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OUTPUT AND INPUT EFFICIENCY OF MANUFACTURING FIRMS IN INDIA: A CASE OF THE INDIAN PHARMACEUTICAL SECTOR

Mainak Mazumdar[1], Meenakshi Rajeev[2] and Subhash C Ray[3]

Abstract

This paper examines the competitiveness of Indian pharmaceutical firms by computing their technical efficiency for the period 1991 to 2005 using the non–parametric approach of data envelopment analysis (DEA). The analysis establishes that even though the output efficiency levels of firms reveal a declining trend, firms have been able to make efficient use of labour and raw material inputs. An analysis carried out to identify the determinants of technical efficiency reveals that in contrast to popular belief, neither R&D and export expenditure nor the use of imported technology improve the technical efficiency of firms.

Introduction

The Drugs and Pharmaceutical sector of India flourished under the process patent regime of 1970 that reigned for more than four decades. The flexible provisions of the Patent Act of 1970 helped the Indian firms to imitate patented products of foreign firms, master the technique of reverse engineering and, in most cases, come out with even better process technology for the same products. The comparative advantage of the industry was therefore, an outcome of the Patent Act of 1970. It favorably influenced the Indian producers to create a niche for themselves (Kumar, 2004; Watal, 1997; Raizada, 2002). However, the Trade Related Aspect of Intellectual Property Right (TRIPS) in the World Trade Organisation(WTO) agreement compelled India to recognise product patent for a period of about 20 years. The recognition of product patent in the amended version of the Patent law passed on 1st January, 2005, posed a major challenge and threat to the Indian pharmaceutical industry that had flourished under the process patent regime of 1970. The change in the policy sparked considerable debate much of which was centered around the future prospect and fate of Indian pharmaceutical firms. It is argued by critics (Pharmaceutical associations like the India Drug Manufacturing Association (IDMA) and scholars like Chaudhuri (2004, 2005), Lanjouw (1997) and Watal (1997, 2000) that because of the policy changes Indian generic firms would be unable to fully exploit their core competencies in reverse engineering and adhere to the age long strategy of imitation. Consequently, the policy change might not be conducive for its future growth and development, unless the firms re-orient their strategies and restructure their modes of operation in tune with the changed scenario.

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Nevertheless, the reforms in the Drugs and Cosmetics Act (1994 and 2002) as a part of the liberalisation policy of 1991 also minimised the hurdles of regulation and facilitated the smooth functioning of firms in response to market forces. Particularly, policies like the abolition of the industrial licensing requirements for all varieties of drugs[i], removing the restrictions on import of bulk drugs, scrapping the linkage requirement, limiting the scope of price control and the automatic approval for foreign ownership up to 100 percent with foreign technology arrangement, allowed firms to import better quality raw-material and technology, introduce new products and processes and face the challenges that might arise due to recognition of Product Patent. It was also felt that the removal of trade restrictions and recognition of product patent would allow more technological collaboration with foreign multinational enterprises (MNE) which in turn would have a positive spillover effect on the productivity of the sector. Thus, while on the one hand the amendment of the patent law was a major challenge, for the Indian pharmaceutical firms, on the other hand the removal of domestic regulation also opened new opportunities for Indian pharmaceutical firms.

In response to the policy changes and growing competition there were some changes in the strategic behaviour of the firms. We may take for example the case of R&D. When the first version of the TRIPS Agreement was enforced in 1995 most of the Indian companies were producing low value generic products because of which the R&D facilities in the industry were scanty. However, from 1995 onwards there was a dramatic rise in the number of pharmaceutical firms having R&D units and large number of Indian pharmaceutical firms started investing in R&D. This was done either to come out with innovative products or to enter into technological collaboration with global pharmaceutical firms. Therefore R&D is now an important parameter of the long term profit maximisation exercise of these firms. Apart from R&D related activities, a large numbers of Indian firms also started exporting their products to capture the global market and establish the network and brand names of the companies[ii].

In view of the changes that are taking place in this industry certain questions pertaining to the future performance of Indian pharmaceutical firms comes to the fore. First, has increased competition and the resulting changes in the strategies of the firms helped only a small section of the firms to perform better and the rest, a large number of small and medium firms, been left behind in the competition? Or is it true that all firms have geared up adequately to the changing scenario and are catching up with the best? If not, what are the factors that explain the differential performance of the firms? Additional queries can also be made- how is the adoption of various strategies reflected in the performance of firms? Such strategies may include R&D, modernisation of plant and machinery to meet the export norms etc. These strategies if adopted, involve heavy investment in plant and machinery but the returns may not be immediate. Thus a relevant question to probe is how such strategies have impacted the performance of the firms.

In this paper we wish to examine some of these questions. An appropriate way to look into these questions is through an efficiency analysis of the firms (methodology is chalked out in section 5). It looks into the production or the technical aspects of firms and compares the output production with the best performing firms in the sample. More precisely it examines how best a firm is using its inputs to arrive at a output level vis-à-vis the firms that produces the same level of output. Alternatively, one can also ask how efficiently a firm is producing output for the same level of inputs vis-à-vis the firms that employ more or less similar level of inputs. This led us to the concept of efficiency, in particular the output and input efficiency of the firms. In efficiency analysis it is assumed that even when faced with a similar environment, not all firms may be able to allocate their resources to carry out their objectives in the most optimal manner. This is reflected in the indicators like the gap between the maximum output producible from its observed input bundle defined by the production frontier constructed with the input -output of similar firms in the sample and the actual output produced by a firm. Such gaps indicate the level of inefficiency faced by a firm. In a sense the above exercise looks at the technical aspects of a firm and places the performance of a firm in terms of production as compared to similar firms in the sample. Thus, there is always a comparison of the firms with the best performing ones in the sample. After calculating the efficiencies we also wish to identify the reasons behind the inefficient functioning of a firm by identifying certain determinants.

Review of Literature

In this connection we mention in brief some of the studies that have been carried out to examine the technical efficiency for various industries in India. On the basis of the technique used for analysis, studies that have examined the efficiency of the Indian manufacturing sector can be broadly classified into two groups a) the parametric approach to efficiency analysis and the b) non-parametric approach to efficiency analysis.

The central question of almost all the papers that have used the frontier analysis was to examine the impact of globalisation on efficiency of the Indian manufacturing firms. Some of the notable studies that have used the parametric frontier approach to efficiency analysis are by Neogi and Ghosh (1994), Mitra (1999), Krishna and Mitra(1998), Kalirajan and Bhide (2005), Jayadevan (1996), Trivedi (2000, 2003), Srivastava(2000) and others. Using a time varying frontier production approach, Neogi and Ghosh (1994) estimated the inter-temporal movement of the technical efficiency of the manufacturing firms. The study indicated that there has been a fall in the efficiency of the firms due to globalisation. An inquiry into the sources of inter-industry efficiency variations shows that skill, labour productivity and profit play significantly positive roles, while capital intensity works against general beliefs. The firm level panel data of some selected manufacturing industry was also employed by Krishna and Mitra (1998) to examine the productivity and efficiency related issues. The study could not find a strong evidence of the productivity or efficiency effect of the reform. Srivastava (2000) examined the efficiency of the manufacturing firms for the periods between 1980-81 and 1996-97. He found that the technical efficiency of the Indian manufacturing firms had gone down in the post liberalisation era. The study by Kalirajan and Bhide (2005) was the first of its kind to use the random coefficient model developed by Swamy (1971) and Swamy and Mehta (1977), to estimate the frontier production function and the efficiency of the Indian manufacturing sector. The study indicates that due to liberalisation, the productivity growth of the manufacturing sector has slowed down which is mainly due to a fall in the technical efficiency of the firms. The impact of liberalisation, FDI flow and spillover on the efficiency gain of the Indian manufacturing firms was studied by Kathurai (2000,2002) and also by Siddharthan and Lal (2004) using the stochastic frontier approach.

A number of studies have also employed the non-parametric Data Envelopment Analysis (DEA) approach to examine the efficiency and productivity of the Indian manufacturing sector. Using the firm level data and employing the non-parametric technique of DEA to estimate the efficiency of the firms, study by Ray (2002) indicates that the average efficiency of the Indian manufacturing sector had declined between 1991 and 1996. There was however, some improvement in the efficiency after 1996. The study also indicates that firms with foreign ownership or Multi-National Enterprises are significant in explaining efficiency. The non-parametric approach has also been employed to examine the dynamics of efficiency for the Indian manufacturing sector located in different states by Mukherjee and Ray (2005). Utilising the concept of super-efficiency, the study indicated that there was no change in the ranking of the firms in the post reform period. Also, no evidence of convergence in the efficiency of the firms was noticed in the post reform period. The impact of the ownership pattern, particularly the public and private ownership, on the efficiency was also studied by Rammohan and Ray (2003) for eight different sectors, namely chemical, electronics, steel, mineral, non-electrical, service, textile and transport, by constructing separate frontiers for each sector. The study indicated that only for chemical, iron and steel and textile industry the private sector's technical efficiency scores were superior; for electronics and services, the public sector's scores are superior and for minerals, non-electrical machinery and transport - there was no difference between the private and public ownership patterns.

