decline) is indicated by values smaller (larger) than unity. However, production technologies represented as Shephard output and input distance functions maintain following measures of efficiency,

6.2.1.1 Measures of Efficiency:

Following O'Donnell (2012), this section defines several input-oriented measures of efficiency in terms of aggregate outputs and inputs. The efficiency measures that feature in an input-oriented decomposition of TFP change are:

$$TFPE_{it} = \frac{TFP_{it}}{TFP^*_t} \leq 1 \qquad \text{(TFP efficiency)}$$

$$ITE_{it} = \frac{Y_{it} / X_{it}}{Y_{it} / \bar{X}_{it}} = \frac{\bar{X}_{it}}{X_{it}} = D_1(x_{it}, y_{it}, t)^{-1} \leq 1 \qquad \text{(Input Oriented Technical Efficiency)}$$

$$\text{ISE}_{it} = \frac{Y_{it} / \bar{X}_{it}}{Y_{it} / X_{it}} \leq 1 \qquad \text{(Input Oriented Scale Efficiency)}$$

Where, Y_{it} *and* X_{it} are the aggregate output and input quantities and $\bar{X}_{it}$ is the maximum aggregate input quantities that is technically feasible to produce a scalar multiple of y_{it} using x_{it}. Technical change measures the movements in the production frontier; technical efficiency change tells about movements towards or away from the frontier; and the scale efficiency change measures the movements around the frontier surface to capture economies of scale.

6.2.2 Hicks-Moorsteen Productivity Index:

Hicks-Moorsteen TFP index, proposed by Bjurek (1996), is the multiplicatively-complete index that can be computed without price data. The Hicks-Moorsteen TFP index is the ratio of Malmquist output and input quantity indexes, so named because Diewert (1992) attributes its origins to Hicks (1961) and Moorsteen (1961). The advantage of this approach over the popular Malmquist productivity index is that it is free from any assumptions concerning firm optimising behaviour, the structure of markets, or returns to scale. However, it is fair to say that it is less widely used in applied research than the Malmquist productivity index (see, e.g., Bjurek et al. (1998) or Nemoto and Goto (2005)). It has been introduced partly to avoid the indeterminateness problem of the Malmquist index. The Hicks-Moorsteen index satisfies the determinateness axiom. This claim of Bjurek (1996) has been formally proved by Briec and Kerstens (2010) under mild conditions (i.e. mainly strong disposability of inputs and outputs).

A Hicks-Moorsteen (or Malmquist TFP) productivity index for the base period t is defined as the ratio of a Malmquist output quantity index at the base period t and a Malmquist input quantity index at the base period t (Kerstens, 2010):

$$HM_{T(t)}\{(x^t, y^t), (x^{t+1}, y^{t+1})\} = \frac{E^O{}_{T(t)}(x^t, y^t) / E^O{}_{T(t)}(x^t, y^{t+1})}{E^I{}_{T(t)}(x^t, y^t) / E^I{}_{T(t)}(x^{t+1}, y^t)} \qquad ....(6.4)$$

Where $E^O{}_{T(t)}$ and $E^I{}_{T(t)}$ refer to the output and input oriented Farrell measures of efficiency respectively. Clearly $y^t < y^{t+1}$ entails $E^O{}_{T(t)}(x^t, y^t) > E^O{}_{T(t)}(x^t, y^{t+1})$ and thus numerator in the above equation becomes greater than unity. Likewise $x^{t+1} < x^t$ makes $E^I{}_{T(t)}(x^t, y^t) > E^I{}_{T(t)}(x^{t+1}, y^t)$ and thus the denominator in the above equation become lesser than unity. In other words, when the Malmquist output quantity index (ratio in numerator) is greater (smaller) than unity, then more (less) outputs were produced in period t+1 than in period t from a given level of inputs. Similarly, when the Malmquist input quantity index (ratio in denominator) is larger (smaller) than unity, then less (more) inputs were needed in period t+1 than in period t to produce a given level of output. When the Hicks-Moorsteen productivity index is larger (smaller) than unity, then it indicates productivity gain (loss).

Similarly for a base period t+1 Hicks-Moorsteen productivity index is defined as follows,

$$HM_{T(t+1)}\{(x^t, y^t), (x^{t+1}, y^{t+1})\} = \frac{E^O{}_{T(t+1)}(x^{t+1}, y^t) / E^O{}_{T(t+1)}(x^{t+1}, y^{t+1})}{E^I{}_{T(t+1)}(x^t, y^{t+1}) / E^I{}_{T(t+1)}(x^{t+1}, y^{t+1})} \qquad .... (6.5)$$

The interpretation of this equation is similar to the above. A geometric mean of these two Hicks-Moorsteen productivity indices is,

$$HM_{T(t),T(t+1)}((x^t, y^t),(x^{t+1}, y^{t+1})) = [HM_{T(t)}((x^t, y^t),(x^{t+1}, y^{t+1})).HM_{T(t+1)}$$
$$((x^t, y^t),(x^{t+1}, y^{t+1}))]^{1/2} \qquad ...(6.6)$$

The interpretation of this equation is also entirely similar to the above.

6.2.3 Malmquist Productivity Index:

We have computed the productivity change and its different components namely the efficiency, technical, and scale efficiency change of the firms. We have applied the Fare et al (1989) adjacent period version of the Malmquist productivity index to compute the productivity of firms. The Malmquist index measures the TFP change between two data points by calculating the ratio of the distances of each data point relative to a common technology. Fare et al (1989) adjacent version of the Malmquist productivity index is defined in terms of Shepherd distance function for period t and t+1 as,

$$MI = \left[\frac{D^t(X^{t+1}, Y^{t+1})}{D^t(X^t, Y^t)}\right] \times \left[\frac{D^{t+1}(X^{t+1}, Y^{t+1})}{D^{t+1}(X^t, Y^t)}\right]^{1/2} \qquad ...(6.7)$$

Where, $D^t(x^t, y^t)$ is the distance function which indicates the maximum proportion by which the output bundle of the firm in period t is expanded keeping the input vector constant. Similarly, $D^{t+1}(x^t, y^t)$ captures the proportional expansion of the same output bundle of the firm relative to the technology set in period t+1. It is evident that the Shepherd distance function is reciprocal to the output efficiency of the firms. The ratio of the distance function $\frac{D^t(X^{t+1}, Y^{t+1})}{D^t(X^t, Y^t)}$ measures the changes in the productivity of a unit taking the frontier for the base period as the benchmark for comparison. Alternatively, if one targets the frontier for the final period as the benchmark for comparison, the productivity changes are captured by the following ratio of the distance function $\frac{D^{t+1}(X^{t+1},Y^{t+1})}{D^{t+1}(X^{t},Y^{t})}$. Since there is no particular reason to prefer the base period frontier to the target period frontier (or vice versa), the index number is calculated as the geometric mean of these two distance function ratios. MI > 1 indicates productivity growth and MI < 1 productivity decline. To measure the productivity change of a firm for two adjacent periods, two separate frontiers are constructed viz., one for the initial period and other for the target period. The main rationale for considering the Malmquist index is that can be decomposed into two mutually exclusive and exhaustive components: technical change (TC) and efficiency change (EC) components (see Fare et al 1989 for a detailed illustration on Malmquist Index). $i.e., MI = TC \times EC$

$$where,\ EC = \left[\frac{D^{t+1}(X^{t+1},Y^{t+1})}{D^{t}(X^{t},Y^{t})}\right], and\ TC = \left[\frac{D^{t}(X^{t+1},Y^{t+1})}{D^{t+1}(X^{t+1},Y^{t+1})}\right] \times \left[\frac{D^{t}(X^{t},Y^{t})}{D^{t+1}(X^{t},Y^{t})}\right]$$

TC > 1 indicates the progress in technical change whereas values less than one indicate regress. The EC component can be interpreted as a relative shift of a firm towards or away from the production possibilities frontier at two different periods and measures the catching up effect of the firms. In empirical context, the TC component represents change of the best practice technology, while the EC component represents adoption of best practices.

6.3 Data and Input-Output Specifications for the Productivity Analysis:

To compute the productivity of the Indian pharmaceutical firms, we have taken the necessary data from CMIE for the period of 2001 to 2010. The study has conceptualised a 4-output, 5-input production technology. The outputs considered in the model are (i) total sales, (ii) total foreign exchange earnings, (iii) profit after tax and (iv) total assets. The inputs in the model are (i) labour (measured in terms of wages and salaries for the workers) (ii) material inputs (measured in terms of the companies' expenditure for raw material), (iii) energy input (measured in terms of the expenditure for power and fuel) and (iv) capital, is the book value for plant and machinery and building, (v) marketing and advertising cost measured in terms of expenditure for marketing and advertising.

6.4 Empirical Analysis:

6.4.1 Analysis of Results of Fare-Primont Productivity Index

This section presents estimates of TFP change in Indian pharmaceutical industry over the period 2001 to 2011. The results are obtained using the Fare-Primont index which is used because of its multi-lateral and multi-temporal comparability. The other widely used Fisher and Tornqvist indexes are theoretically implausible in comparing more than two sectors or more than two time periods. This study assumes variable returns to scale (VRS) which allows both technical progress and technical regress.

Table 6.1 presents indexes comparing TFP change, technical change and efficiency change for indigenous and MNCs group of firms from 2001 onwards. All the estimates reported in this table are meaningfully comparable in performance spatially or inter-temporally as the indexes are transitive. The second column of the table depicts the mean TFP change (dTFP) for indigenous firms group and a value of 0.895 in 2002 implies that TFP has declined by around 11% as compared to 2001. In the next column technical change has been reported and the value of 0.949 means that there has been technical regress by around 5% in the Indian pharmaceutical industry in the year 2002 as compared to 2001. In case of technical efficiency change the trend has been more or less same as in technological change but in case of scale efficiency change there has been a progressive trend through the study years.

