*International Journal of Business and Economics*, 2009, Vol. 8, No. 2, 159-181

# Comparing the Efficiency and Productivity of the Indian Pharmaceutical Firms: A Malmquist-Meta-Frontier Approach

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**Abstract**

This paper examines the technical efficiency, technological gap ratio, and productivity change of Indian pharmaceutical firms across different groups. The groups are formed based on size, strategies, and product varieties. The analysis indicates that vertically integrated firms that produce both bulk drug and formulation exhibit higher technological innovation and efficiency. However, in contrast with popular belief, the analysis reveals that increased export earnings do not necessarily lead to higher efficiency.

*Key words*: data envelopment analysis; efficiency; global frontier; group frontier; pharmaceutical; technological gap ratio; Malmquist productivity index

*JEL classification*: C14; C61; D21; L6

## 1. Introduction

The Indian pharmaceutical industry flourished under the process patent regime of 1970. Taking flexible provisions of the patent act of 1970, which recognized only process patent, the Indian firms "reverse-engineered" the patented innovative products of foreign multinationals. In most cases, they eventually came out with better versions than the original products. The comparative advantage of the industry

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Received September 21, 2009, accepted October 11, 2009.
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is therefore an outcome of the patent act of 1970, which facilitated the Indian producers to carve a niche for itself (Chaudhuri, 1997).

This situation has however, changed in the recent past. Under the Trade Related Aspects of Intellectual Property Rights, India amended the Patent Act of 1970 first in 1995 and again in 2005, thereby paving the way for product patenting. Second, 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 restrictions, with automatic approval for foreign ownership up to 100% and foreign technology arrangement.

While these changes have brought forth increased competition in the pharmaceutical sector from multinational enterprises (MNEs), it has also opened new opportunities for 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 shift its operational base in the global market, and also 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 merging with firms that allow vertical integration. The implementation of some of these moves however, requires new investment in plant and machinery. Consequently, the large number of small firms that populate the Indian pharmaceutical industry may not be able to adopt such strategies. Hence, they may not remain competitive.

The important question that arises in this context is whether the small firms were indeed left behind in the process of competition while 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 this paper, we consider two important performance indicators: efficiency and productivity of firms.

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.

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: a change in efficiency in the level of production and 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 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 studied the efficiency issue in the Indian pharmaceutical industry. Using firm level data for the period 1990–2001, Chaudhuri and Das (2006) estimated the efficiency of the Indian pharmaceutical sector using the parametric frontier approach. They found that the mean efficiency scores of the industry improved over the sub-period 1999–2001 against the sub-period 1990–1998. Further, they found evidence that large firms or firms exporting more of their product in the international market reduced their inefficiency. The non-parametric DEA approach was applied by Majumder (1994) and Saranga and Phani (2002) to study the output efficiency of the Indian pharmaceutical sector. Majumder (1994) studied the capabilities and resource utilization of the firms. The study, however, covered only nine large firms and used data from 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 estimating not only the efficiency of the pharmaceutical firms but also their technological and productivity changes. More precisely, we would like to examine how the adoption of new strategies has affected the efficiency and technical change of the firms. Also, 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.

The rest of the paper unfolds as follows. Section 2 outlines the methodology adopted for the study. Data sources are reported in Section 3. The main finding from the empirical analysis is presented in Section 4. A concluding section follows.

## 2. Methodology

### 2.1 Classification of Firms

To examine the relationship between the efficiency and different categories of firms, we classified firms into various groups keeping in view the diverse production opportunities that they encounter. In the Indian pharmaceutical industry, differences in the opportunities among the firms arise mainly because of the R&D focus, the focus on the global market, the size of the firm, and product varieties.

Let us first take the case of R&D. Firms successful in their R&D or innovation efforts can come out with new methods or technological processes. Consequently, the opportunities that firms from this group face are different from those faced by firms without any R&D unit.

Second, as compared to small firms, as measured in terms of market share, large firms (i.e., firms with higher market share) may enjoy economies of scale or scope in costs of production, R&D, and marketing-related activity. They may also have greater access to resources for upgrading the technology base. Therefore, large firms may have better access to production opportunities compared to small firms.

Third, pharmaceutical firms exploring the global market keep in view differences in disease patterns, 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 in 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: (i) firms engaged in the production of bulk drug, which is basically the raw material of medicine, (ii) firms engaged in the production of formulation or final product, and (iii) firms engaged in the production of both varieties of product. Production of alternative varieties of a drug is also closely related to the structure of the firms. Thus, firms producing bulk drug compete vertically in the intermediate goods 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 and Efficiency Measurement

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

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 (denoted $y$), four-input technology. The specific elements of the input bundle (denoted $x$) 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 efficiency levels of the firms.