As we can make out from the above review, there are ample numbers of studies examining the efficiency of the manufacturing sector at the inter-industry level. The impact of policy changes however, cannot be assessed adequately by doing an inter-industry study, because these studies assume that firms in an industry behave alike and therefore the industry level characteristics can be attributed to all firms in an industry (Siddharthan, 2004). However, with free market, new firms can enter the market with advanced technology. Further, the existing firms can also develop new strategies to cope with the changing scenario. Under such circumstances, the assumption that all firms in the industry are alike is highly restrictive (Liu and Tybout, 1996; Liu 1993 and Bartelsman and Doms, 2000). Instead a more in-depth micro-level study is required to understand, in a better way, the coping strategies of the firms due to policy changes.

Consequently, a number of studies have also been conducted examining the efficiency at firm level at higher digit levels (three digits or four digits). Existing empirical studies at the intra-industry level can again be re-classified into two groups, viz., parametric and non-parametric. The first group of empirical works mainly applies the parametric stochastic frontier approach to evaluate the efficiency of the firms from different industries like the sugar industry (Ferrantino & Ferrier; 1995), engineering industry (Goldar et.al. 2004) and textiles (Bhandari and Maiti, 2007), and also for firms with different ownership patterns (Agarwal, 2001). The earliest attempt to examine efficiency was however made by Page (1984) and Little, *et al* (1987), by collecting survey data for firms from industries like shoes, printing, soap and machine tools. Applying the parametric deterministic approach to construct the frontier, the studies did not find any significant differences in the efficiency of the firms. Since an overwhelming proportion of the manufacturing sector is crowded by small firms, a number of studies also examined the efficiency of the small scale units (for e.g, Bhavani, 1991 for the metal-product industry, Goldar, 1985 for soap industry Ramaswamy, 1994 for machine tools, plastic products and motor-vehicles industry). Most of these studies have however, recorded low level of inefficiency with little dispersion.

The second group of studies employs the non-parametric frontier technique to compute the efficiency. In this regard, the study by Majumdar (1998) evaluates the slack in resource utilisation by the state-owned enterprises due to soft budget constraint. The differences in the technical efficiency for the Indian textile firms were compared by Bhandari and Ray (2008) for different locations and ownership patterns by constructing a grand frontier and also location and ownership specific local frontiers non-parametrically.

Concentrating on the Indian pharmaceutical sector, we found that both the parametric and the non-parametric approach for efficiency analysis have been used to study efficiency for the sector. Using firm level data for the period 1990 to 2001, Chaudhuri and Das (2006) estimated the stochastic frontier production function to measure the output efficiency of the Indian pharmaceutical sector. The study has shown that the mean efficiency scores of the industry had improved over the sub–period 1999 to 2001 against the sub-period 1990-1998. Further, the study also shows that large sized firms and 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) and 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 covers only nine large firms and from 1987 to 1990. The inefficiency levels of the public sector firms as compared to the private players are the main findings of the study.

From the above review it is evident that there are ample numbers of studies examining the efficiency of various industries in India. However, the relevant efficiency related questions have not been adequately addressed for the pharmaceutical sector in India. Further, while measuring efficiency earlier studies either used an output oriented or an input oriented measure of efficiency by imposing a prior assumption that firms either maximise the level of output or minimise the level of input use. But optimising the behaviour of a firm requires that a firm maximises its level of output and minimises the input usage simultaneously. In our study we have, therefore, used a more comprehensive non-parametric non-radial measure of efficiency that simultaneously incorporates both the potential for the increase in the output as well as the reduction in each of the inputs employed by the firms. This gives an estimate of input-specific inefficiencies and the output efficiency of the Indian pharmaceutical firms. The use of this advanced technique is not common. Only a limited number of studies have used this approach (See Ray, 2007). In this respect the findings of the current study are new contributions to the literature. Further, studies that have examined the efficiency of Indian pharmaceutical firms using DEA have limited coverage. Our sample covers firms of different sizes and over a longer time period. The sample size is a panel of 2492 firms and the time span is 15 years (from 1991 to 2005). Banker (1993) has proved that DEA based estimators are weakly consistent, but with such a large sample the estimates of efficiency are more precise and accurate. Additionally, in the existing paper the second stage analyses to identify the determinants of efficiencies consider mainly the size, age and ownership patterns of the firms. However, our data base allows us to consider a number of other important firm specific factors.

Given this background, the rest of the paper is structured in the following manner. Section 2 outlines the non-parametric approach of the DEA methodology to compute the input and output efficiency of the firms. The databases are reported in section 3. The main finding from the empirical analysis is discussed in section 4. Section 5 identifies the determinants of the efficiency scores of the firms through an appropriate model and a concluding section follows thereafter.

Non-Parametric Data Envelopment Analysis (DEA)

The production or technical efficiency of the firms is computed in this paper by empirically constructing the frontier or the benchmark technology considering the input-output bundles of the best performing firms in the sample using the non-parametric technique of DEA[iii]. While the non-parametric approach cannot take care of the randomness of the data generating process, in our study it is still preferred over the parametric approach because it does not impose an explicit functional form on the observed data points. Further, if the underlying functional form or the production correspondence is not known imposing single functional form could lead to the problem of misspecifications because there is a wide degree of heterogeneity in the structure of Indian pharmaceutical firms[iv]. Further, non-parametric DEA efficiency scores satisfy asymptotic statistical properties (Banker, 1993). Banker has shown that DEA is indeed equivalent to the maximum likelihood estimation, when the production function is specified as a non-parametric monotone and concave function instead of a parametric form. DEA efficiency scores are also consistent and converge faster than the estimators from other frontier methods (Grosskoop, 1996, Kneip et al, 1998) for a large sample. DEA is best suited to examine the efficiency of firms with a fairly large sample of an unbalanced panel of 2492 firms for 15 years.

To construct the frontier, the input-output set (X, Y) of the firms in our sample is conceived as the production possibility set the equation of which is given by

$$T = \{(X, Y); X \in R_{+}^{N}, Y \in R_{+}^{M} \text{ :X can produce Y}\} \quad (1)$$

The dimension of the input bundle *X* in the sample is (4×1). The specific elements of the input bundle *X* are labour, raw material, power and fuel and capital. The study also conceptualises a single output, with (1×1) dimension for the output bundle *Y*. Additionally it is also assumed that (a) inputs and outputs are freely disposable and (b) the production possibility set is convex (Ray, 2005). Imposing the above assumption and employing the Debreu-Farell definition of efficiency the input oriented radial measure of efficiency proposed by Charnes, Cooper, and Rhodes (CCR) (1978) and further extended by Banker, Charnes, and Cooper (BCC) (1984) of a firm is

$$TE^{I}(X,Y) = \min q : (qX,Y) \in T \qquad (2)$$

Similarly, the corresponding output-oriented radial measure of technical efficiency is

$$TE^{O}(X,Y) = \frac{1}{f}\max f : (X,fY) \in T \qquad (3)$$

Both are radial measures because either all the inputs in the input bundle are contracted or all the outputs in the output bundle are expanded by the same proportion. The non-radial measure for efficiency analysis on the other hand, captures the potential to expand each of the output and contract each of the inputs of the firms separately to get the output specific efficiency and input specific efficiency of the firms.
To measure the input-specific efficiencies we first define the input set associated with the technology set *T*. For the output vector $\hat{y}$ the input set $V(\hat{y})$, is set of collection of all inputs *I* which can produce $\hat{y}$, the equation of which is given by

$$V(\hat{y}) = \{I: (I,\hat{y}) \in \mathrm{T}, \text{ for each } \hat{y} \in \mathrm{R}_{+}^{M}\} \qquad (4)$$

It is assumed that input sets satisfy the monotonicity and the nestedness property (Varian, 1984). Monotonicity property implies that if $\hat{I} \in \mathrm{V}(\hat{y})$ and $\tilde{I} \geq \hat{I}$ then $\tilde{I} \in \mathrm{V}(\hat{y})$ this follows from the assumption of the free disposability of the input in the technology set *T*. The nestedness property follows from the assumption of free disposability of the output in the technology set *T* and it implies that if $\hat{\mathrm{I}} \in \mathrm{V}(\hat{y})$ and $\tilde{y} \leq \hat{y}$, then $\hat{\mathrm{I}} \in \mathrm{V}(\tilde{y})$. Lastly it is also assumed that $V(\hat{y})$ is convex.
The interior points of the input set are its inefficient points while the boundary points are the efficient point. The isoquants are the boundary point of $V(\hat{y})$ which is denoted by the following equation:

$$IsoV(\hat{y}) = \{I : I \in V(\hat{y}) \text{ and } lI \notin V(\hat{y}) \text{ if } l < 1\} \qquad (5)$$

If $\hat{I} \in IsoV(\hat{y})$ the input oriented radial measure of technical efficiency $(\hat{I},\hat{y})$ will be equal to unity with the possible presence of input slacks[v]. The presence of input slacks however does not guarantee that the input specific technical efficiencies will be equal to unity. Input specific technical efficiency is equal to unity only if it is an element of the efficient subset of the isoquant the equation of which is given by

$$EffV(\hat{y}) = \{I : I \in V(\hat{y}) \text{ and } \bar{\mathrm{I}} \notin V(\hat{y}) \text{ if } \bar{\mathrm{I}} \leq \mathrm{I}\} \qquad (6)$$

If $I \in EffV(\hat{y})$ the input bundle is efficient in Koopman sense (1951), there is no way to produce $\hat{y}$ with fewer inputs. Clearly, $\forall$ y $EffV(\hat{y}) \in Iso\,\mathrm{V}(\hat{y})$, but the converse is not always true. The non-radial measure proposed by Färe and Lovell (1978) measures the input-specific technical efficiency of the firms relative to the points in the efficient subset of the isoquant.