The TFP in case of MNCs group has shown a decreasing trend but seems to perform better than the indigenous firms group. In case of technical change, there is technological progress in the starting years up to 2007 and then starting declining in the last four years. The technical efficiency and scale efficiency change is showing a declining trend. Overall cross comparison shows that indigenous firms group shows better performance compared to MNCs in case of technical efficiency and scale efficiency change where as in case of TFP and technical change MNCs have been relatively better than the indigenous firms group.

Table 6.1: Productivity Changes for Indigenous Firms and MNCs firms Group

	Indigenous Firms				MNCs			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….
2002	0.895	0.949	0.970	1.035	0.921	1.061	0.932	0.984
2003	0.887	0.868	0.980	1.035	0.908	0.841	0.935	0.970
2004	0.911	0.913	0.980	1.032	0.908	1.030	0.910	0.963
2005	0.899	0.983	0.982	1.016	0.933	1.061	0.885	0.962
2006	0.895	0.983	0.983	1.016	0.933	1.061	0.885	0.962
2007	0.870	0.822	0.987	1.026	0.917	1.051	0.876	0.975
2008	0.858	0.954	0.963	1.009	0.904	0.998	0.897	0.976
2009	0.835	0.848	0.970	1.013	0.868	0.863	0.910	0.974
2010	0.820	0.817	0.985	1.025	0.825	0.839	0.946	0.975
2011	0.793	0.782	0.979	1.014	0.797	0.891	0.943	0.957

Table 6.2 reports the productivity change and its various components for different products group of firms namely; bulk & formulation, only formulation and only bulk

drugs. Column 2 of the table shows the TFP change for bulk & formulation group and a value of 0.832 in 2002 implying that TFP of this group has come down by around 17% compared to the previous year i.e. 2001. The TFP in this group shows a decreasing trend in all the years from 0.832 (17%) in 2002 to 0.744 (26%) in 2011. The technical change shows positive change four times and then regressed from 2007 to 2011. The technical efficiency has been almost constant in most of the years and scale efficiency depicted an improvement in all the years from 2002 to 2011. In case of only formulation group, the TFP, technical efficiency and scale efficiency change have shown a declining tendency in all the years but the technical change is showing progressive sign 6 times but this positive change does not seem to enhance TFP in this group. In case of only bulk group, all measures are depicting declining behaviour except technical change which is positive in all the year apart from 2010.

Table 6.2: Productivity Changes for Bulk & Formulation, Only Formulation and Only Bulk Firms Group

	Bulk & Formulation				Only Formulation				Only Bulk			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….	….	….	….	….
2002	0.832	0.891	0.998	1.075	0.610	1.010	0.936	0.999	0.891	1.092	0.982	0.975
2003	0.849	1.004	0.993	1.057	0.633	0.982	0.972	0.995	0.902	1.174	0.982	0.994
2004	0.821	1.086	0.978	1.059	0.647	0.997	0.966	0.984	0.910	1.069	0.979	0.988
2005	0.827	1.088	0.968	1.051	0.659	1.011	0.940	0.935	0.977	1.147	0.979	0.997
2006	0.833	1.088	0.968	1.051	0.659	1.011	0.940	0.935	0.977	1.147	0.979	0.997
2007	0.816	0.959	0.956	1.062	0.628	1.001	0.964	0.948	0.953	1.096	0.946	0.985
2008	0.800	0.937	0.976	1.086	0.635	1.001	0.973	0.902	0.977	1.049	0.955	0.974
2009	0.769	0.906	0.985	1.077	0.623	0.978	0.983	0.929	0.950	0.996	0.973	1.000
2010	0.759	0.852	1.006	1.074	0.597	1.003	0.995	0.890	0.881	1.049	0.985	0.998
2011	0.744	0.966	1.000	1.076	0.550	0.954	0.993	0.945	0.925	1.049	0.969	0.950

A cross comparison of these groups indicate that only bulk firms group has performed better relative to bulk and formulation and only formulation in case of TFP and technical change. Whereas in case of technical efficiency and scale efficiency change, bulk & formulation firm group has been comparatively better than the other two groups i.e. only formulation and only bulk group.

The table 6.3 depicts the productivity change and its components for big and small firms group. The TFP change for big firms group has been reported in the second column of the table which is showing a consistently decreasing trend from 0.854 (15%) in 2002 to 0.748 (26%) in 2011. The other measures of efficiency such as technical change, technical efficiency and scale efficiency change are showing a mix trend and having no impact on TFP of this group.

Table 6.3: Productivity Changes for Big Firms and Small Firms Group

	Big Firms				Small Firms			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….
2002	0.854	1.135	0.999	1.027	1.117	0.903	1.016	1.102
2003	0.852	1.026	1.010	1.014	1.144	0.960	1.033	1.115
2004	0.841	1.107	0.988	0.997	1.126	0.965	0.998	1.122
2005	0.836	1.094	0.984	1.018	1.124	0.940	1.009	1.124
2006	0.836	1.094	0.984	1.018	1.124	0.940	1.000	1.124
2007	0.818	0.924	0.984	1.027	1.173	0.974	1.017	1.124
2008	0.807	0.957	0.987	1.024	1.161	0.957	1.000	1.121
2009	0.785	0.936	0.999	1.009	1.161	0.897	0.967	1.120
2010	0.769	0.868	1.021	1.024	1.047	0.875	0.991	1.112
2011	0.748	0.936	1.012	1.001	1.073	0.883	0.977	1.095

In case of small firms, the TFP change is positive for all the years and same with scale efficiency change whereas technical change is concerned, it is declining throughout the years. A cross comparison of both the groups reflects that small firms group has been more productive and performed more efficiently than the big firms group in all measures of efficiency except technical change.

Table 6.4 shows the productivity change for the firms with R&D expenditure and without R&D expenditure. The column 2 of the table shows that TFP change for the R&D outlays group of firms which is depicting a declining trend for all the years. The technical change and scale efficiency change are showing a mix trend for some years they are improving and for some other years declining. The technical efficiency change is declining throughout the period. In case of firms without R&D outlays, the TFP change in the first year is positive and then started declined for the remaining years. The other measures of the efficiency revealed the mix trend in this group. Overall firms without R&D have shown better performance in case of TFP change and technical efficiency that is more productive and technically efficient compared to the firms with R&D related outlays.

Table 6.4: Productivity Changes for Firms With and Without R&D Outlays

	R&D				Without R&D			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….
2002	0.766	1.118	0.971	1.020	1.014	0.995	0.994	0.996
2003	0.774	1.011	0.976	1.021	0.961	0.873	0.984	0.999
2004	0.779	1.128	0.956	1.001	0.947	0.920	0.991	0.992
2005	0.793	1.060	0.928	0.988	0.963	1.183	0.991	0.988
2006	0.795	1.060	0.928	0.988	0.963	1.183	0.991	0.988
2007	0.773	1.048	0.921	1.005	0.980	0.847	0.997	0.999
2008	0.765	1.022	0.935	1.010	0.920	0.778	1.000	0.997
2009	0.742	0.948	0.944	1.006	0.894	0.768	1.006	1.008
2010	0.719	0.916	0.977	0.996	0.882	0.766	0.988	0.991
2011	0.696	0.961	0.980	1.003	0.870	0.739	1.003	0.991

The TFP and its different components for total high export intensive firms group and low export intensive firms group have been reported in the table 6.5. The TFP, for total high exporting firms in the second column of the table, is showing a declining trend where as the scale efficiency change is showing positive change throughout the years. The technical change and technical efficiency change have exhibited a mix of improvement and declined. The productivity for total low exporting firm has declined along with technical efficiency and scale efficiency for all time period and the technology has been progressive for all the years except 2011. Comparing both the group, it is clear that the total high export intensive firms are more productive and technically efficient relative to the low export intensive firms group.

Table 6.5: Productivity Changes for High and Low Exporting Firms Group

	High Exporting Firms				Low Exporting Firms			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….
2002	0.920	1.133	0.997	1.084	0.651	1.067	0.937	0.977
2003	0.892	0.901	0.996	1.095	0.662	1.199	0.953	0.979
2004	0.912	1.078	0.993	1.094	0.671	1.084	0.943	0.976
2005	0.902	1.001	1.010	1.109	0.673	1.096	0.919	0.958
2006	0.902	1.001	1.010	1.109	0.673	1.096	0.919	0.958
2007	0.896	0.913	0.986	1.100	0.685	1.062	0.920	0.949
2008	0.888	0.983	0.989	1.106	0.692	1.119	0.916	0.956
2009	0.867	0.940	0.998	1.088	0.693	1.081	0.931	0.971
2010	0.857	0.954	1.020	1.098	0.655	1.067	0.960	0.939
2011	0.847	0.922	1.008	1.093	0.604	0.953	0.962	0.953

Table 6.6 reports the productivity and efficiency change for all firms group over the period of 2001 to 2011. The value 0.781 of TFP change in the year 2002 reflects that the firms have experienced a decline in its average productivity level by around 22% compared to the previous year i.e. 2001. The trend for the TFP for all firms group has shown a declining pattern for all the years. On the other hand, scale efficiency change depicts the positive change for all the years and a value of 1.075 in the year 2002 implies that there is improvement in scale efficiency by around 7.5% compared to 2001. The

technical change shows progress in technology 2 times and for remaining times decline reflecting mix behaviour. The technical efficiency has shown decreasing trend for all the years. Overall on an average the firms have shown productivity decline and technically inefficient performance throughout the period.

