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A Comparative Analysis of Efficiency and Productivity of the Indian Pharmaceutical Firms: A Malmquist-Meta-Frontier Approach

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A COMPARATIVE ANALYSIS OF EFFICIENCY AND PRODUCTIVITY OF THE INDIAN PHARMACEUTICAL FIRMS: A MALMQUIST-META-FRONTIER APPROACH

Mainak Mazumdar[1] and Meenakshi Rajeev[2]

Abstract

This paper examines the technical efficiency, technological gap ratio (TGR) and productivity change of Indian pharmaceutical firms across different groups. The groups are formed based on their size, strategies and product varieties. The study indicates that vertically integrated firms that produce both bulk drug and formulation exhibit higher technological innovation and efficiency. However, in contrast to the popular belief, the analysis reveals that increased export earnings do not necessarily lead to higher efficiency. We also find that installing capital-intensive techniques or imported technology propel the technological growth of firms.

Introduction

The Indian pharmaceutical sector flourished under the process patent regime of 1970 with supportive policies of the government of India that were in force for more than four decades. Taking flexible provisions of the patent act of 1970 (that recognized only process patent), the Indian firms 'reverse-engineered' the patented innovative products. In most cases, they could eventually come out with better version for the same products. The comparative advantage of the industry was therefore an outcome of the patent act of 1970, which facilitated the Indian producers to create a niche for themselves (Chaudhuri, 1997, 1999; Kumar and Pradhan, 2002).

This situation has however, changed in the recent past. Under the Trade Related Aspect of Intellectual Property Right (TRIPS), India amended the Patent Act of 1970 first in 1995, and subsequently in 2005, thereby paving the way for product patenting. Secondly, as a part of the liberalization policy of 1991, the Drugs and the Cosmetic Act was also amended. The amended act abolished the industrial licensing requirements for all varieties of drugs and reduced the scope of price control. The act also paved the way for removal of trade restriction with automatic approval for foreign ownership up to 100 percent and foreign technology arrangement.

While these changes have brought forth increased competition in the pharma sector from the multinational enterprises (MNEs), it has also opened new opportunities for the Indian pharmaceutical firms. In order to compete effectively with the MNEs Indian firms need to change their age-old strategies. The new emphasis of the domestic firms should be on research and development (R&D) 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. In addition, they can also consider collaboration with foreign firms or merger with firms that allows vertical integration. The implementation of some of these moves however, requires new investment in plant and machinery. Consequently, a large number of small firms that largely populates the Indian pharmaceutical industry may not be able to adopt such strategies. Hence, they may

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not remain competitive. The important question that arises in this context is whether the small firms are indeed left behind in the process of competition, on the other hand, large firms that have adopted some of the new policies for future development have actually succeeded. More specifically, we wish to examine whether in the liberalized regime only a handful of firms, performed better in maximizing its output while many others have lagged behind. This can be studied by undertaking an efficiency analysis. In efficiency analysis, we estimate a frontier with the input output bundle of the best performing firms in the sample. Any shortfall of output that a firm produces with the one that is given by the frontier is its inefficiency. In a sense, the efficiency of the firms captures their ability to catch up with the best performing firms in the sample that employ similar level of inputs. Apart from measuring the efficiency of the firms we also compute the productivity of the firms in our paper. The productivity of a firm defined as the ratio of output to the level of inputs it employs is also closely related to efficiency. A change in the productivity can happen through two routes; one is the change in efficiency in the level of production and the other is the technological change. While the former is understood as the ability of an inefficient firm to catch up with the frontier firms, the latter is understood as the shift in the production possibilities of the frontier firms itself due to technological innovation. Thus by undertaking productivity analysis, we can assess to what extent the firms in the industry has experienced technological innovation by investing in R&D or by installing advanced plants and machinery. We can also analyze whether such innovation has increased the efficiency gap between the frontier firms and other firms in the sample.

A few authors have so far concentrated on the efficiency issue in the context of Indian pharmaceutical industry. Using firm level data for the period 1990 to 2001, Chaudhuri and Das (2006) estimated the efficiency of the Indian pharmaceutical sector using the parametric frontier approach. The study has shown that the mean efficiency scores of the industry have improved over the sub–period 1999 to 2001 against the sub-period 1990-1998. Further, it identifies that large sized firms or firms exporting more of their product in the international market have reduced their inefficiency. The non-parametric DEA approach has also been applied by Majumder (1994), Saranga, and Phani (2002) to study the output efficiency of the Indian pharmaceutical sector. Majumder (1994) studied the capabilities and resource utilisation of the firms by employing the DEA methodology. The study however covers only nine large firms and use data at the pre-liberalization era. The higher level of inefficiency of the public sector firms as compared to the private players are the main findings of the study.

In this paper, we wish to explore the efficiency related issues by not only estimating the efficiency of the pharmaceutical firms but also their technological and the productivity changes. More precisely, we would like to examine how the adoption of new strategies affects the efficiency and technical change of the firms. Also, the existing studies do not consider the fact that access to technology may differ across the firms due to investment in R&D, or due to small scale of operation. A single frontier is often constructed by considering all firms in the industry to compute their efficiency levels. The present study evaluates the relative efficiency of the Indian pharmaceutical firms by acknowledging the differences in their investment capacity. This has been achieved by estimating its efficiency relative to a group specific frontier as well as the global frontier. By adopting this new approach, the paper contributes to the applied empirical research.

Given this background, the rest of the paper unfolds in the following manner. Section 2 outlines the methodology adopted for the study. The data sources are reported in section 3. The main finding from the empirical analysis is presented in section 4. A concluding section follows thereafter.

Methodology

2.1. Classification of firms

To examine the relationship between the efficiency and different types of firms we have classified the firms into various groups keeping in view the differences in the technology. They are firms with R&D expenditure, with larger market share, firms serving the markets abroad and producing different product varieties.

Firms that want to do R&D needs sophisticated equipments to carry out its research activities. If successful in their R&D efforts, the firms can reap substantial benefits in terms of turnover or profit. However, if the effect of R&D is realized over a period of time, a firm may also suffer from high-level inefficiency in the short run because of the 'sunk-cost' incurred for R&D with no visible benefit.

Secondly, as compared to small firms (measured in term of market share) large firms (or firms with higher market share) may enjoy economies of scale or scope in its cost of production, R&D and marketing related activity and may have greater access to resources for upgrading the technology base. Therefore, large firms may have better technology compared to small firms.

Thirdly, firms exploring the global market, produce their product keeping in view the differences in the disease pattern, population structure, and regulatory norms in the global context. Studies also indicate the possibility of technological transfer and collaboration with foreign buyers (see Clerides *et al* 1998, World Bank Report, 1993, 1997) for firms exposed in the international market. Consequently, the production possibilities that firms across these groups face are different from the firms that target the domestic market exclusively.

Finally, based on the products produced firms in the industry are classified into three groups viz., i) firms engaged in the production of bulk drug which is basically the raw-material of medicines ii) firms engaged in the formulation or final product and iii) firms engaged in the production of both the varieties of product. 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.

2.2. Data Envelopment Analysis (DEA) and Efficiency Measurement

We use the non-parametric approach of data envelopment analysis (DEA) introduced by Charnes, Cooper, and Rhodes (1978) and further generalized by Banker, Charnes, and Cooper (1984) to compute the technical inefficiency of the firms.

In order to construct the group specific frontiers, the input and output set of the firms are classified into *H* distinct and exhaustive groups. The study conceptualizes a single output (y) and four input technology. The specific elements of the input bundle (x) are labor, raw material, power-fuel and capital. With the assumption of free disposability of inputs and outputs and convexity of the production possibility set one can empirically construct the technology set and compute inefficiency levels of the firms.