The production possibility set for the $k$ th firm group in year $t$ is then:

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

The set $S^{kt}$ is the free disposable hull of the observed input-bundle set of the firms in group $k$ in year $t$. Let $n_{kt}$ denote the total number of firms in this group in this year. The average efficiency for the $i$ th firm in this group, producing output $y_i^{kt}$ from input $x_i^{kt}$, is given by $\Phi_i^{kt} = \max\{\Phi : (x_i^{kt}, \Phi y_i^{kt}) \in S^{kt}\}$. A measure of the *within-group* (output-oriented) technical efficiency of firm $i$ in year $t$ is:

$$TE_i^{kt} = \frac{1}{\Phi_i^{kt}} . \tag{2}$$

To measure $\Phi_i^{kt}$, one solves the following linear programming (LP) model:

$$\max \Phi_i^{kt}, i = 1,\ldots,n_k \tag{3}$$

$$\text{s.t.} \sum_{j=1}^{n_{kt}} \sum_{t=1991}^{2005} \lambda_{jt} x_j^{kt} \le x_i^{kt} , \tag{4}$$

$$\sum_{j=1}^{n_{kt}} \sum_{t=1991}^{2005} \lambda_{jt} y_j^{kt} \ge \phi_i^k y_i^{kt} , \tag{5}$$

$$\sum_{j=1}^{n_{kt}} \sum_{t=1991}^{2005} \lambda_{jt} = 1 \text{, and } \lambda_{jt} \ge 0 . \tag{6}$$

The LP model is solved for each firm in group $k$ to derive its output efficiency.

We next consider the technical efficiency of the same firm $i$ in group $k$ 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 is given by:

$$\begin{aligned} S^{Gt} = \{(x,y) : x \ge \sum_{k=1}^{H} \sum_{t=1991}^{2005} \sum_{j\in k} \lambda_{kjt} x^{kjt},\ y \le \sum_{k=1}^{H} \sum_{t=1991}^{2005} \sum_{j\in k} \lambda_{kjt} y^{kjt}, \\ \sum_{k=1}^{H} \sum_{t=1991}^{2005} \sum_{j\in k} \lambda_{jt} = 1,\ \lambda_{kjt} \ge 0,\ k = 1,\ldots,H\}. \end{aligned} \tag{7}$$

When measured against the global frontier that considers all the firms in the sample, the mean technical efficiency for firms from group $k$ in the year $t$ is given by $\Phi_i^{Gt} = \max\{\Phi : (x_i^{Gt}, \Phi y_i^{Gt}) \in S^{Gt}\}$ .

The technical efficiency of the firm with respect to the global frontier is given by $TE_i^{Gt} = 1/\Phi_i^{Gt}$ . Here $\Phi_i^{Gt}$ is the factor by which the output of firm $i$ is scaled up to reach the global frontier. Thus, the associated LP is:

$$\begin{aligned} &\Phi_i^{Gt} = \max \Phi \\ &\text{s.t.} \sum_{k=1}^{H} \sum_{t=1991}^{2005} \sum_{j\in k} \lambda_{kjt} x_j^{kt} \le x_i^{kt} , \\ &\sum_{k=1}^{H} \sum_{t=1991}^{2005} \sum_{j\in k} \lambda_{kjt} y_j^{kt} \ge \phi\, y_i^{kt} , \\ &\sum_{k=1}^{H} \sum_{t=1991}^{2005} \sum_{j\in k} \lambda_{kjt} = 1 ,\ \lambda_{kjt} \ge 0 ,\ k = 1,\ldots,H \text{, and } j = 1,\ldots,n , \end{aligned} \tag{8}$$

where $n$ is the total number of firms in the sample. The technological gap ratio (TGR) of firm $i$ in year $t$ is given by Battese and Rao (2002) and Battese et al. (2004):

$$TGR = \frac{\mathrm{TE}_i^{Gt}}{\mathrm{TE}_i^{kt}} = \frac{\Phi_i^{Gt}}{\Phi_i^{kt}} . \quad (9)$$

A pointwise measure of the distance of group $k$ in year $t$ from the global frontier is the geometric mean of $\beta_i^{kt} = \mathrm{TE}_i^{Gt} / \mathrm{TE}_i^{kt}$, i.e., $(\prod_{j \in r} \beta_i^{kt})^{1/n_{kt}}$. The ratio is defined in the literature as the TGR for the group. The efficiency of a firm with respect to the global frontier can then be decomposed into the product of the group-specific efficiency and the gap between the group and the global frontier (Battese et al., 2004).

To measure efficiency over time, one needs to take into account the availability of technology. We assume sequential technology in our model; that is, in each year $t$, the technology or the input-output set of the previous years is available but the input-output set of 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 supplement our efficiency analysis by computing the productivity change and its components: the efficiency and technical change of the firms. We apply the Färe et al. (1989) version of the Malmquist productivity index to compute the productivity of firms. See Grosskoff (1993, 2003) and Färe et al. (1994) for a detailed illustration of the Malmquist productivity index and its different decompositions. The Färe et al. (1989) adjacent version of the Malmquist productivity index is defined in terms of Shepherd distance function for periods $t$ and $t+1$ as:

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

where $D^t(x^t, y^t) = \min\{\Phi_j^k : (x_j^k, \Phi^{-1} y_j^k) \in S^{kt}\}$. 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 $D^t(x^{t+1}, y^{t+1}) / D^t(x^t, y^t)$ 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 $D^{t+1}(x^{t+1}, y^{t+1}) / D^{t+1}(x^t, y^t)$.