Table 6.6: Productivity Changes for All Firms Group

Year	dTFP	dTech	dITE	dISE
2001	….	….	….	….
2002	0.781	1.007	0.964	1.075
2003	0.775	0.908	0.973	1.063
2004	0.779	1.017	0.957	1.046
2005	0.788	0.951	0.927	1.036
2006	0.790	0.951	0.927	1.036
2007	0.774	0.941	0.927	1.045
2008	0.757	0.918	0.934	1.045
2009	0.737	0.848	0.941	1.052
2010	0.712	0.824	0.983	1.034
2011	0.691	0.862	0.984	1.043

6.4.1.1 Comparison of Productivity Change, Technical Change and Efficiency Change of all the Firms:

Table 6.7 shows the indexes comparing TFP change, technical change and efficiency change for all the firm groups for the period of 2001 and 2011. All the measures reported in the table are meaningfully comparable in performance spatially or inter-temporally as the indexes are transitive. The first column shows the estimates of TFP where the firm's group without R&D outlays is the most productive group and only formulation group of the firms is the least productive group in the year 2001. The change in productivity between these two groups is 111% (ΔTFP= 0.775/0.367= 2.11) i.e. the firms without R&D outlays are 111% more productive than the firms producing only formulations in 2001. The second column shows that by the year 2011 only bulk has become the most productive group and only formulation has been the least productive group in Indian pharmaceutical industry. The productivity change between the highest and the least productive group has now come down to 99% (ΔTFP = 0.640/0.321 = 1.99). The third column indicates that during the study period only bulk group experiences the largest 12% increase in productivity. On the other hand, all the remaining groups have shown a decline in productivity over the period of 2001 to 2011. Interestingly, without R&D group experiences the largest decrease in productivity by around 20%. The average estimates of all firms together have been reported in the last row of the table which shows that, on average, the Indian pharmaceutical industry experiences around 11% of productivity decline between the periods 2001 and 2011.

Table 6.7 also reports the estimates of technical change and efficiency components of TFP over the period 2001 to 2011. The third column of TFP* estimates indicates that over the periods between 2001 and 2011 each group in Indian pharmaceutical industry experiences technical regress except the only bulk group that shows technical progress by around 5%. The maximum technical regress has been observed in case of without R&D group of firms by around 26%. The industry as a whole has experienced technical regressed by around 14% (ΔTFP*= 0.611/0.709 = 0.862). Further, table presents the estimates of the technical efficiency and scale efficiency change in the subsequent columns over the period of 2001 to 2011. The third column of ITE estimates reveals that technical efficiency has improved over the periods for all the groups except small, bulk & formulation and R&D group. In case of the scale efficiency change, the estimates show a mixed picture of progress and regress of all groups over time and for industry as a whole it has declined slightly. Overall, the results of the analysis clearly show that the change in productivity is combined effect of technical change and efficiency change.

Table 6.7: TFP Change, Technical Change and Efficiency Change for All Firms Groups: 2001-2011

	TFP			TFP*			ITE			ISE		
Firm's Group	2001	2011	Δ	2001	2011	Δ	2001	2011	Δ	2001	2011	Δ
Indigenous	0.592	0.511	0.862	0.947	0.74	0.782	0.964	0.979	1.016	0.97	0.969	1
MNCs	0.43	0.383	0.89	0.757	0.675	0.891	0.941	0.943	1.002	0.981	0.957	0.976
Big	0.48	0.417	0.868	0.71	0.665	0.936	0.949	0.951	1.002	0.972	0.955	0.982
Small	0.601	0.572	0.952	0.824	0.728	0.883	0.996	0.977	0.981	0.975	0.975	1
Bulk & Formulation Only	0.452	0.39	0.862	0.688	0.664	0.965	0.949	0.948	0.998	0.963	0.981	1.018
Formulation	0.363	0.321	0.885	0.615	0.587	0.954	0.969	0.993	1.024	0.986	0.945	0.959
Only Bulk	0.57	0.64	1.122	0.814	0.853	1.049	0.99	0.969	0.979	0.999	0.95	0.952
R&D	0.372	0.339	0.914	0.647	0.622	0.961	0.921	0.911	0.989	0.956	0.953	0.996
Without R&D	0.775	0.623	0.804	0.994	0.734	0.739	0.995	1	1.005	0.996	1	1.004
High Exporting	0.558	0.509	0.912	0.785	0.723	0.922	0.95	0.975	1.026	0.95	0.975	1.027
Low Exporting	0.393	0.363	0.923	0.612	0.584	0.953	0.962	0.962	1	0.987	0.953	0.966
All	0.373	0.332	0.889	0.709	0.611	0.862	0.916	0.915	0.998	0.952	0.946	0.994

Both technical regress and efficiency falls are acting together and resulting in a decrease in productivity in most of the groups. For example 5% productivity decline in small firms group is the combined effect of 12% technical regress and 2% efficiency fall.

On the other hand, in spite of an efficiency improvement in some groups, they experience a slight fall in productivity due to the falling technical change. In general, these results reveal that the decline in productivity of the firms over the sample period is mainly due to the technical regress. This suggests that there is a scope of improving productivity the Indian pharmaceutical firms by improving technical change.

6.4.2 Analysis of Results of Hicks-Moorsteen Productivity Index:

The results of the analysis of the Hicks-Moorsteen productivity index are given in the following tables. Table 6.8 shows the productivity and efficiency change for indigenous firms group and MNCs group for the period 2001 to 2011. Column 2 of the table depicts the TFP change for the indigenous firms group and a value of 1.087 in 2002 implies that the productivity of the firms has improved by 8.7% compared to 2001.

Table 6.8: Productivity Changes for Indigenous Firms and MNCs firms Group

	Indigenous Firms				MNCs			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….
2002	1.087	0.904	1.006	1.020	1.036	0.965	0.990	1.003
2003	0.982	1.067	1.010	1.000	1.057	1.036	1.003	0.986
2004	1.061	0.856	1.000	0.997	1.030	1.140	0.974	0.993
2005	0.951	1.003	1.002	0.985	1.075	1.289	0.973	0.998
2006	0.994	0.998	1.001	0.999	1.005	1.006	1.003	1.003
2007	1.022	1.020	1.004	1.010	1.003	0.966	0.990	1.014
2008	0.961	1.147	0.976	0.983	1.077	1.060	1.024	1.001
2009	0.960	1.234	1.008	1.004	0.951	0.915	1.015	0.998
2010	0.979	0.825	1.016	1.012	1.002	0.839	1.040	1.000
2011	1.011	1.043	0.994	0.990	1.068	1.188	0.996	0.982

On the other hand, in case of technical change, the value 0.904 in 2002 means that the firms have experienced technical regress by around 10% compared to 2001. The technical efficiency and scale efficiency change have shown positive sign for considerable times. In case of MNCs group, there is productivity improvement in all the years except 2009. The other measures of the efficiency i.e. technical efficiency and scale efficiency, also observed improvement in the performance for a number of times over the sample period. While comparing both the groups, it is obvious that MNCs have performed better that the indigenous firms group.

Table 6.9 reports the productivity and its components for bulk & formulation, only formulation and only bulk firms group. The TFP for bulk & formulation is depicted in the second column of the table. A value of 0.983 in the year 2002 implies that the TFP of this group has declined by around 2 percent when compared with the previous year i.e. 2001. The table indicates an improvement in the productivity for 7 times out of 10 years under consideration i.e. 2003, 04, 05, 06, 07, 10 and 11. The technical change, technical efficiency and scale efficiency change have shown a mix trend for this group. In case of only formulation group, the TFP has shown positive change up to 2008 and then declined up to 2011. The firms from this group have experienced improvement in technical efficiency for a number of years (5 times out of total 10 years considered in the study). Now we consider the case of only bulk firms group, the productivity of the firms from this group has regressed 3 times i.e. 2002, 03 and 09 and for the remaining years it has shown an improvement. If we look at the trend for technical efficiency of this group, we find that out of 10 years under consideration, the firms have observed a positive shift in their frontier for 6 years. A comparison of these three groups of the firms producing various products varieties revealed that the firms producing only formulations have performed relatively better among these three groups and the bulk & formulation have performed comparatively better than the only bulk firms group over the period of 2001 to 2011.