The production possibility set for the kth group of firms is given by the following equation

$$S^k = \{(x,y): x \geq \sum_{t=1991}^{2005}\sum_{j\in k} l_{kjt} x^{kjt}; y \leq \sum_{t=1991}^{2005}\sum_{j\in k} l_{kjt} y^{kjt}; \sum_{t=1991}^{2005}\sum_{j\in k} l_{jt} = 1; l_{kjt} \geq 0; (k = 1,2,.....,H)\} \quad (1)$$

The set S^k is the free disposable hull of the observed input-bundle set of the firms from the k^{th} group. The average efficiency for the j^{th} firms producing y_j^k output from x_j^k input from group k is given by Φ_k^j where $\Phi_j^k = \max\{\Phi : (x_j^k, \Phi y_j^k) \in S^k\}$ and n_k is the number of firms in-group k. A measure of the *within-group* (output-oriented) technical efficiency of the j^{th} firm is given by

$$TE_k^j = \frac{1}{\Phi_k^j} \tag{2}$$

To measure Φ_k^j one solves the following linear programming (LP) model

$$\text{Max}\,\Phi_k^j \quad j = 1(1)N \tag{3}$$

subject to

$$\sum_{j=1}^{N} l_j x_j^k \le x_i^k; \text{ (x= labor, capital, power \& fuel and raw-material)} \tag{4}$$

$$\sum_{j=1}^{N} l_j y_j \ge f^t y_t \tag{5}$$

$$\sum_{j=1}^{N} l_j = 1 \quad \text{and} \quad l_j \ge 0 \quad \text{N = number of firms in the sample} \tag{6}$$

The LP model is solved for each firm in the k^{th} group to derive its output efficiency.

We consider next the technical efficiency of the same j^{th} firm in the k^{th} group relative to the global technological frontier. The *global-frontier,* which is the outer envelope of all the *local frontiers,* consists of the boundary points of the free disposal convex hull of the input-output vector of all firms in the sample and given by the following equation

$$S^G = \{(x,y) : x \ge \sum_{k=1}^{H} \sum_{t=1991}^{2005} \sum_{j \in k} l_{kjt} x^{kjt}; y \le \sum_{k=1}^{H} \sum_{t=1991}^{2005} \sum_{j \in k} l_{kjt} y^{kjt}; \sum_{k=1}^{H} \sum_{t=1991}^{2005} \sum_{j \in k} l_{jt} = 1; l_{kjt} \ge 0; (k = 1,2,.....,H)\} \tag{7}$$

When measured against the global frontier that considers all the firms in the sample, the mean technical efficiency for firms from group k will be given by Φ_G^j where $\Phi_G^j = \max\{\Phi : (x_G^j, \Phi y_G^j) \in S^G\}$.

The technical efficiency of the firm with respect to the global frontier is given by $TE_G^j = \frac{1}{\Phi_G^j}$. Here Φ_G^j is the factor by which the output of the jth firm is scaled up to reach the global frontier.

Thus Φ_G^j = max Φ

$$\text{s.t} \sum_{k=1}^{H} \sum_{j \in k} l_{kj} x_j \le x_k^j \quad \text{; (x = labor, capital, power \& fuel, raw-material)} \tag{8}$$

$$\sum_{k=1}^{H} \sum_{j \in k} l_{kj} y_j \ge f\, y_k^j; \sum_{k=1}^{H} \sum_{j \in k} l_{kj} = 1 \quad l_{kj} \ge 0 \; (k = 1(1)H; j = 1(1)n$$

The Technological Gap Ratio *(TGR*) or Technological Closeness Ratio *(TCR)* of the j^{th} firm is given by (Battese, Rao, and Donnell, 2002, 2004)

$$TGR = \frac{\mathrm{TE}^{\mathrm{j}}_{\mathrm{G}}}{\mathrm{TE}^{\mathrm{j}}_{r}} = \frac{\Phi^{j}_{G}}{\Phi^{j}_{k}} \tag{9}$$

A point wise measure of the distance of group *r* from the global frontier is the geometric mean of b^{j}_{k}, $\left(\prod_{j\in r} b^{j}_{k}\right)^{\frac{1}{n_k}}$ where $b^{j}_{k} = \frac{\mathrm{TE}^{\mathrm{j}}_{\mathrm{G}}}{\mathrm{TE}^{\mathrm{j}}_{k}}$. The ratio is defined in the literature as the technology gap ratio (Battese, Rao, and Donnell, 2002, 2004). TGR captures the distance and hence relative strength of a group to catch up with rest of the firms in the sample. It is therefore a surrogate of performance differential of the firms. Two distinct possibilities can arise in this context. One the efficiency of the firms is high if only the group members are considered, and low if all other firms are considered. This implies that firms from a group are quite efficient amongst themselves. However, because of certain environmental constraint (that may arise due to lagged effect of R&D or the investment undertaken to upgrade its production base, or due to limited market reach etc) the efficiency is low when the canvas of comparison is increased and all other firms are considered in the analysis. Under such circumstances, the group frontier will lie below the global frontier. If however, the efficiency of firms is low with respect to both the group and global frontier, then it implies that only few firms from a group are efficient and the rest of the firms are lagging behind even though they are following similar strategies or have same size of operation. Therefore, the two-way comparison of the efficiency of firms will also help us to locate the frontier firms from each strategic group and will also help us to assess if the frontier firms from a group also constitute the global frontier that is constructed by considering all firms in the sample.

To measure efficiency over time one needs to take into account the availability of technology. We assume sequential technology in our model, that is for any year, say t, the technology or the input-output set of the previous years is available but the input-output set of the future years is not available. The LP model specified above captures this aspect of the technology.

2.3. Malmquist Productivity Index and Productivity of Firms

We have also supplemented our efficiency analysis by computing the productivity change and its different components namely the efficiency and technical change of the firms. We apply the Färe *et al* (1989) adjacent period version of the Malmquist productivity index to compute the productivity of firms. One can refer to the work of Grosskoff (1993, 2003), Färe *et al* (1994) for a detailed illustration on Malmquist productivity index and its different decomposition. Färe *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

$$MI = \left[\frac{D^{t}(x^{t+1}, y^{t+1})}{D^{t}(x^{t}, y^{t})} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t}, y^{t})}\right]^{1/2} \tag{10}$$

where $D^{t}(x^{t}, y^{t})$ = min $\{\Phi^{k}_{j} : (x^{k}_{j}, \Phi^{-1} y^{k}_{j}) \in S^{kt}\}$. The distance function indicates the maximum proportion by which the output bundle of the firm in period t is expanded holding 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 indicate 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 Färe *et al* 1989 for a detailed illustration on Malmquist Index).

$$i.e, MI = TC \times EC \tag{11}$$

where

$$EC = \left[\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}\right] \quad and \quad TC = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}\right] \tag{12}$$

Values greater than one for *TC* indicate 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 period 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.

For measuring the Malmquist productivity index, we have constructed a year wise balanced panel data from our unbalanced panel data set. In other words, for each two adjacent year, we have selected the same firms in order to arrive at the efficiency, technical and the productivity changes of the firms. To solve the distance functions one has to solve standard LP problem however for the same as well as for the cross periods.

Description of Data

We consider firm level information for the years 1991 to 2005. The number of firms in the sample varies from 70 to 289 over the years and in total, we consider an unbalanced panel of 2492 firms for 15 years. The data for analysis are collected from the PROWESS database that provides the balance sheets of the companies registered with the Bombay Stock Exchange. This database is provided by the Centre for Monitoring Indian Economy. The study conceptualized a one output, four input production technology. The ideal way of computing the efficiency is to use the physical volume of output and inputs. However, in the absence of data following standard practice (see Caves and Barton, 1990; Tybout *et al* 1991, Aw et al 2001, Pavcnik, 2002), we use values of production and input. Such an approach can be useful particularly when firms produce differentiated products and product varieties differ across firms. In a sense, the efficiency measures, therefore, closely correspond to indices of revenue per unit of input expenditure.

The output in the current model is the value of total output (y)defined as the total output of the firms plus the change in the stock of output measured in terms of the opening stock minus the closing stock of output. The inputs in the model are (i) labor (l) (measured in terms of wages and salaries for the workers), (ii) material inputs (rw) (measured in terms of the firm's expenditure on raw material), (iii) energy input (pf) (measured in terms of the expenditure on power and fuel and (iv) capital (k) (is the replacement value for plant and machinery and building).

To bring the variables in real terms, each variable is appropriately deflated. The value of output is deflated by the price index for the drug and the pharmaceutical sector collected from the Reserve Bank of India (RBI) monthly bulletins. Expenditure for worker is deflated by the Consumer Price Index (CPI) for both the manual and non-manual workers, expenditure on fuel and power is deflated by the price index for Fuel, Power Lights and Lubricants collected from the RBI bulletins to arrive at the real figure; the firm expenditure on raw–material is deflated by the average price index for chemical and chemical products from the (Annual Survey of Industry, ASI) data base. The capital stock (the figures for plant and machinery and building) is available at historic cost, it has to be converted into asset value at replacement cost. Following Balakrishnan *et al* (2000), and applying the perpetual inventory method (PIM) taking 2003 as the base year, the value of capital at replacement cost for the base year is arrived at by revaluing the base year capital.