The index number is calculated as the geometric mean of these two distance function ratios. $MI > 1$ indicates productivity growth and $MI < 1$ indicates productivity decline. To measure the productivity change of a firm for two adjacent periods, two separate frontiers are constructed, one for the initial period and other for the target period. The main rationale for considering the Malmquist index is that it 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 discussion of the Malmquist index) as follows:

$$MI = TC \times EC \tag{11}$$

where

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

Values of TC greater than 1 indicate progress in technical change whereas values less than 1 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 the empirical context, the TC component represents change in the best practice technology, while the EC component represents adoption of best practices.

To measure the Malmquist productivity index, we constructed a year wise balanced panel data set from our unbalanced panel data set. In other words, for two adjacent years, we have selected the same firms in order to arrive at the efficiency and technical and productivity changes of the firms. To solve the distance functions, we solved the LP problems for the same as well as for the cross periods (see Ray, 2004).

## 3. Description of Data

We consider firm-level information for the years 1991–2005. 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 were collected from the PROWESS database, which provides 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 for instance 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 produced by the firms plus the change in the stock of output as measured in terms of the opening stock minus the closing stock of output. The inputs in the model are (i) labor as measured in terms of wages and salaries for the workers, (ii) material inputs as measured in terms of the firm's expenditure on raw material, (iii) energy input as measured in terms of the expenditure on power and fuel, and (iv) capital as measured in terms of the replacement value for plant, machinery, and building.

To bring the variables into 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 workers is deflated by the Consumer Price Index for both the manual and non-manual workers, for fuel and power by the price index for Fuel, Power Lights and Lubricants collected from the RBI bulletins, and for raw material by the average price index for chemical and chemical products from the Annual Survey of Industry database. The capital stock is available as book value for plant and machinery, therefore the perpetual inventory method (see Balakrishnan et al., 2000) is used to deflate the value of capital, treating 2003 as the benchmark year.

## 4. Empirical Findings

### 4.1 Comparing Efficiency of Pharmaceutical firms

Table 1 summarizes the main findings of our analysis. The second column, the value of $\Phi$ from (8), captures the average efficiency of the firms. More precisely, in 1991, the average efficiency attained by the firms was 81%. This implies that, on average, about 19% further expansion in the output of the firms was possible without employing any additional inputs. The figures in the table, however, suggest a persistent fall in the mean efficiency for the sector. The consistent fall in mean efficiency for the sector also implies that, compared to the output produced by frontier firms, the production levels of inefficient firms are falling over the years.

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. Second, the efficiencies of the firms that lie below the frontier may worsen in an absolute sense over the study period. This led us to look at the shift in the frontier, i.e., the occurrence of technical change.

The third column of Table 1 captures the average value of the technical change component of the firms arrived at by computing the Malmquist productivity index. A value of MI greater than 1 for the technical change component implies technological progress whereas a value less than 1 implies technological regress. More precisely, a value of 1.511 for technical change in 1992 implies that, relative to 1991, the firms achieved an outward shift in the production frontier by about 51%. Estimates for the technical change component indicate that, on average, the industry experienced technological progress for 10 years. It regressed by 10% in 1995 (when India joined the World Trade Organization) and by 40% and 58% in 1996 and 1998, respectively. Overall, it can be concluded that the sector 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.

**Table 1. Input- and Output-Specific Efficiency of the Pharmaceutical Sector, 1991–2005**

| (1) Year | (2) Output efficiency | (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 |

The shift in the frontier magnifies the output distance of the firms that lie below the frontier. In other words, the efficiency of the firms in this industry appears to have regressed more when compared with this advancing target. This is evident from the efficiency change component for the firms summarized in the fourth column. The efficiency change component captures the relative change in the efficiency of the firms at two different periods. More precisely, a value of 0.641 implies that compared to 1991 the average efficiency of the firms had regressed by 35%. A comparison of the trends in the efficiency and technical change components implies that, on average, efficiency for the firms in this sector regressed whenever there is technological progress. We also notice that, while on average firms in this industry experienced increment growth in efficiency in years like 1995, 1996, 1998, and 2001, technological change regressed in those years. On the whole, this implies that, while technological innovation has offered new production opportunities for the sector, a large number of firms have failed to appropriate the benefit of technological innovation. Such a case may arise for the Indian pharmaceutical firms because a large chunk of firms (mainly small firms) in this industry came into business due to the absence of product patent. Because of the absence of patent protection, most of these firms were not engaged in R&D related activities and therefore lacked products with good margin. Further, there have been few efforts on the part of the firms to upgrade their resource base by installing advanced plant and machinery or providing appropriate training to their workers. Thus, they are found to miss the new opportunities that the sector has offered in recent years.

