Measuring the Efficiency of Pharmaceutical Firms in India: An Application of Data Envelopment Analysis and Tobit Estimation

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Abstract

The pharmaceutical industry of India has been identified as one of the main drivers of India's recent high export-led growth and an employment generator possessing enormous positive externalities. This paper examines the levels and determinants of efficiency of firms of this vital sector of the Indian economy by using firm-level data. For this purpose, a two stage data envelopment analysis has been used.

In the first stage, technical efficiency analysis of 90 sample firms has been undertaken. One output, viz. sales of the sample firms for the years 2001-02 to 2007-08, and three inputs; viz. (i) Raw material cost; (ii) Cost of salaries and wages; and (iii) Cost of advertising and marketing; have been considered. In the second stage, the efficiency scores obtained from the first stage are regressed on external environmental factors like the age of the firms, export of goods, import of capital goods, profit rate, R&D intensity, ownership, patent regime and foreign direct investment using a censored regression model, viz. Tobit model.

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

Keywords: Efficiency, pharmaceutical firms in India, Data Envelopment Analysis, Tobit Analysis
JEL Classification: D24, C14

1. Introduction

The pharmaceutical industry of India has been identified as one of the main drivers of the high export-led growth of India during 2003-04 to 2007-08 (GOI, 2008) and an employment generator, possessing enormous positive externalities (GOI, 2009). The industry ranks third worldwide, accounting for 10% of the world's production by volume and fourteenth globally, constituting around 1.5% in terms of value (GOI, 2009). It meets about 70% of the domestic requirements of bulk drugs[1] and almost the entire domestic requirement of formulations[2]. Besides, the industry exports both bulk drugs as well as formulations.

The extant vitality of the pharmaceutical industry in India has been earned over the years primarily because of strategic policies of Government of India (GOI) including a process patent regime, deliberately initiated under the Indian Patents Act, 1970. Between 1970 and 2005 the Indian pharmaceutical firms successfully competed with Multinational Corporations (MNCs) both in India and abroad and the industry progressed from an importer of Active Pharmaceutical Ingredient (API) to a competitive manufacturer of bulk drugs and formulations. Concurrently, the dominance of monopolistic MNCs in the Indian pharmaceutical industry transformed into the flourishing of domestic oligopolies. The key features of the four-phased evolution of the pharmaceutical industry of India have been summarized in Table 1.

Table 1: Key Features of the Evolution of the Pharmaceutical Industry of India

Phase	Period	Key Features
I	Up to 1970	TNC Domination. Bulk drugs and API imported.
II	1970 to 1995	Indian Patents Act, 1970 enacted. Growth of indigenous firms.
III	1995 to 2005	WTO came into effect. Compulsory to introduce product patents by 2005.
IV	Since 2005	Shift from process-based patenting to product patents. Focus on R&D.

Up to 1970, the pharmaceutical industry of India was dominated by MNCs which imported most of the bulk drugs, from their parent companies abroad and sold the formulations in India. The Indian Patents Act, 1970 introduced patents on the manufacturing process and not on the end-product (Jha, 2007; Chittoor et al., 2008). In

1995, when the World Trade Organisation came into being, India being one of its founder members automatically became a signatory of the Trade-Related Intellectual Property Rights agreement and was under compulsion to introduce a product patent regime by 2005 (EXIM, 2007). During the process patent regime (1970-2005) the pharmaceutical industry of India grew not only in terms of the number of producers, but also in terms of catering to the domestic market requirements. At present, there are around 300 medium and large pharmaceutical firms in India, including both domestic and MNCs and the number of small firms is estimated to be around 10,000 (GOI, 2009).

In the year 2005, a new scenario emerged in the Indian pharmaceutical sector. The 35-year old process patent regime was replaced by the more rigorous product patent regime. Thus, post-2005, the importance of research and development (R&D) activities for the Indian pharmaceutical industry has gone up, with a number of firms setting up their own R&D units (Jha, 2007), and collaborating with research laboratories (FICCI, 2005). The focus of pharmaceutical firms has come to be governed by the size of their operations, with large firms emphasizing on discovery and development of new drugs; medium firms stressing on producing generics[3] and small firms opting for contract manufacturing (Rao, 2008).

R&D comprises the search for various novel pathways and the development of expertise which facilitate faster product development. On the one hand, it generates new technologies and, on the other, it enhances a firm's ability to exploit existing technology (Cohen and Levinthal, 1989). The importance of R&D for a technology-intensive industry like the pharmaceuticals cannot be over-emphasised. However, despite Indian pharmaceuticals enjoying cost advantages in the form of Indian tax rebates on R&D expenditure, and drugs developed using indigenous R&D being exempted from price controls in India, the industry has a low average R&D intensity, (the ratio of expenditure on R&D activities to total sales) of only 3.5% (ISID, 2007), as compared to 8-10% in USA (Congressional Budget Office (CBO), 2006) and 10-12% in Europe (Sharp and Patel, 1996).

The competitive advantage that Indian pharmaceutical firms had in the global markets from 1970 to 2005 is due to a variety of factors. The scenario for the pharmaceutical sector has changed significantly in recent years due to two major factors; one, the introduction of the new patent regime on January 1, 2005, and the second factor is the current economic crisis, which has engulfed the entire world and has resulted in inter alia shrinking global demand for exports and stifled rates of growth. The global pharmaceutical industry has not been unscathed by the on-going global crisis. In this context, it is important to understand whether the internal efficiencies of individual pharmaceutical firms have undergone any change. The utilization of resources available to the firms of the pharmaceutical sector warrants a probe.