In an output-oriented measure for technical efficiency the objective is to produce the maximum output from a given quantity of inputs. For this we first define the output set to be the set of all outputs y produced from the input vector $\hat{I}$ denoted by the following equation

$$U(\hat{I}) = \{y : (\hat{I}, y) \in T \text{ for each } \hat{I} \in R_{+}^{N}\} \quad (7)$$

Like the input set it is also assumed that the output set also satisfies certain properties. Thus if $\hat{y} \in I(\hat{L})$ and if $\tilde{L} \geq \hat{L}$ then $\hat{y} \in I(\tilde{L})$. This property follows from the free disposability of inputs. From free disposability of output, if $\hat{y} \in I(\hat{L})$ and if $\tilde{y} \leq \hat{y}$, then $\tilde{y} \in I(\hat{L})$. Finally, the convexity of the technological set T also implies that the output set $I(\hat{L})$ is also convex. In an analogous manner the boundary point of the output set is the production possibility frontier which is denoted by the following equation

$$IsoU(\hat{I}) = \{y : y \in U(\hat{I}) \text{ and } qy \notin U(\hat{I}) \text{ if } q > 1\} \quad (8)$$

Thus if $y^0 \in IsoU(\hat{I})$, the output oriented radial measure of the technical efficiency for the output-input vector $(y^0, \hat{I})$ equals unity because it is not possible to increase all the outputs holding the inputs constant. This does not however preclude the possibility to increase some components of the output vector y^0 which is not possible only if the projection of the output vector is on the efficient subset of the output isoquant the equation of which is given by

$$EffU(\hat{I}) = \{y : y \in U(\hat{I}) \text{ and } \bar{y} \notin U(\hat{I}) \text{ if } \bar{y} \geq y\} \quad (9)$$

The non-radial measures of the output and input specific technical efficiencies of the firms are computed with reference to the efficient subset of the firms.

The earliest attempt to compute the non-radial measure of technical efficiency was made by Färe and Lovell (1978) which they also call the Russell measure. The output oriented Russell measure takes the following form in the model:

$$RM_y(\hat{I}, \hat{y}) = \frac{1}{r_y} \text{ where } r_y = \max \frac{1}{m} \sum_r f_r \quad (10)$$

subject to $\sum_j l_j y_{rj} \geq f_r y_{ro}; r = 1(m)$ [$r = 1$ in our model]

$$\sum_j l_j I_{ij} \le I_i;\ i = 1(\mathrm{n})$$ [*i=4* in our paper] (10a)

$$\sum_{j=1}^{N} l_j = 1 \text{ and } \sum_{j=1}^{N} l_j \ge 0; j = 1(N)$$

With multiple outputs, if output slacks exists at the optimal solution of a radial DEA model, the non-radial Russell measure falls below the radial BCC model. This is because the radial projection is always a feasible point for the non-radial measure and hence the value of non-radial technical efficiency never exceeds the radial efficiency measure.

The analogous input-oriented non-radial measure of technical efficiency is

$$RM_I(\hat{I}, \hat{y}) = r_I \quad \text{where } r_I = \min \frac{1}{n}\sum_i q_i \tag{11}$$

subject to $\sum_j l_j y_{rj} \ge y_{ro}; r = 1(m)$

$$\sum_j l_j I_{ij} \le q_i I_i;\ i = 1(\mathrm{n}) \tag{11a}$$

$$\sum_{j=1}^{N} l_j = 1 \text{ and } \sum_{j=1}^{N} l_j \ge 0; j = 1(N)$$

Analogous to the output oriented technical measure the optimal projections of the observed input bundle $\hat{I}$ takes place in the efficient subset of the isoquant of the output $\hat{y}$.

Output and Input Efficiencies: The PRS model

None of the non-radial measures presented above consider the output oriented and input oriented slacks simultaneously; since, these are either output –oriented or input-oriented measures, either the input slacks or the output slacks are ignored. The non-radial measure by Cooper and Pastor (1995) and extended by Pastor, Ruiz, and Sirvent (1999) however takes care of both the output and inputs slacks simultaneously and is therefore more comprehensive measure of efficiency. Pastor, Ruiz, and Sirvent (1999) utilises the concept of the familiar Pareto-Koopman criteria to devise the method of efficiency measurement. According to the Pareto-Koopman criteria, an input-output combination is not considered as efficient if it violates the following postulates:

i) It is possible to increase at least one output in the output bundle $\hat{y}$ without reducing any other output and without increasing any other input bundle $\hat{I}$; or

ii) It is possible to reduce at least one input in the input bundle $\hat{I}$ without increasing any other input and without reducing any output in the bundle $\hat{y}$.

Clearly, unless $RM_y(\hat{I},\hat{y}) = RM_I(\hat{I},\hat{y}) = 1$, at least one of the inefficiency postulates are violated and $(\hat{I},\hat{y})$ bundle is not Pareto-Koopman efficient. An Input-output bundle is Pareto-Koopman efficient only when the following conditions hold:

(i) $\hat{I} \in EffV(\hat{y})$ and (ii) $\hat{y} \in EffU(\hat{I})$

In the parlance of economic theory suppose that with reference to $EffU(\hat{x})$, the potential amount of r^{th} output that firm t can produce is y_r* which is obviously higher than the actual output y^t produced from the same inputs $I_{i.}$ (y_r*) is the expanded output (virtual) of the firm on the efficient subset and y^t / y_r* is the technical inefficiency of the firm for the r^{th} output. Suppose f_r be the value of the factor by which the r^{th} output is scaled up into the efficient subset of the firm then $y* = f_r\ y^t$ and the technical efficiency (TE) for the r^{th} output of the firm $= \frac{1}{f_r}$. Similarly, corresponding to the $EffV(\hat{y})$ the potential reduction for the i^{th} input by the firm is say I_i^*, $q_i = I_i^* / I_i$ is the input inefficiency for the i^{th} input. A non-radial measure Pareto-Koopman measure of technical efficiency for the input-output pair $(\hat{I},\hat{y})$ is computed as:

$$\Gamma = \min \frac{\frac{1}{n}\sum_i q_i}{\frac{1}{m}\sum_r f_r} \equiv \min \frac{\frac{1}{4}(q_L + q_K + q_E + q_{RW})}{f} \tag{12}$$

subject to

$$\sum_j l_j y_j \geq f\ y_o \quad \text{(Output)} \tag{13}$$

$$\sum_j l_j L_j \leq q_L L_0 \quad \text{(Labor)} \tag{14}$$

$$\sum_j l_j K_j \leq q_K K_0 \quad \text{(Capital)} \tag{15}$$

$$\sum_j l_j E_j \leq q_E E_0 \quad \text{(Energy)} \tag{16}$$

$$\sum_j l_j RW_j \leq q_{RW} RW_0 \qquad \text{(Raw-Material)} \qquad (17)$$

$$\sum_{j=1}^{N} l_j = 1 \qquad \text{and} \qquad \sum_{j=1}^{N} l_j \geq 0; j = 1(N)$$

Note that the efficient input-output projection (L^*, y^*) satisfies

$$I^* = \sum_j l_j^* I^j \leq \hat{I} \text{ and } y^* = \sum_j l_j^* y^j \geq \hat{y} \qquad (18)$$

Thus, $(\hat{I}, \hat{y})$ is Pareto-Koopman efficient, iff $f_r^* = 1$ for each output r and $q_i^* = 1$ for each input *i*, implying that $\Gamma = 1$. The Pareto-Koopman efficiency measure is a global efficiency measure (GEM) and is the product of two factors g_1 and g_2. The first factor $g_1 = \frac{1}{n}\sum_i q_i$ is the input oriented component (GEMIN) and the second factor $g_2 = \frac{1}{m}\sum_r f_r$ is the output–oriented component (GEMOUT). Thus, which $\Gamma = g_1 g_2$. The objective function Γ in this mathematical programming problem is a non-linear problem. Following Charnes and Cooper (1968), the form of normalisation used by PRS to transform this fractional functional programming problem in to a LP problem restricted the technology set in the model by non-increasing returns to scale, which is unnecessarily restrictive. Applying the first order Taylor series for Γ at $\Gamma = q_i^* = 1 \forall$ i and $f_r^* = 1 \forall$ r, Ray (2007) has shown that it is possible to lineralise the objective function as $\Gamma = 1 + \frac{1}{n}\sum_i q_i - \frac{1}{m}\sum_r f_r$ and retain the VRS assumption.