Table 6.9: Productivity Changes for Bulk & Formulation, Only Formulation and Only Bulk Firms Group

	Bulk & Formulation				Only Formulation				Only Bulk			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….	….	….	….	….
2002	0.983	0.756	0.996	1.018	1.121	1.447	0.965	1.014	0.925	1.061	0.992	0.976
2003	1.029	1.101	0.995	0.983	1.041	0.971	1.039	0.995	0.904	1.006	1.000	1.020
2004	1.016	0.886	0.985	1.002	1.030	1.045	0.994	0.990	1.225	0.889	0.997	0.993
2005	1.061	1.200	0.990	0.992	1.092	1.255	0.973	0.950	1.014	1.092	1.000	1.009
2006	1.000	1.000	1.002	0.999	1.001	1.000	0.999	1.000	1.011	1.008	1.000	1.009
2007	1.026	0.838	0.987	1.010	1.030	0.985	1.026	1.014	1.008	0.845	0.966	0.988
2008	0.972	0.947	1.021	1.023	1.098	0.977	1.009	0.951	1.096	1.168	1.009	0.989
2009	0.940	0.980	1.010	0.992	0.985	1.024	1.010	1.030	0.849	0.868	1.019	1.026
2010	1.051	0.939	1.021	0.997	0.969	0.736	1.013	0.958	1.003	0.868	1.012	0.999
2011	1.044	1.193	0.994	1.001	0.980	1.077	0.997	1.062	1.014	1.104	0.984	0.952

Table 6.10 depicts the productivity and its various components for big firms and small firms group. Column 2 reports the TFP change for the big firms and we find that this group has experienced growth in its average productivity for all the years except 2003 and 09. The value 1.057 in 2002 implies that firms have gained productivity growth around 5.7% compared to 2001. The other measures of efficiency have shown mix behavior of ups and down for example if we look at trend for TE there is progress around 6 times but regressed in 2002, 04, 05 and 2011. In case of small firms group, the TFP has declined in the years 2005, and 09 and for remaining years it has improved. The firms have observed the technical progress and growth in technical efficiency around 6 years which implies that technical change and technical efficiency has supported the enhancement in the productivity of the firms from this group. The cross comparison of both the groups indicates that big firms are marginally more productive compared to the small firms but from the point of view of TE and scale efficiency the small firms are relatively more efficient than big firms.

Table 6.10: Productivity Changes for Big Firms and Small Firms Group

	Big Firms				Small Firms			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….
2002	1.057	0.936	0.989	1.007	1.052	1.123	1.004	1.006
2003	0.997	1.000	1.012	0.988	1.079	1.222	1.025	1.011
2004	1.078	1.052	0.978	0.983	1.040	0.838	0.998	1.006
2005	1.038	1.103	0.996	1.021	0.928	0.701	1.002	1.002
2006	1.001	0.997	1.000	1.000	1.015	1.000	0.999	1.023
2007	1.026	0.917	1.001	1.009	1.147	1.293	1.005	1.002
2008	1.036	1.059	1.003	0.997	1.031	1.264	1.000	0.997
2009	0.921	0.954	1.012	0.985	0.671	0.435	0.967	1.000
2010	1.015	0.840	1.021	1.015	1.025	0.951	1.025	0.993
2011	1.101	1.255	0.992	0.977	1.033	1.171	0.986	0.985

Table 6.11 shows the productivity of firms with R&D related expenditure and without R&D expenditure. Column 2 of the table reports the TFP change for R&D firms group and it is clear from the table that the firms from this group have experienced productivity growth for all the years except 2009. From the point of view of the technical efficiency change, this group has observed positive shift in the frontier for about 6 years.

Table 6.11: Productivity Changes for Firms With and Without R&D Outlays

	R&D				Without R&D			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….
2002	1.050	0.943	0.980	1.013	0.938	0.785	0.999	1.001
2003	1.032	1.044	1.005	1.001	0.788	0.862	0.990	1.002
2004	1.012	1.049	0.979	0.980	1.020	0.806	1.008	0.994
2005	1.024	1.227	0.971	0.987	1.160	1.485	1.000	0.996
2006	1.005	1.000	1.002	1.001	1.023	1.051	1.000	1.005
2007	1.022	0.963	0.992	1.017	0.991	0.716	1.007	1.011
2008	1.053	1.015	1.016	1.005	0.813	0.808	1.003	0.998
2009	0.915	0.910	1.009	0.996	1.043	1.279	1.000	1.003
2010	1.024	0.929	1.035	0.990	0.896	0.367	1.011	1.007
2011	1.043	1.135	1.003	1.007	0.853	0.961	1.007	1.019

In case of firms without R&D related outlays, the TFP has declined about 5 times i.e. in the year 2002, 03, 07, 08, 10 and 11; whereas the technical efficiency of this group is concerned it has either progressed or remained constant. Overall R&D firms group has performed well in terms of TFP while the firms group without R&D outlays has performed relatively well in case of technical efficiency. This implies that the technical efficiency is not directly influencing the TFP of the firms.

The productivity change and its various components for the group of total high exporting firms and total low exporting firms are reported in the table 6.12. The TFP for total high exporting firms is shown in the second column. If we look at the trend of productivity of this group, out of 10 years under consideration, the firms have experienced productivity growth for about 6 years. The firms from this group have observed the growth in technology and technical efficiency around 4 and 6 times respectively. Considering the case of total low exporting firms, we find that firms from this group have shown productivity growth in all the years except 2010 and ’11. The progress in technology and technical efficiency has been observed about 7 and 6 times by the firms of this group.

Table 6.12: Productivity Changes for High and Low Exporting Firms Group

	High Exporting Firms				Low Exporting Firms			
Year	dTFP	dTech	dITE	dISE	dTFP	dTech	dITE	dISE
2001	….	….	….	….	….	….	….	….
2002	0.988	0.837	1.015	1.018	1.069	1.069	0.973	0.990
2003	0.989	1.061	0.999	1.010	1.127	1.155	1.018	1.001
2004	0.971	0.674	0.997	0.999	1.032	1.229	0.989	0.998
2005	1.019	1.083	1.017	1.014	1.120	1.208	0.975	0.981
2006	1.011	1.000	1.001	1.000	1.011	1.000	1.004	1.005
2007	1.030	0.940	0.977	0.992	1.040	1.381	1.002	0.990
2008	1.078	1.116	1.003	1.005	1.013	0.747	0.995	1.008
2009	0.946	0.978	1.009	0.984	1.009	0.929	1.016	1.016
2010	1.016	0.894	1.021	1.009	0.972	0.763	1.032	0.966
2011	0.972	0.980	0.988	0.995	0.960	1.021	1.002	1.015

If we look at comparison of the two groups, we find that total low exporting firms group is more productive and technically efficient compared to the total high export intensive firms group.

Table 6.13 shows the TFP change and its components for all firms group for the period 2001 to 2011. In the Column 2, the value 1.052 of TFP for all firms group in the year 2002 implies that compared to 2001, productivity of this group has increased by 5.2%. The trend of the productivity shows that the firms from this group have experienced productivity growth in all the years except 2009 and ’10. The firms in this group have observed technical progress around 6 times. In case of technical efficiency change component, the firms have experienced progress a considerable time; 7 out of 10 times and it has regressed for 3 times i.e. in the year 2002, ‘04 and ’05. For scale efficiency also firms have experienced growth a number of times. Overall it can be concluded that the sector has experienced technical progress and productivity growth for a considerable period of time over the study period.

Table 6.13: Productivity Changes for All Firms Group

Year	dTFP	dTech	dITE	dISE
2001	….	….	….	….
2002	1.052	0.949	0.977	1.024
2003	1.007	1.048	1.010	0.988
2004	1.017	1.021	0.983	0.985
2005	1.041	1.210	0.968	0.990
2006	1.003	1.000	1.000	1.000
2007	1.020	0.920	1.000	1.009
2008	1.037	1.008	1.008	1.000
2009	0.943	0.961	1.007	1.007
2010	0.987	0.874	1.044	0.983
2011	1.018	1.083	1.002	1.009

6.4.2.1 Comparison of Productivity Change, Technical Change and Efficiency Change of all the Firms:

Table 6.14 reports the TFP change, technical change and efficiency change between 2001 and 2011 for all the groups and all firms together. The estimates of TFP in the first column show that small firms are the most productive group whereas the R&D group of firms is the least productive group in 2001. The change in productivity between these two groups is 18% (ΔTFP= 0.990/0.838= 1.18) i.e. the small firms are 18% more productive compare to the R&D group of firms in 2001. The TFP estimates in the second column show that by 2011, without R&D has become the most productive group and R&D remains the least productive group in Indian pharmaceutical industry. The productivity change between the highest and the least productive group has now increased to 88% (ΔTFP = 1.841/0.977 = 1.88). The third column shows that during the sample period only bulk group experiences the largest around 86% increase in productivity whereas, all firms group has shown least improvement in productivity over the period of 2001 to 2011.

The table also shows estimates of technical change and efficiency components of TFP over the sample period. The third column of TFP* estimates reveals that over the periods between 2001 and 2011 each group in Indian pharmaceutical industry experience technical progress except the bulk & formulation group that shows technical regress by around 7%. The maximum technical progress has been observed in case of without R&D group by around 155%. The industry as a whole has experienced technical progress by around 8% (ΔTFP*= 1.387/1.281 = 1.083). Further, the table shows the estimates of the technical efficiency and scale efficiency change in the subsequent columns. The third column of ITE estimates reveals that technical efficiency has improved over the periods for all the groups except small, bulk & formulation and R&D group.