This paper examines the levels of efficiency of pharmaceutical firms in India and discusses the determinants of efficiency. The remainder of the paper is divided into five sections. The literature review has been presented in section 2. Section 3 delineates the framework used for measuring efficiency, i.e., Data Envelopment Analysis (DEA) and Tobit estimation and discusses the research methodology which has been adopted for the analysis. The results of DEA and Tobit are presented in section 4. Drawing on the results, section 5 gives the concluding remarks, including prescribing some policy options. The last section dwells on the limitations of the study and enumerates the possible areas of further research.

2. Literature Review

The two principal methods of studying comparative efficiency are parametric and non-parametric methods. Stochastic Frontier Analysis (SFA) is a parametric method which determines comparative efficiency levels by hypothesising a functional form. Data Envelopment Analysis (DEA) is a non-parametric method which employs mathematical programming (linear programming model) (Coelli et al. 1998). The popularity of DEA rests on its capability to consider multiple inputs and outputs for calculating relative efficiency. DEA comes up with a single scalar value as a measure of efficiency and does not require any specification of functional forms as is required under SFA.

2.1 Data Envelopment Analysis

DEA is a linear programming model used to measure technical efficiency. It comes up with a single scalar value as a measure of efficiency. Efficiency of any firm can be defined in terms of either output maximization for a set of inputs or input minimization for a given output. In DEA, relative efficiencies of a set of decision-making units (DMUs) are calculated. Each DMU is assigned the highest possible efficiency score by optimally weighing the inputs and outputs. DEA constructs an efficient frontier composed of those firms that consume as little input as possible while producing as much output as possible. Those firms that comprise the frontier are efficient, while those firms below the efficient frontier are inefficient. For every inefficient DMU, DEA identifies a set of corresponding benchmark efficient units (Coelli et al. 1998).

Researchers have used DEA to measure the performance of firms, especially in the banking (Jackson and Fethi, 2000; Mukherjee, et al., 2002; Mostafa, 2007; Delis and Papanikolaou, 2009) and health care sectors (Chilingerian, 1995, Luoma, et al., 1998, Akazili, et al., 2008; Kirigia et al., 2008). Some researchers have studied the pharmaceutical industry also (Feroz, et al., 2008; Hashimoto and Haneda, 2008; Saranga and Phani, 2009). Besides comparing individual firms, DEA has been used to compare efficiencies of nations too (Tan, et al., 2007; Sharma and Thomas, 2008) (Table 2).

Table 2: Select Studies on Efficiency using DEA

Author (Year)	Region	Author (Year)	Region
Banks		**Pharmaceuticals**	
Jackson & Fethi (2000)	Turkey	Feroz et al. (2008)	USA
Mukherjee et al. (2002)	India	Hashimoto and Haneda (2008)	Japan
Mostafa (2007)	Arab world	Saranga and Phani (2009)	India
Delis and Papanikolaou (2009)	European Union	**Other Sectors**	
Health Centres		Fethi et al. (2000)	Europe
Chilingerian (1995)	USA	Chen et al. (2004)	Taiwan
Luoma et al. (1998)	Finland	Leachman et al. (2005)	MNCs
Akazili et al. (2008)	Ghana	Wang and Huang (2007)	30 countries
Kirigia et al. (2008)	Seychelles	Tan et al. (2007)	12 countries
		Sharma and Thomas (2008)	22 countries
		Hwang and Oh (2008)	Korea
		Hsu and Hsueh (2009)	Taiwan

Feroz, et al. (2008) have demonstrated the usefulness of DEA in performance measurement in the US pharmaceutical industry and have shown the applicability of DEA in arriving at an unbiased account of relative performance in a set of companies. Applying DEA, Hashimoto and Haneda (2008) observed that the R&D efficiency of Japanese pharmaceutical industry has worsened throughout the decade 1983-92. In the Indian context, after controlling for firm size and initial efficiency levels, Saranga and Phani (2009) found that in the era prior to the introduction of the product patent regime, higher R&D investments in pharmaceutical firms translated into higher efficiencies.

2.2 Two-stage DEA

Apart from measuring the performance of firms, empirical studies have also been carried out to study the determinants of efficiency. In this context, a two-stage DEA has been employed by a number of researchers. This entails obtaining DEA efficiency scores in the first stage. In the next stage the efficiency scores are used as the dependent variable, which is regressed on the external environmental factors to determine what causes differences in efficiency levels across the DMUs under study.

Chilingerian (1995) analyzed both technical and scale efficiency using DEA and a multi-factor Tobit model to study the variables which were associated with higher levels of performance of physicians. The study revealed that a substantial amount of money could be saved if every physician practised medicine as efficiently as the most competent physicians. Jackson and Fethi (2000) investigated the performance of Turkish commercial banks using DEA. Using a Tobit model they identified the variables which explained the efficiency of some banks as the size of the bank, the number of branches, profitability, ownership and capital adequacy ratio. They found that larger and more profitable banks are more likely to operate at higher levels of technical efficiency.

A study conducted by Luoma, et al. (1998) to examine the productive efficiency of Finnish health centres applied DEA and Tobit analysis to evaluate how various economic, structural and demographic factors affect inefficiency. The results indicated

that a higher level of central government grants and a higher taxable income per inhabitant are predictors of inefficiency. Using data from eight major automobile manufacturers, Leachman, et al. (2005) adopted a two-stage DEA to examine the manufacturing performance and showed that a strong R&D commitment and ability to compress production time can explain differences in manufacturing performance.