Thus solving the linear programming problem:

$$\Gamma = 1 + \frac{1}{n}\sum_i q_i - \frac{1}{m}\sum_r f_r \qquad (19)$$

subject to the same set of constraints illustrated above and substituting the optimal (q_i^*, f_r^*) value $\Gamma^* = \dfrac{\frac{1}{n}\sum_i q_i^*}{\frac{1}{m}\sum_r f_r^*}$ the efficiency measure for is $(\hat{I}, \hat{y})$ is arrived at.

In this regard t is worth mentioning here that the dual of the above programming has some interesting interpretation. Ray and Jeon (2007) have shown that the dual of Γ^* can be interpreted as the shadow cost per unit of shadow revenue at the optimal input-output bundle for a firm. In other words in the absence of market price for the inputs and outputs the objective of minimising Γ^* closely corresponds to the maximisation of the shadow profit for the firms that in turn, gives the profit efficiency for the firms.

It is to be noted here that this LP is a more generalized optimisation problem with the same set of constraints, but with the objective function

$$\min\ \Omega = \sum_i a_i q_i - \sum_r b_r f_r \tag{20}$$

subject to

$$\sum_j l_j y_{rj} \geq f_r y_{ro}; r = 1(m) \tag{21}$$

$$\sum_j l_j I_{ij} \geq q_i I_i; i = 1(n) \tag{21a}$$

$$\sum_{j=1}^{N} l_j = 1 \quad \text{and} \quad \sum_{j=1}^{N} l_j \geq 0; j = 1(N)$$

If $a_i = \frac{1}{n} \forall \mathrm{i}$ and $b_r = \frac{1}{m} \forall r,$ we get the usual Pareto-Koopman problem. If, on the other hand we set $b_r = 0 \forall r,$ we get the usual input-oriented Russell measure. Additionally if we set, $a_i = a$, we get the usual input-oriented radial DEA problem. Similarly, the restriction $a_i = 0 \forall i$ leads to the output oriented Russell measure. Further, with the restriction $b_r = b\ \forall r,$ we get the usual output – oriented radial DEA problem.

Data Sources and Modeling Frontiers Over Time

To examine the efficiency of the pharmaceutical companies, firm level information was considered from 1991 to 2005[vi]. The number of firms in the sample varies from 70 to 289 over the years and in total there is an unbalanced panel of 2492 firms for 15 years. The firms considered in the study together account for about 80 percent of the total output and 87 percent of the input usage for the sector for almost all the years. Thus the sample of firms considered in the study can be viewed as representative of the sector. The relevant data necessary for the computation was collected from the financial balance sheets of the companies provided by the prowess data source of the Centre for Monitoring of Indian Enterprises. The study conceptualises a 1-output, 4-input production technology. The output in the model is the value of total output (y) defined as the total sales of the firms plus the change in the stock of output measured in terms of the opening stock minus the closing stock in output. The inputs in the model are (i) labour (l) (measured in terms of wages and salaries for the workers) (ii) material inputs (rw) (measured in terms of the companies' expenditure for raw material), (iii) energy input (pf) measured is terms of the expenditure for power and fuel and (iv) capital (k) is the book value for plant and machinery and building.

To bring the variables in real terms each variable was appropriately deflated. The value of output was deflated by the price index for the drug and the pharmaceutical sector collected from the Reserve Bank of India (RBI) monthly bulletins. The expenditure for workers was deflated by the Consumer Price Index (CPI) for manual and the non-manual workers, expenditure for fuel and power was deflated with the price index for fuel, power lights and lubricants collected from the RBI bulletins to arrive at the real figure, the company expenditure for raw–material was deflated by the average price index for chemical and chemical products from the (Annual Survey of Industry, ASI) data base. The capital stock was available as book value for plant and machinery, therefore the Perpetual Inventory Method (PIM) by Balakrishnan *et al* (2000) is used to deflate the value of capital with 2003 as the benchmark year.

To measure efficiency one needed to account for the availability of technology and construct frontiers at different point in times. In DEA literature (Tulkens and Vanden Eeckaut, 1995) three forms of frontiers were distinguished viz*., i) the contemporaneous frontier ii) the sequential frontier and iii) the intertemporal frontier.*

For any given year say t, the contemporaneous frontier was constructed by considering only the data point of the t^{th} year. On the other hand to construct the sequential frontier for the t^{th} year it was assumed that the data points and the technology of the previous years $\{(t-1), (t-2)...\}$ are feasible but technology for the future years $\{(t+1), (t+2)...\}$ were not available. For inter-temporal frontier however, all data points are considered to construct the frontier. In other words, to calculate the inte-temporal frontier for t^{th} year it was assumed that the data points and the technology of the previous years $\{(t-1), (t-2)...\}$ as well as the future years $\{(t+1), (t+2)...\}$ were available.

In the literature the three types of frontiers were conceptualised keeping in mind the possible technical progress (regress) in the model (Tulkens and Vanden Eeckaut, 1995). With technical progress the production possibility set and the frontier shifts out; however, this important component of the change could not be captured in the contemporaneous frontier because the benchmark kept changing from year to year. In other words, it was assumed that at each point in time the reference set was completely different. Thus, the efficiency of the firms computed for different years were not comparable and hence could not be used to understand whether or not the performance of the firms had improved during the span of the study period. In the intertemporal frontier, a single frontier was constructed for all the years and, therefore, it assumed away any technical progress or regress and no shift in frontier were considered. The sequential frontier some sort of dependence was assumed between the production possibility sets that allowed for outward shift of the frontier. It thus allowed for enlarged production possibility set over the years assuming implicitly no technical regress.

We used the sequential frontier because it was assumed that for the sample years the sector might have experienced technological progress because of greater involvement in R&D, import of capital goods and investments in modern plant and machinery etc.

Empirical Findings

Comparing Efficiency of Pharmaceutical firms:

In our empirical analysis, the Pastor, Ruiz, and Sirvent (1999) model (see equation 12 and 19), that allows for the simultaneous increase in the output that a firm produces and also reduces the inputs that it employs, was employed to get the output and input efficiency scores of a firm. Since a single output four input technology was conceived for the pharmaceutical firms efficiency scores were available for (i) raw-material, (ii) power and fuel (iii) labour (iv) capital (v) and output. Table 1 provides the average efficiency scores obtained for the firms in the sample for each year.

Table 1: Input and output specific efficiency of the pharmaceutical sector (1991-2005)

(1) Year	(2) Output Efficiency f	(3) Material Efficiency q_{RM}	(4) Power and Fuel Efficiency q_E	(5) Labor Efficiency q_L	(6)Capital Efficiency q_K
1991	0.811	0.933	0.613	0.863	0.672
1992	0.662	0.681	0.418	0.854	0.547
1993	0.623	0.718	0.389	0.808	0.558
1994	0.603	0.724	0.442	0.923	0.638
1995	0.507	0.873	0.434	0.907	0.701
1996	0.462	0.869	0.399	0.926	0.713
1997	0.418	0.898	0.451	0.920	0.661
1998	0.531	0.984	0.387	0.886	0.362
1999	0.452	0.918	0.502	0.919	0.548
2000	0.415	0.891	0.347	0.895	0.708
2001	0.371	0.899	0.365	0.909	0.739
2002	0.318	0.911	0.323	0.885	0.700
2003	0.307	0.843	0.364	0.927	0.756
2004	0.402	0.928	0.322	0.928	0.614
2005	0.387	0.675	0.402	0.946	0.669

Consider first the case of output efficiency of a firm. The first column in table 1 depicts the value of f (see equation 12 and 19) that represents the unrealised potential increase in the output of a firm that could be achieved without employing any additional inputs. More precisely in 1991 the average efficiency attained by the firms in the sample was 81 percent. Further, there was a fall in the average efficiency for the sector. Similar conclusions have been arrived at by earlier studies (see Ray, 2002; Mukherjee and Ray, 2004; Ray, 2004; Srivastava, 2001; and Parameshwaran, 2001) for the Indian manufacturing sector. Consistent fall in the mean output efficiency for the sector also implies that compared to the output produced by the frontier firms the production level of the inefficient firms have been falling over the years. In the context of our study we also found that from 1995 onwards there was a fall in the average level of the output efficiency of the firms. Since 1995 was the year when the Government of India instituted a number of policies to infuse competition for the sector, we found that contrary to the popular perception, gradual liberalisation and higher competition had an adverse effect on the general efficiency level of the sector and the gap between the efficient and inefficient firms had risen over time.

Three distinct possibilities might arise in this context. First, since we were using a sequential frontier for the panel data, in the initial years the degrees of freedom were less and therefore this might have artificially caused a number of observations to have a measured efficiency of one. That in turn could be reflected in a higher average efficiency value for the sector for the initial years. Secondly, the form of production frontier constructed for the sector incorporated the possibilities of technological progress; in other words, an outward shift in the frontier was possible for the subsequent years. This implies that if there was technological progress for this sector leading to an outward shift in the production frontier, for the inefficient firm the distance from the frontier was increasing even though their performance may not have declined in an absolute sense of the term. This could happen if the efficient firms become more efficient over the study period pulling the frontier outward. Finally, it could so happen that the inefficiencies of the firms that lie below the frontier worsen in absolute terms.