Last, we also consider the value of total factor productivity change, reported in the fifth column of Table 1. 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 22% increment in the total factor productivity for the firms. The trend for the value in total factor productivity indicates that, on average, the total factor productivity of the firms regressed when the technical change regressed drastically or when the efficiency change was less than 1. Consider for example 1992. While technical change recorded a spectacular growth of about 51%, the efficiency regressed by about 34%. Consequently, the total productivity change 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 number of firms, and, hence, on average, the total factor productivity changed less than 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 about 10,000 small and very small firms and by a few large firms resembling a fragmented market structure (Pradhan, 2007). Accordingly, the firms in the sample are classified into small and large firms based on their relative market size as follows. Firms in the sample are first sorted in the descending order by market share. Then the largest firms that jointly capture about 75% of the market are defined as the large firms, and the rest are small firms.

Table 2 summarizes the mean efficiency scores for the small and large firms. The second column shows the (geometric) mean efficiency scores of small firms measured against the global frontier. A value of 0.76 in 1991 computed against the global frontier implies that small firms could further maximize their level of production by another 24% without employing any additional inputs. However, in the same year, the magnitude of efficiency computed against the local frontier stands at around 0.918 (see the third column). In other words, estimated against its own group members, on average, small firms cannot increase their level of production by more than 8%. 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 the TGR, the geometric mean of the ratio of efficiency scores in the second and third columns. TGR is an index of proximity of the local frontier to the global frontier. Bounded between 0 and 1, a value of TGR close to 1 does not necessarily imply that a firm is efficient. It only indicates that, on average, the maximum output that a firm could produce within a group would be almost same even if it had chosen to locate in the corresponding alternative group. Here the TGR captures the distance between the local and global frontier that may arise *due to differences in size*. A value of 0.84 in TGR for 1991 implies that small firms could additionally gain an efficiency of around 16% just by expanding its scale of operation.

**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 |

Consider now the efficiency trend of small firms. We also notice that there has been a fall in the efficiency levels of small firms, whether it is estimated against the local or the global frontier. We find that over the years, on average, for small firms the magnitude of efficiency is only 35% when estimated against the global frontier. It increases to 42% when estimated against the local frontier. The value of TGR also stands at around 80% in most years, whereas for large firms it is close to 100%. Comparing the TGR for small and large firms, we can infer that if small firms merge and grow in size, they can gain an efficiency of around 20%. This also implies that the "low level of efficiency" for small firms is not just due to the "size factor" that may arise from economies of scale in production but also due to other firm-specific intrinsic factors. In a related study, Pradhan (2009) noted that managerial incompetence, low skill, lack of information about market opportunity, lack of new product, falling prices in old products, and lack of automation in production systems plague a large number of small pharmaceutical firms. These explanations may account for the remaining fraction of the inefficiencies of small firms.

The trend in the efficiency scores for the large firms implies that the efficiency level has remained more or less the same whether we estimate it against the local or the global frontier. A unit value of TGR for most years implies that the local and the global frontier coincide.

We next consider productivity changes and its various components, estimated separately for the small and large firms. We first concentrate on the technical change component of large firms. The statistics (available upon request) indicate that, out of the 14 years under consideration, large firms experienced a positive shift in their frontier for about 9 years. For certain years, like 1997, 1999, and 2005, the technical change for large firms was close to 100%. Overall, we observe that the efficiency changes for large firms have either progressed or have remained constant. For certain years, like 1992, 1997, 1999, 2002, and 2005, the efficiency regressed, mainly due to an outward shift in the technological frontier.

Last, the total factor productivity change exceeded 1 for many (9 out of the 14) years. We also notice that total factor productivity change increases mainly because of the technical change component.

We consider next the case of small firms. We find that an outward shift in the technological frontier for the small firms is observed in 1993, 1997, 2000, 2002, 2004, and 2005. We also notice that, on average, even small firm experienced increases in the technical change component, though for a much shorter period than large firms. This is to be expected due to the size factor: large firms are better positioned to undertake various forms of innovative activities.

It is also evident that, barring 1992 and 2001 when both the efficiency and technical change of small firms regressed, the efficiency of the firms regressed whenever there was an outward shift in the production frontier. This is noticed in 1993, 1997, 2000, 2002, and 2005. In the remaining years, however, there is some improvement in the efficiency change component of small firms. Yet such improvement does not arise because of the ability of the firms to catch up with the frontier firms from the group but rather mainly because there was technological regress for those years. More precisely, consider the years 1997 and 1998. In 1997, on average, small firms experienced a rise of about 40% in the technical change component, and the efficiency for small firms also regressed by about 25% in the same year. Moving now to 1998, we find a rise of about 81% in the efficiency change component. However, the technology has also regressed by about 57%. This again implies that, even among the small firms, the inefficiency that is noticed is mainly because of the outward shift in the frontier due to few efficient firms.

