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Sources of Heterogeneity in the Efficiency of Indian Pharmaceutical Firms

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Abstract: Using the non parametric approach of Data Envelopment Analysis (DEA) this paper examines firm's heterogeneity in the Indian pharmaceutical industry by measuring their input and output efficiencies for the period 1991 to 2005. The analysis establishes that even though firms have been able to make efficient use of inputs like labor and raw material the output efficiency of the firms reveals a declining trend. The phenomenon can be attributed to the differences in the size of firms and the presence of economies of scale in production. Further analysis reveals the importance of firm specific factors like its strategies and structure for variation in output efficiency. We find firms that are vertically integrated with down-stream raw-material industry are more efficient. We also find that R&D is a possible strategic option for firms to gain higher efficiency but only for the large sized firms.

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Sources of Heterogeneity in the Efficiency of Indian Pharmaceutical Firms

Performance of firms may differ widely even if they use the same set of inputs and identical production technology. Although the neo-classical theory of firm does not underline such differences, a vast body of recent literature provides evidence of firm heterogeneity in a narrowly defined industry (Caves, 1998; Bartelsman and Doms, 2000; Tybout, 200o; Ahn, 2001). The studies underline the importance of firm specific intrinsic factors, technical and managerial skills for such persistent differences. Theoretical models of firm dynamics have formalized this concept of firm heterogeneity and discussed its importance on the productive performance at the firm level (see Ahn, 2001). In this paper, we examine the importance of firm specific factors for persistent performance differences for the Indian pharmaceutical firms, which are undergoing through a phase of transition due to policy changes.

The Indian pharmaceutical industry has the distinction of being the leader in the production of generic drugs sought eagerly throughout the world. Starting from a barebones existence under total dominance by multinational companies, the industry has emerged as a major player in the international stage as the 4th largest manufacturer of pharmaceutical drugs in the world and widely respected for its high quality low cost generic drugs. Over the first two decades since independence, the 50s and the 60s, the domestic market in India was almost entirely import dependent and drug prices were among the highest in the world. Virtually all of the pharmaceutical drug patents in India were held by multinational companies. In order to ensure self sufficiency in the supply of basic drugs and to end foreign domination of the industry in general, the Government of India introduced a number of important regulatory changes facilitating entry by a large number of small firms. What contributed most to the phenomenal growth of the domestic industry was the *Patents Act* of 1970 which replaced *product patents* by *process patents.* Process patent allows an indigenous firm to manufacture through reverse engineering a generic substitute of an existing *patented* pharmaceutical product without paying a licensing fee so long as the production process for the generic substitute differed from the one used by the patent owner. Further, the *Drug Price Control Order*, also introduced in 1970, imposed rigid price control on most of the drugs in the market with explicitly stipulated "maximum retail price" for the product. While these policies fostered competition, the industry remained highly regulated through import restrictions, high tariff rates, and ceiling on foreign equity participation.

In many ways, the experience of the Indian pharmaceuticals industry is a "poster child" for the infant industry argument for protective trade policies. It effectively nurtured the domestic industry into a sustainable stage of development. The consumers benefited from greater access to basic drugs at reasonable prices. The only drawback was that it permitted a large number of smaller firms, the so called *unorganized sector* of the industry to operate profitably in a highly knowledge-based industry by essentially copying the processes developed by others without having to develop their own Research and Development (R&D) capabilities.

The era of protected development virtually ended with the enactment of the Amended patents Act in 2005 reintroducing *product patents* in place of *process patents*. Under the provisions of this amended Act, it was no longer legal to manufacture generic substitutes for products patented in 1995 or later. Also, as a part of the liberalization policy following the economic reforms, restrictions on importation of bulk drugs were removed and the scope of price control was limited to fewer drugs with the expectation that the liberalized market environment would allow firms to function freely in response to market forces by entering into technological collaboration with the foreign firms, exploiting economies of scale due to market expansion, and introducing new products and processes. This in turn would enable firms to achieve higher efficiency and productivity.

However, all firms may not benefit equally from a competitive environment in a knowledge-intensive sector like pharmaceuticals, where firms differ with respect to their access to technology and state-of-knowledge. In the Indian pharmaceutical industry, firms flourished by imitating the patented products of the foreign firms under the process patent regime of 1970. Also a number of protective policies and assured market from the government of India (see, Pradhan and Sahu, 2009) supported the growth of large number of small firms in this sector. Most of these firms invested little in Research and Development (R&D) and undertook few initiatives to upgrade their production base. On the other hand, the imposition of product patent, increased liberalization, global exposure and the bio-technological revolution in the drug discovery and manufacturing process have led to rapid technological change (see Mazumdar and Rajeev, 2009) and opened up new production opportunities that these firms might have failed to appropriate. Consequently, the process of liberalization may create gainers and losers and performance differential may arise between firms. In this regard, analyzing efficiency of the firms is one of the most appropriate methods to examine the performance differential. This paper is primarily devoted to such an investigation.