Empirical Findings

4.1. Comparing Efficiency of Pharmaceutical firms:

Table 1 summarizes the main findings of our analysis. The second column of the table depicts the value of f (see equation 9) that captures the average inefficiency of the firms. More precisely in 1991, the average efficiency attained by the firms was 81 percent. This implies that on an average further expansion in the output of the firms is possible by about 19 percent without employing any additional inputs. The figures in the table however suggest a persistent fall in the mean efficiency for the sector. 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.

Table no 1: Input and output specific efficiency of the pharmaceutical sector (1991-2005)

(1) Year	(2) Output Efficiency f	(3) Technical change	(4) Efficiency Change	(5) Total factor productivity change
1991	0.811	----	----	----
1992	0.662	1.511	0.641	0.968
1993	0.623	1.134	0.966	1.095
1994	0.603	1.051	1.160	1.219
1995	0.507	0.896	1.037	0.930
1996	0.462	0.591	1.461	0.864
1997	0.418	1.657	0.678	1.122
1998	0.531	0.420	1.879	0.789
1999	0.452	1.764	0.705	1.243
2000	0.415	1.361	0.801	1.090
2001	0.371	0.942	1.002	0.944
2002	0.318	1.713	0.575	0.985
2003	0.307	1.039	0.980	1.017
2004	0.402	1.531	0.856	1.309
2005	0.387	1.326	0.768	1.018

Two distinct possibilities might arise in this context. First, due to technological progress there is an outward shift in the production frontier. As a result, the distance from the frontier for an inefficient firm is increasing. However, its performance may not decline in the absolute sense of the term. Secondly, it may so happen that the inefficiencies of the firms that lie below the frontier worsen in an absolute sense over time. This led us to look at the shift in the frontier or occurrence of technical change.

Column 2 captures the average value of the technical change component of the firms arrived at by solving equations 11, 12 and 13. A value of greater than one for the technical change component implies technological progress whereas a value of less than one implies technological regress. More precisely, a value of 1.511 for technical change in 1992 implies that relative to 1991 the firms had achieved an outward shift in the production frontier by about 51 percent. Figures for technical change component indicate that on an average, the industry has experienced technological progress for ten years. It regressed by 10 % in 1995 (the year when India became a member of WTO) and drastically by 40 % in 1996 and 58% by 1998. Overall, it can be concluded that the sector has experienced technical progress for a considerable period of time. Such a shift in the frontier is possible 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.

However, such shift in the frontier has also magnified the output distance of the firms that lie below the frontier. In other words, it had also regressed the efficiency for the firms in this industry. This is evident from the efficiency change component for the firms summarized in column 4. The efficiency change component captures the relative change in the efficiency of the firms at two different periods. More precisely a value of .641 implies that compared to 1991 the average efficiency of the firms had regressed by 35 percent, whereas a value of 1.46 in 1996 implies that the average efficiency of the firms have improved by 46 percent in 1996 in comparison to their efficiency in 1995. A cross comparison of the trend in efficiency and technical change component implies that on an average efficiency for the firms in this sector has regressed whenever there has been technological progress. We also notice that while on an average firm in this industry have experienced a positive change in their efficiency change component in years like 1995, 1996, 1998 and 2001 the technology also 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 innovation. Such differences in the efficiency and technical change components for the Indian pharmaceutical firms may arise because a large chunk of firms (mainly small firms) in this industry came into business due to the absence of a strong patent regime. Because of absence of patent protection, they never engaged in R&D related activities and thereby lacking products with good margin. Further, there have been little efforts on the part of the firms to upgrade their resource base either by installing advanced plant and machinery or by providing appropriate training to their worker. Thus, they are found to lose the new opportunities that the sector has offered in recent years.

Lastly, we also consider the value of total factor productivity change. A more than unit value for the total factor productivity change again implies a percentage increment in the total factor productivity of the firms. Thus a value of 1.219 in 1994 implies that compared to 1993 there was a 21 percent increment in the total productivity for the firms, whereas a value of .968 in 1992 implies that total factor productivity regressed by only 4 percent. The trend for the value in total factor productivity indicates that on an average the total factor productivity of the firms has regressed whenever the technical change has regressed drastically or when the efficiency change is less than unity. Consider for example the case of 1992, while the technical change has recorded a spectacular growth by about 51 percent the efficiency has also regressed by about 34 percent. Consequently, the total productivity change has also regressed in 1992. This reinforces our earlier arguments

that even though some firms from this sector have experienced technical change, such positive change has not benefited a large chunk of firms in the sample, and hence, on an average, the magnitude for total factor productivity change is less than the magnitude of the technical change and for certain years, it has also regressed.

4.2. Comparison of technical efficiency scores across different groups of firms

4.2.1. Size Specific Efficiency and Productivity Analysis

The Indian Pharmaceutical sector is largely populated by small and tiny firms (about 10,000) and a few large firms resembling a fragmented market structure (Pradhan, 2007). Accordingly, the firms in the sample are classified into two mutually exclusive groups: the large firms and the small firms based on their relative market size. To construct the group for large firms, the following criterion is adopted. Firms in the sample are first arranged in the descending order according to their total market share. The firms, which jointly capture about 75 percent of the market, are defined as the large firms and the rest as small firms.

Table 2: Mean efficiency scores for Large Firms and Small firms

	Small Firms			Large Firms		
(1) YEAR	(2) VRS (global)	(3) VRS (local)	(4) TGR	(5) VRS (global)	(6) VRS (local)	(7) TGR
1991	0.767	0.918	0.836	0.827	0.868	0.953
1992	0.541	0.825	0.656	0.781	0.781	1.000
1993	0.454	0.535	0.642	0.761	0.761	1.000
1994	0.467	0.659	0.709	0.745	0.745	1.000
1995	0.398	0.520	0.766	0.714	0.718	0.993
1996	0.358	0.458	0.782	0.705	0.714	0.988
1997	0.314	0.384	0.817	0.717	0.717	1.000
1998	0.260	0.329	0.790	0.675	0.675	1.000
1999	0.302	0.356	0.849	0.722	0.722	0.999
2000	0.231	0.247	0.860	0.673	0.675	0.998
2001	0.291	0.332	0.876	0.681	0.683	0.998
2002	0.254	0.295	0.861	0.705	0.705	1.000
2003	0.245	0.282	0.867	0.677	0.677	1.000
2004	0.333	0.369	0.903	0.791	0.791	1.000
2005	0.338	0.389	0.868	0.711	0.711	1.000

Table 2 summarizes the mean efficiency scores for the large and the small sized firms. Let us first take the case of small firms. Column 1 shows the mean (geometric mean) efficiency scores of small firms measured against the global frontier constructed by considering all the firms in the sample. A value of .76 in 1991 computed against the global frontier implies that small firms can further maximize its level of production by another 24 percent without employing any additional inputs. However, for the same year the magnitude of efficiency computed against the local frontier stands at around .918 (see column 2). In other words estimated against its own group members on an average small firms cannot increase their level of production by more than 8 percent. The differences in the efficiency between the local and global frontier arises mainly because of 'economies of scale in production'. This is also captured by technological gap ratio (TGR) (or technological closeness ratio, TCR) that is measured as the geometric mean of the ratio of efficiency scores of the first two columns. A high level of TGR does not imply that firms in a specific group are, on an average, more efficient. The TGR of any group is an index of the proximity of the *group* frontier to the *grand* or *meta-frontier* over the relevant range of variation in the input bundles. Bounded naturally between 0 and 1, a high value of the TGR for

any group implies that, on an average, the maximum output producible from an input bundle by a firm required to produce within a group would be almost as high as what could be produced if the firm could choose to locate in the corresponding alternative group. Here the TGR or the TGR captures the distance between the local and global frontier that may arise due to differences in size. A value of .84 in TGR for 1991 implies that small firms can additionally gain an efficiency of around 16 percent just by expanding its scale of operation.

Consider now the efficiency trend of small firms estimated against the global and local frontier. We also notice that there has been a drastic fall in the efficiency level of small sized firms whether estimated against the local or the global frontiers. We find that over the years on an average for small firms the magnitude of efficiency is only 35 percent when estimated against the global frontier. It increases by about 42 percent when computed against the local frontier. The value of TGR also stands at around 80 percent for most of the years whereas for large firms it is close to unity. Comparing the TGR for small and large firms we can conclude that if small firms merge and grow in size it can gain an efficiency of around 20 percent. This also implies that the 'low level of efficiency' for small firms is not just due to the 'size factor' that may arise due to economies of scale in production but also due to other firm specific intrinsic factors. In a related study, Pradhan (2009) noted managerial in competency, low skill, lack of information about market opportunity, lack of new product, price fall in old products, lack of automation in production systems plague a large number of small pharmaceutical firms. This possibly explains the remaining fraction of the inefficiencies of small sized firms.