Estimates for the total factor productivity change also indicate that a value greater than 1 is observed only when there is positive technological change. Combining our findings from the efficiency and productivity analyses, we notice that large firms have shown healthy performance on all counts. However, small firms have failed to perform adequately, not just because of their size but also due to other firm-specific intrinsic factors. However, a few frontier firms from this group also experienced a spurt in the production possibility frontier due to technological innovation. Generally, efficient small firms that have complied with the good manufacturing requirements set by the government of India have also upgraded their technological base by importing foreign technology, besides having overseas operations/collaborations in various semi-regulated developed and developing countries.

### 4.2.2 Efficiency and Productivity Analysis for Firms with and without R&D Related Outlays

In this section we consider the case of R&D. Table 3 summarizes the mean efficiency scores for firms with and without any R&D related outlays.

**Table 3. Mean Efficiency Scores for Firms with and without R&D Units**

| | 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 |

First consider firms with R&D related outlays. An efficiency value of 0.887 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%. However, the efficiency figure takes a value of 1 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 0.887 in 1991, indicating that the gap between the local and global frontier for firms with R&D activity remains at 11%. Since Indian pharmaceutical firms embarked on R&D related activities in the early 1990s, we infer that such differences in TGR arise mainly because of a 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 score for firms with R&D outlays (over the years) turns out to be around 49%. This increases to about 56% when measured against the local frontier. The TGR is also found to be reduced over the years for the R&D group, with an average value of around 0.92. This implies that R&D activities might have played some role in bridging 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 0.789 in 1991. It takes a value of 0.796 even when the canvas of comparison is restricted to its own group. The TGR also takes a value of 0.99 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 in this group, whether estimated against the local or global frontier. Estimates 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 onward, the technical efficiency level of R&D firms gradually improved over firms without any R&D units. We also notice that the TGR fell from about 0.85 to about 0.91 for firms engaged in R&D. In contrast, the TGR for firms without any R&D units was about 0.85. *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 average, if firms without any R&D activities spent for R&D, they could gain an efficiency of only 6%. R&D efficiency has then played a *negligible role in enhancing the production capability of firms* and 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 moves have not enabled them to perform better via attaining higher efficiency.

Here, we also compare the productivity and its various components for firms with and firms without R&D related outlays. The trend in the technical change component for firms with R&D related outlays indicates that, out of the 14 years under consideration, firms experienced an increase in the 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 of about 50% in the technical change is also noticed in 1992, 1997, 1999, 2004, and 2005. The trend in the efficiency change component for firms with R&D related outlays, however, reveals that it has drastically regressed only when there was a substantial rise in the technical change component. The estimates for productivity change also indicate that, on average, firms from this group experienced productivity progress only when both the efficiency and technical change components registered growth or when the magnitude of fall in the efficiency change component was less than the corresponding rise in the technical change component.

If we now consider firms without any R&D related outlays, we find that firms from this group also experienced an outward shift in the production possibility frontier but for fewer years. We also notice that the efficiency progress that is noticed for this group mainly arises because of technology regress. This clearly indicates that the inefficient firms from this group have been unable to develop their own internal strength to catch up with the frontier firms. A similar trend is also noticed in 1996, 1997, 1998, and 2003. It is also noticed that firms without any R&D

related outlays experienced an increment in their total factor productivity change of significant proportion only in 2000, 2004, and 2005, mainly driven by technological progress of few frontier firms.

On the whole, we conclude that firms that invested in R&D as a group benefited from technological progress, though it has not been shared equally among all its members. This is also evident from a fall in the efficiency change component corresponding to the years when the magnitude of technical change is quite large. In contrast, few firms without any R&D related outlays 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 played an important role for technological growth of the firms.

Generally, we observe that there is a strong association between the size of firms that undertake R&D and their technological progress. We also noticed that frontier firms from the R&D group had some technological collaboration with the foreign multinational companies or with public research institutes.

We also find that, among firms without any R&D related outlays, firms that were newly invested in plant and machinery and that took initiatives to upgrade their technological base by importing foreign technology were the ones that experienced growth in the technical change component. 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 Markets

We next consider firms targeting the international market. Due to intense competition in the domestic market, many Indian firms targeted the global generic market (Agarwal, 2007). In this paper, the export-oriented firms are classified into two groups: high-exporting firms (firms earning more than 25% of their revenue in the international market) and low-exporting firms (firms with export earnings less than or equal to 25%). The rest of the firms are considered non-exporting firms.