Numerous papers have appeared both in the business press and in academic journals focusing on the opportunities as well as the threats faced by the Indian pharmaceutical firms as the industry make the transition from one patent regime to the other. Joshi (2003) anticipates the opportunities that Indian and foreign manufacturers were likely to face when the process patent regime would come to an end in 2005. The well known report by KPMG (2006) notes that "soaring costs of R&D and administration are persuading drug manufacturers to move more and more of their discovery research and clinical trials to the subcontinent or to establish administrative centers there, capitalizing on India's high level of scientific expertise as well as low wages" (KPMG 2006, p 2). It notes that India's current Good Manufacturing Practice (cGMP) and US FDA compliance level is an important advantage for off shoring. Greene (2007) also notes that with the reintroduction of product patents, many of the smaller firms would exit and many of the remaining would move away from plain vanilla generic production and turn towards contract manufacturing, contract clinical trials, outsourcing, and other forms of tie in with multinational companies.

A number of the academic papers examine the impact of the change in the Patent regime on the financial performance of the Indian pharmaceutical companies. Dutta Chaudhuri and Kumar (2009) look at the Price-Earnings (PE) ratios of a number of the major companies over the years 2006-2008 and conclude from their fundamentals analysis that the market perception about them is that they have been able to withstand the change successfully. The authors notice in passing that over the year raw materials cost as percentage of sales has gone down which in turn has helped raise profitability. Mishra and Chandra (2010) used data from 52 companies in a panel data regression for the years 2001-8 to examine the importance of mergers and acquisitions (M&A) in explaining the profitability of firms in the Indian pharmaceuticals industry. They concluded that there is no evidence of any significant impact of M&A in the long run. Further, they conclude that in-house R&D activity is not a significant determinant of profitability either. In view of the fact that technological capability built through R&D as well as scale economies achieved through M&A are both perceived to be important in the product patent regime, these conclusions are somewhat surprising.

While financial efficiency is the ultimate goal of a company, market perception about a manufacturing firm is ultimately driven by its operational or productive efficiency. A firm cannot remain profitable unless it succeeds in eliminating surplus (or unutilized) inputs while at the same time achieving the potential output levels from the quantities of inputs used. In other words, it has to attain full technical efficiency. Few studies in the existing literature have examined the productive or technical efficiency of the pharmaceutical firms in India. Majumdar (1994) is one of the earliest studies that examined input-oriented efficiency of a small number of pharmaceutical companies over the years 1987 through 1990 using the nonparametric method of Data Envelopment Analysis (DEA). He concluded that, in general, public sector firms performed worse than the private sector firms. His empirical findings are of no particular relevance in the present context because (a) the sample size is extremely small and (b) the data relate to a period that is well before the change in the Patents act.

Saranga and Phani (2002) and Saranga (2007) also employed DEA to measure input-oriented efficiency of a sample of 44 firms from the Indian pharmaceuticals industry. Majumdar and Rajeev (2009) measured output-oriented technical efficiency along with Malmquist productivity indexes of an unbalanced panel of firms over the years 1991-2005. The number of firms varied between 70 and 289 across years. The study found that while the industry experienced rapid technical change, most firms failed to fully benefit from technological progress and lagged behind the advancing frontier leading to a decline the levels of technical efficiency. Chaudhuri and Das (2006) differ from the other studies in that they use the parametric stochastic frontier analysis (SFA) to measure technical efficiency from an econometric model. The study applied the stochastic frontier production function using firm level data for the year 1990 to 2001 to measure technical efficiency of the Indian pharmaceutical sector. Their study showed that the mean efficiency scores of the industry have improved over the sub–period 1999 to 2001 against the sub-period 1990-1998. Further, the study also identified that large sized firms or firms exporting more of their product in the international market have reduced their inefficiency.

In the efficiency literature there are two alternative ways to measure efficiency of a firm viz., the output efficiency, that captures how far an inefficient firm needs to scale up its observed output to reach the frontier for the same level of inputs it employs and the input efficiency that identifies how far a firm can reduce its inputs for the observed given level of output. The input and output oriented measures of efficiency may not be equal particularly when the underlying production technology *exhibits variable returns to scale*. All of the previous studies have either given priority to the output expansion of firms to compute their *output efficiency* or have computed the *input efficiency*. However, in order to maximize profit, a firm has to attain both input and output efficiencies[2].

In this analysis, we simultaneously measure output and input efficiencies for Indian pharmaceutical firms. The Pareto-Koopmans model that we use to compute the efficiency reflects all potential increase in outputs[3] alongside all potential reduction in inputs. We provide a decomposition of this overall efficiency into two separate factors reflecting the output and input efficiencies of a firm.

While the DEA efficiency score of a firm provides an assessment of its performance, a statistical analysis of the relationship between the measured efficiency scores and a number of relevant characteristics of a firm can identify how efficiency varies with changes in these attributes. This can be quite useful for policy. For example, if it is found that investment in R&D does enhance efficiency, government policy fostering such investment would be recommended.

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[2] This a necessary but not a sufficient condition for profit maximization.