A two-stage methodology was followed by Delis and Papanikolaou (2009) as well to analyze the efficiency of ten banks operating in the European Union. They found that bank size, industry concentration and the investment environment had a positive impact on the efficiency of banks. Hwang and Oh (2008) measured the performance of Korean software firms. With efficiency measured by using DEA, they used a Tobit regression to investigate whether the presence of Intellectual Property Rights (IPR) have a stronger effect on efficiency. Their results indicated that the average efficiency of software firms which possess any kind of software IPR was higher than that of firms not having them. Fethi, et al. (2000) used a two-stage DEA application to assess the efficiency of European airlines. Their empirical findings confirmed that concentration and subsidy policies have a negative impact on the efficiency of European airlines.

2.3 Three-stage DEA

Wang and Huang (2007) used a three-stage DEA to evaluate the relative efficiency of R&D activities across 30 countries. In the second stage, the input slacks obtained from the first stage of DEA were used as dependent variables in the Tobit regression. The estimated coefficients from the Tobit regression were used to predict the total input slack for each input and for each country. The empirical analysis indicated that less than one-half of the countries are fully efficient in R&D activities, while more than two-thirds were at the stage of increasing returns to scale. A three-stage DEA has been adopted by Hsu and Hsueh (2009) as well to assess the relative efficiency of government-sponsored R&D projects in Taiwan. Firm size and the ratio of public subsidy to R&D budget of the recipient firm were the determinants of technical efficiency of these projects.

2.4 Determinants of efficiency of firms

A review of the literature throws light on the factors which have been considered as determinants of efficiency of firms. Amongst the determinants of the performance of firms, Fethi, et al. (2000) and Delis and Papanikolaou (2009) considered liberalisation as one of the explanatory factors.

The impact of foreign ownership on the level of efficiency was considered by Delis and Papanikolaou (2009), Jackson and Fethi (2000) and Fethi, et al. (2000). To determine the efficiency of banks, another independent variable which was considered is their profitability (Jackson and Fethi, 2000).

The age of the firm can also be a determinant of its efficiency level (Hwang and Oh, 2008). In his study of the clinical efficiency of 36 physicians in a single hospital, Chilingerian (1995) employing a two-stage DEA, took the age of the physicians as one of the independent variables in the Tobit model.

Technological knowledge is important for a firm to attain and sustain its competitive advantage (Narasimha, et al., 2003). Leachman, et al. (2005) considered R&D intensity (ratio of expenditure on R&D and sales) as one of the explanatory variables determining the level of efficiency of manufacturing performance. Hwang and Oh (2008) took R&D intensity as one of the determinants of Korean software firms. Some empirical studies found that the long-run performance of firms depends on the firm-specific advantages such as R&D (Gregory and McCorriston, 2005).

From the literature review it emerges that DEA has been used extensively to study the efficiency of firms of various sectors. However, for the Indian pharmaceutical sector, very few studies have analysed the levels and determinants of efficiency of the firms, especially in the post-2005 era. Moreover, the number of studies comparing the efficiency of R&D-intensive and non-R&D pharmaceutical firms in India, are conspicuously limited. The current study aims to cover these gaps.

3. Research Methodology

This research study uses a two-stage DEA to achieve its research objectives. In the first stage, a set of observed inputs and outputs is used to derive efficiency scores for all the sample pharmaceutical firms. The first stage analysis using DEA is elaborated in section 3.1. In the second stage, the efficiency estimates obtained are regressed on factors which influence efficiency. For this purpose, a censored regression, Tobit, has been used. This is discussed in section 3.2.

3.1 Data Envelopment Analysis

3.1.1 DEA framework

In this study, an input orientation as opposed to an output orientation has been adopted. While the former seeks to minimize the usage of inputs given a fixed level of output, the latter maximizes the level of output for a given level of inputs. Since the DMUs are in control of the inputs which they use, the usage of an input-orientation was deemed appropriate here. The efficiency score depends on how well the DMU is performing vis-à-vis other firms. Under DEA, the Constant Returns to Scale (CRS) model states that the optimal mix of inputs and outputs is independent of the firm's scale of operation. Following the notations used by Coelli (1996), the objective of CRS is:

$$\text{Maximise}_{uv} \quad (u'y_i / v'x_i) \qquad (1)$$

$$\text{Subject to} \quad u'y_j / v'x_j <= 1$$

$$j = 1, 2, 3, \ldots, N \qquad u, v >= 0$$

where

N = number of DMUs

K = number of inputs

M = number of outputs

x_i = vector of inputs for i^{th} DMU

y_i = vector of outputs for i^{th} DMU

$X = K \times N$ input matrix for N DMUs

$Y = M \times N$ output matrix for N DMUs

$v = K \times 1$ vector of input weights

$u = M \times 1$ vector of output weights

The constant returns to scale (CRS) DEA model states that the optimal mix of inputs and outputs is independent of the firm's scale of operation, which implies that a proportionate increase in the inputs results in the same proportionate increase in the output. The objective function specified in (1) involves finding values for u and v, so that the efficiency of the i^{th} DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to 1. The above model is non-linear in nature and has infinite number of solutions. Since linear programming cannot handle fractions, the above formulation needs to be transformed in such a way that the denominator of the objective function is limited and maximization of the numerator is allowed. For this purpose, an additional constraint needs to be added. Thus, the above non-linear model transforms into the following linear model.

$$\text{Maximise}_{\mu\, v} \quad (\mu' y_i) \qquad (2)$$

$$\text{Subject to} \quad \nu' x_i = 1$$

$$\mu' y_j - \nu' x_j <= 0$$

$$j = 1, 2, 3, \ldots, N \qquad \mu, \nu >= 0$$

where the notation changes from u to μ and from v to ν representing the transformation.