Let us now consider the case of large sized firms. Column 5 shows the mean (geometric mean) efficiency scores of large firms measured against the global frontier. The efficiency figures of 0.827 estimated against the global frontier in 1991 implies that the large firms have been able to maintain an efficiency level of around 83 percent in 1991. This implies that on an average large firm can further increase its level of production by another 17 percent without any additional employment in the factors of production. The efficiency figure takes a value of 0.868 in 1991 when computed against their own group members or local frontier. Thus, there is a difference of around 4 percent when compared against the local frontier. Such size specific differences in inefficiency for large firms can arise only when there are diseconomies of scale in production. A value of .95 in TGR in 1991 implies if large sized firms that suffer from diseconomies of scale in production reduce its size of operation, it can gain an efficiency of around 5 percent. By examining the efficiency trend of large sized firms, we find that the magnitude and trend in the efficiency level of large sized firms has remained more or less same whether estimated against the local or the global frontier. A unit value of TGR for most of the years implies the local and the global frontier coincides.

We next consider the productivity changes and its various components estimated for the large and small sized firms. We first concentrate for the technical change component of the large firms. Column 3 in table 2 summarizes the technical change component for large sized firms. Thus, a value of 1.648 of technical change for large firms in 1992 implies that compared to the technological frontier in 1991, the frontier for the large firms has shifted up by about 65 percent. For the same year, we again notice that the efficiency change is less than one and takes a value of .61. This implies that compared to 1991 the efficiency of the firms in 1992 has reduced by 39 percent. If we look at the trend for technical change for large firms we find that out of 14 years under consideration, the large firms have experienced a positive shift in their frontier for about nine years. For certain years like 1997, 1999, and 2005 the technical change for large firms is found to be close to 100 percent. Overall, we observe that the efficiency changes for large firms either has progressed or has remained constant. For certain years like 1992, 1997, 1999, 2002 and 2005 the efficiency is found to be regressing but mainly due to an outward shift in the technological frontier.

Lastly, the total factor productivity change that is defined as the product of efficiency and technical change for large sized firms registered a more than unit value for a large number of years (9 out of the 14 under consideration). We also notice that increase in total factor productivity change of firms arises mainly because of positive change in the technical change component.

Table 3: Productivity changes for large and small firms

	Large Firms			Small Firms		
(1) YEAR	(2) Efficiency Change	(3) Technical Change	(4) Productivity Change	(5) Efficiency Change	(6) Technical Change	(7) Productivity Change
1991	----	-----	----	----	----	----
1992	0.616	1.648	1.015	0.992	0.965	0.957
1993	0.973	1.083	1.054	0.796	1.412	1.124
1994	1.175	1.058	1.244	1.151	0.913	1.050
1995	1.075	0.879	0.945	1.014	0.917	0.930
1996	1.599	0.522	0.836	1.212	0.733	0.888
1997	0.671	1.844	1.237	0.769	1.405	1.081
1998	1.960	0.428	0.840	1.810	0.433	0.784
1999	0.701	1.960	1.373	1.437	0.579	0.832
2000	0.810	1.308	1.060	0.801	1.379	1.105
2001	1.072	0.931	0.998	0.997	0.930	0.928
2002	0.676	1.534	1.037	0.554	1.757	0.973
2003	1.403	0.581	0.815	1.423	0.593	0.844
2004	1.113	1.594	1.775	1.079	1.542	1.663
2005	0.496	2.942	1.460	0.477	2.814	1.342

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 1993, 1997, 2000, 02, 04, 05. Thus for example in 1993 the technical change component takes a value of 1.412 for small firms. This implies that compared to 1992 there has been a shift in the production possibility frontier for small sized firms in 1993. 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 due to 'size factor' the large firms are better positioned to undertake various forms of innovative activities.

It is also evident that barring the years 1992 and 2001, when both the efficiency and technical change of small firms regressed, for the rest of the years, the efficiency of the firms regressed whenever there was an outward shift in the production frontier. This is noticed for the years 1993, 1997, 2000, 02, and 05. For the rest of the years there is however some improvement in the efficiency change component of the small firms. However, such improvement does not arise because of the ability of the firms to catch up with its frontier firms but mainly because the frontier firms from this group has suffered from technological regress for those years. More precisely take the case of 1997 and 98. In 1997 on an average small firm experienced a rise in its technical change component by about 40 percent. The corresponding figures for the efficiency change component is however .765. This implies that compared to 1996 efficiency for small firms regressed by about 25 percent. Moving now to the case of 1998, we find a significant rise in efficiency change component by about 81 percent. Such rise in efficiency change component arises because of drastic fall in the technical change component by about 57 percent. This again implies that even among the small firms the inefficiency that is noticed is due to an upward shift in the frontier because of few efficient firms.

Figures for the total factor productivity change also indicates that a more than unit value is observed only when there is positive technological change. Combining our findings from efficiency and productivity analysis, we notice that large sized firms have shown healthy sign of performance on all counts. However, small firms have failed to perform adequately not just because of its size factor but also due to other firm specific intrinsic factors. However, few frontier firms from this group also experienced a spurt in its production possibility frontier due to technological innovation. This also implies that some of the production possibilities that were available to the small firms are now being eliminated due to rapid technological changes being experienced by the frontier firms from this group also.

Generally, it is noticed that all 'small efficient frontier firms' have complied with the good manufacturing requirements set by the Government of India and have also upgraded their technological base by importing foreign technology. The average capital intensity, measured in terms of capital per unit of labor turns out to be around 2.19 for the efficient small firms, whereas for small inefficient firms it is around 1.5. The efficient firms also spend modestly on marketing related activities (about 10 percent of their revenue) besides having overseas operations/collaborations in various semi-regulated developed and developing countries. We also notice that in contrast to small inefficient firms, 'frontier small efficient firms' either has niche products or produce licensed products of the foreign MNCs. All these activities have generated more production possibilities for the small efficient firms, which might have resulted in their technological innovations. Thus, a possible source for a large number of small inefficient firms to gain efficiency and technological innovation would be to adopt capital-intensive technique, enter into technological collaboration with large firms and produce niche products.

4.2.2. Efficiency and productivity Analysis for Firms with and without R&D related outlays

We can now consider the case of R&D; table 4, summarizes the mean efficiency scores for firms with and without any R&D related outlays.

Table 4: Mean efficiency scores for firms with and without R&D unit

	Firms engaged in R&D			Firms not engaged in R&D		
(1) YEAR	(2) VRS (global)	(3) VRS (local)	(4) TGR	(5) VRS (global)	(6) VRS (local)	(7) TGR
1991	0.887	1.000	0.887	0.789	0.796	0.992
1992	0.582	0.662	0.879	0.623	0.774	0.804
1993	0.301	0.646	0.845	0.521	0.542	0.750
1994	0.560	0.654	0.857	0.497	0.631	0.787
1995	0.550	0.616	0.893	0.461	0.501	0.790
1996	0.522	0.575	0.908	0.351	0.436	0.805
1997	0.508	0.556	0.914	0.285	0.359	0.795
1998	0.442	0.453	0.976	0.248	0.322	0.772
1999	0.502	0.559	0.898	0.289	0.366	0.791
2000	0.477	0.525	0.877	0.307	0.366	0.826
2001	0.466	0.488	0.954	0.275	0.328	0.829
2002	0.447	0.476	0.938	0.217	0.263	0.826
2003	0.415	0.455	0.912	0.219	0.250	0.875
2004	0.496	0.540	0.918	0.301	0.348	0.866
2005	0.474	0.519	0.912	0.307	0.359	0.856

Let us first consider the case of firms with R&D related outlays. A value of efficiency at .887 in 1992 estimated against the global frontier implies that when all firms are taken into consideration firms engaged in

R&D activity can further increase their level of production by another 11 percent. However, the efficiency figure takes a value of unity when estimated against the local frontier. This implies that when compared against their group members all firms are efficient and hence no further improvement in efficiency is possible. The TGR also takes a value of .887 in 1991 indicating that the gap between the local and global frontier for firms with R&D activity remains at 11 percent. Since Indian pharmaceutical firms embarked on R&D related activities in the early nineties we find that such differences in TGR arise mainly because of *lagged effect in R&D*. The trend in the efficiency score for this group of firms also indicates a gradual fall in its value. Estimated against the global frontier, the mean efficiency scores for the firms with R&D outlays (over the years) turn out to be around 49 percent. This increases to about 56 percent when measured against the local frontier. The TGR also is also found to be reduced over the years for the R&D group with an average value of around .92. This implies that R&D activities might have played some role to bridge the gap between the local and global frontier.