[3] Since we have a single output case, the possibility to increase each of the output in the output bundle at different proportion does not arise. While measuring the input specific efficiencies we have however, incorporated such possibilities.

The rest of the paper unfolds methodology applied in this paper. Section 2 explains briefly the nonparametric DEA methodology and the non-radial models used in this paper. Section 3 describes the data and reports the DEA findings. Section 5 uses a second-stage regression to identify the determinants of the efficiency scores of the individual firms. Section 6 is the conclusion.

2. The Nonparametric Methodology

2.1 The Technology and Technical Efficiency

Consider an industry producing bundles of *m* outputs *y* from bundles of *n* inputs *x*. The production technology is defined by the production possibility set

$$T = \{(x, y): y\ R \in^{m}_{+} \text{ can be produced from } x \in R^{n}_{+} \}, \quad (1)$$

An input-output bundle (x^0, y^0) is feasible if $(x^0, y^0) \in T$.

The bundle (x^0, y^0) is *weakly efficient* in its *input-orientation* if it is not possible to reduce all inputs simultaneously without reducing any output. That is,

$$(x^0, y^0) \in T \text{ and } \beta < 1 \Rightarrow (\beta x^0, y^0) \notin T. \quad (2a)$$

Similarly, (x^0, y^0) is *weakly efficient* in its *output-orientation* if

$$(x^0, y^0) \in T \text{ and } \alpha > 1 \Rightarrow (x^0, \alpha y^0) \notin T. \quad (2b)$$

That is all outputs cannot be increased simultaneously without increasing any input. Note that input-oriented weak efficiency does not preclude reduction in one or more (though not all) inputs. Similarly, output-oriented weak efficiency is compatible with increase in one or more individual outputs. Thus, weak efficiency does not imply Pareto efficiency. Both input- and output-oriented weak efficiencies are essentially *radial* in nature because one considers radial contraction of the input bundle or a radial expansion of the output bundle.

By contrast, (x^0, y^0) is *strongly* input-efficient only if a reduction in *any* component of the x^0 input bundle would render the output bundle y^0 infeasible. That is

$$(x^0, y^0) \in T \text{ and } x \le x^0 \Rightarrow (x, y^0) \notin T. \quad (3a)$$

In an analogous manner, (x^0, y^0) is *strongly* input-efficient only if

$$(x^0, y^0) \in T \text{ and } y \ge y^0 \Rightarrow (x^0, y) \notin T. \quad (3b)$$

Finally, $(x^0, y^0) \in T$ is Pareto-Koopmans efficient if both of the following conditions simultaneously hold

(i) $x \le x^0 \Rightarrow (x, y^0) \notin T$; (4a) and

(ii) $y \ge y^0 \Rightarrow (x^0, y) \notin T$. (4b)

Thus, strong input- and output-efficiency are both necessary and are together sufficient for Pareto-Koopmans efficiency.

2.2 Data Envelopment Analysis

In order to calibrate any of the various technical efficiency measures considered above, we need to construct the production possibility set empirically from observed data. In parametric models, one starts with an explicit specification of the production technology in the form of a production function (in the single output case) or a transformation function (in the multiple output case) and uses appropriate statistical methods to obtain estimates of the parameters of the specified function from sample data. By contrast, in the nonparametric approach of Data Envelopment Analysis (DEA) one makes a number of fairly general assumptions about the underlying technology but specifies no explicit functional form. Introduced by Charnes, Cooper, and Rhodes (CCR) (1978) and further generalized by Banker, Charnes, and Cooper (BCC) (1984), DEA allows one to construct the production possibility set empirically from observed data. Specifically, one makes the following assumptions:

(i) Each input-output bundle (x^j, y^j) $(j = 1,2,\ldots,N)$ actually observed in the sample is feasible.

(ii) The production possibility set T is convex.

(iii) Inputs are strongly disposable. That is, if $(x^0, y^0) \in T$ and $x^1 \ge x^0$, then $(x^1, y^0) \in T$.

(iv) Outputs are freely disposable. That is, if $(x^0, y^0) \in T$ and $y^1 \le y^0$, then $(x^0, y^1) \in T$.

It can be easily verified that the free disposal convex hull of the observed input-output data

$$S^V = \left\{ (x, y) : x \ge \sum_{1}^{N} \lambda_j x^j ; y \le \sum_{1}^{N} \lambda_j y^j ; \sum_{1}^{N} \lambda_j = 1; \lambda_j \ge 0 \ (j = 1,2,\ldots,N) \right\} \qquad (5)$$

is the smallest set satisfying assumptions (i)-(iv)