We next tried to understand the characteristics of the inefficient firms[vii]. First, it was observed that most of the inefficient firms were also small sized firms; it also appears that there was a significant negative correlation between the size of the firm and its efficiency. Almost all the firms with an inefficiency score of less than .45 were tiny firms with a very small scale of operation; whereas most of the large and medium sized firms were either efficient or moderately efficient. The tiny and the smaller units accounts for about 45 percent of the units but contribute less than 17 percent of the total value of output produced in the sector. Thus the overall inefficiency for the sector can be attributed mainly to the inefficient small sized firms.

In the next step we compared the efficient small firms with the inefficient ones. Compared to its peers with an average turnover (or revenue per unit of the labour employed) between 1.5 to 2.4, the overall turnover for the inefficient small firms were abysmally low at around .74 to about .87. While the performance of the efficient small firms (measured in terms of revenue earned per unit of the labour employed) had improved over the study period, not much improvement was also noticed for the inefficient small firms. We also compared the average turnover of the efficient large and medium firms with the inefficient ones. We also find that the efficient medium and large sized firms had the highest ratio of output to labour (almost 2.5 to 4.2) in the sample and the ratio was rising over the years. Compared to its peers the inefficient firms (large and medium) had an average turnover of around 1.8 to 2.7. The performance of the large and medium sized firms had also improved over the years (in an absolute sense) even though the improvement was not sufficient to catch up with the rise in the average turnover of its peers. This indicates that possibly the sector might have experienced technical progress due to the efficient frontier firms. This in turn might have led to an outward shift in the frontier, resulting in a rise in the output distance between the inefficient and the efficient firms. A cross comparison of the revenue earned between efficient small and large firms also indicates that a possible frontier shift was much more pronounced at higher levels of output.

To provide some tentative explanations as to why most of the tiny units were inefficient we have examined its capacity utilisation ratio, the working to fixed capital ratio and the product mix. It was noticed that the capacity utilisation ratio of the tiny inefficient units was considerably low and stood at around 21 to about 24 percent. In contrast, capacity utilisation ratio increased from 24 per-cents to about 80 percent with the rise in the size of the firms. The peers of the tiny inefficient firms had capacity utilisation ratio of about 60 percent. It was also noticed that the working to fixed capital ratio was only .35 for the inefficient small units whereas it was about 1.36 for its peers and reached as high as 3.4 for the large sized firms. The low value of working to fixed capital for the tiny units possibly indicated the inability of tiny units to secure sufficient funds to meet their credit requirements. The inadequate availability of working capital may hamper the smooth functioning of the production process and lead to high capacity utilization ratio and inefficiency for tiny sized firms. The product mix of the tiny firms clearly indicates that most of them produced low-value products and hence the return was also low which was reflected in the low level of inefficiency. The poor performance of small Indian pharmaceutical firms was also revealed by the study of Pradhan and Sahu (2008). The study brought out the fact that "the lack of expertise, training and finance for technological up-gradation and adoption of good manufacturing practices (GMP) by small enterprises to meet global quality standards; limited exposure and expertise on Intellectual Property Rights (IPR) issues; limited adoption of information technology (IT) techniques in production and processes; low or negligible R&D expenditure which affects the ability of small Enterprises to offer innovative solutions; and the inability of Small enterprises to access finance on easy terms for import of capital goods" were the main reasons for poor performance of small enterprises in the Indian pharmaceutical sector.

Input Efficiency

Moving now to the input-wise measure of inefficiencies, columns 3 to 6 in table 1 summarises the value of q_i,s which represents the maximum possible contraction on an average in the use of a particular input that a firm employs without reducing the output or the employment of other remaining inputs. The average input-wise measures in inefficiencies reveal certain interesting features for the industry. It was noticed that even though the output efficiency revealed a declining trend, the firms on an average were able to make efficient use of labour, material and capital. The average efficiency scores for labour, raw material and capital fluctuated around the mean value of .90, .85 and .63, respectively, over the years. On the other hand, over the years, the mean efficiency for power and fuel is only .40. What could be the possible reasons for efficient use of raw material and labour and inefficient use of power-fuel by Indian pharmaceutical firms?

Raw material is a factor of production which can be used in appropriate quantity if the industry does not suffer bottlenecks in supply of raw material and has good backward linkages with the raw-material industry. India has a well developed chemical industry (Kaul, 2007), which provides raw materials to the pharmaceutical industry. The bulk–drug industry in India procures raw materials, processes it and produces the essential component, the active pharmaceutical ingredient (API), of the medicine for the formulation companies. India also has a vibrant bulk-drug industry that produces almost all varieties of API required for synthesising the formulation or the final medicine for consumption. With good linkages with the raw-material industry it was expected that the Indian firms would be able to synthesise the raw material efficiently. In this regard we also calculated the ratio of stock to annual consumption of raw material. We found that the ratio was steadily falling from a value of about .16 to about .12 for the study years. It rose marginally to about .22 in 2005 for which the raw-material inefficiency was also the highest. Noteworthy to mention here that there was no significant difference in the value of the ratio for firms of different sizes indicating possible efficient use of raw-material for almost all types of firms.

Labour was another factor of production that showed high efficiency. Perhaps after liberalisation, the firms have greater flexibility in utilising the labour in conjunction with other factors of production to meet the demand for output. It became possible to hire and fire labour comparatively more easily than before[viii]. This may account for efficient use of labour by the industry. In this regard it is worth mentioning here that the annual average real wage rate of employees (in Rs.) has gradually risen over the year from Rs. 8000 to about Rs. 12,000 over the years. If we assume that higher wage rate is monotonically related to the quality of labour we can infer that the sector is employing more and more high quality labour.

Another important factor of production is capital. The efficiency figures for capital revealed that it was inefficiently used compared to labour and raw material whereas its efficiency was much higher compared to the use of power and fuel. On the whole it can be argued that firms were moderately efficient in using capital. It must be remembered that returns from capital generally flow over a period of time; hence it may not be possible for a firm to fully utilise the capital stock in the year it is installed. In India most of the firms invested heavily in plant and machinery to adhere to the new rules in the recently amended Drugs and Cosmetic Act which might have lead to a rise in unused capital stock[ix]. Underutilisation of capital stock can also arise if firms are slow in applying and adapting new technology or when in lean a period the demand for the product is low. Accumulation of underutilized capital stock can be checked by plotting the growth rate of capital stock and the growth rate of output against time. Figure 1 (Appendix A), reveals that for most of the years the growth rate of the capital stock in this sector was higher than the growth rate of output, which implies the presence of underutilized capital stock. The Capacity Utilization Ratio has also reduced from about .80 percent to about .60 percent for the sector during the study period. Thus whatever inefficiency was noticed for the stock of capital was mainly due to its underutilization.

We also observed that power and fuel was utilised in the pharmaceutical sector to generate energy for the distillation process. The energy consumption note of the firms (that is available in the balance sheet of the companies) revealed that firms (mainly the large firms) that had undertaken initiatives to conserve energy in the production process by replacing the old technology with modern ones were the efficient ones. The rest of the firms still used technology that consumed more energy per unit of the output generated and incurred energy wastage (that also leads to high level of energy inefficiency for the sector). It is note-worthy that the consumption of power and fuel increased for the sector from about 4.5 per cent to about 8 per cent of the total cost of production from 1995 to 2005. However, for large firms (efficient and the inefficient firms) the share of power and fuel consumption in the total expenditure remained constant at around 2 per cent. For tiny, small and medium firms the share of power and fuel consumption was around 4 to 5 per cent leading to fuel usage inefficiency.

Determinants of Efficiency

After estimating the efficiency levels, it was of interest to examine the factors that determine the efficiency of the firms. Since the efficiency scores are bounded between 0 and 1, one way to examine the determinants of efficiency is to use a Tobit model (Ray 1991; McCarty and Yaisawarng 1993; Lovell *et al* 1994; Duncombe *et al* 1997). We used a random effect Tobit model to identify the determinants of the efficiency scores of the firms. Instead of using a random effect model, a fixed effect model cannot be used because estimating the unobserved firm specific effect (v_i) along with b, s creates the incidental parameter problem (Wooldridge, 2002), which leads to inconsistent estimate of the b ,s[x]. The problem arises when the number of parameters particularly the v_i ,s increases as $N \to \infty$, for a fixed *T.*

The model is specified as $z^*_{jt} = x_{jt} b + m_{it} + v_i$ (22)

where *j* represents the *jth* firm j=1(1) N; subscript *t* denotes time[xi], (in our model it spans from 1991 to 2005). The analysis was done for two sets of efficiency scores namely, output efficiency and total input efficiency[xii] separately.

To explain the variation in the efficiency scores of the firms we selected a number of explanatory variables. The explanatory variables can be broadly classified in to three groups (A) Firm's Structural Variables and (B) Firm Specific Strategy Variables and (C) Policy related Variable.

Structural Variables

The structure of a firm is determined largely by its size, technological parameters, product mix, and ownership pattern and also by geographical location (Caves and Barton, 1990; Caves, 1992). We took each of these factors into consideration.

From the theoretical viewpoint the relationship between the size of firm and its efficiency was not clear (Audrestch, 1999). On the one hand it can be hypothesised that large size firms will be more efficient because the presence of threshold limit in production, scale economies, imperfection in capital market and market power may favourably influence the size factor (Kumar, 2003). However, beyond a certain limit, higher market power may also plague the firm with X-inefficiency (Leibenstein, 1976) which may lead to lower efficiency.