Table 6.14: TFP Change, Technical Change and Efficiency Change: 2001-2011

	TFP			TFP*			ITE			ISE		
Firm's Groups	2001	2011	Δ	2001	2011	Δ	2001	2011	Δ	2001	2011	Δ
Indigenous	0.928	1.315	1.416	1.386	1.739	1.255	0.964	0.979	1.016	0.970	0.969	1.000
MNCs	0.887	1.089	1.228	1.170	1.413	1.208	0.941	0.943	1.002	0.981	0.957	0.976
Big	0.902	1.244	1.379	1.340	1.621	1.210	0.949	0.951	1.002	0.972	0.955	0.982
Small	0.993	1.449	1.459	1.623	1.986	1.224	0.996	0.977	0.981	0.975	0.975	1.000
Bulk & Formulation Only	0.900	1.110	1.234	1.368	1.274	0.931	0.949	0.948	0.998	0.963	0.981	1.018
Formulation	0.938	1.370	1.460	1.229	2.144	1.745	0.969	0.993	1.024	0.986	0.945	0.959
Only Bulk	0.980	1.377	1.405	1.130	1.779	1.574	0.990	0.969	0.979	0.999	0.950	0.952
R&D	0.838	0.977	1.152	1.268	1.351	1.065	0.921	0.911	0.989	0.956	0.953	0.996
Without R&D	0.990	1.841	1.859	1.123	2.864	2.550	0.995	1.000	1.005	0.996	1.000	1.004
High Exporting	0.908	1.220	1.345	1.269	1.384	1.091	0.950	0.975	1.026	0.950	0.975	1.027
Low Exporting	0.923	1.187	1.286	1.329	1.407	1.059	0.961	0.962	1.002	0.986	0.953	0.966
All	0.840	1.000	1.191	1.281	1.387	1.083	0.916	0.915	0.998	0.952	0.946	0.994

The estimates of scale efficiency change show a mixed picture of progress and regress of efficiency for all groups over time and for industry as a whole it has declined slightly. The results of the estimates show that the change in productivity is combined effect of technical change and efficiency change. For example 46% productivity improvement in only formulation group is combined effect of 74% technical progress and 2% efficiency increase. Further the estimates shown in the table suggest that, in spite of efficiency decline, the groups experience productivity improvement due to technical progress i.e., efficiency decline is being fully offsetted by the technical progress which causing an improvement (decline) in productivity. For example, 40% productivity improvement of bulk % formulation is a combined effect of 57% technical progress and 3% efficiency decline. Overall, the analysis reveals that the positive productivity change of the groups over the sample period is mainly due to the technical progress.

6.4.3 Analysis of Results of Malmquist Productivity Index:

Tables 6.15 to 6.20 show the results of the TFP change for all groups of firms considered in the study. Table 6.15 depicts the productivity change and its various components estimated for the indigenous and MNCs groups. In case of indigenous firms group, we find that the group has experienced a growth in efficiency change for 5 times. The value 1.027 in 2002 implies that compared to 2001 firms has moved close to frontier by 2.7 percent. We notice that in the same year there is regress in technical and productivity change. We also notice a growth in productivity change for only 2003, 05 and 11 which is driven by technical change. In case of MNCs group, there is a growth in the technical change in a considerable number of times, but it has been driven by the regress in the efficiency change except in 2008. In 2008, there is an interesting observation that there is growth in productivity change and at the same time efficiency and technical change also shown a positive change. However for the remaining period productivity change is supported positively by technical change and negatively by efficiency change i.e. when efficiency change is regressed, productivity change is progressed. Overall on an average there has been a positive change in technology and productivity over the period of time.

A cross comparison of these two groups indicates that MNCs has benefited most in case of technical and productivity change whereas indigenous firms have performed well in case of efficiency change. Overseas investment with marketing or technical collaboration with foreign MNCs seems to be an attractive strategy for the frontier firms from MNCs group.

Table 6.15: Productivity Changes for Indigenous and MNCs Group of Firms

	Indigenous Firms				MNCs			
year	effch	techch	sech	tfpch	effch	techch	sech	tfpch
2001	….	….	….	….	….	….	….	….
2002	1.027	0.931	1.02	0.957	0.993	1.014	1.003	1.007
2003	1.01	1.04	1	1.05	0.989	1.043	0.986	1.032
2004	0.997	0.983	0.997	0.98	0.967	1.058	0.993	1.022
2005	0.986	1.021	0.985	1.007	0.971	1.098	0.998	1.067
2006	1	0.993	0.999	0.993	1	1	1	1
2007	1.015	0.982	1.01	0.996	1.003	0.979	1.014	0.982
2008	0.96	1.034	0.983	0.993	1.025	1.067	1.001	1.093
2009	1.011	0.969	1.004	0.98	1.012	0.968	0.997	0.979
2010	1.028	0.914	1.012	0.939	1.042	0.948	1.002	0.987
2011	0.983	1.031	0.99	1.014	0.978	1.021	0.982	0.998

In table 6.16 the estimated results the productivity changes and its various components for firms producing various products have been reported. We have justified how the product varieties produced by a firm is associated with their efficiency change. For technical change component, we can justify that firms producing bulk drug and formulation may have accumulated expertise in process as well as in product technology. Further, firms producing both bulk drug and formulation may also enjoy the economies of scope in their innovative activities because of producing different product varieties. For bulk drug, it is expected that firms may have specialized capabilities in process technology and for formulation in product manufacturing. First we consider the case of firms producing bulk drugs; we notice that firms from this group have experienced a growth in its technical change component in the years 2002, 04, 05, 08 and 11. Thus, for example we notice that in 2002 it takes a value of 1.132. More precisely it implies that compared to the production possibility frontier available for firms producing bulk drug in 2001 we find that there was an outward shift in its frontier by about 13 percent. We notice that productivity has regressed in the years 2003, 07, 09 and 10 mainly because the technical change component has also regressed for those years. Thus for example in 2009 the efficiency change registered a growth of about 4.6 percent. However, the technical change has also regressed substantially by an amount of about 13 percent. This has pulled down the total productivity change by about 9 percent. This implies that the technical change component has played an important role for the productivity changes of the firms.

In the case of firms producing both bulk drug and formulation, we notice that the efficiency change regressed by 1 to 2 percent in 2003, 04, 05 and 11 when the corresponding figures for technical change have experienced growth but with fewer margins around 1 to 5 percent. A growth in the efficiency change for the firms is also noticed when we find that technological has regressed.

Overall, we can conclude that performance of the firms from this group have progressed both in terms of its efficiency and technical change component. In case of firm producing only formulation, the growth of productivity change has been observed for the maximum number of times 7 out of 10 years. In the year 2003 we find that productivity change has progressed by 5.2 percent driven by both the growth in technical change by 1.8and efficiency change by 3.4 percent. However, for the remaining period we find that the productivity change of the firms is mainly driven by the technological growth of the firms.

Table 6.16: Productivity Changes for Firms from Different Product Groups

	Bulk and Formulation				Only Formulation				Only Bulk			
Year	effch	techch	sech	tfpch	effch	techch	sech	tfpch	effch	techch	sech	tfpch
2001	….	….	….	….	….	….	….	….	….	….	….	….
2002	1.014	0.951	1.018	0.964	0.979	1.064	1.014	1.042	0.968	1.132	0.976	1.097
2003	0.979	1.056	0.983	1.034	1.034	1.018	0.995	1.052	1.02	0.962	1.02	0.981
2004	0.987	1.02	1.002	1.006	0.984	1.024	0.99	1.008	0.99	1.029	0.993	1.019
2005	0.982	1.057	0.992	1.038	0.924	1.183	0.95	1.093	1.01	1.061	1.009	1.071
2006	1	1.002	1	1.002	1	1	1	1	1	1	1	1
2007	0.997	0.983	1.01	0.98	1.041	0.932	1.014	0.97	0.955	0.963	0.988	0.919
2008	1.044	0.958	1.023	1.001	0.96	1.122	0.951	1.076	0.999	1.159	0.989	1.158
2009	1.001	0.949	0.992	0.95	1.04	0.978	1.03	1.017	1.046	0.879	1.026	0.919
2010	1.018	1	0.997	1.018	0.97	0.919	0.958	0.892	1.011	0.932	0.999	0.942
2011	0.996	1.001	1.001	0.996	1.06	0.982	1.062	1.04	0.937	1.091	0.952	1.022

On a whole a cross comparison of these three product groups indicates that firms producing only formulation benefited most from technological growth followed by firms producing only bulk drugs and firms producing both bulk and formulation. With respect to efficiency-change, we find that firms producing both bulk drugs and formulation performed better as compared to the other groups. This implies that the firms producing both bulk and formulation has benefited from the advantages of vertical integration. This also implies that integrating vertically with the downstream intermediary industry reduces the cost of transaction and, hence, a higher efficiency gain is possible. A close correspondence with efficiency regress and a positive technological growth is uniformly noticed for firms from these three-product groups. This again implies that while the frontier firms from these product groups have benefited from an expansion of their production possibilities due to technological innovation, such benefits have not trickled down to the inefficient firms.

Table 6.17 shows the productivity changes and its various components estimated for the large and small firms group. We first concentrate for the technical change component of the large firms. Column 3 depicts the technical change component for large sized firms. Thus, a value of .988 of technical change for large firms in 2002 implies that compared to the technological frontier in 2001, the frontier for the large firms has shifted down by about 2 percent.

Table 6.17: Productivity Changes for Big Firms and Small Firms Group

	Big Firms				Small Firms			
Year	effch	techch	sech	tfpch	effch	techch	sech	tfpch
2001	….	….	….	….	….	….	….	….
2002	0.996	0.988	1.007	0.983	1.01	0.9	1.006	0.909
2003	0.999	1.024	0.988	1.023	1.011	1.079	1.011	1.091
2004	0.961	1.064	0.983	1.023	1.004	0.875	1.006	0.879
2005	1.017	1.04	1.021	1.057	1.004	0.997	1.002	1.001
2006	1	1	1	1	1	1	1	1
2007	1.01	0.967	1.009	0.976	1	1.022	1	1.022
2008	1	1.049	0.997	1.049	0.997	1.144	0.997	1.141
2009	0.997	0.963	0.985	0.961	0.967	0.806	1	0.779
2010	1.037	0.942	1.015	0.977	1.017	0.945	0.993	0.961
2011	0.969	1.039	0.977	1.007	0.971	1.018	0.985	0.988

If we look at the trend for technical change for large firms we find that out of 10 years under consideration, the large firms have experienced a positive shift in their frontier for about five years. Column 4 explains the scale efficiency change and a value of 0.988 in the year 2003 means compared to 2002 SE has declined by 2 percent. Overall, we observe that the efficiency changes and scale efficiency changes for large firms either has progressed or has remained constant. In case of the TFP change of the group, there have been positive changes for 5 years out of the 10 years under consideration. We also notice that increase in TFP change of firms arises mainly because of positive change in the technical change. We consider now the case of small firms; we find that an outward shift in the technological frontier for the small firms is also noticed in the year 2003, 07, 08, 11. We also notice that on an average even small firm have experienced increase in its technical change component though for a much lesser period as compared to large firms. This is expected because of ‘size factor’ the large firms are better positioned to undertake various forms of innovative activities. Combining our findings from efficiency and productivity analysis, we notice that large sized firms have shown slightly healthy sign of performance on almost all counts but in case of efficiency change the trend has been more or less same.