To solve the Linear Programming specified in (2) a dual of the primal can be formulated in the following form:

$$\text{Minimise}_{\theta,\, \lambda}\ \theta \qquad (3)$$

$$\text{Subject to} - y_i + Y\lambda >= 0$$

$$\theta x_i - X\lambda >= 0,$$

$$\lambda >= 0$$

where θ is a scalar and is the efficiency score of the i^{th} DMU. λ is a N x 1 vector.

If θ = 1, it indicates a technically efficient DMU. The linear programming mentioned in (3) will be solved N number of times, once for each DMU, providing a value of θ for each DMU. The CRS assumption is appropriate in cases where all DMUs operate at an optimal scale. However, there might exist constraints on DMUs which do not allow them to operate at the optimal scale. Using CRS for such DMUs will yield

Technical Efficiency (TE) scores, which are affected by Scale Efficiencies (SE). Therefore, one needs to use the Varying Returns to Scale (VRS) model of DEA. VRS implies that an increase in inputs may result in either more or less than proportionate increase in the output. The VRS model incorporates the dual of CRS model, with an extra convexity constraint on λ.

$$\text{Minimise}_{\theta,\lambda}\ \theta \qquad (4)$$

$$\text{Subject to } -y_i + Y\lambda >= 0$$

$$\theta x_i - X\lambda >= 0,$$

$$N1'\lambda = 1$$

$$\lambda >= 0$$

where N 1 is a N x 1 vector of ones.

A Malmquist DEA, which is an application of DEA to a panel data to calculate indices of total factor productivity change (a productivity measure involving all factors of production), technological change, technical efficiency change and scale efficiency change, has been used in this paper. The Malmquist productivity index takes a value of more than one, if there is productivity growth. In case the index is equal to one, there is stagnation. If there is productivity decline, the index will take a value of less than one.

The input-oriented Malmquist productivity index or TFP growth can be defined using the technology of period t or period t+1. Therefore, it is defined as the geometric means of the index of the periods t and t+1. It is estimated as the ratios of distance functions of observations from the frontier.

$$M(q, x_t, q_{t+1}, x_{t+1}) = \left\{ \frac{d_{t+1}(q_{t+1}, x_{t+1})}{d_t(q_t, x_t)} \times \frac{d_t(q_{t+1}, x_{t+1})}{d_{t+1}(q_{t+1}, x_{t+1})} \right\}^{1/2} \qquad (5)$$

where

q_t is the output vector of period t

q_{t+1} is the output vector of period t+1

x_t is the input vector of period t

x_{t+1} is the input vector of period t+1

d is the input distance function

Equation (5) can be rewritten as:

$$M(q, x_t, q_{t+1}, x_{t+1}) = \frac{d_{t+1}(q_{t+1}, x_{t+1})}{d_t(q_t, x_t)} \left\{ \frac{d_t(q_{t+1}, x_{t+1})}{d_{t+1}(q_{t+1}, x_{t+1})} \times \frac{d_t(q_t, x_t)}{d_{t+1}(q_t, x_t)} \right\}^{1/2} \quad (6)$$

The ratio outside the brackets in equation (5) calculates the technical efficiency change between period t and t+1. The remaining part of the TFP index measures the technological change.

3.1.2 Data used for DEA

From the population of 300 large pharmaceutical firms in India, including both domestic and MNCs, a sample of 90 firms[4] having an annual sales of more than Rs. 1 crore during the year 2007-08 was selected. These firms together comprised 87% of the total sales of all the firms in the population during 2007-08. All the data relating to the inputs and output for the years 2001-02 to 2007-08 was culled out from the Prowess database of Centre for Monitoring Indian Economy (CMIE).

3.1.3 Selection of Input and Output

While making use of the DEA application, one needs to be careful about the choice of inputs and outputs. The efficiency scores could be very sensitive to changes in the data and depend heavily on the number and type of input and output factors considered. In this study, akin to the study by Saranga and Phani (2009), one output and three inputs have been considered (Table 3).

Table 3: Inputs and Output Used for DEA

Output / Inputs	Mean	Standard Deviation	Maximum	Minimum
Sales (Rs. Crore)	355.5	632.2	4,295.2	0.03
Raw Material cost (Rs. Crore)	169.5	290.6	2,178.3	0.08
Cost of salaries and wages (Rs. Crore)	51.2	121.8	1,187.3	0.05
Cost of Advertising and Marketing (Rs. Crore)	36.4	77.3	695.5	0.01

The total sales of the sample firms for the years 2001-02 to 2007-08 have been taken as the output for DEA. The choice of inputs is governed by the fact that the three inputs together constitute a substantial part of the total operating costs (more than two-thirds) which the pharmaceutical firms incur in their effort to produce the output, viz. sales of the firms. The three inputs which have been considered are:

(i) Raw material cost which includes the cost of all raw materials, spares, packaging, purchase of finished goods, printing, stationery and outsourced manufacturing jobs. This accounts for 48% of the total cost incurred by the 90 sample firms during the period under study. Over the period of the study, material cost rose by 146%.