The output share of a firm in the total industry (Kwoka, 1978) was taken as a proxy for its size. To capture the possible non-lineralities between the output efficiency and the size of the firms we also included the size of a firm and its square in the regression analysis.

The capital-labour ratio measured in terms of the ratio of the company's expenses for plant-machinery, building, and other fixed assets to its expenditure for wages and salaries was an important technological variable and captured the degree of mechanisation in the production process. It is hypothesised that higher the degree of automation in the production system higher the efficiency of the firm as workers perform repetitive works more efficiently with better automation.

Imported technology measured in terms of the ratio of the firm's expenditure for imported capital goods to its total value of sales was an additional technology-related variable considered in our model. Generally, Indian pharmaceutical firms re-engineer imported technology and learn amount new designs, product and process[xiii]. Such activities enable firms to build up internal production capabilities and competency. Also, firms selling new technology share their experience and skill in managing the technology and send their personnel to adapt the technology to local conditions. All these may positively affect the efficiency of the firms. Since imported technology remains in the stock of the firm, the variable imported technology usages for the t^{th} year is constructed by adding the figures for the imported technology from the base period to the t^{th} period by taking 5 per cent as the rate of depreciation.

Product Mix: The product variety that a firm supplies also indicates its structure. Three categories of firms were identified based on the products produced, viz., the formulation companies that produce only the final product, the bulk drug companies that produce the basic raw materials and the bulk and formulation companies that produce both bulk and formulation products. Firms producing both the bulk and formulation products are vertically integrated with the raw material industry and are expected to enjoy the advantages of vertical integration (Coase, 1937; Hess, 1983; Williamson, 1981) against the other two categories of firms. However, if the internal cost of organising the activities exceeds the benefit of vertical integration and there is control loss (Coase, 1937, Williamson, 1967) firms may lose efficiency. Firms have been differentiated based on the products with dummies treating the formulation companies as the benchmark for our analysis.

Ownership Pattern: We also distinguished the structure of firms based on the ownership pattern. Two important forms of ownership were observed in the Indian pharmaceutical industry - foreign MNCs and the private domestic companies. We examined in our paper whether MNCs are more efficient than the domestic firms by differentiating them with a dummy that takes a value 1 if the firm is an MNC and zero (0) otherwise.

Experience: From the point of economic theory the relationship between a firm's age with its performance was again ambiguous in nature. Some authors suggest that older firms enjoy superior performance since they are more experienced and enjoy the benefits of learning (Stinchcombe, 1965). Others however have argued that older firms are prone to inertia and less flexible to changed economic circumstances (Marshall, 1920). The age of the firm was calculated from the year of incorporation. The square of the firm's age was also included in the model to allow for non-linearity in our model.

Geographical Location: Three important geographical agglomerations were noticed in the context of Indian pharmaceutical industry, viz; Western region (Mumbai, Baroda, and Ahmedbad), Southern region (in and around Hyderabad, Chennai and Bangalore) and Northern region (in and around Delhi). Historically most of the firms are located in the Western region because of the presence of a vibrant chemical industry. Due to dense clustering, firms in that region enjoy some sort of natural location-specific advantage[xiv] in the form of greater knowledge spillover (Krugman, 1991; Antonelli, 2003), or superior linkage with the raw material industry (Baptista and Swann, 1998; Porter, 1998, 2003). A location-specific intercept dummy was used to capture this feature with a value 1 for differentiating the firms of the western region from the rest of the country.

Strategy Variables

The strategies that firms adopt reflect the changing behaviour of firms in response to policy changes. Three important strategy variables considered in our model are R&D intensity, marketing intensity and export intensity.

R&D intensity measured in terms of the ratio of the firm's expenditure on R&D to its value of sales is supposed to favourably affect the efficiency factor (see Ornaghi, 2006). This is because firms doing R&D can invent superior processes technology or can produce better products for which they can earn higher revenue employing the same level of inputs (Aghion and Howitt, 1992; Grossman and Helpman, 1991). However, heavy allocation of resources for R&D can also reduce efficiency if firms fail to get the benefit of R&D (Helpman, 1992).

Marketing and advertisement intensity measured in terms of the ratio of marketing and advertisement expenditure incurred per unit of revenue generated by a firm captures the firm's allocation on sales and marketing efforts. A higher allocation of resources for marketing activities indicates an effort to strengthen the firm's brand and product image which may lead to higher revenue and in turn enhance output efficiency (Mark and Caves, 1988; Leffer B 1981).

We also constructed a measure for competition in the industry utilising the marketing expenses of a firm in the total marketing expenditure of the industry. The share of marketing measures the effectiveness of the firm's marketing effort when the total marketing expenses in the industry also increases. If competition is intense the value of this variable falls and vice versa

A number of studies have also indicated that firms selling their products in the international market also gain higher efficiency (see Aw and Hang 1995, Robert and Tybout 1997, Clerides *et al* 1998, World Bank Report, 1997). There can be two sources of efficiency gains for firms selling their products in the international market. One is high prices for their products and hence higher returns; the second is 'learning by exporting' (see Clerides et al 1998, World Bank Report, 1993, 1997). Outward orientation of the firms measured in terms of the export earning of the firms per unit of the sales is included as an explanatory variable in our model to examine its impact on the efficiency of the firms.

Raw material import intensity also captures the firm's outward orientation. While a firm has to pay more to import high quality raw material it also improves its production efficiency of the firms if proportionate returns is more. Evidence also suggests that the import of intermediary goods is an important channel through which technological diffusion takes place (see, Tybout 2000); this may also affect the efficiency factor favourably. However, for imported raw-material a firm has to pay more; consequently if the benefit exceeds the cost it may reduce the input efficiency.

Many pharmaceutical companies are also undertaking a number of training programme to improve the proficiency of workers. There has been a surge in such activities to improve the operational efficiency of the firms, particularly after 1995. Generally, the internal resources that firms do not distribute to the share-holders act as a source of funds for such activities. Internal resources measured in terms of the reserve surplus and the retained profit per unit of the sales generated is taken as a proxy for various efficiency improving activities.

Policy Related Variable

A time dummy was also introduced taking value 1 from 1995 onwards and 0 for the rest of the year to examine the impact of policy reform on the efficiency of the firms. Specifically, we wanted to check whether or not the increased competition had benefited the firms positively. The effect of the policy change on the efficiency of the firms was not straight-forward. Apart from the policy of trade openness and free functioning of firms, an important component of the regulatory changes related to good manufacturing practices that required heavy investment in plant and machinery. Heavy investment may increase the cost of production and detoriate the efficiency of the firms. As argued earlier increased competition may benefit only a handful of firms and the rest may fall behind. Under such circumstances policy changes may reduce the efficiency of the firms.

Empirical results and findings

Table 2 summarises the main findings from the panel data model for output efficiency and total input efficiency of the firms (Appendix A provides the details of the estimated results). It can be observed (See Appendix A) that the estimated model is highly significant suggested by the high values of Wald–Chi square statistics. This implies that the explanatory variables together explain significant variations in the efficiency level of the firms. The log-likelihood test rejects the null-hypothesis that sigma μ is zero and therefore a random-effect Tobit model is preferred against the pooled Tobit model. This implies the presence of unobservable firm specific capability to influence the efficiency of the firms. Unobservable firm specific characteristics that influence the efficiency (competitiveness) of the firm may arise in the context of the Indian pharmaceutical industry for a variety of reasons. One important factor could be the managerial and entrepreneurial skill. The entrepreneurial skill of the managers includes, for example, the skill to implement and experiment with new ideas, explore new areas of research and business, motivate the workers and so on. Other firm specific intrinsic factors could be the competency and capabilities acquired because of age and experience in business. All of these factors make significant differences in the efficiency of the firms. The findings pertaining to the individual independent variables are discussed below.

Table 2: Determinants of Efficiency

Variables	Output efficiency Estimated signs	Input Efficiency Estimated signs
Capital –labour ratio	Insignificant	+ve ***
Bulk Drug	Insignificant	Insignificant
Bulk and Formulation	+ve ***	-ve***
Multi-national companies	+ve ***	+ve***
Marketing /Sales	+ve***	Insignificant
Competition	-ve***	Insignificant
Time dummy	-ve*	+ve*
Export/sales	-ve*	Insignificant
Imported raw-material	+ve*	+ve*
R&D/Sales	Insignificant	Insignificant
Imported Technology	Insignificant	-ve***
Firm size	+ve*	+ve*
Age	+ve*	+ve*
Square of Age	-ve*	-ve*
Reserve /Sales	+ve*	Insignificant
Western Region	+ve ***	Insignificant
Constant	+ve*	+ve*

*** Significant at 10 per cent level, ** significant at five per cent level, *significant at one per cent level.

Structural Variables

The firm's size is positively significant for its output efficiency. This implies that with an increase in the size of a firm, the output as well as the input efficiency of the firm increases. However, a negative coefficient with the square of the size of the firm for output efficiency and a positive coefficient for input efficiency also imply that diseconomies in scale of production emerge beyond a certain threshold limit and therefore output efficiency of the firm falls.