Table 6.18 shows the productivity changes and its various components for firms with R&D and without R&D outlays. The trend in the technical change for firms with R&D related outlays indicates that out of the 10 years under consideration firms has experienced increment in technical change component for 5 years. This implies that there might be some association between the R&D initiatives of the firms and their technological progress. The trend in the efficiency change component for firms with

R&D related outlays however, revealed more or less similar to the technical change component. The figures for productivity change indicate that on an average firm from this group have experienced productivity progress for 7 years out of 10 years.

Table 6.18: Productivity Changes for Firms With and Without R&D Related Outlays

	Firms Engaged in R&D				Firms Not Engaged in R&D			
Year	Effch	techch	sech	tfpch	effch	techch	sech	tfpch
2001	….	….	….	….	….	….	….	….
2002	0.992	1.019	1.013	1.012	1	0.879	1.001	0.879
2003	1.007	1.02	1.001	1.027	0.992	0.954	1.002	0.946
2004	0.96	1.058	0.98	1.016	1.001	0.914	0.994	0.915
2005	0.958	1.093	0.987	1.047	0.995	1.24	0.996	1.235
2006	1	1.001	1	1.001	1	1	1	1
2007	1.009	0.972	1.017	0.981	1.017	0.883	1.011	0.898
2008	1.021	1.036	1.005	1.058	1.001	0.904	0.998	0.904
2009	1.006	0.954	0.996	0.959	1.003	1.298	1.003	1.303
2010	1.025	0.96	0.99	0.984	1	0.791	1	0.791
2011	1.01	0.999	1.007	1.009	1	0.973	1	0.973

We now consider the case for firms without R&D related outlays, we find that firms from this group have also experienced an outward shift in its production possibility frontier or technical change but for a much lesser number of years. We also notice that firms without any R&D related outlays have experienced a positive value in its TFP change of only in 2005 and 09 mainly driven by technological progress of few frontier firms. In case of SE the performance has been similar as it was in case of R&D group of firms. On a whole, we can conclude that R&D as a group have benefited from technological progress, though it has not reciprocated equivalent among all its members. On the other hand, few firms without any R&D related outlays also experienced an expansion in their production possibility frontier. The efficiency analysis also suggests that R&D has played a negligible role to enhance the capability of the inefficient firms to catch up with the frontier firms. However, it appears that R&D has played an important role for technological growth of the firms.

Table 6.19 reports the productivity change and its various components for the total high exporting firms and the low-exporting firms in the Indian pharmaceutical industry. Now, we compare the productivity change and its various components for these two groups of firms. We have argued that exposure to the international market can benefit firms in terms of positive technical change provided there is technology transfer and collaboration. Such activity arises when firms undertake overseas direct investment through collaboration with host country firms.

Table 6.19: Productivity changes for High and Low Export Intensive Firms Group

	High Export				Low Export			
Year	effch	techch	sech	tfpch	effch	techch	sech	tfpch
2001	….	….	….	….	….	….	….	….
2002	1.034	0.932	1.018	0.963	0.964	1.028	0.99	0.99
2003	1.009	0.977	1.01	0.986	1.019	1.11	1.001	1.131
2004	0.996	0.938	0.999	0.934	0.987	1.08	0.998	1.065
2005	1.031	1.014	1.014	1.045	0.956	1.093	0.981	1.045
2006	1	1	1	1	1	1	1	1
2007	0.969	0.999	0.992	0.968	0.992	1.015	0.99	1.007
2008	1.009	1.084	1.005	1.093	1.002	0.975	1.008	0.977
2009	0.993	0.994	0.984	0.986	1.033	1.005	1.016	1.038
2010	1.03	0.965	1.009	0.995	0.997	0.905	0.966	0.902
2011	0.984	0.998	0.995	0.981	1.018	0.968	1.015	0.985

Let us first consider the technical change component of the high exporting firms. A value of 0.932 in 2002 implies that compared to 2001 the firms from these group have suffered from technical regress by about 7 percent. The corresponding figure for the efficiency change component is 1.034. This implies that compared to 2001 firms have moved closer to the frontier in 2002 by about 3.4 percent not because of their better performance but mainly due to technical regress. We notice that for the same year there has been a positive change in the scale efficiency of the firms by around 1.8 percent. However, the total factor productivity of the firms is regressed by around 4 percent mainly driven by the negative technical change of the inefficient firms.

Moving now to the case of low exporting firms, we find that low export intensive firms have experienced a growth in the technical change component for a longer period 6 years out of 10 years. It is interesting to note here that in 2003 and 09, the technical change, efficiency change and productivity change has registered a growth. For the rest of the years the efficiency change component has either regressed mainly because of a phenomenal rise in the technical change component or has remained constant. On an average the total factor productivity of the firms has progressed with the pace of technical change and efficiency change. On a whole, we can conclude that firms from low export intensive group have benefited most because of technological progress as well as from efficiency change. In case of high exporting firms we find the frontier firms having evenly distributed their market in the regulated and semi-regulated country. Firms from this group seem to be benefited from overseas investments with marketing or technological collaboration with foreign MNCs as explained by Mazumdar (2009). Among the low export-intensive group firms that lie at the realm of technological frontier, also have technological collaboration with foreign partners, spend more on marketing related outlays and have greater automation in the production process.

Table 6.20 shows the productivity changes and its various components for the all firms group. Column 3 depicts the average value of the technical change of all the firms from 2001 onwards. Thus, a value of 0.992 for technical change in 2002 which is closer to unity implies that relative to 2001 the firms have been almost unchanged and a value of 1.025 for technical change in 2003 implies that relative to 2002 the firms had achieved an outward shift in the production frontier by about 2.5 percent.

Table 6.20: Productivity Change for All Firms Group

	All Firms			
Year	effch	techch	sech	tfpch
2001	….	….	….	….
2002	1.001	0.992	1.024	0.993
2003	0.998	1.025	0.988	1.022
2004	0.968	1.046	0.985	1.012
2005	0.959	1.103	0.99	1.057
2006	1	1	1	1
2007	1.009	0.961	1.009	0.97
2008	1.007	1.041	1	1.049
2009	1.015	0.964	1.007	0.978
2010	1.026	0.946	0.983	0.971
2011	1.011	0.997	1.009	1.008

Overall, it can be concluded that the sector has experienced technical progress for a considerable period of time. Such a shift in the frontier may be either because of the entry of new efficient firms in the market with superior technology or because the frontier firms are also experiencing technological change due to new investment.

In context of efficiency change we find that on an average efficiency for the firms in this sector has regressed whenever there has been technological progress. We also notice that whenever the firms have experienced a progress in their efficiency change in years like 2002, 07, 09, 10 and 11 the technology regressed for those years. On a whole, this implies that while technological innovation has offered new production opportunities for the sector, a large chunk of firms have failed to appropriate the benefit of technological innovations. Next we consider the value of TFP change and a value of 1.022 in 2003 implies that compared to 2002 there was a 2 percent increment in the TFP for the firms, whereas a value of .993 in 2002 implies that TFP regressed by only 1 percent. The trend for the value in total factor productivity indicates that on an average the total factor productivity of the firms has progressed whenever the technical change has progressed. In other words, the table suggests that, in spite of efficiency regress in the year 2003, 04, 05 the firms experience productivity improvement due to their improvement in technology i.e., technical progress is being fully offset by the efficiency regress which causing an improvement in productivity. For example, 2.2% productivity improvement in the year 2003 is a combined effect of 2.5% technical progress and 1.8% efficiency decline.

6.5 Concluding Remarks:

The Indian pharmaceutical industry has come a long way since independence when multinational corporations dominated the industry. Over the years, under a favorable policy regime, the industry has grown phenomenally and consolidate its position in a competitive environment. In the present study we have analyzed the productivity and its various components of pharmaceutical firms over the period of 2001 and 2011. The study indicates that the industry has experienced rapid pace of technical progress opening up new production possibilities. However, most of the firms have failed to appropriate the benefits of such technological change. The study further reveals that overall productivity change shows an increasing trend but interestingly this increase in productivity is mainly driven by technical change.

Further, the study categorised the firms on the basis of size, expenditure on R&D and other characteristics. The results of the group wise analysis indicate that there is a positive association between the size of firms and their technical efficiencies and TFP. In turn we may conclude that scale of economies is prevailed in the pharmaceutical industry of India. The results of the study also reveal that inefficient firms investing in R&D related activities have not benefited much to achieve higher efficiency. However, such firms have benefited from technological innovation. This suggests that the efficient firms have benefited most from their R&D related outlays whereas such activities have widened the gap between inefficient and efficient firms. The results indicate that the overall average technical efficiency and productivity change of MNCs group of firms are higher than that of indigenous firms. However in case of efficiency change and scale efficiency change there is no such difference between MNCs and indigenous firms group. The study also reveals in case of productivity and technical change low exporting firms have performed better than high exporting firms group. The study also finds that vertically integrated firms have benefited much from efficiency change whereas firms producing only formulation performed well in terms of technical change and productivity change and the firms producing only bulk performed well in overall average technical efficiency.