Radial Measures of Technical Efficiency

Following Banker, Charnes, and Cooper (1984), the input-oriented radial technical efficiency of a firm with an observed input-output bundle *(x^0, y^0)* under the variable returns to scale assumption is obtained as:

$$\tau_x(x^0, y^0) = \min \theta$$

$$\text{s.t. } \sum_1^N \lambda_j y^j \geq y^0;$$

$$\sum_1^N \lambda_j x^j \leq \theta x^0; \qquad (6)$$

$$\sum_1^N \lambda_j = 1;$$

$$\lambda_j \geq 0; \ (j = 1,2,..., N)$$

Similarly, the output-oriented radial technical efficiency under VRS is measured as

$$\tau_y(x^0, y^0) = \tfrac{1}{\varphi^*}$$

where $\varphi^* = \max \varphi$

$$\text{s.t. } \sum_1^N \lambda_j y^j \geq \varphi y^0;$$

$$\sum_1^N \lambda_j x^j \leq x^0; \qquad (7)$$

$$\sum_1^N \lambda_j = 1;$$

$$\lambda_j \geq 0; \ (j = 1,2,..., N)$$

It is obvious that neither the input- nor the output-oriented radial measure of technical efficiency is affected by the presence (or magnitude) of slacks in any of the individual input or output constraints in (6) or (7).

Non-Radial Measures of Technical Efficiency

The problem of slacks in any optimal solution of a radial DEA model arises because we seek to expand all outputs or contract all inputs by the same proportion. In non-radial models, one allows the individual outputs to increase or the inputs to decrease at different rates. Färe and Lovell (1978) introduced the following input-oriented, *non-radial* measure of technical efficiency called the Russell measure:

$$\rho_x(x^0, y^0) = \min \tfrac{1}{n}\sum_i \theta_i$$

$$\text{s.t.} \quad \sum_j \lambda_j y_{rj} \geq y_{r0}; \; (r = 1,2,\ldots,m);$$

$$\sum_j \lambda_j x_{ij} \leq \theta_i x_{i0}; \; (i = 1, 2,\ldots, n); \qquad (8)$$

$$\sum_j \lambda_j = 1; \; \lambda_j \geq 0; \; (j = 1, 2,\ldots, N).$$

When input slacks do exist at the optimal solution of a radial DEA model, the non-radial Russell measure in (8) falls below the conventional measure obtained from an input-oriented BCC model (6). Because the radial projection is always a feasible solution for (8), $\rho_x \leq \tau_x$. That is, the non-radial Russell measure of technical efficiency never exceeds the corresponding radial measure.

The analogous output-oriented non-radial VRS measure of technical efficiency is:

$$RM_y(x^0, y^0) = \frac{1}{\rho_y},$$

where $$\rho_y = \max \tfrac{1}{m}\sum_r \phi_r$$

$$\text{s.t.} \quad \sum_j \lambda_j y_{rj} \geq \phi_r y_{r0}; \; (r = 1,2,\ldots,m);$$

$$\sum_j \lambda_j x_{ij} \leq x_{i0}; \; (I = 1, 2,\ldots, n); \qquad (9)$$

$$\sum_j \lambda_j = 1; \; \lambda_j \geq 0; \; (j = 1, 2,\ldots, N).$$

While no input slacks can exist at the optimal solution of (8), presence of any output slack is not ruled out. Similarly, input slacks may remain at the optimal solution of (9). Thus, non-radial technical efficiency (whether input-oriented or output-oriented) by itself does not ensure over all Pareto efficiency.

A non-radial Pareto-Koopmans measure of technical efficiency of the input-output pair *(x^0, y^0)* can be computed as:

$$\gamma(x^0, y^0) = \min \frac{\frac{1}{n}\sum_i \theta_i}{\frac{1}{m}\sum_r \phi_r}$$

$$\text{s.t.} \quad \sum_{j=1}^{N} \lambda_j y_{rj} \geq \phi_r y_{r0}; \qquad (r = 1,2,..., m);$$

$$\sum_{j=1}^{N} \lambda_j x_{ij} \leq \theta_i x_{i0}; \qquad (i = 1,2,..., n); \qquad \textit{(10)}$$

$$\sum_{j=1}^{N} \lambda_j = 1; \qquad \lambda_j \geq 0; \quad (j = 1,2,..., N).$$

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

$$x^* = \sum_{j=1}^{N} \lambda_j^* x^j \leq x^0 \qquad \text{and} \qquad y^* = \sum_{j=1}^{N} \lambda_j^* y^j \geq y^0 \ .$$

Thus, *(x^0, y^0)* is Pareto-Koopmans efficient, if and only if $\phi_r^{\ *} = 1$ for each output *r* and $\theta_i^{\ *} = 1$ for each input *i*, implying $\gamma(x^0, y^0) = 1$. We can visualize the Pareto-Koopmans global efficiency measure as the product of two factors. The first is the input-oriented component

$$\gamma_x = \tfrac{1}{n}\sum_i \theta_i \qquad \text{(11a)}$$

and the second is an output-oriented component

$$\gamma_y = \frac{1}{\frac{1}{m}\sum_r \phi_r} \ . \qquad \text{(11b)}$$

Thus,

$$\gamma(x^0, y^0) = \gamma_x . \gamma_y . \qquad \text{(12)}$$

Tone (1997) introduced essentially the same measure of overall efficiency and called it a slack based measure (SBM). The objective function in (10) is non-linear. Tone transformed this linear fractional functional programming problem into an LP problem by normalizing the denominator to unity. Alternatively, as shown in Ray (2004), one may replace the objective function by a linear approximation.