We consider next the case of firms without any R&D related outlays. We notice that the efficiency score estimated against the global frontier turns out to be .789 in 1991. As already described, this implies that firms from this group can further expand its level of production by around 20 percent when estimated against the global frontier. It takes a value of .796 even when the canvas of comparison is restricted to its own group member. The TGR also takes a value of .99 in 1991. This implies that in 1991 the local frontier for firms without any R&D related activity almost coincides with the global frontier. The trend in the efficiency score also indicates there has been a gradual fall in the efficiency of the firms from this group whether estimated against the local or global frontier. Figures in table 4 also indicate that until 1994, there was not much difference in the mean efficiency scores for firms with R&D units and firms without R&D units. However, from 1994 onwards, the technical efficiency level of R&D firms gradually improved over the firms without any R&D units. We also notice that the TGR has reduced from about .85 to about .91 for firms engaged in R&D. In contrast, the TGR for firms without any R&D units is about .85. *The role of R&D in reducing the gap between the local and the global frontier can be connoted as the R&D efficiency of the firms.* The value of TGR here suggests that on an average if firms without any R&D activities spend for R&D it can gain an efficiency of only 6 percent. R&D efficiency has then played a *negligible role in enhancing the production capability of firms* to catch up with the rest of the firms in the sample. Our analysis therefore reveals that although a large number of firms are investing in R&D related activities, such move has not enabled them to perform better at least in terms of higher efficiency.

Here, also we compare the productivity and its various components for firms with R&D and firms without any R&D related outlays.

Table 5: Productivity changes for Firms with and without any R&D related outlays

	Firms with R&D related outlays			Firms without any R&D related outlays		
(1) YEAR	(2) Efficiency Change	(3) Technical Change	(4) Productivity Change	(5) Efficiency Change	(6) Technical Change	(7) Productivity Change
1991	----	-----	----	----	----	----
1992	0.528	1.700	0.897	1.037	0.927	0.961
1993	1.011	1.065	1.077	0.844	0.335	0.876
1994	1.032	1.342	1.384	1.187	0.864	1.025
1995	1.059	0.875	0.926	0.964	0.923	0.890
1996	1.632	0.506	0.826	1.037	0.842	0.874
1997	0.713	1.661	1.185	1.642	0.616	1.037
1998	1.886	0.404	0.763	1.631	0.495	0.807
1999	0.709	1.775	1.258	0.740	1.111	0.822
2000	1.176	0.650	0.764	0.661	1.792	1.184
2001	0.938	0.981	0.920	0.982	0.950	0.933
2002	0.933	1.044	0.974	0.538	1.815	0.975
2003	1.389	0.584	0.811	1.018	0.812	0.826
2004	1.021	1.629	1.663	1.079	1.542	1.663
2005	0.697	2.063	1.438	0.428	2.950	1.263

The trend in the technical change component for firms with R&D related outlays indicates that out of the 14 years under consideration firms has experienced increment in technical change component for 8 years. This implies that there might be some association between the R&D initiatives of the firms and their technological progress. A phenomenal rise in the technical change of a magnitude of about 50 percent is also noticed in 1992, 97, 99, 04 and 05. The trend in the efficiency change component for firms with R&D related outlays however, revealed that it has drastically regressed only when there was a substantial rise in the technical change component. The figures for productivity change also indicate that on an average firm from this group has experienced productivity progress only when both the efficiency and technical change component has registered a growth or when the magnitude of fall in the efficiency change component is not so large for a corresponding rise in the technical change component.

If we now consider the case for firms without any R&D related outlays, we find that firms from this group has also experienced an outward shift in its production possibility frontier or technical change but for a much lesser number of years. Consider for example the case of 1992; the efficiency change component is 1.037 in 1992. It implies that compared to 1991 in 1992 the firms from this group has reduced its inefficiency gap with the frontier firms by about 3.7 percent. However, the technology has also regressed by 7 percent in the same year. In other words, the efficiency progress that is noticed for this group mainly arises because of downward shift in the production frontier itself. This clearly indicates that firms from this group have been unable to develop its own internal strength to 'catch-up' with the frontier firms. Similar trend is also noticed in 1996, 97, 98 and 2003. We also notice that firms without any R&D related outlays have experienced a more than unit value in its total factor productivity change of significant proportion only in 2000, 04 and 05 mainly driven by technological progress of few frontier 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. This is also evident from a fall in its efficiency change component corresponding to the years when the magnitude of technical change is quite large. 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 best performing ones. However, it appears that R&D has played an important role for technological growth of the firms.

In the next step, we have, investigated the characteristic features of frontier firms in the R&D group. We find a strong association, in a statistical sense, (Krusal –Wallis $?^2$ test to examine the mean differences for technical change across size of R&D intensive firms) between the size of firms that undertake R&D and their technological progress. It is also noticed that frontier firms from R&D group had some technological collaboration with the foreign multinational companies or with the public research institutes. Besides, frontier firms from this group spend heavily on marketing related activities.

We also find that amongst the firms without any R&D related outlays, firms that have invested newly on plant and machinery and taken initiatives to upgrade their technological base by importing foreign technology, are the ones that have experienced a growth in the technical change component. We again notice a strong association, in a statistical sense, between the high capital intensity and the technical change of firms without any R&D units. However, no significant correlation exists between the size of firms and their technological progress across this group.

4.2.3. Efficiency and Productivity Analysis across Firms targeting International and Domestic Market

We next consider the firms targeting the international market. Due to intense competition in the domestic market, many Indian firms are targeting the global generic market to realize a higher price for their product and also increase their market share (Agarwal, 2007). In this paper, the export-oriented firms are classified into two groups viz., the high exporting firms (for firms earning more than 25% of their revenue in the international market) and the low-exporting firms (for firms with an export earning less than or equal to 25%). The rest of the firms are considered non-exporting firms.

Figures in Table 6, summarize the efficiency scores for the export-oriented firms in the Indian pharmaceutical industry. Let us first consider the case of high exporting firms. Compared to the global frontier we find that in 1991 the firms from this group have an efficiency level of around .87. This increases by .927 when we compare the efficiency with respect to their own frontier. In other words, this implies that compared to all firms in the sample the firms can increase its output production by about 13 percent. This however reduces to 8 percent when we compare output production against their own group members. The value of TGR is .90 in 1991; this implies that firms from this group suffered from a technological gap of a magnitude of around 10 percent due to certain environmental constraint. In case of high export intensive group, such constraint can arise due to wrong choice of market or others. The trend in the efficiency component computed against the global and local frontier reveals that a noticeable fall in its value. However, the magnitude of efficiency level has remained at much higher levels compared to its own group member. Particularly, up to 1995 the differences in the efficiency scores have been quite significant compared to the local and global frontier. This implies that firms from this group are quite efficient amongst themselves. The low level TGR of around 65 percent over the years implies that firms could have performed much better if they have relocated themselves in other group by following a different strategy.

In the next step, we have therefore compared the efficiency scores from the low exporting firms and firms targeting only the domestic market to understand how best the firms could have performed if they would have relocated in those groups. We first consider the case of low exporting firms. We find that compared to the global frontier the efficiency level is around .74 in 1991 for low exporting firms. This improves to .78 when we estimate its efficiency considering only its own group members. A value of TGR of about .95 (that is close of

almost unity) indicate that group frontier also lies close to the global frontier. However, in the subsequent years, the magnitude of efficiency level has reduced and the differences in the efficiency scores between the local and global frontier has also magnified though not by significant proportion. We thus find that on an average TGR takes a value of .85 for the rest of the years

Cross comparison of the efficiency scores calculated for the high and the low export intensive group, however, reveals two interesting trends. First, on an average, it is noticed that until 1996, average efficiency scores for the firms from high export intensive group, was higher than the firms from the low export intensive group do (when compared to the global frontier). However, we find a rise in the average efficiency of firms from the low–export intensive group from 1997 onwards. Secondly, the efficiency scores calculated as against the local frontier are found to be higher for the high export intensive group than for the low export intensive one. Comparing the TGR for firms across these two groups indicates that the local frontier for the low export intensive group lies closer to the global frontier. The value of TGR also reveals that if firms from the high export intensive group re-orient its strategies and maintain a balance between the global and domestic market they can on an average, gain efficiency of around 20 percent.