We first consider high-exporting firms. The statistics indicate that the efficiency level of these firms is 0.87 compared to the global frontier in 1991. This increased to 0.93 when efficiency is estimated against the local frontier. In other words, compared to the global frontier, firms from this group could increase their output production by about 13%. This reduces to 8%, however, when estimated against the local frontier. The value of TGR is 0.90 in 1991; this implies that firms from this group suffered from a technological gap of around 10%. This gap arose due to the wrong choice of market. The trend in the efficiency component computed against the global and local frontiers also reveals a noticeable fall. However, the efficiency level remained much higher compared to its own group members. In particular, up to 1995, differences in the efficiency scores were quite significant compared to the local and global frontiers. This implies that firms from this group were quite efficient among themselves. The low TGR of around 65% over the years implies that firms could have performed much better if they would have relocated themselves in other groups by targeting a different global market.

In the next step, we therefore compare the efficiency scores from the low- and non-exporting firms to understand how best the firms could have performed if they would have relocated in those groups. We first consider low-exporting firms. We find that, compared to the global frontier, the efficiency level is around 0.74 in 1991 for low-exporting firms. This improves to 0.78 when we estimate efficiency against the local frontier. A value TGR of about 0.95 indicates that the group frontier also lies close to the global frontier. However, in subsequent years, the magnitude of efficiency level falls, and differences in the efficiency scores between the local and global frontier grows, though not by a significant proportion. We thus find that, on average, TGR takes a value of 0.85 in other years.

Comparison of the efficiency scores calculated for the high- and low-exporting group, however, reveals two interesting trends. First, until 1996, average efficiency scores for firms in the high-exporting group were higher compared to the firms in the low-exporting group relative to the global frontier. However, we find a rise in the average efficiency of firms from the low-exporting group from 1997 onward. Second, the efficiency scores calculated against the local frontier are found to be higher for the high-exporting group than for the low-exporting one. Comparing the TGR for firms across these two groups indicates that the local frontier for the low-exporting group lies closer to the global frontier. The value of TGR also reveals that if firms from the high-exporting group reorient their strategies and maintain a balance between the global and domestic market, they can, on average, gain around 20% in efficiency.

This result arises because the majority of exporters from the high-exporting group export their products to the unregulated markets of the less developed countries. The unregulated market closely resembles the perfectly competitive market. There is almost cost-free entry and even small firms with a negligible resource base can export their products without undertaking any substantial risk (Chaudhuri, 2005, p. 186). To gain entry in those markets, producers pursue a strategy of price cutting. This results in low prices. 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, these firms invested heavily in plant and machinery. The return to such investment turned out to be low because they had to break the already established brand name of the incumbent foreign firms. Thus, even the large firms from this group incurred losses. On the other hand, most firms (almost 65%) in the low-exporting group targeted the semi-regulated market of the European Union, where there are fewer entry barriers, such as product standards and good manufacturing practices. As a result, on average, price realizations were found to be higher there.

Finally, we examine the efficiency of the non-exporting firms. As usual, we find that the magnitude of efficiency computed against the global frontier is much lower compared to the local frontier. For example, in 1992, the mean efficiency score estimated against the global frontier turned out to be 0.556, while it is 0.916

when estimated against the local frontier. This implies that the local frontier for firms targeting the domestic market lied way below the global frontier in 1992. A value of 0.614 for TGR indicates that the efficiency that we notice for this group was not because of its bad performance but due to the wrong choice of market, perhaps due to exclusive focus on 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 was 0.566; it then sharply fell to 0.22 in 2005. The situation improves to a moderate extent when we compare efficiency with respect to its own peer group. This is also captured by the value of TGR, which fluctuates at around 0.74 over the years. In other words, an additional efficiency improvement of around 26% was possible by just focusing on the global market.

A comparison of efficiency scores of the exporting and non-exporting firms reveals that, on average, firms exporting their product in the international market have always fared better. However, if we compare the average efficiency figures estimated against the local frontier for non-exporting firms with low-exporting firms, we notice that, up to 1996, on average, non-exporting firms performed equivalently. Differences in the efficiency scores estimated against the global frontier for these two groups are striking. This clearly indicates that if firms targeting the domestic market would have opted for semi-regulated or unregulated global markets, a higher efficiency gain of around 20% was possible. However, from 1997 onward, the efficiency of the firms has deteriorated even the local frontier. This situation might have occurred because almost all 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).

We next compare the productivity change and its various components for firms from these groups. 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 while exporting their products.

First consider the technical change for high-exporting firms. The trend in technical change for high-exporting firms reveals that a more than unit change in technology is noticed in 1993, 1999, 2004, and 2005. There was also a marginal upward shift by 2%–5% in the production frontier in 1994, 1997, and 2002. In the other years, technology regressed. The change in the efficiency change indicates is driven mainly by the technical change component. In other words, inefficient firms moved closer to the frontier only when the technology for this group regressed, or their distance from the frontier was magnified only when there was an outward shift in the production frontier due to technological progress. On average, growth in productivity changes is driven mainly by the efficiency or technological change of firms. More precisely, we find that, on average, in 1992 and 2002, total efficiency change or the catching up effect of firms mainly drove total productivity growth of the firms. It must be remembered here that a positive efficiency change of a magnitude of 15% and 30% seen in those years arises mainly because of technological regress.