Define

$$\gamma(x^o, y^o) = f(\theta, \varphi)$$

Using $\theta_i^0 = 1$ for all *i* and $\phi_r^0 = 1$ for all *r* as the point of approximation,

$$f(\theta, \varphi) \approx 1 + \tfrac{1}{n}\sum_i \theta_i - \tfrac{1}{m}\sum_r \phi_r . \qquad (13)$$

We may, therefore, replace the objective function in (10) by (13) and solve (10) iteratively using the optimal solution from each iteration as the point of approximation for the next iteration until convergence. Once we obtain the optimal (θ^*, ϕ^*) from this problem, we evaluate

$$\gamma(x^0, y^0) = \frac{\tfrac{1}{n}\sum_i \theta_i^*}{\tfrac{1}{m}\sum_r \phi_r^*} \qquad (14)$$

as a measure of the Pareto-Koopmans efficiency of (x^0, y^0).

Apart from an overall measure, (14) also provides information about the potential for reducing individual inputs (θ_i^*) and increasing individual outputs (φ_r^*). Also a decomposition of (14) into the input- and output-oriented components can be obtained from (12).

3. The Empirical Analysis using DEA

The study conceptualized a 1-output, 4-input production technology. Output in the model is the value of total output (y) defined as the total sales of 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) labor (measured by the total wages and salaries paid, (ii) material inputs (measured by the total expenditure on raw materials), (iii) energy input (measured by the expenditure for power and fuel) and (iv) capital (the book value for plant and machinery and building).

The nominal values of the output and input variables were appropriately deflated[4]. The value of output is deflated by the price index for the drug and the

[4] An ideal approach to compute the efficiency of the firms will be to use the physical output and inputs. However, in the absence of data on physical output and inputs we use the values of production and inputs

pharmaceutical sector collected from the Reserve Bank of India (RBI) monthly bulletins. Expenditure for worker is deflated by the Consumer Price Index (CPI) for the manual and the non-manual worker, expenditure for fuel and power is 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 is deflated by the average price index for chemical and chemical products from the ASI data base. The capital stock is available as book value for plant and machinery, therefore the Perpetual Inventory Method (PIM) (see Balakrishnan *et al*, 2000) is used to deflate the value of capital treating 2003 as the benchmark year.

Firm level information for the years 1991 to 2005 collected from the PROWESS database[5] was used for this study. 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 accounts for about 85 % of the total output and 87 % of the input usage for the sector for almost all the years[6]. Thus the sample of firms considered in the study can be viewed as representative of the sector. The relevant data necessary for the computation are collected from the financial balance sheets of the companies provided by the prowess data of the Centre for Monitoring of Indian Enterprises (CMIE).

In an inter-temporal analysis of efficiency, one needs to make explicit assumptions about the nature of technological change over time. In DEA literature (see Tulkens and Vanden Eeckaut, 1995) three forms of frontiers are distinguished viz*., i) the contemporaneous frontier ii) the sequential frontier and iii) the inter-temporal frontier.*

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as done in the earlier literature (see Caves and Barton, 1990; Tybout et al, 1991; Aw *et al,* 2001; Pavcnik, 2002 and so on). This is useful particularly when firms produce differentiated products and /or face differentiated input market and also the product varieties differ across the firms. In a sense the efficiency measures computed in these research works including the current ones closely corresponds to indices of revenue per unit of input expenditure (see Katayama, Lu and Tybout, 2009).

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

[6] The figures has been arrived at by taking the ratio of the output manufacturing by the registered Indian pharmaceutical companies (provided by the CMIE prowess data base) to the total value of output produced by the sector (provided by the Ministry for Chemical and Petro-Chemical).

In this analysis, we use sequential frontier. It is assumed that in any given year the input-output bundles from previous years remain feasible but no such assumption is made about observations from the subsequent years. This allows for an outward shift of the frontier and an enlarged production possibility set over the years but technological regress is ruled out. An outward shift of the frontier over time may be caused by a greater degree of involvement of firms in R&D, import of capital good and investments in modern plant and machinery.

In our empirical analysis the DEA model (10) above has been employed. Given the choice of inputs and output, specific efficiency scores are available for output and the four inputs: (i) raw material, (ii) power and fuel, (iii) labor, and (iv) capital. Table 1 reports the average output and input-specific efficiency scores of the Indian pharmaceutical firms for each year.

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

(1) Year	(2) Output Efficiency ϕ	(3) Material Efficiency θ_{RM}	(4) Power and Fuel Efficiency θ_E	(5) Labor Efficiency θ_L	(6) Capital Efficiency θ_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

The first column in table 1 depicts the value of ϕ that represents the unrealized potential increase in the output of a firm that could be achieved without employing any additional inputs. More precisely, in the year 1991, on an average, the firms in the industry could further expand their output without employing additional inputs by about 19 percent which has given rise to an output efficiency score of 81 (see Col 2, 2nd row). Figures for the output efficiency over the years reveal that there has been a fall in the average efficiency for the sector, which is in line with the similar conclusions derived by the earlier studies as well for the Indian manufacturing sector (see Ray, 2002; Mukherjee and Ray, 2004; Srivastava, 2001; Parameshwaran, 2001, Siddharthan, 2004, Siddharthan and Lal, 2004). A steady decline in the mean output efficiency for the sector no doubt is an indication of the fact that difference between the output produced by the frontier firms and the firms that lie below the frontier are increasing over the years.