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7. Summary and Conclusion

It has been observed that the Indian pharmaceutical industry has affected in a big way due to the changes in various policies related to the implementation of ‘Process Patent’ and ‘Product Patent’ regime and also the policy of liberalisation of Indian economy in the recent years created a dynamic environment in the industry. These changes in various policies related to trade and entry of multinational companies in Indian pharmaceutical industries have started during early seventies. However, the pace of growth of this industry has shown a remarkable upswing only after 1991 and it shows a major jump after 2005. Up to 1970, the Indian pharmaceutical industry was very small in terms of number of firms and production level and largely dominated by the foreign MNCs and therefore remained dependent on external supplies. During 1970s, government of India introduced many policies to promote and encourage the domestic industry by imposing various restrictions on the entry and business operations of the foreign companies in the form of price control, absence of product patents, limiting equity share etc. This led to the drastic change in the industry by laying strong foundation of manufacturing base for bulk drugs and formulations and accelerated the growth of the industry. During the decade of 1990s, as a part of liberalization of Indian economy, all the restrictions, related to trade and entry of foreign firms were reduced leading to highly competitive environment. Moreover, the introduction of pharmaceutical product patents in 2005 attracted the foreign MNCs because of the low manufacturing cost in India and brought new business opportunities to the Indian pharmaceutical industry.

During the last two decades, India has emerged as one of the leading global pharmaceutical players in the world with the help of escalating foreign direct investment in the domestic industry, increasing expenditure on R&D related activities by setting up their own R&D units and collaborating with research laboratories, merger and acquisitions activities and some other strategies such as, contract research and manufacturing services (CRAMS), co-marketing, increasing patent filings. The export performance of the Indian pharmaceutical industry also has been very impressive during this time. At the same time, the increase in competitive pressure has possibly induced the exit of inefficient firms from the markets. Hence in order to survive and maintain the pace of growth in future, the Indian pharmaceutical firms need to further improve their performance in this competitive and dynamic environment.

Research Questions

Indian pharmaceutical industry is undergoing a phase of transition due to policy changes. Under the process patent regime of 1970 the industry flourished with supportive policies of the government of India that were in force for more than three decades. This situation has however, changed in the recent past under the TRIPS, in 1995, and subsequently in 2005, thereby paving the way for product patenting. Taking into consideration all these significant policy changes, which are expected to have important implications for operating performance of the pharmaceutical industry, it has become imperative to analyze the performance of the Indian pharmaceutical firms in terms of efficiency and productivity measurement. The efficiencies of the firms play a major role in dictating the survival and growth of companies in various segments of pharmaceutical industry. It is also important to focus on the efficiency and productivity changes of various groups such as indigenous, MNC, big, small, and firms with and without R&D expenditure etc. It is also important to examine the overall relative performance of all the firms of the Indian pharmaceutical industry.

Study Objectives:

The study aims to evaluate the performance of Indian pharmaceutical industry by examining the levels of technical efficiency and TFP of individual firms from the industry covering the period 1997 to 2011.

The specific objectives of the study are as follows:

1. To present a brief background of pharmaceutical industry in India since independence and examine the implications of process patent regime and product patent regime.
2. To examine the levels of efficiency of pharmaceutical firms in India and discuss the determinants of efficiency.
3. To analyze the relative performance of Indian pharmaceutical industry in the process patent regime and in the product patent regime and undertake a comparison of efficiency gains across different groups of firms.
4. To examine the productivity change of pharmaceutical companies over the period 2001 to 2011.
5. To estimate the technical efficiency of Indian pharmaceutical industry from 1997 to 2011 using the parametric, Stochastic Frontier Analysis (SFA) and non-parametric, Data Envelopment Analysis (DEA) techniques.

Hypotheses:

In this study the following hypotheses are formulated:

- The MNCs group of firms is relatively more efficient compared to the indigenous firms.
- The firms with R&D related outlays are technically more efficient compared to the firms without any R&D related outlays.
- The big firms are more efficient compared to the small firms group.
- The firms producing both bulk and formulation are technically more efficient compared to the firms producing only bulk drugs and only formulations.
- The high export intensive firms are more efficient compared to the low export intensive firms.
- Technical efficiency of firms is not time invariant especially in the post TRIPS and post product patent regime.
- Raw material as an input plays a significant role in explaining firm's outputs such as total sales, profit etc.

Methodology:

The concept of firm's efficiency relates how well a firm employs its resources relative to existing production possibilities frontier. An upward change in efficiency measures the increment in output without a rise in input or the amount by which inputs may be reduced without reducing output. Farell proposed that efficiency of a firm consists of two components namely technical efficiency which reflects the ability of firm to obtain maximal output from a given set of inputs and allocative efficiency which reflects the ability of a firm to use inputs in optimal proportions given their respective prices. In the present study we have confined to the analysis of technical efficiency only, as consistent price data is not available for studying allocative, profit and cost efficiencies. The present study has utilised the parametric; stochastic frontier analysis (SFA) and nonparametric; data envelopment analysis (DEA) and three productivity indexes namely, Malmaquist index, Hicks-Moorsteen index and Fare-Primont index, to compute the efficiency and productivity of Indian pharmaceutical firms.

SFA, developed by Aigner et al. (1977), is a parametric technique that generates a stochastic error term and an inefficiency term by using the residuals from an estimated production frontier. This approach measures the technical inefficiency of a production unit as the ratio of a firm's production over its optimal level. The optimal level is the maximum level of output a firm can achieve given the technology and a given level of inputs represented by a production function or a frontier. The first step of this approach is to estimate the practice frontier obtained from the sample information using their best observations. If a firm produces this optimal level of output it is technically efficient and will be on the frontier. If a firm produces less than the optimal level, it is inefficient and we can measure the degree of technical inefficiency as the distance from each individual observation and a corresponding point on the frontier.

DEA is a mathematical programming technique which is used to measure technical efficiency of the firms. It comes up with a single scalar value as a measure of efficiency. DEA provides the efficiency of each of the firms relative to a given set of firms. These firms are assumed to be in the business of producing various outputs by consuming a set of inputs. Charnes et al. (1978) first developed the DEA technique based on the same concept of technical efficiency given by Farrell (1957). "DEA in essence is a linear programming technique that converts multiple inputs and outputs into a scalar measure of efficiency. Each firm is evaluated against a hypothetical firm with an identical output mix that is constructed as a combination of efficient firms. DEA identifies the most efficient firms in a population and provides a measure of inefficiency for all others. The most efficient firms are rated to have an efficiency score of one, while the less efficient firms score between zero and one. Though DEA does not give a measure of optimal efficiency, it however differentiates the least efficient firms from the set of all firms. Thus, the efficient institutions calculated using DEA establish the best practice frontier" (Siems and Thomas, 1992).

Efficiency of a firm in DEA can be measured as the maximization of a set of outputs (output-oriented) for a given set of inputs or minimization of a set of inputs (input-oriented) for a given set of outputs. The technical efficiency may be measured under the assumptions of either constant returns to scale (CRS) or variable returns to scale (VRS). The CRS assumption is only appropriate when all firms are operating at an optimal scale. Imperfect competition, constraints on finances, and other limitations may hinder the firms to operate at optimal scale. In this context, use of VRS specification would permit the calculation of TE devoid of these SE effects. While TE efficiency refers to manager's capability to utilize firms' given resources SE refers to exploiting scale economies by operating at a point where the production frontier exhibits constant returns to scale. In the present study we have used the VRS specification to measure TE and also calculated SE in addition to CRS.

There are several productivity indexes in the literature for computing the TFP such as Tronqvist index, the Fisher index, and Malmquist index etc which have been extensively used in empirical research. However, both the Tronqvist index and the Fisher index follow neither transitive nor identity axioms, which make them inappropriate to be used to make multi-lateral or multi-temporal comparisons (O'Donnell, 2012). On the other hand, Malmquist productivity index is one of the standard approaches in productivity literature that can be decomposed exhaustively especially in nonparametric specifications (Bjurek, 1996). Recently, two other indexes namely Hicks-Moorsteen TFP index proposed by Bjurek (1996) and Färe-Primont index proposed by O'Donnell (2011) are used in constructing productivity indexes. They are more reliable and can be broken into several components without requiring data on prices and any restrictive assumptions concerning statistical noise.

Empirical Analysis:

The present study has been carried out for the period of 1997 to 2011 which covers the period of post TRIPS and post product patent regime in the Indian pharmaceutical industry. The unit level data on the given inputs and outputs variables, necessary for the computation of efficiency and productivity of Indian pharmaceutical industry for the period from 1997 to 2011, has been compiled from the 'Prowess Database' of Centre for Monitoring Indian Economy (CMIE).