Table 6: Mean efficiency scores for the high export intensive, low export intensive and non-exporting group of firms

(1) YEAR	HIGH EXPORTING FIRMS			LOW EXPORTING FIRMS			NON-EXPORTING FIRMS		
	(2) VRS (global)	(3) VRS (local)	(4) TGR	(5) VRS (global)	(6) VRS (local)	(7) TGR	(8) VRS (global)	(9) VRS (local)	(10) TGR
1991	0.874	0.927	0.909	0.740	0.781	0.948	0.854	1.000	0.854
1992	0.694	0.900	0.771	0.585	0.642	0.911	0.566	0.916	0.618
1993	0.646	0.910	0.710	0.552	0.618	0.893	0.415	0.701	0.591
1994	0.561	0.944	0.594	0.535	0.631	0.848	0.528	0.645	0.751
1995	0.538	0.771	0.698	0.469	0.542	0.865	0.395	0.534	0.740
1996	0.513	0.686	0.749	0.401	0.466	0.862	0.394	0.538	0.731
1997	0.359	0.423	0.598	0.436	0.511	0.852	0.303	0.393	0.805
1998	0.332	0.555	0.480	0.385	0.422	0.913	0.223	0.316	0.706
1999	0.362	0.453	0.599	0.413	0.466	0.848	0.326	0.413	0.790
2000	0.388	0.638	0.608	0.423	0.476	0.889	0.280	0.371	0.753
2001	0.327	0.336	0.716	0.421	0.470	0.896	0.264	0.336	0.785
2002	0.340	0.503	0.675	0.378	0.426	0.887	0.198	0.250	0.790
2003	0.343	0.503	0.683	0.365	0.425	0.860	0.172	0.209	0.820
2004	0.435	0.600	0.725	0.452	0.500	0.905	0.261	0.337	0.776
2005	0.438	0.646	0.678	0.470	0.528	0.891	0.228	0.291	0.784

The result appears counter-intuitive because majority of the exporters from the high export intensive group export their products to the unregulated markets of the less developed countries. The unregulated market also resembles the perfectly competitive market condition. There is almost cost free entry condition and even small firms with negligible resource base can export their products without undertaking any substantial risk (Chaudhuri, 2005, pp-186). To gain the market share, the producers in those markets pursue the strategy of price cut. Consequently, this may result in very poor price realization. A few large firms from this group have also targeted the regulated markets of the US. To comply with the legal and regulatory barriers of the US, the firms have invested heavily on plant and machinery. While the cost of investment is high, the return on such investment turned out to be low because the incumbent foreign firms have their own established brand name. Thus, even the large sized firms from this group have incurred losses. On the other hand, most of the firms from the low export intensive group (almost 65 percent) have targeted the semi-regulated market of the European

Union (EU) where there is some entry barrier in terms of product standard and good manufacturing practice. As a result, on an average, the price realizations are found to be higher.

Finally, we compare the efficiency of the firms that target only the domestic market. As usual, we find that the magnitude of efficiency computed against the global frontier is much lower compared to the local frontier. Consider for example the case in 1992, the mean efficiency score estimated against the global frontier turned out to be .556, while it is about .916 when estimated against the local frontier. This implies that local frontier for firms targeting the domestic market lie way below the global frontier in 1992. A value of TGR at around .614 indicates that the inefficiency that we notice for this group is not because of its bad performance but due to wrong choice of market, perhaps due to its exclusive focus in the domestic market. The trend in the efficiency scores estimated against the local and global frontier clearly indicates a drastic fall in its value. Thus, for example in 1992, the mean efficiency scores estimated against the global frontier turned out to be .566 and it sharply reduced to about .22 in 2005. The situation improves to a moderate extent when we compare their efficiency with respect to its own peer group members. This is also captured by the value of TGR, which fluctuates at around .74 over the years. In other words, an additional efficiency improvement of a magnitude of around 25 percent is possible by just focusing for the global market.

A cross comparison of efficiency scores of the exporting firms and the firms targeting only the domestic market reveals that, on an average, firms exporting their product in the international market have always fared better. However, if we compare the average efficiency figures estimated against local frontier for firms without export earnings with the low-exporting firms we notice that up to 1996 on an average even firms from this group have performed equivalently. However, differences in the efficiency scores estimated against the global frontier for these two groups of firms are striking. This clearly indicates that if firms targeting the domestic market would have opted for the semi-regulated or even unregulated global market a higher efficiency gain of a magnitude of around 20 percent is possible. However, from 1997 onward the efficiency of the firms has deteriorated even when they are compared against the local frontier. Such a case might have arisen because almost all the firms exposed in the global market have some sort of collaboration with the foreign firms. There might be a possibility of technological transfer and collaboration with foreign firms (see Clerides *et al* 1998, World Bank Report, 1993, 1997) for firms exposed in the international market that might have facilitated to gain higher efficiency.

We next compare the productivity change and its various components for these three 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 7: Productivity scores for the high export intensive, low export intensive and firms targeting domestic market

(1) YEAR	HIGH EXPORTING FIRMS			LOW EXPORTING FIRMS			NON-EXPORTING FIRMS		
	(2) Efficiency Change	(3) Technical Change	(4) Productivity Change	(5) Efficiency Change	(6) Technical Change	(7) Productivity Change	(8) Efficiency Change	(9) Technical Change	(10) Productivity Change
1991	-----	-----	-----	-----	------	------	----	------	-----
1992	1.158	0.901	1.044	0.612	1.585	0.970	0.995	0.815	0.811
1993	0.965	1.101	1.062	1.042	1.012	1.054	0.908	1.374	1.247
1994	1.019	1.054	1.074	1.026	1.280	1.313	1.201	0.860	1.033
1995	0.894	0.978	0.874	1.077	0.887	0.955	0.901	0.945	0.852
1996	1.109	0.862	0.956	1.540	0.516	0.796	1.484	0.562	0.833
1997	0.890	1.051	0.935	0.601	2.170	1.305	0.887	1.215	1.078
1998	1.061	0.845	0.897	2.080	0.387	0.806	1.402	0.506	0.710
1999	0.861	1.243	1.069	0.637	2.142	1.365	1.009	1.028	1.037
2000	1.303	0.939	1.223	1.082	1.036	1.121	1.841	0.617	1.136
2001	0.800	1.021	0.817	0.908	1.010	0.917	1.185	0.911	1.079
2002	1.102	0.836	0.921	0.901	1.130	1.018	0.515	1.830	0.942
2003	1.110	0.815	0.905	1.500	0.529	0.793	1.096	0.729	0.799
2004	0.977	1.746	1.705	1.033	1.580	1.633	0.946	1.718	1.625
2005	0.898	1.461	1.312	0.668	2.386	1.594	0.487	2.565	1.250

Let us first consider the technical change component of the high exporting firms. A value of .901 in 1992 implies that compared to 1991 the firms from these group have suffered from technical regress by about 10 percent. The corresponding figure for the efficiency change component is 1.158. This implies that compared to 1991 firms have moved closer to the frontier in 1992 by about 16 percent not because of their better performance but mainly due to technical regress. We notice that for the same year there has been a change in the total factor productivity of the firms by a magnitude of around 4 percent mainly driven by the positive efficiency change of the inefficient firms. The trend in the technical change component for the high exporting firms reveals that a more than unit change in its technology is noticed significantly in 1993, 99, 04 and 05. There has also been a marginal upward shift in the production frontier in 94, 97 and 02 by a magnitude of around 2 to 5 percent. For the rest of the years the technology has however regressed. The figures in the efficiency change component indicate that its direction of change is driven mainly by technical change component. In other words, the inefficient firms have moved closer to the frontier only when the technology for this group has regressed or its distance from the frontier has magnified only when there was an outward shift in the production frontier due to technological progress. On an average, we also notice a growth in the productivity changes for a significantly number of times driven mainly by the efficiency or the technological change of the firms. More precisely, we find that on an average in 1992 and 2002 total efficiency change or the catching up effect of the firms mainly drives the total productivity growth of the firms. It must be remembered here that a positive efficiency change of a magnitude of 15 and 30 percent that is noticed for those years arises mainly because of technological regress.

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 and with higher magnitude. Thus a value of 2.170 in 1997, 2.142 in 1999 and 2.386 in 2005 implies that firms from the low export intensive group has registered a more than 100 percent change in its technical change for those years. Barring the years in 1995, 96, 98 and 2003, we find that for the rest of the years firms also experienced technological progress by significant proportion.