The coefficient for the capital–labour ratio is negative but it was statistically insignificant for output efficiency. This implies that increasing capital to labour ratio does not have any relation with the output efficiency of the firms. However, the coefficient was positively significant for input efficiency. This implies that a firm can reduce its input usage by installing capital intensive techniques and increase input efficiency. Increased mechanisation may prevent wastage, by synthesising the raw material in a better way and by rationalising the use of energy. This may therefore positively affect the input efficiency of the firms. This may be surprising because a firm that uses its input more efficiently is also supposed to produce its output efficiently. The difference arises because of returns to scale property of the technology. Compared to firms that are in the Increasing Returns to Scale (IRS) zone and have the same level of output efficiency firms in the Decreasing Returns to Scale (DRS) zone can cut down input use by larger amounts. Alternatively, for the same level of input efficiency the output inefficiency will be much more pronounced in the IRS zone.

Since most of the firms that invest heavily in plant and machinery are large or medium firms and are in the DRS zone of the production frontier such differences in the result was observed.

However, imported technology was statistically significant with negative coefficient but for input efficiency. This implies that even though the firms are importing technology they have not yet realised the benefit of the technology. Thus for the same level of output, firms importing foreign technology incur higher cost and are input inefficient.

Figures in the table also indicate that firms producing both bulk and formulation products are more efficient compared to firms that produce only bulk drug or formulation. This also reveals that in the context of the pharmaceutical industry vertically integrated companies are more output efficient. However, companies from both groups are input inefficient compared to firms that produce only formulation. Since per unit input requirement for producing formulation was less compared to other varieties of product, we found that firms producing formulation were more input efficient.

Figures in the table also suggest that MNCs operating in India are more efficient compared to the domestic companies. MNCs have a long history of undertaking R&D and use modern technology for production which has resulted in higher efficiency.

Age and age square was statistically significant for output and input efficiency of the firms with negative and positive coefficient, respectively. This established a U-shaped relationship between the age of the firms and the efficiency level achieved by them. This indicates that young and more experienced firms are efficient in India because they might use advanced technology.

In relation to geographical location we found that firms from the western region were more output efficient compared to firms located in other regions of the country.

Strategy Variables

Among the strategy variables considered in our study the marketing intensity was significant for output efficiency. This confirmed our hypothesis that in a differentiated pharmaceutical market firms that spend more for marketing, commands higher prices for their product by establishing brand names and subsequently earn more. The coefficient of competition was also negative and statistically significant for output efficiency of firms. This also implies that when competition is intense and rivals also spends more on marketing or advertisement related outlays and firm's efficiency improves.

We found that in spite of the growing importance of R&D, the variable was statistically insignificant to explain the efficiency of the firms. This might arise because R&D is a recent phenomenon for most of the pharmaceutical companies and therefore firms may take time to fully realise the benefits of R&D.

Contrary to the general perception, we also found that with a rise in export intensity the output efficiency of the firms fell. The export markets for the generic products are of two types, viz., the regulated generic market and the unregulated generic market. Exporting to the global regulated market for both the bulk drug and formulation is costly given the stringent regulatory norm that a firm has to follow to sell its product (Chaudhuri, 2005, pp188-195). The stricter the regulation the tougher the entry barrier and higher the price realisations. Though the regulated markets account for about 38.5 per cent of India's total export and 50 per cent of the bulk drug export, only a handful of them target the regulated market because of high cost of regulation. Therefore, a vast majority of the firms export their products to the unregulated market which also includes around 200 small–sized bulk drug exporters (Chaudhuri, 2005). Out of the total revenue earned, the share of export by these firms was quite high and some firms relied completely on the global market for revenue. However, competition is high in the unregulated market and the price realisation is low. We thus found that, on an average, a rise in export intensity resulted in a fall in the output efficiency of the firms[xv].

The use of imported raw materials however improved the output efficiency of firms. Our discussion with the pharmaceutical firms revealed that generally imported raw-material was used to produce high quality products that priced higher, and hence, a rise in imported raw-material increased the output efficiency of a firm.

Lastly, as expected the more a firm undertakes training programme, the higher is its output efficiency.

Policy Related Variables

The coefficient of time dummy takes a negative value for output efficiency and positive value for input efficiency of firms. This implies that while on the one hand policy changes and increased liberalisation improved the input-wise measure of inefficiency of firms on the other hand the change also worsened the output efficiency of firms. With liberalisation and increased competition, firms were undertaking different measures to economise and make the best possible use of inputs. Hence there has been a gain on the input front. However, it is possible that the frontier has shifted outward due to entry of new efficient firms leading to a rise in the distance between frontier firms and the inefficient firms. Consequently, we found that there was a fall in the average output efficiency of the firms.

Conclusion

The pharmaceutical industry of India is going through a stage of transition because of various policy changes. A look into the characteristics of the efficient and the inefficient firms indicates that the efficient firms have become more efficient over a period of time. This might have shifted the frontier outward for this sector and resulted in an increase in the gap between inefficient and efficient firms over the years. We however found that many small and tiny sized firms that mushroomed in the secure market under government policy had to face the burnt of new challenges after the amendment of the Drugs and Cosmetic Act. The high Capacity Utilization Ratio, low value of working to fixed capital and limited market reach for their products were the main reasons for their poor performance and low efficiency. In the phase of liberalisation and free functioning of the market, whether or not the government should continue with its policy of assured market is a matter of intense debate and discussions. However, it is worth-mentioning here the small scale sector played a pivotal role in keeping the prices of the essential drugs low and in providing drugs in remote villages of the country (Pradhan, 2007). One way to overcome this problem is to provide more funds to this sector, to upgrade their technology base and also encourage them to merge and grow in size to reap the benefits of economies of scale in production. Public hospitals and the Health Care Units still purchase essential medicines from these firms provided they follow the quality control norms laid down by medical ethics. In this regard it is worth mentioning that the government has proposed certain policy measures for the better performance of the small scale units. This includes availability of financial assistance up to Rs.1 crore with 15% capital subsidy to upgrade their technological base; additional 5 per cent interest subsidy to upgrade the technological base on the basis of Schedule 'M' of the Drugs and Cosmetic Rules and other supportive measures to undertake innovative R&D.

A look in to the determinants of efficiency of the firms indicates that large firms are more efficient. A possible route for the small as well as the medium sized firms to gain efficiency would be to merge and grow in size. However, if large firms merge additional benefits in the efficiency is not possible without change in the strategy. Our study also indicates that vertical merger is better than horizontal merger. Therefore firms producing only formulation or final products should merge with the firms that produce the raw-material or the bulk drugs for the industry.

The study also indicates that MNCs are more efficient than domestic firms. The Indian firms can enter into technological collaboration with MNCs to gain more efficiency. The large number of technological collaborations noticed in the Indian pharmaceutical sector is therefore a welcome move.

Our study also establishes that exporting to the global market always improves the efficiency (see footnote xv). In the short terms firms targeting the domestic market can sell their products in the semi-regulated market which requires modest investment in plant and machinery. The long run strategy will be to target the regulated market of the developed nations like the US, UK and others. However, exporting to the regulated market is not easy given the stringent regulatory norms that a firm has to satisfy. Further, it has to invest heavily in plant and machinery to maintain the standards set by the developed countries. In such a scenario, the Government should extend its support to the firms to upgrade their production systems on a par with global standard.

The study indicates that adopting capital-intensive techniques or importing technology and investing more in R&D does not improve output efficiency of firms. We have argued that it takes time to realise the benefit of new technology or R&D. Thus due to the sunk cost incurred for R&D and related activities, the firm's performance may drop in the short run if the success from R&D is not immediate. In the face of uncertainty in R&D, one possible way to encourage the firms to do more of R&D and upgrade the technology base will be to involve in more private–public partnership in R&D. In the context of the developed nations like the US, a study by NICHM (2000) indicates that out of the 50 top selling drugs, 48 were fully funded by government at some stage or the other. Thus public support played a very important role in boosting the R&D in developing nations. It is worth-mentioning here that the positive spill-over effect of the R&D activities of research institutes and the transfer of technology from the public sector units also played an important role in the growth of this sector (Sahu, 1998; Chaudhuri, 2005). The existing studies also indicate that in the context of India, public-private co-operation is inadequate and there is enough scope for such co-operation in future (Chaudhuri, 2005). Such co-operation will enable firms to share the risk of R&D and will also help public institutes earn revenue for successful innovative products. Another possible route to boost R&D activities and upgrade technology in the Indian pharmaceutical firms will be to facilitate the role of venture capitalists.

We found that by importing raw-material firms can improve their efficiency. However, in the recent amendment of the Drugs and Cosmetic Act of 2002, there still exist a number of provisions to control the import of raw-material. Generally, it is the advanced bio-tech product that a firm imports from the international market. The current policy however, regulates the free import of bio-tech products. Import of bio-tech products involves trade in micro-organism and therefore the question of bio-ethics is intricately attached to it. It is therefore recommended that the hurdles of regulation be minimised for the free import of bio-tech products, if achieving efficiency is a criteria of the policy markers. Thus instead of controlling the import of bio-tech products one possible way to ensure quality and good manufacturing ethics is to adhere to good manufacturing practice and strict quality control.