(ii) Cost of salaries and wages comprises 10% of the total cost incurred by sample firms. This is inclusive of remuneration in all forms made to the employees, viz. salaries, wages, bonus ex gratia, contribution to Provident Fund, outsourced professional jobs and directors' fees. Between 2001-02 and 2007-08, the manpower cost increased by 150%.

(iii) Cost of Advertising and Marketing which includes the cost of advertising, marketing, distribution, travel and communication, account for 10% of the total cost of the sample firms. During the study period, marketing cost hiked up by 122%.

Mostafa (2007) highlighted that in case the minimum number of firms chosen for DEA is more than three times the total number of inputs and outputs, the chances of an inefficient firm being declared efficient reduces. In this study, there being three inputs and one output, the minimum requirement for the number of sample firms for using DEA is 12. Another condition that is required for DEA is that the function relating inputs and outputs should possess the monotonicity property, which essentially means that an increase in the inputs will increase the output. This relation is observed in the inputs and outputs which have been considered for analysis in the study. The third condition that all inputs and outputs should be positive is also satisfied. The input and output data has been used for computing VRS technical efficiency (VRS TE) scores of the firms using DEA software, version 2.1 (DEAP 2.1).

3.2 Tobit Analysis

3.2.1 Model

Once the relative efficiencies have been calculated, the determinants of the DEA efficiency scores can be investigated into. It is customary to regress the DEA efficiency scores on the relevant control variables (Luoma et al., 1998; Fethi, et al., 2000; Chilingerian, 1995; Hwang and Oh, 2008). Since the DEA efficiency score lies in the interval 0 and 1, the dependent variable is 'a limited dependent variable'. Therefore, it is apt to use the Tobit model, which is a censored regression model, applicable in cases where the dependent variable is constrained in some way. The Tobit model may be defined as:

$$y = \begin{cases} y^*; & 0 <= y^* <= 1 \\ 0; & y^* < 0; \\ 1; & 1 < y^* \end{cases} \qquad (7)$$

$$y^* = \beta x_i + \varepsilon_t$$

where y is the DEA VRS TE score. $\varepsilon_t \sim i\ e\ N(0, \sigma^2)$

y^* is a latent (unobservable) variable.

β is the vector of unknown parameters which determines the relationship between the independent variables and the latent variable.

x_i is the vector of explanatory variables, which are discussed in section 3.2.2.

3.2.2 Variables

Taking into account the characteristics of the Indian pharmaceutical industry and following the literature, the explanatory variables which are considered in the Tobit model to estimate the factors which determine efficiency of pharmaceutical firms are ownership, new patent regime, age, export of goods, FDI, import of capital goods, profitability and R&D intensity. Both the dependent and independent variables are

elaborated in Table 4. The panel data for the independent variables for the years 2001-02 to 2007-08 for all the 90 firms was taken from CMIE's Prowess database.

Table 4: Description of Variables used for Tobit Estimation		
Variables	**Description**	**Hypothesis**
Dependent Variable : DEA efficiency scores of firms obtained from stage I of DEA		
Independent Variables:		
1. Ownership (Dummy)	Odum = 1, if domestic ownership; = 0, otherwise	Foreign ownership increases efficiency.
2. Regime (Dummy)	Rdum= 1 for the years 2004-05 to 2007-08 = 0 for the years 2001-02 to 2003-04	New patent regime increases efficiency.
3. Age	A is the age of the firm.	+
4. Export of Goods	X is the absolute amount of exports.	+
5. FDI (Dummy)	FDIdum= 1, if firms receive FDI, = 0, otherwise	Presence of FDI enhances efficiency.
6. Capital Imports	M is the amount of capital imports.	+
7. Profit Rate	P is the ratio of profits to sales.	+
8. R&D intensity	RDI is the ratio of R&D to sales.	+
Note: A '+' sign indicates a positive influence of the explanatory variable on the dependent variable.		

Ownership: The management decides the magnitude and combination of inputs which go into producing an output. Thus, ownership of the firms is an important variable.

New Patent Regime: To retain their competitiveness in the new patent regime introduced in the year 2005, it is assumed that the pharmaceutical firms would have to step up their efficiency levels. Thus, it is postulated that the stricter new regime would lead to a higher level of efficiency.

Age: With age, firms gain the experience needed to be technically efficient. Therefore, it is hypothesized that the older firms have a higher level of efficiency.

Export of Goods: The pharmaceutical industry of India is looked upon as one of the drivers of India's export led growth. It is, thus, hypothesized that the efficiency of a pharmaceutical firm may be a fall-out of its level of exports.

Foreign Direct Investment: The pharmaceutical firms of India have been recipients of FDI flows since the opening up of the economy in 1991. It is postulated that FDI inflows increase the efficiency of firms.

Import of capital goods: The magnitude of capital goods imported by pharmaceutical firms has been taken as an explanatory variable, with the expectation that imports would enhance the efficiency of these firms.

Profitability: It is hypothesized that higher profits would enable a firm to overcome its shortcomings in terms of utilization of available resources.

R&D intensity: It is postulated that the investments made by pharmaceutical firms in R&D may enhance their performance in terms of efficiency.

Thus, the Tobit model used in this study may be specified as:

$$y^* = \alpha + \beta_1 Odum + \beta_2 Rdum + \beta_3 A + \beta_4 X + \beta_5 FDIdum + \beta_6 M + \beta_7 P + \beta_8 RDI + \varepsilon_t \quad (8)$$

4. Empirical Results

4.1 Results of DEA

The results obtained by running DEA are presented in two parts. The first part, elaborated in section 4.1.1 presents the results of Malmquist DEA for all the 90 firms for the years 2001-02 to 2007-08. The second part is discussed in section 4.1.2 and provides results of Malmquist DEA run separately for the two groups of firms, viz. R&D intensive and non-R&D firms.