The efficiency change component that captures the relative change in the efficiency of the firms at two different periods indicates more than unit value for a significant number of times. It is interesting to note here that in 1993, 94, 2000 and 04, both the technical and efficiency change has registered a value of more than

unity. In other words, there has been technical progress and at the same time, the inefficient firms from these group have catch up with the frontier firms from this group. 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. Lastly, the trend for the total productivity change component for the firms implies that on an average the total factor productivity of the firms has regressed whenever the technical change has regressed drastically or when the efficiency change is less than unity. Thus for example in 1996 although the efficiency change takes a value of 1.541 the technology for the same year has however regressed by 50 percent pulling down the value of total factor productivity by 30 percent compared to what was achieved by the firms in 1995. 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.

Lastly, we consider the case of firms targeting the domestic market. A look into the technical change component for firms from this group implies that the technical change component either has remained close to unit or regressed for most of the years. We notice that in 1992, 97, 99, 2002, 03, and 04 the technical change has progressed even for firms targeting the domestic market. Obviously, the sources of technological change are different from firms that target only the global market. Here also, we notice the efficiency change regressing whenever there was an outward shift in the technological frontier for firms from this group. In other words, we find that few firms from this group have experienced a unit change in their technical change component. However, such shift in the frontier has also magnified the output distance of the firms that lie below the frontier. In other words, it had also regressed the efficiency for the firms in this industry. Figures for total factor productivity changes for firms from this group also indicate it has regressed for most of the years. We find that the technical change of the frontier firms played an important role for the productivity growth of firms from these group. More precisely, we notice that in 1993, 2004 and 05 the technological growth for firms is as high 37 percent, 71 percent and 150 percent. This has also reciprocated into a growth in the total productivity change by about 42, 62 and 25 percent. The discrepancy arises mainly because of efficiency regress. This led us to look into the characteristics features of the frontier firms from this group. In this regard, we have also examined the characteristics features of the frontier firms from the high exporting and low exporting group.

Examining the characteristic features of the frontier firms from these three groups revealed certain interesting facts. First, among the high export intensive group, we found the frontier firms having evenly distributed their market in the regulated and semi-regulated country. Overseas investments with marketing or technological collaboration with foreign MNCs seem to be an attractive strategy for the frontier firms from this group. However, firms that have undertaken overseas investment without any foreign collaboration have failed to appropriate adequate benefits. A large proportion of small sized firms from high export intensive group were found to have experienced technological change mainly due to imported technology and increased automation in the production process.

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. Here we do not find any association between the size of firms and the technical change that they experience. Firms that target the domestic market and experience an outward shift in its technological frontier are relatively new entrants, capital intensive and spend more on imported technology. Further, firms from this group also have some form of association with the foreign or the domestic multi-national firms (mainly in the form of contract manufacturing) producing niche products.

4.2.4. Comparing the Efficiency and Productivity of firms from different product groups

The figures in Table 8 summarize the mean efficiency scores for firms from different product groups. We first consider the case of firms producing both bulk drug and formulation.

Table 8. Mean efficiency scores of firms from different product groups

(1)	BULK DRUG			BULK AND FORMULATION			FORMULATION		
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
YEAR	VRS(global)	VRS(local)	TGR	VRS(global)	VRS(local)	TGR	VRS(global)	VRS(local)	TGR
1991	0.853	0.906	0.942	0.734	0.778	0.944	0.630	0.917	0.758
1992	0.629	0.847	0.742	0.605	0.627	0.966	0.421	0.913	0.675
1993	0.588	0.725	0.811	0.632	0.667	0.948	0.375	0.856	0.591
1994	0.535	0.638	0.839	0.587	0.665	0.882	0.375	0.855	0.596
1995	0.458	0.458	1.000	0.539	0.559	0.965	0.332	0.614	0.701
1996	0.403	0.459	0.879	0.526	0.632	0.832	0.301	0.534	0.709
1997	0.352	0.412	0.855	0.518	0.668	0.775	0.241	0.470	0.658
1998	0.304	0.385	0.790	0.509	0.622	0.818	0.216	0.401	0.715
1999	0.316	0.391	0.808	0.489	0.573	0.852	0.227	0.415	0.688
2000	0.328	0.371	0.882	0.379	0.536	0.708	0.279	0.504	0.836
2001	0.273	0.319	0.856	0.457	0.507	0.900	0.223	0.444	0.708
2002	0.285	0.279	0.858	0.444	0.471	0.942	0.180	0.441	0.603
2003	0.270	0.347	0.777	0.392	0.415	0.946	0.158	0.347	0.777
2004	0.379	0.502	0.754	0.464	0.483	0.962	0.229	0.529	0.630
2005	0.337	0.537	0.627	0.441	0.464	0.950	0.233	0.581	0.587

A cross comparison of efficiency levels for firms producing both bulk drug and formulation against the local and global frontier indicates that until 1995 no noticeable differences in the efficiency score is observed. Thus, for example in 1992 we notice that the efficiency score computed against the global frontier is .605. 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 40 percent without employing any additional inputs. Similarly, with respect to the group specific local frontier we find its efficiency score is .63. Thus, there has been a marginal improvement in its efficiency performance when we compare the firms amongst themselves. The technological gap ratio here captures the benefit that accrues to a firm by producing a different product mix. We find that until 1993 the group frontier has remained close to global frontier. The trend in TGR signifies that the distance magnified after 1995, though not by significant proportion. However, from 2001 onwards the local frontier has moved closer to the global frontier. In other words, this implies that there exist marginal differences in the efficiency scores of firms computed against the local and global frontier. The trend in the efficiency of the firms estimated against the local and global frontier also indicates a gradual fall in its value. This again implies that few firms from this group have either become efficient pulling the frontier outward or the performance of the inefficient firms have deteriorated in the absolute sense of the term. To check for such possibility we have to look into the productivity changes of the firms. However, before we describe our findings from the productivity analysis let us first consider the case of firms producing bulk drug and formulation. A cross comparison of the efficiency scores measured against the local and global frontiers for firms producing bulk drug again reveals a gradual fall in its efficiency. However, discrepancy is noticed in the efficiency score computed against the local and global frontier. Thus for example in 1992 the efficiency score estimated against the local frontier turned out to be .62, it increases to .85 when we estimate it against the global frontier. In other words, firms are quite efficient when they are compared amongst themselves and a fraction of the low level of efficiency that is noticed when it is computed against the global frontier mainly arises because of wrong product mix. A value of .74 for

the TGR in 1992 indicates that firms can gain an additional efficiency of around 20 percent by changing its product mix.

We also find a similar trend in the efficiency scores for firms producing only formulation. More precisely, we notice that firms producing formulation are moderately efficient when they are compared amongst themselves. It reduces by an margin of 15 to 20 percent when the canvas of comparison is expanded and a global frontier is constructed. A cross comparison of the efficiency estimated against the local and global for all these three group indicates that firms producing both bulk drug and formulation are the most efficient ones followed by the firms producing only formulation and firms producing bulk drug. Among the firms producing only formulation or bulk drug we find that, firms producing formulation are the most efficient ones when they are compared amongst themselves. It is even close to the efficiency score computed against the local frontier for firms producing both bulk drug and formulation.

Together this indicates that in the context of the Indian Pharmaceutical industry, the vertically linked firms producing both bulk drug and formulation are the most efficient ones in the industry. This also implies that integrating vertically with the downstream intermediary industry reduces the cost of transaction and, hence, a higher efficiency gain is possible. The value of TGR indicates that if firms, producing only formulation or bulk drug, re-orient their production strategies in order to produce both categories of product, a significant gain in the efficiency level can be achieved by them that can be as high as 30 percent for formulation group and 10 to 20 percent for bulk drug groups for certain years.

In the next step, we have also estimated the productivity changes and its various components for different product groups. 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. Thus, they might have experienced innovation on both the front. Further, firms producing both bulk drug and formulation may also enjoy the economies of scope in their innovative activities because of producing different product varities. For bulk drug, it is expected that firms may have specialized capabilities in process technology and for formulation in product manufacturing.