There are several possible (and not mutually exclusive) explanations for the observed downward trend in the mean level of output efficiency. The first is methodological. As we use a sequential frontier, owing to availability of fewer observations in the initial years, proportionately more firms are found to operate at the frontier which in turn may have caused a higher average efficiency for the sector. Second, the form of production frontier constructed for the sector incorporates the possibilities of technological progress; in other words, an outward shift in the frontier is possible for the subsequent years. This implies that if there is technological progress for this sector leading to an outward shift in the production frontier, for the inefficient firm the distance from the frontier is increasing even though their performance may not decline in an absolute sense. Finally, it may so happen that the efficiencies of the firms that lie below the frontier indeed became worse in absolute term. In a related study, Mazumdar and Rajeev (2009) have demonstrated that the efficiency of the firms in this sector has deteriorated mainly due to an outward shift in the production frontier as a result of new investment in technologically advanced plant and machinery. From output efficiency measures we next concentrate on efficiency of the firms in their use of inputs.

Input-Specific Measures of efficiency of Firms

Columns 3 to 6 in Table 1 summarize the value of the θ_i's, the input inefficiencies of the firms. A value of 0.863 for the labor efficiency in 1991 implies that on an average firm in this industry can cut down their labor cost by about 14 percent[7] without employing any additional inputs or hindering their output level. Similarly, a value of 0.933 for the raw-material efficiency implies that firms on an average can reduce its raw-material expenditure by about 7 percent. One can similarly interpret the efficiency scores for capital and power and fuel. On an average, the input wise measures in efficiency suggest certain interesting trend for the industry. It is noticed that even though the output efficiency reveals a declining trend, firms on an average have been able to make efficient use of labor, raw material, and moderately efficient in their use of capital. The average efficiency scores for labor, raw material, and capital are fluctuating at around 0.90, 0.85, and 0.63, respectively, over the years. On the other hand, over the years, the mean efficiency for power and fuel is only 0.40.

It is interesting to speculate on the possible reasons for the observed efficient use of raw material and labor alongside inefficient use of power and fuel by the Indian pharmaceutical firms. Raw material easily fits the textbook description of a variable input that can be easily adjusted with a change in the level of output. India has a well-developed chemical industry (see Kaul, 2007), which provides the raw materials to the pharmaceutical industry. With good linkages with the raw-material industry, it is expected that the Indian firms will be able to use raw material as and when required in appropriate quantities efficiently. Input use efficiency is found to be quite high in respect of labor also. In the recent years most with liberalized labour laws, firms being able to hire and fire labor possibly accounts for the observed efficiency in respect of this particular input.

Compared to raw materials or labor, firms are only moderately efficient in their use of capital. Generally, returns from capital flow over a number of years. It is not possible for a firm to utilize fully the capital stock in the year it is installed. In India, most of the firms have invested heavily in plant and machinery in order to comply with the recently amended Drugs and Cosmetic Act. This may have resulted in an increase in unutilized capital stock[8] for the sector. Underutilization of capital stock can arise in lean period

[7] A value of 0.863 for labor efficiency implies that labor inefficiency is about 0.177. This is computed by deducting 0.863 from unity.

[8] Our discussions with the companies reveal that a firm has to install high quality capital stock of worth rupees thirty millions to fulfill the requirement of the Schedule M of the newly amended Drugs and

when the demand for the product is low or if firms are slow in applying and adapting to new technology. Extent of utilization of capital stock can be examined by plotting the growth rate of capital stock and the growth rate of output against time. Figure A.1 and A.2 (see Appendix) which depicts this comparative scenario reveals that for most of the years growth rate of the capital stock in this sector is higher than the growth rate of output, implying presence of underutilized capital stock. The Capacity Utilization Ratio has also decreased from about 80 percent to about 60 percent for the sector during the study period.

Electricity, coal, and natural gas are used in the Pharmaceutical Sector to generate energy for the distillation process. The Energy consumption notes of the firms (available in the balance sheet of the companies) reveal that firms (mainly the large ones) that have undertaken initiative to conserve energy for the production process by replacing the old with the modern technology are the efficient ones. The rest of the firms still use technology that consumes more energy per unit of the output generated and thereby lead to energy wastage. It is noteworthy that the share of consumption of power and fuel has increased for the sector from about 4.5 % to about 8 % of the total cost of production from 1995 to 2005. However, for large firms the share of power and fuel consumption in the total expenditure has remained at around 2 %. For tiny, small and medium size firms the share of power and fuel consumption has increased by around 4 percent to 5 percent due to inefficient use of fuel. It is important to note here that in the small and medium size group a few firms that have replaced coal-based technology to diesel and gas to generate power display lower share of power and fuel consumption. As expected they are the efficient firms within this group.