Lastly, it is well known that pharmaceutical firms spend heavily on marketing activities. We found that spending more for promotional activities improves the technical efficiency of firms. Also when competition is more and rivals also spends for marketing related outlays the demand for the product increases which in turns also brings higher returns to the firms and its efficiency improves.

End Notes

[i] Except for those produced by the recombinant DNA technology, those requiring in-vivo uses of nucleic acid and specific cell/tissue targeted formulations.

[ii] Establishing the brand name and network is necessary to appropriate the benefit of the first-mover advantage soon after the patent expiry of the drugs in the market for the developed nations.

[iii] The benchmark technology or the frontier can also be constructed by using the parametric technique of stochastic approach.

[iv] Thus in our sample we have companies producing high value products with sophisticated technology which in turn has helped to generate sales of more than Rs 40 billion rupees. On the contrary, almost 80 per cent of the manufacturers in this industry operate on a small scale and have annual sales volume of less than a billion rupees.

[v] In the input-oriented radial measure for technical efficiency all the inputs in the input bundle are contracted at the same proportion. This approach for efficiency measurement however ignores the possibility of further reduction in each of the inputs in the input vector and the problem of slacks arises. For example, assume that due to the construction of the technology set it is possible for a firm to reduce capital

about 20 per cent and labor by say 30 per cent. The technical inefficiency for capital is .20 and labor .30; the radial approach for efficiency measu rement however calculates the input oriented technical inefficiency of the firm as .20 and omits the possibility of further reduction in the labour by another 10 per cent. The difference .10 is the input slack for labour.

[vi] The Prowess Data-Base provides firm level information from 1989 to the current year. However, data is consistently available only 1991. Therefore the study period from 1991 to 2005 is considered in this paper. Also most of the policy changes for this sector were implemented between 1995 and 1998.

[vii] We have re-classified the inefficient firms into three groups, viz., firms with inefficiency scores falling between .99 and .75, firms with inefficiency scores within .76 to .45 and firms with inefficiency scores of less than .45. It is interesting to notie that the proportions of firms with an efficiency score of less than .45 have been steadily rising over the years. From 1995 onwards the proportion is as high as 60 per cent.

[viii] Labour efficiency of a firm is arrived at by keeping its output and employment of other factors of production constant. If because of labour unions a firm cannot cut down its cost of labour even when there is over-employment of labor it will show high labor inefficiency. But with liberalisation firms have more flexibility to employ labour. Further, there is no dearth of specialised and skilled labour for the sector. Together this implies that labour efficiency is high for this sector.

[ix] Discussions with the companies revealed that a firm has to install high quality capital stock of worth Rs 3 core to fulfill the requirement of Schedule M of the newly amended Drugs and Cosmetics Act. Moreover, many companies have also upgraded their production system on par with the standards set by the regulatory body of the developed countries to export their products. Since, return from capital stock generally takes time to realise it may not be possible for a firm to realise fully the potential benefit of the capital stock at least in the short run.

[x] See also Baltagi (2005) for a detailed discussion on the problem and use of censored regression panel data model.

[xi] The observed efficiency scores is right censored at 1 as it is equal to the actual score whenever the actual score is <1. When the actual score is ≥ 1, the observed efficiency score =1.

[xii] The total input efficiency is arrived at by taking an average of the input wise inefficiencies of different inputs.

[xiii] See World Bank Report (1993, 1997) about the firm's import of foreign technology and its positive impact on its efficiency.

[xiv] See Cooke, Heidenreich and Braczyk, 2004, for a overview of firm's spatial location and its advantages and disadvantages.

[xv] It is worth mentioning here that a large number of firms (almost 40 to 45 per cent of the total sample) sell their products in the domestic market. By differentiating the firms that target only the domestic market with a dummy variable we find that the earning from the international market is always more and hence the efficiency is also more. However, in our study firms with higher export intensity target mainly the unregulated market and thus we find with more export earnings the efficiency of the firms falls.

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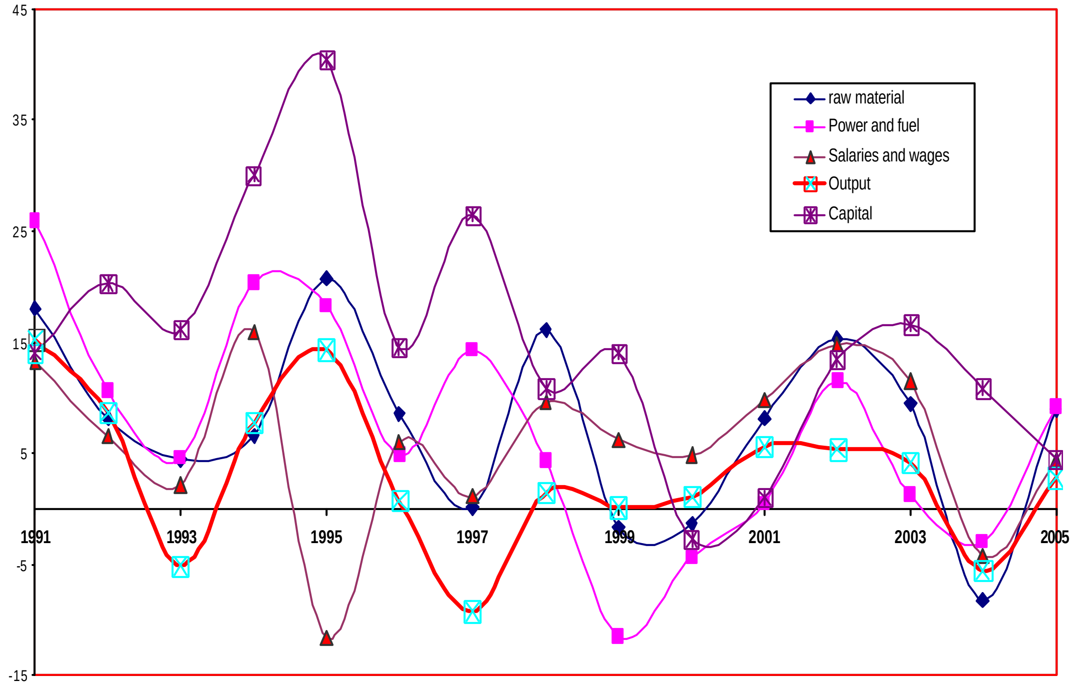
Appendix A

Figure 1: Growth Rate in Inputs and Output



Appendix B

Table no 1a: Results from Panel Data Analysis (Output efficiency)

Variables	Coefficients	Z-values	Prob> ¦ Z¦ >0
Capital –labour ratio	-5.03e -06	-0.61	0.543
Bulk Drug	.0264419	0.82	0.415
Bulk and Formulation	.0729986	2.55	0.011
Multi-national companies	.0450431	1.17	0.241
Marketing /Sales	.0117858	1.71	0.087
Competition	-2.360432	-1.92	0.055
Time dummy	-.1165368	-7.92	0.000
Export/sales	-.0509853	-2.96	0.003
Imported raw-material	.0939484	4.15	0.000
R&D/Sales	.0494315	0.63	0.529
Imported Technology	-.0063294	-0.51	0.610
Reserve /Sales	.0003611	2.96	0.003
Firm size	19.40632	11.15	0.000
Square Firm size	-49.77589	-4.03	0.000
Age	-.0172499	-8.58	0.000
Square of Age	.0002121	8.28	0.000
Western Region	.0439482	1.74	0.082
Constant	.7006724	19.50	0.000

*** Significant at 10 per cent level, ** significant at five per cent level, *significant at one per cent level.

Number of observations: 2492, Number of groups: 289 — Wald chi = 1203.05

Log likelihood = 415.23759 — Prob > chi2 = 0.000

Prob > chi2 = 0.0000

Likelihood-ratio test of sigma_u=0: chibar2(01)= 514.54 — Prob>=chibar2 = 0.000

Table no 1b: Results from Panel Data Analysis (Input efficiency)

Variables	Coefficients	Z-values	Prob> ¦ Z¦ >0
Capital –labour ratio	9.32e-06	1.66	0.097
Bulk Drug	-.0464452	-3.17	0.002
Bulk and Formulation	-.0369152	-2.32	0.021
Multi-national companies	.04291	1.94	0.052
Marketing /Sales	-.0004892	-0.11	0.915
Competition	.3310995	0.47	0.640
Time dummy	.0331529	3.63	0.000
Export/sales	.0040559	0.32	0.748
Imported raw-material	-.0011524	-0.09	0.932
R&D/Sales	.0751191	1.30	0.192
Imported Technology	-.008792	-2.73	0.006
Reserve /Sales	.0000969	1.19	0.234
Firm size	2.779591	2.98	0.003
Age	-.0055969	-5.23	0.000
Square of Age	.000069	4.97	0.000
Western	-.3720002	-0.87	0.382
Constant	.8312879	43.74	0.000

*** Significant at 10 percent level, ** significant at five percent level, *significant at one percent level.

Number of observations: 2492, Number of groups: 289 Wald chi =96.02

Log likelihood = 629.71797 Prob > chi2=0.000

Prob > chi2 = 0.0000

Likelihood-ratio test of sigma_u=0: chibar2(01)= 496.47 Prob>=chibar2 = 0.000

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