Table 9: Productivity scores of firms from different product groups

	BULK			BULK AND FORMULATION			FORMULATION		
(1) YEAR	(2) Efficiency Change	(3) Technical Change	(4) Productivity Change	(5) Efficiency Change	(6) Technical Change	(7) Productivity Change	(8) Efficiency Change	(9) Technical Change	(10) Productivity Change
1991	------	-----	-----	-----	------	------	------	-----	------
1992	1.097	0.947	1.039	0.617	1.449	0.895	0.984	1.009	0.993
1993	0.663	1.821	1.207	1.096	1.013	1.111	0.985	0.987	0.972
1994	1.217	0.862	1.050	1.032	1.358	1.401	0.910	1.432	1.304
1995	1.076	0.835	0.899	1.014	0.944	0.956	0.895	1.022	0.915
1996	1.125	0.792	0.891	1.496	0.565	0.846	1.675	0.503	0.842
1997	0.762	1.314	1.001	0.651	1.914	1.246	0.696	1.665	1.159
1998	2.275	0.386	0.878	1.237	0.611	0.756	1.856	0.435	0.808
1999	0.793	1.505	1.194	0.624	1.892	1.180	0.914	1.460	1.335
2000	0.915	1.239	1.134	2.065	0.616	1.272	0.992	0.974	0.966
2001	0.909	0.959	0.872	0.957	1.067	1.021	0.891	0.983	0.876
2002	1.035	0.980	1.014	0.861	1.194	1.028	0.625	1.515	0.946
2003	1.312	0.629	0.825	1.361	0.583	0.794	1.136	0.701	0.796
2004	0.991	1.804	1.788	1.074	1.500	1.612	1.027	1.531	1.572
2005	0.755	1.622	1.225	0.401	3.327	1.333	0.974	1.621	1.578

We take the case of firms producing bulk drugs first; we notice that firms from this group have experienced a more than unit value in its technical change component in years like 1993, 97, 99, 2000, 04 and 05. The magnitude of technical change is also high for those years. Thus, for example we notice that in 1993 it takes a value of 1.821. More precisely it implies that compared to the production possibility frontier available for firms producing bulk drug in 1992 we find that there was an outward shift in its frontier by about 82 percent. A close correspondence with efficiency regress and a positive technological growth is noticed for firms from this product group. Thus, for example we notice that efficiency has regressed by 36 percent in 1993 when there was a technological progress. We also notice similar trend in 1997, 99, 2000, 04 and 05. For the rest of years on an average we find that efficiency change has registered a more than unitary change in its value, the corresponding figures for technical change is however less than unity. This implies that even few frontier firms from this group has experienced technological growth that has not equivalently diffused among the inefficient firms leading to a rise in its inefficiency over the years. Here also we notice that productivity has regressed in the years 1995, 96, 98 2001 and 2002 mainly because the technical change component has also regressed for those years. Thus for example in 1998 the efficiency change registered a growth of about more than 127 percent. However, the technical change has also regressed substantially by an amount of about 72 percent. This has pulled down the total productivity change by about 20 percent. This implies that the technical change component has played an important role for the productivity changes of the firms. This again motivated us to examine the frontier firms for bulk drugs. Before we narrate the characteristics of the frontier firms producing bulk drug let us describe the productivity changes and its component for firms producing bulk drug and formulation, and firms producing formulation.

We first consider the case of firms producing both bulk drug and formulation. The technical change component for this group of firms reveals that firms producing both bulk drug and formulation have experienced technological progress for a maximum number of years (9 out of 14 years under consideration). For certain years like 1997, 1999 and 2005 there has been a phenomenal rise in the technical change for even close to 100 percent. Even the efficiency change component registered a positive change for more than 100 percent value for a substantial period. We also notice that in 1993, 94 and 2004 firm from this group has registered a more than unit value in its efficiency change component. Here also we notice that the efficiency change regressed substantially in 1992, 1997, 1999 and 2005 when the corresponding figures for technical change has experienced a percent growth for close to 100 percent. A substantial growth in the efficiency change for the firms is also noticed when we find that technological has regressed. On a whole, we can conclude that performance of the firms from this group have progressed both in terms of its efficiency and technical change component. Thus, for example in 1994 we find a productivity growth of around 40 percent. This is driven both by the growth in the magnitude of efficiency change by about 3 percent in its efficiency change component and 35 percent in their technical change component. However, here also the frontier firms have played an important role for the inefficiency change of the firms that lies below the frontier. Thus for example in 2005 the group as a whole has experienced a technical change of around 232 percent. However, the efficiency change has regressed by 60 percent. In other words such high shift in the production possibility frontier has not benefited a large chunk of firms that lay below the frontier, thereby the magnitude of total productivity change for the group as a whole has progressed by only 33 percent.

Lastly, considering the case of firm producing only formulation we find that firms from this group have also experienced a more than unit change in its technical change component for a considerable number of times. A value of 1.43, 1.66, 1.46, 1.51, 1.53 and 1.62 in 1994, 97, 99, 2000, 04 and 05 implies that compared to previous years firms producing formulation have experienced a change in their technical change component by

about 50 percent. However, the efficiency change component either regressed or remained constant. It is also noticed that firms has moved closed to the frontier firms by an magnitude of about 67 percent, 85 percent and 13 percent in 1996, 1998 and 2003. The corresponding figures for the technical change also suggest that technological has regressed substantially for those years. We also find that the productivity changes of the firms is mainly driven by the technological growth of the firms.

On a whole a cross comparison of the technical change across firms from these three product groups again indicate that firms producing both bulk drug and formulation benefited most from technological growth followed by firms producing formulation and firms producing bulk drug. With respect to efficiency-change, we have, found that firms producing bulk drugs performed better as compared to firms producing formulation per se. 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. Comparing the characteristics features of frontier firms from all these product groups with the inefficiency ones reveal some common features. First, the frontier firms producing both bulk drug and formulation, are comparatively large, and spend more on R&D (about 8 to 10 percent of their revenue). A moderate proportion of small firms producing bulk drug have also experienced technological growth. However, the source of technological growth for these firms lies mainly in terms of adapting to capital-intensive techniques. Firms from this group also spend heavily on marketing related activities. Firms that lie at the realm of the frontier technology and produce only bulk drug or formulation, have some association with the domestic multi-national companies in the form of contract manufacturing and contract R&D. We also find that frontier firms producing only bulk drug or formulation possess or produce either niche products or licensed products of the foreign MNCs.

Conclusion and Policy Implication

The Indian pharmaceutical firms have flourished because of the absence of patent protection and various preferential policies of the government. While the protected ambience has enabled the firms to gain competency in process engineering, a large fraction of the firm, also lack genuine product for competing in the changed scenario. On the contrary, our study indicates that the sector has experienced rapid pace of technological progress opening up new production possibilities. However, most of the firms have failed to appropriate the benefits of such technological change. This has resulted in rising inefficiency in this sector.

A cross comparison of efficiency and technical change indicates that most of the large sized 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. Since many small firms do not have adequate funds and resources to upgrade their technological base, availability of low cost finance could be a viable policy option for assisting the firms to avail of the new production possibilities. Another important policy option could be the clustering of small pharmaceutical enterprises. Since small enterprises suffer from various forms of size-related constraints, clustering the firms based on common spatial location and pooling resources for co-operative research, joint marketing and trading activities could be an effective strategy.

Our study also reveals that R&D as a strategy has not benefited much to achieve higher efficiency. However, firms pursuing the strategy R&D have benefited from technological innovation. This suggests that the efficient firms have benefited most from their R&D related outlays, whereas such activities have magnified the

distance between the inefficient and efficient firms. This implies that government should encourage the R&D environment of the country, which was historically low, and that it should also remove the obstacles for facilitating better participation of the firms in R&D related activities.

The study also indicates 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. We have argued in that if firms target the regulated market where the entry barrier is more, they can realize a higher price for their product. However, exporting a product in the regulated market is not so easy given the stringent requirement for quality control and good manufacturing practice; for that, a firm has to invest substantially in plant and machinery. However, not all firms have the financial capacity and resources to upgrade their production system on par with the international standards. In the meanwhile, firms can target the semi-regulated or the unregulated global market for which the regulatory norms are not so stringent but the returns are more; and they can target the regulated market in the long run. We also notice that firms that are large and have invested more on R&D, have benefited from technological growth. Thus, increasing the scale of operation backed by sufficient R&D activity, can be an effective strategy for firms to expand their production possibilities and thereby enabling themselves to realize high margin.

We also find that in the context of the Indian pharmaceutical industry merging vertically with the downstream raw-material firms could be an extremely effective strategy for firms to benefit from efficiency and technological gains. Also, firms producing only bulk drug and formulation, should identify their own competency and produce specialized products backed by marketing efforts.

Lastly, our study also indicate that embracing capital-intensive techniques, importing advanced technology can ensure technological growth of the frontier firms across all possible groups of firms conceived for the analysis of our study.

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