On the whole, we observe that the average efficiency of the sector in its use of different factors of production is high, although output efficiency scores display much lower values. There are two possible reasons for this. First, because of the non-availability of data on physical output we have used the value of output in our efficiency

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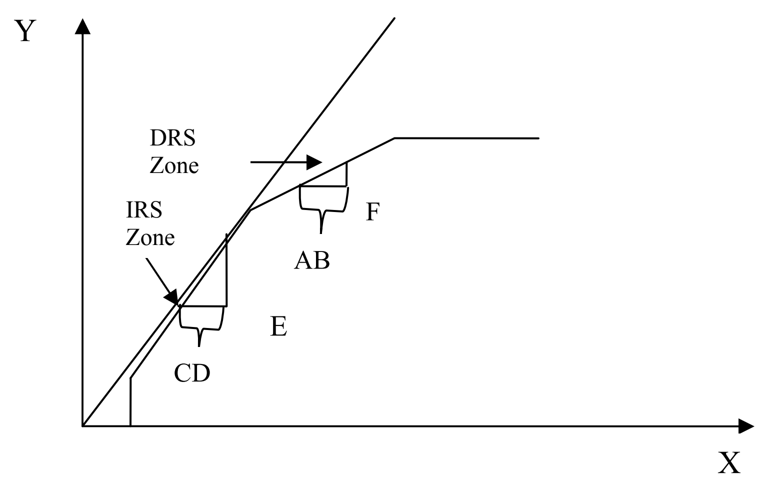
Cosmetic Act. Moreover, many firms have also upgraded their production system to comply with the standard set by the regulatory body of the developed countries to export their product there. Firms undertake such investment keeping in view the possible market expansion. Since, return from capital stock generally takes time to realize it may not be possible for a firm to realize fully the potential benefit of the capital stock at least in the short run.

analysis. Thus, price of an output may be a determining factor for output efficiency of the firms. The price of an output depends on the underlying market structure and the demand for the product. If a firm uses its input comparatively efficiently but fails to get a fair price for its product due to low level of demand, it will show low level of output efficiency. The second reason is more compelling and could be due to the *returns to scale (RTS) in production.* When the underlying production technology exhibits *'economies of scale' in production*, the output and the input inefficiencies of firms differ. Consider, for example, Figure 1 which depicts a production technology with returns to scale in production.

Fig1**: Input and Output (In) Efficiency with VRS Technology**



E and F in the diagram represent two inefficient firms. Firm E lies in the Increasing Returns to Scale (IRS) zone of the production frontier and firm F lies in the Decreasing Returns to Scale (DRS) zone. By construction, both the firms have same level of input inefficiency as AB = CD; however, it is evident from the diagram that the output inefficiency for firm E (=BG) is much higher compared to firm F (=DH) that lies in the DRS zone of the production frontier. Thus compared to a firm that lie in the DRS zone, the magnitude of output inefficiency can be much higher for a firm in the IRS zone, even though they have same level of input inefficiency. As a large number of firms in our sample lie in the IRS zone, this may be one source of difference between output and input efficiency scores[9] (see table A.1 in Appendix). In other words, the analysis establishes that the '*size of a firm*' is an important reason for heterogeneous performance of the Indian pharmaceutical firms.

4. Firm Specific Factors and Firm Efficiency

In the non parametric approach for efficiency analysis using DEA, it is a common practice to estimate a regression model in the second stage explaining the variation in the measured efficiency scores on the basis of a set of explanatory variables (Ray 1991; McCarty and Yaisawarng 1993; Duncombe et al 1997; Chilingerian and Sherman 2004; Ray, 2004; and Ruggiero, 2004). The approach to link the mathematically computed DEA efficiency scores with its determinants was first introduced and further developed by Ray (1988, 1991). Since DEA efficiency scores lie naturally within the (0, 1] interval, use of a Tobit model[10] instead of the ordinary square regression has often been justified (see Ray 2004 among others). However, this *ad hoc* approach lacks a serious data-generating process (DGP)(see Kennedy, 1998; Härdle and Simar, 1999 and so on for a detailed discussion on DGP) that would conceptually link the non-parametric deterministic DEA efficiency score with the statistical two-stage regression analysis. Responding to the need for developing a proper framework, Simar and Wilson (2007) defined a DGP that would make the second stage regression analysis sensible. Simar and Wilson (2007) paper established that due to the serial correlation present in the efficiency estimates the inferences drawn for the second stage regression are invalid. The authors suggested the use of truncated regression and smooth bootstrapping for valid inferences in the second stage. Banker and Natarajan (2008) have advanced a DGP that has a less restrictive form than the DGP advanced by Simar and Wilson (2007) and they theoretically justify the use of simple ordinary least square (OLS) or even Tobit

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[9] We have also fitted a production function to estimate the economies of scale in the Indian pharmaceutical industry. The estimated value of the scale parameter ***is*** 0.85 for the industry and .77 for the small sized firm. This implies that if output rises by one unit then cost rises by 0.85 units for the industry and .77 for the small- sized firms, indicating the presence of Increasing Returns to Scale in the industry as well as for the small sized firms.