Moving now to low-exporting firms, we find that low-exporting firms experienced growth in technical change for a longer period and with higher magnitudes. Thus values of 2.170 in 1997, 2.142 in 1999, and 2.386 in 2005 imply that firms from the low-exporting group registered doublings in technical change for those years. Barring the years in 1995, 1996, 1998, and 2003, we find that firms also experienced significant technological progress.

The efficiency change exceeds 1 for a large number of times. It is interesting to note here that, in 1993, 1994, 2000, and 2004, both technical and efficiency changes exceeded 1. In other words, while there was technical progress in some firms, the inefficient firms from this group caught up with the frontier firms from this group. In other years, the efficiency change either regressed, mainly because of a phenomenal rise in technical change, or remained constant. Last, the trend for the total productivity change for the firms implies that, on average, the total factor productivity of the firms regressed whenever technical change regressed drastically or efficiency change was less than 1. Thus, for example, in 1996, although the efficiency change takes a value of 1.541, the technology for the same year regressed by 50%, pulling down the value of total factor productivity by 30% compared to what was achieved by the firms in 1995. On the whole, we can conclude that firms from low-exporting group benefited most because of technological progress as well as from efficiency change.

Last, we consider non-exporting firms. A look into the technical change component for firms from this group indicates that the technical change component either remained close to 1 or regressed in most years. We notice that, in 1992, 1997, 1999, 2002, 2003, and 2004, technical change progressed even for non-exporting firms. Obviously, the sources of technological change are different from firms that target 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 experienced an increase in their technical change component. Figures for total factor productivity changes for firms from this group also indicate it regressed in most years. We find that the technical change of the frontier firms played an important role for the productivity growth of firms from this group. More precisely, we notice that, in 1993, 2004, and 2005, the technological growth for firms is 37%, 71%, and 150%. These translated into growth in total productivity change 42%, 62%, and 25%. The discrepancy in the magnitude of technical and productivity changes arises mainly because of efficiency regress.

Examining the characteristic features of the frontier firms from these three groups revealed certain interesting facts. First, among the high-exporting group, we found the frontier firms had evenly distributed their exports between regulated and semi-regulated countries. Overseas investment with marketing or technological collaboration with foreign multinationals seems to be an attractive strategy for the frontier firms from this group. The low-exporting group firms that approached the technological frontier also had technological collaboration with foreign partners and greater automation in their production process. Firms that targeted the domestic market and experienced an outward shift in the technological frontier were relatively new entrants, typically spending more on imported technology.

#### 4.2.4 Comparing the Efficiency and Productivity of Firms from Different Product Groups

Here we consider the case of firms producing both bulk drug and formulation. A 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 0.605. Similarly, with respect to the local frontier we find the efficiency score is 0.63. 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 remained close to the global frontier. The trend in TGR signifies that the distance magnified after 1995, though not by a significant proportion. However, from 2001 onward, the local frontier moved closer to the global frontier. The trend in the efficiency of firms estimated against the local and global frontiers also indicates a gradual fall. This implies either that few firms from this group have become efficient, pulling the frontier outward, or that the performance of the inefficient firms deteriorated in absolute terms.

Consider now firms producing only bulk drug. A comparison of the efficiency scores measured against the local and global frontiers for firms producing bulk drug again reveals a gradual fall in efficiency. However, a discrepancy is noticed in the efficiency score computed against the local and global frontiers. Thus, for example, in 1992, the efficiency score estimated was 0.62 against the local frontier and 0.85 against the global frontier. In other words, firms were quite efficient when they were compared among themselves. However, part of the low efficiency noticed when estimated against the global frontier arises because of the wrong product mix. A value of 0.74 for the TGR in 1992 indicates that firms could gain an additional 26% efficiency by changing their product mix.

We 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 among themselves. Inefficiency reduces by 15%–20% when the comparison is made against the global frontier. A comparison of the efficiency estimated against the local and global frontiers for all three groups indicates that firms producing both bulk drug and formulation are the most efficient ones, followed by firms producing only formulation, and least efficient are firms producing bulk drug. Among firms producing only formulation or bulk drug we find that firms producing formulation are the most efficient ones when compared among themselves. They are close to local frontier for firms producing both bulk drug and formulation.

Together this indicates that, in the context of the Indian pharmaceutical industry, 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 transactions and, hence, a higher efficiency gain is possible. The value of TGR indicates that, if firms producing only formulation or bulk drug reorient their production strategies to produce both kinds of product, they could gain as much as 30% efficiency for firms producing formulation and 10%–20% for firms producing bulk drug in certain years.