4.1.1 DEA Results for All 90 Firms

Frequency Distribution

The yearly analysis reveals that 70 (78%), 68 (76%), 61 (68%), 64 (71%), 65 (72%), 70 (78%) and 67 (74%) firms operated inefficiently in the years 2001-02, 2002-03, 2003-04, 2004-05, 2005-06, 2006-07 and 2007-08, respectively (Table 5). These firms needed to reduce their inputs to attain a given level of output to become efficient.

Table 5: Frequency Distribution of VRS TE

VRS TE	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
<.5	4	2	3	3	5	3	12
.5 to .7	22	18	16	16	15	13	18
.7 to less than 1	44	48	42	47	45	54	37
1	20	22	29	26	25	20	23
Total	90	90	90	90	90	90	90

Average Efficiencies

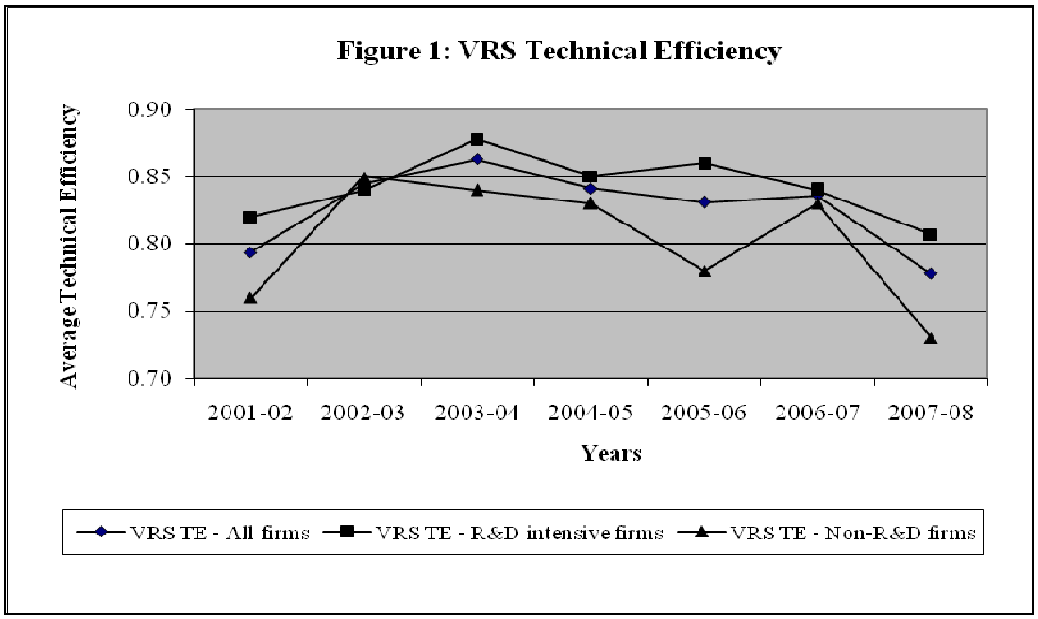
Table 6 gives the summarized form of the average efficiency figures of all firms. The average VRS TE for the firms was 0.79, 0.85, 0.86, 0.84, 0.83, 0.84 and 0.78 for 2001-02 to 2007-08. Had the firms been efficient, they could have reduced their inputs by 21%, 15%, 14%, 16%, 17%, 16% and 22%, respectively, for the given level of output.

Table 6: Average VRS TE of Sample Firms

Description of Firms	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
All firms (90)							
Mean	0.79	0.85	0.86	0.84	0.83	0.84	0.78
Standard Deviation	0.18	0.16	0.16	0.16	0.18	0.16	0.22
Maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Minimum	0.03	0.04	0.04	0.05	0.02	0.02	0.02
R&D intensive firms (55)							
Mean	0.82	0.84	0.88	0.85	0.86	0.84	0.81
Standard Deviation	0.15	0.13	0.13	0.14	0.14	0.12	0.18
Maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Minimum	0.03	0.04	0.04	0.06	0.03	0.03	0.02
Non-R&D firms (35)							
Mean	0.76	0.85	0.84	0.83	0.78	0.83	0.73
Standard Deviation	0.22	0.21	0.21	0.20	0.22	0.21	0.27
Maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Minimum	0.50	0.52	0.48	0.48	0.41	0.52	0.32
Note: Figures in brackets are the number of firms in each category.							

Efficiency of R&D intensive firms vis-à-vis non-R&D firms

The VRS TE of firms categorized by R&D intensity over the period 2001-02 to 2007-08 is depicted in Figure 1. Except for 2002-03, when the mean VRS TE of non-R&D firms was marginally higher than that of R&D intensive firms, in all other years R&D intensive firms were more efficient. Throughout the study period, non-R&D firms show more variability in performance than the R&D intensive firms (Table 6).



The null hypothesis stating that the mean technical efficiency of R&D firms and non-R&D firms is not different, was tested using a one-tailed t-statistic. Since the calculated t-value is greater than the probability value of a two-tailed t-test, the null hypothesis was rejected. Therefore, it may be concluded that the difference between the mean VRS TE of R&D firms and that of non R&D intensive is statistically significant.