Under SFA, the ML estimates of stochastic frontier function of the firms, group-wise as well as all the firms taken together are presented. The estimates refer to the panel frontier for a given output measure and a set of input variables. Associated with the panel frontier, along with the input coefficients estimates, four parameter estimates namely of σ^2, γ, μ and η are given. Here σ^2 is variance of composite error term i.e. u_{it} and

v_{it}. If it is significant, then one can infer that the difference between actual output and frontier output is because of the factors which are under the control of firms. U_{it} measures the technical effect of the firms and v_{it} (iid normal with mean 0 and variance σ^2_v) captures the effects of omitted variables/ measurement errors. The term γ is the ratio of σ^2_u and σ^2, which measures the extent of the difference between actual output and frontier output, which is due to technical inefficiency. The parameter μ is the mean of the distribution of the u_{it}, assuming that error term follow truncated normal distribution. If μ is not significant then error term will follow half normal distribution. The parameter η shows whether the technical efficiency is time varying or not. If it is significant technical efficiency of the firm will be time varying otherwise it is time invariant. Further, Log likelihood and χ^2 test statistic are computed on the assumption that γ, μ and η are equal to zero.

The technical efficiency measures are given for each of the frontiers, output-wise and firm-group wise over the sample period with a view to comment on the technical efficiency of the pharmaceutical firms. Considering the goals of Indian pharmaceutical industry and previous studies we have considered four measures of outputs (Y_i) namely; (i) total sales (ii) profit and (iii) foreign exchange (forex) earnings and (iv) total assets. The inputs in the model are (i) labour measured in terms of wages and salaries for the workers; (ii) material inputs measured in terms of the companies' expenditure for raw material; (iii) capital the book value for plant and machinery and building; (iv) marketing and advertising cost measured in terms of expenditure on marketing and advertisement.

For measuring the efficiency using DEA, the first step is to specify the inputs and outputs variables of firms. The outputs we have used are total sales, total foreign exchange earnings, profit and total assets. The inputs are labour, raw material, power and fuel, capital, marketing and advertising cost and net fixed assets. Under DEA technical efficiency assuming CRS (crste), technical efficiency assuming VRS (vrste) and scale efficiency (SE) are calculated for firm groups wise as well for all the firms together for the year 1997 to 2011.

The DEA scores at firm level are shown in the study for the input-output combination mentioned as above. The efficiency scores are given for the year 1997, 1999, 2002, 2006, 2009 and 2011. Though scores are generated for all the years in the sample period, results for the select years mentioned above are given the tables for two reasons namely, space constraint and the results being reflecting a similar trend for the intervening years. It may be noted that firms with efficiency score one are said to be on frontier and regarded as technically efficient. Efficiency score less than one indicates technical inefficiency. A score being zero indicates that the firm is totally technically inefficient. As the score of a firm moves away from one it will be away from the frontier.

The Malmquist index (MI) measures the TFP change between two data points by calculating the ratio of the distances of each data point relative to a common technology. The index number is calculated as the geometric mean of these two distance function ratios. MI > 1 indicates productivity growth and MI < 1 productivity decline. To measure the productivity change of a firm for two adjacent periods, two separate frontiers are constructed viz., one for the initial period and other for the target period.

The main rationale for considering the Malmquist index is that can be decomposed into two mutually exclusive and exhaustive components: technical change (TC) and efficiency change (EC) components $i.e., MI = TC \times EC$. We have applied the Fare et al (1989) adjacent period version of the Malmquist productivity index to compute the productivity change and its different components namely the efficiency, technical, and scale efficiency change of the firms.

The Fare-Primont index, recently proposed by O'Donnell (2012), is the only total factor productivity index that can be constructed from distance functions without violating important transitivity and identity axioms from index theory. It also has the important property that it can be exhaustively decomposed into various measures of technical change and efficiency change without having any residual effects. It can be used to compute quantity data only i.e. price data are not required to compute the indexes. The present study uses the Fare-Primont index to compute and decompose total factor productivity into a measure of technical change and several measures of efficiency change of Indian pharmaceutical industry for the period 2001 to 2011.

Hicks-Moorsteen TFP index, proposed by Bjurek (1996), is the multiplicatively-complete index that can be computed without price data. The Hicks-Moorsteen TFP index is the ratio of Malmquist output and input quantity indexes, so named because Diewert (1992) attributes its origins to Hicks (1961) and Moorsteen (1961). The advantage of this approach over the popular Malmquist productivity index is that it is free from any assumptions concerning firm optimising behaviour, the structure of markets, or returns to scale. However, it is fair to say that it is less widely used in applied research than the Malmquist productivity index. It has been introduced partly to avoid the indeterminateness problem of the Malmquist index. The Hicks-Moorsteen index satisfies the determinateness axiom. A Hicks-Moorsteen (or Malmquist TFP) productivity index for the base period t is defined as the ratio of a Malmquist output quantity index at the base period t and a Malmquist input quantity index at the base period t. If the ratio is more than one then there is improvement in productivity level of the firms, otherwise there is a decline in the productivity level.

Main Findings:

From the DEA, the following conclusions emerge:

1. The study reveals that prior to 2005, the sector has witnessed a gradual fall in its efficiency values and after 2005 i.e. the post product patent regime, and the industry has witnessed an increasing trend in the level of efficiency across the groups as well as all firms together.

2. The results of the group wise analysis indicate that there is a positive association between the size of firms and their technical efficiencies.

3. The firms without R&D related outlays have been found more efficient in terms of TE score compared to the firms engaged in R&D activities. The firms with R&D related outlays have not benefited much to achieve higher efficiency.

4. The overall average technical efficiency of MNCs group of firms is higher than that of indigenous firms.

5. The group of firms producing only bulk drugs is technically more efficient compared to the firms producing both bulk and formulation and only formulation group of firms.

From SFA, the following conclusions emerge:

1. The mean technical efficiency (TE) of output for all firm groups has registered a mixed trend. For some outputs it has increased over the period of 1997-2011 and for some others over the same period has decreased. In case of indigenous firms, small firm and only formulation group, the mean TE of all outputs has shown increasing trends. On the other hand, in case of big firms, bulk and formulation, and total high export firms group, the TE of all outputs has decreased except for total assets. With reference to MNCs group, the TE has decreased in total sales and profit outputs whereas it has increased for foreign exchange earnings and total assets. In case of all firms groups, a declining trend has been observed for total sales and profit and for foreign exchange earnings and total assets the TE shows an increasing trend.

2. If we take into consideration the TE for raising total sales, indigenous firms performed more efficiently compared to MNCs group and all other groups of the firms. While in case of forex earning, both MNCs and indigenous group have performed more efficiently compared to the other groups of firms. Likewise, taking into consideration the TE scores for rising profit, R&D firms group performed more efficiently compared to non-R&D group and all other groups of firm in terms of efficiency scores and in case of total assets, MNCs group has

been technically more efficient than indigenous and all other groups of the firms in the industry. Overall in all groups, small firms have performed better than big firms and only formulation group have performed well followed by only bulk group and the bulk and formulation group. Low export intensive firms have been found more efficient compared to high export intensive firms group.

3. In all the firms groups, raw material as an input has emerged the most significant variable influencing total sales and foreign exchange earning.

4. Labour has been found the most significant input variable influencing the profit of firms, and capital has played dominant role in enhancing the total assets of the firms across all the groups and all firms together.

5. On the other hand, the marketing and advertising cost has been found to have marginal influence on firms' output.

6. Technical efficiency has been found to be time varying in almost all the groups of firms.

Findings from productivity analysis;

1. The average productivity change shows an increasing trend but interestingly this increase in productivity is mainly driven by the technical change in all the firm groups and all firms together.

2. The results of the group wise analysis of productivity indicate that the big firms are more productive compared to the small firms which indicates that the economies of scale exist in the Indian pharmaceutical industry.
3. The results of the study also reveal that inefficient firms investing in R&D related activities have not benefited much to achieve higher efficiency. However, such firms have benefited from technological innovation.
4. The results indicate that the overall average productivity change of MNCs group of firms is higher than that of indigenous firms. However in case of efficiency change and scale efficiency change, there is no such difference between MNCs and indigenous firms group.
5. The high exporting firm's group has experienced more efficiency gain than low exporting firms group. However in case of productivity and technical change low exporting firms have performed better than high exporting firms group.
6. The study also finds that vertically integrated firms producing both bulk and formulation have benefited much from efficiency change whereas firms producing only formulation performed well in terms of technical change and productivity change.

Policy Implication of the Findings of the Study:

The pharmaceutical industry has transformed itself over the period of time since independence due to various policy changes that took place in India namely, product patent regime in seventies, economic reforms in nineties and recently implementation of product patent regime in 2005. These have had a significant impact on the efficiency and productivity of the pharmaceutical industry in two different ways namely, witnessing significant changes in the policy environment enabling the firms to expand their operations efficiently under the new liberalized atmosphere, and making them competitive at global level.

Keeping in view the difference in technology, we have classified the firms into various groups based on their size, origin, export performance and expenditure on R&D etc. There are considerable evidences that the observed outputs are less than their respective potential outputs due to technical inefficiency of firms. Based on the methodologies, the study shows that there is a positive association between the size of firms and their technical efficiencies and TFP. In turn we may conclude that scale of economies is prevailed in the pharmaceutical industry of India. The results of the study also reveal that inefficient firms investing in R&D related activities have not benefited much to achieve higher efficiency. However, such firms have benefited from technological innovation. This suggests that the efficient firms have benefited most from their R&D related outlays, whereas such activities have widened the gap between the inefficient and efficient firms. The results indicate that the overall average technical efficiency and productivity change of MNCs group of firms are higher than that of indigenous firms. However in case of efficiency change and scale efficiency change there is no such difference between MNCs and indigenous firms group. This implies that the technological gap between Indian and foreign pharmaceutical firms has to be reduced so that negative spillovers of backward linkages with foreign firms are reduced and made positive. The study also indicates that adopting capital-intensive techniques, importing advanced technology and R&D can ensure technological growth of the frontier firms across all possible groups of firms considered for the study.

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