Next, we estimate productivity changes for firms from different product groups. We justify that the product varieties produced by a firm can be related to its technological change as follows. First, firms producing both bulk drug and formulation may have accumulated expertise in process as well as in product technology. Further, they may enjoy the economies of scope in their innovative activities because of producing varieties of product. This might favorably affect technological growth for those firms. Second, for bulk drug, it is expected that firms may have specialized capabilities in process technology and for formulation in product manufacturing. This may also enable them to experience technical change.

Consider firms producing bulk drugs. W notice that firms from this group experienced technical change exceeding 1 in 1993, 1997, 1999, 2000, 2004, and 2005, often by a large magnitude. Thus, for example, we notice that, in 1993, technical change reaches 1.821. Thus, there was an outward shift by 82% in the frontier in 1993. A close correspondence between efficiency regress and positive technological growth is noticed for firms from this product group. We notice that the efficiency regressed by 36% in 1993. We also notice a similar trend in 1997, 1999, 2000, 2004, and 2005. In other years, on average, we find that efficiency change increased, and corresponding estimates of technical change are less than 1. This implies that few frontier firms from this group experienced technological growth that was not diffused among inefficient firms, leading to a rise in inefficiency over the years. Here also we notice that productivity regressed in 1995, 1996, 1998, 2001, and 2002 mainly because the technical change component also regressed in those years. Thus, for example, in 1998, efficiency change was 127%. However, technical change also regressed by 72%. This pulled down total productivity change by 20%.

Now we describe productivity changes for 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 experienced technological progress for 9 out of the 14 years under consideration. For years like 1997, 1999, and 2005 there was a phenomenal rise in the technical change even for those close to 100%. The efficiency change component increased by more than 100% in several years. Here we also notice that the efficiency change regressed substantially in 1992, 1997, 1999, and 2005 when the corresponding technical change increased by nearly 100%. A substantial growth in efficiency change is also noticed when technology regressed. On the whole, we can then conclude that performance of the firms from this group progressed both in terms of efficiency and technical change.

Finally, we find that firms producing only formulation also experienced increased growth in technical change for several years. Values of 1.43, 1.66, 1.46, 1.51, 1.53, and 1.62 in 1994, 1997, 1999, 2000, 2004, and 2005 imply that, compared to previous years, firms producing formulation experienced a change of about 50% in their technical change component. However, the efficiency change component either regressed or remained constant. It is also noticed that firms from this group moved closer to the frontier firms by 67%, 85%, and 13% in 1996, 1998, and 2003. Corresponding figures for technical change also suggest that technological change regressed substantially in those years. We also find that the productivity change is mainly driven by the technological growth.

On the whole, a comparison of the technical change across firms from these three product groups indicates that firms producing both bulk drug and formulation benefited most from technological growth, followed by firms producing formulation, and last firms producing bulk drug. With respect to efficiency change, we find that firms producing bulk drugs performed better than firms producing only formulation. A close correspondence with efficiency regress and positive technological growth is noticed for firms from these three product groups. This implies that, while the frontier firms from these product groups 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 product groups with the inefficient ones reveals some common features. First, the frontier firms producing both bulk drug and formulation are comparatively large and spend more on R&D (8%–10% of their revenue). Firms that approach the technology frontier and produce only bulk drug or formulation adopted capital-intensive techniques, undertook R&D, and developed connections with domestic multinationals via contract manufacturing and contract R&D.

## 5. Conclusion and Policy Implications

In this paper we examine the efficiency and the productivity of firms in the Indian pharmaceutical industry. Our study indicates that in recent years the sector experienced rapid technological progress. However, most firms have failed to appropriate the benefits of this technological change, leading to a rise in the inefficiency for this sector.

A comparison of efficiency and technical change indicates that most large firms were efficient and experienced technological innovation longer. However, a few small firms also experienced technological progress, mainly by importing foreign technology and by complying with the good manufacturing requirements set by the government. Since small firms did not have adequate funds and resources to upgrade their technological base, availability of low cost finance could have been a viable policy option for assisting these firms to help them achieve the expanding production possibilities.

Our study also reveals that R&D did not provide much benefit for achieving greater efficiency. However, firms that invested in R&D benefited from technological innovation. This suggests that the few frontier firms benefited most from their R&D related outlays, but that this investment magnified the distance between the inefficient and efficient firms. We also notice that large firms that invested more in R&D benefited from technological growth. Thus, increasing the scale of operation backed by sufficient R&D activity could have helped firms to expand their production possibilities, enabling themselves to realize higher margins.

The study also indicates that exporting in global markets without any discrimination does not help firms to realize higher efficiency. Efficiency depends on the type of global market a firm targets. We argue that firms should target semi-regulated markets in the short run and global regulated market in the long run.

We also find that, in the context of the Indian pharmaceutical industry, merging vertically with downstream raw material firms could have been an extremely effective strategy for firms to benefit from efficiency and technological gains.

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