Malmquist Productivity Index

For Malmquist productivity index, the first year of the study period, viz. 2001-02, has been taken as the technology reference period. Over the period 2001-02 to 2007-08, the average total factor productivity of the sample firms has remained at the same level

(Table 7). While efficiency change (CRS TE) regressed by 6%, pure efficiency change by 1% (VRS TE) and scale efficiency by 5%, technological change gained by 6% over the same period. Efficiency change (0.94) is a product of the pure efficiency change (0.99) and scale efficiency change (0.95). The technological change of 1.06 indicates that during the period under study, there has been a 6% technical progress.

Table 7: Summary Results of Malmquist DEA for all 90 Firms

Year	Efficiency Change*	Technological Change	Pure Efficiency Change**	Scale Efficiency Change	Malmquist Index of Total Factor Productivity Change
2003	1.16	0.85	1.08	1.08	0.98
2004	0.95	1.06	1.02	0.93	1.01
2005	0.98	1.01	0.98	1.01	0.99
2006	0.89	1.10	0.98	0.91	0.98
2007	1.10	0.87	1.01	1.09	0.96
2008	0.65	1.63	0.90	0.72	1.06
Average	**0.94**	**1.06**	**0.99**	**0.95**	**1.00**

*: Technical Efficiency change relative to CRS technology
**: Pure Technical Efficiency Change relative to VRS Technology

Having established in Table 6 that for R&D-intensive firms the efficiency level is higher and having rejected the hypothesis that the mean VRS TE of R&D firms is equal to that of non-R&D firms, the firms were categorized into two groups according to the presence or absence of R&D activities. Thereafter, a Malmquist DEA was run for both the groups separately for the years 2001-02 to 2007-08. The results are presented in Tables 8 and 9. It may be noted that these results yield the efficiency levels of the firms within their respective groups and their individual efficiency levels cannot be compared across groups. The efficiency of a firm in the total sample set of 90 firms would be different from that in the groups categorized as per the presence or absence of R&D.

4.1.2 DEA Results for the Group of R&D-intensive firms

Between 2001-02 and 2007-08, the number of R&D intensive firms which are efficient has gone up from 13 to 17, after having reached a peak of 21 efficient firms in

2004-05, the year in which the patent regime changed (Table 8). The mean VRS TE of inefficient firms has declined from 0.76 in 2001-02 to 0.74 in 2007-08, although in some years in between, the mean had crossed 0.80 and in 2002-03 it had reached 0.85.

Table 8: Average VRS TE of R&D intensive Firms							
Description of Firms	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**
All firms (55 firms)							
Mean	0.82	0.85	0.88	0.86	0.89	0.86	0.82
Standard Deviation	0.15	0.13	0.13	0.13	0.10	0.12	0.17
Efficient TE=1							
Number of Firms	13	12	17	21	19	15	17
Inefficient							
Number of Firms	42	43	38	34	36	40	38
Mean	0.76	0.85	0.83	0.78	0.84	0.80	0.74
Standard Deviation	0.13	0.13	0.12	0.10	0.08	0.10	0.14

4.1.3 DEA Results for the Group of Non-R&D firms

The number of efficient firms which are non-R&D has nearly doubled between 2001-02 and 2007-08, from 8 to 15 (Table 9). However, the mean VRS TE of inefficient firms over the same period has gone down from 0.71 to 0.56, although the standard deviation has remained the same.

Table 9: Average VRS TE of non R&D Firms							
Description of Firms	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**
All firms (35 firms)							
Mean	0.77	0.86	0.84	0.86	0.82	0.82	0.76
Standard Deviation	0.22	0.21	0.21	0.19	0.22	0.21	0.27
Efficient TE=1							
Number of Firms	8	12	14	11	13	11	15
Inefficient							
Number of Firms	27	23	21	24	22	24	20
Mean	0.71	0.77	0.74	0.80	0.70	0.74	0.56
Standard Deviation	0.21	0.22	0.22	0.21	0.22	0.21	0.21

4.2 Results of Tobit Analysis

After obtaining the DEA scores, the next step is to regress through the Tobit model these scores on variables which are considered as determinants of efficiency. The results of the Tobit estimation using the STATA software are presented in Table 10. Four models have been presented in the table. For each of the four models used, the Prob > χ^2 is zero, implying that the set of independent variables considered together satisfactorily explain the variations in the dependent variable.

Table 10: Results of Tobit Estimation

Variables	**Model I**	**Model II**	**Model III**	**Model IV**
1	**2**	**3**	**4**	**5**
Dependent Variable	VRS TE (All Firms)	VRS TE (R&D) 1	VRS TE (R&D) 2	VRS TE (Non R&D)
Independent Variables	**Coefficients**			
Odum	0.8827573	0.0332265	0.0328079	
Rdum	0.0241874*	0.0067488*	0.0082413*	0.0322066*
A	-0.0006655	-0.0002829*	-0.0002879*	-0.0115441**
X	0.0002565**	0.0007917*	0.0008107*	0.0001028
FDIdum	0.0141862*	-0.0157963	-0.0152869	0.4696286**
M	-0.0000237	0.0001723	0.0001667	0.0001114*
P	0.0000265*	0.0058958**	0.0059263**	0.0000272
RDI	-0.0000129	0.0000142*		
Constant	0.8600945**	0.8505905**	0.8495158**	1.086546**
No. of observations	630 = 90 X 7	385 = 55 X 7	385 = 55 X 7	245 = 35 X 7
LR χ^2	58.74	42.68	42.57	63.90
Prob > χ^2	0.0000	0.0000	0.0000	0.0000
Log likelihood	-94.75	-11.87	-11.93	-80.70
*: Significant at 10% level; **: Significant at 1% level.				

Column 2 of Table 10 presents results of the Tobit model wherein the VRS TE scores obtained by running DEA on all 90 firms has been taken as the dependent variable. It is observed that the coefficients of Rdum, X, FDIdum and P are significant and bear the expected positive sign. The new patent regime, the level of exports, the presence of FDI and profitability positively influences efficiency. The signs of the coefficients of other variables, A, M and RDI, are negative, contrary to expectations. But these are not significant.

In Model II, results of which are presented in column 3 of Table 10, the VRS TE obtained by using Malmquist DEA on R&D intensive firms has been taken as the dependent variable. The variables whose coefficients are observed to be significant are Rdum, A, X, P and RDI. In the new patent regime, the efficiency of firms has increased. The results imply that younger the firm, higher is its efficiency. More profitable firms are more efficient. A higher level of outward orientation of firms in the form of exports increases their efficiency. The intensity of R&D expenditure has a positive and significant impact on the firms' efficiency.

To facilitate comparison between the efficiency levels of R&D-intensive firms and non-R&D firms, another model has been adopted and the results are provided in column 4 of Table 10. In this model too, the dependent variable is the VRS TE of R&D intensive firms. The difference between the models presented in columns 3 and 4 is the non-inclusion of the R&D variable in the latter. The coefficients of the variables, Rdum, A, X and P, which were significant in Model II, continue to be significant in Model III.

In Model IV, the VRS TE derived by utilizing Malmquist DEA on non-R&D intensive firms is the dependent variable. Since all the non-R&D firms are domestically owned, the variable Odum, has not been considered as an explanatory variable here. Unlike the models for R&D-intensive firms, in this model the coefficient of FDIdum and M, in addition to Rdum and A, are found to be positive and significant. This implies that for non-R&D firms, the presence of FDI, the level of capital imports, the new patent regime and the age of the firm have a positive influence on the firm's level of efficiency.

5. Implications and Conclusion

The first stage of DEA model of this study finds that the performance of a large number of sample firms was sub-optimal, ranging between 68% and 78%. To become efficient, these firms need to reduce their inputs to attain a given level of output. Further, R&D intensive firms are more efficient than non-R&D firms. Given the importance of

the sector for the Indian economy, it is important that efforts be taken to increase the efficiency of the firms whose performance is sub-optimal.

The second stage of the analysis involving a Tobit estimation identifies the important determinants of the efficiency of pharmaceutical firms as the introduction of the new patent regime, export of goods, inflow of FDI and the profitability of firms. For R&D intensive firms, in particular, their R&D intensity adds to their efficiency. This is similar to the findings of Saranga and Phani (2009). For non-R&D firms, the import of capital goods increases their technical efficiency.

The findings hold important managerial and policy implications. With the onset of the product patent regime, the management of pharmaceutical firms has become more conscious of the survival and competitiveness of their firms. As indicated by the second stage of analysis, most parameters which affect a pharmaceutical firm's efficiency are dependent on its outward orientation like exports, imports and FDI. Therefore, the integration of the Indian economy with the rest of the world has an important influence on a firm's internal efficiency. The export of goods may require meeting stringent standards set by the importing countries, which mandates the efficient utilization of available resources. Pharmaceutical firms may like to enhance their efficiency through augmentation of their outward orientation. Non-R&D firms which do not have their own R&D units, tend to import foreign capital goods to enhance their performance. Thus, the import of foreign capital goods acts as a substitute of local R&D activities.

In terms of policy implications for the Government, the empirical results yield that the availability of foreign funds in the form of FDI has proved to be beneficial for the firms. In this context, GOI has been providing alluring opportunities to foreign investors. Attracting further funds from abroad may prove to be advantageous for the pharmaceutical industry. The GOI's role in encouraging pharmaceutical firms to take up R&D activities has been overwhelmingly positive (GOI, 2009). Various tax exemptions for R&D-intensive firms are some of the steps taken by the GOI. The importance of encouraging pharmaceutical firms to invest in R&D assumes importance not only

because R&D is considered the backbone of the pharmaceutical industry (EXIM, 2007), but also because results of this study indicate that R&D intensity has a positive and significant influence on the firms' efficiency.

Despite the progress made by the pharmaceutical industry in recent years, the sector has not been left unscathed by the current global economic crisis. A shrinking demand for exports from the destination countries, along with a fluctuating Rupee vis-à-vis the US Dollar, can adversely affect the growth prospects of the pharmaceutical sector. The findings of this study corroborate the fact that the Indian pharmaceutical sector is heavily integrated with the global economy. The determinants which affect efficiency are primarily dependent on the world economic order. Therefore, the task for GOI in promoting this sector and creating an environment where the internal efficiencies can be maintained will definitely be a challenging one in the near future.

A limitation of this study is that it has used data up to 2007-08, i.e. prior to the spread of the global economic crisis to the developing world. It would be interesting to see the levels and determinants of efficiency by including data on the period which has been affected by the crisis. Also possible is a study employing the three-stage DEA model, where the estimated coefficients from the Tobit regressions can be used to predict the total input slack for each input.

End Notes

1. Bulk drug production involves the production of the active ingredients present in the drug, called the Active Pharmaceutical Ingredient (API).
2. Formulation production involves the processing of bulk drugs into finished dosage forms such as tablets, capsules, injections, ointments, syrups, etc.
3. Off-patented drugs.
4. Includes only those firms for which the full set of observations during the sample period was available because DEA requires balanced datasets.

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