[10] Ideally a 2-limit Tobit would be warranted. But because efficiency never takes the value 0, the lower limit never applies.

estimation for the second stage parametric regression analysis[11].Later McDonald (2009) has argued strongly against a Tobit model on the ground that the DEA efficiency scores are not *censored* but can be seen as a special type of *fractional* dependent variable. He recommends a quasi-maximum likelihood estimation (QMLE) procedure as proposed earlier by Papke and Wooldridge (1996) in the context of fractional data; but he also notes that the OLS procedure would provide a reasonable approximation. Thus it is evident that there is no clear consensus in the profession about how the second stage analysis (following up on DEA) should be carried out[12]. In this paper, we opt for the simple OLS method because there is no compelling reason for performing the bootstrap.

An important objective of this paper is to explain the heterogonous performance of the Indian pharmaceutical firms and identify the *firm specific intrinsic factors* that explain such heterogeneity. This is achieved by carrying out a regression analysis for the logarithmic transformation of the output efficiency scores of firms[13]. The independent variables considered in our model are mainly firm specific attributes and can be broadly classified into three groups: (a) strategy variables, (b) structural variables, and (c) policy related variable.

Strategy Variables

A strategy is a plan of action designed to achieve a particular set of goals. Whether or not to invest in research and development is an important strategic decision

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[11] The Monte-Carlo Stimulation carried out in the second stage indicate that the two stage method with DEA based efficiency in the first stage and OLS, maximum likelihood or even Tobit estimations, in the second stage performs far better than the parametric methods. Banker and Nataranjan (2008) paper assumes a form of Data Generating Process (DGP) that is much more flexible and less restrictive than the one assumed by Simar and Wilson(2007) that has also examined the impact of contextual variables on the efficiency of firms in a two-stage process. While Simar and Wilson(2007) paper argues that ML estimation of a truncated regression rather than the Tobit model is the preferred approach in the second stage; the Banker and Natarajan (2008) results are more robust and appropriate than the Simar and Wilson (2007) approach.

[12] Recent, as yet unpublished, simulation studies by Banker and his coauthors have shown that the simple OLS procedure performs better than the Simar-Wilson bootstrap methods which are computationally overwhelming.

[13] We have also tried to estimate a regression model each of the input as well as for the total input efficiency scores of the firms. Since the explanatory powers of the models were low, we concentrate here primarily on output efficiency scores. Intuitively also it makes more sense to consider only output efficiency scores in our regression model because we notice that on an average firms are input efficient.

for a firm, since a pharmaceutical firm *not* involved in R&D activities may in fact achieve higher output level by operating in the generic drugs segment. Secondly, liberalization has made available increased opportunities for Indian firms to sell their products in the international market. However, not all markets abroad are equally attractive in terms of costs and returns and therefore can have direct impact on production as well. Hence catering to the domestic market some time can be more profitable. Thus, choice of markets either domestic or international or an appropriate mix of both is a decision problem faced by the firms.

A suitable proxy for the R&D effort of a firm is its R&D intensity measured in terms of ratio of firm's expenditure on R&D to its value of sales. Firms successful in their R&D efforts can invent superior processes technology and can produce more of output for the same level of inputs employed. They can also invent new products for which they can earn higher level of revenue by employing the same level of inputs (Aghion and Howitt, 1992; Grossman and Helpman, 1991). However, heavy allocation of resources for R&D activity can also reduce efficiency if firms fail to reap the benefit of R&D (Helpman, 1992).

It can also be hypothesized that large sized firms have natural advantages to do more of R&D related activities. This may arise if there is scale or scope effect in R&D intensity of the firms. Mazumdarand Rajeev, (2007) in their study noted the presence of scale economies in the R&D activity of the Indian pharmaceutical firms. Additionally, large firms have greater market reach and more reputation, thus it is easier for large firms to market its new products successfully and earn higher returns. An interaction between the market share of firms and the R&D intensity is also considered to examine the joint effect of the size of the firms and its R&D efforts on its efficiency.

Increased participation in the international market is captured by the export earning of the firms and by their import of raw material and capital good. A number of studies have indicated that by exporting their products in the international market firms can 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 product in the international market. One is through 'learning by exporting' (see Clerides *et al,* 1998, World Bank Report, 1993, 1997) and the other is by high prices for their products and hence higher value of output. However, to export in the international market a firm also has to invest heavily in resources to identify the foreign market and the potential customers through market research, building off shore marketing infrastructure, obtaining necessary legal documents etc (see Pradhan, 2009). The return from such investment may not be immediate and firms may not get appropriate value for their products from their offshore investment if they fail to identify the potential markets[14]. Accordingly, the export earning of the firms per unit of its sales is included as an explanatory variable in our model to examine its impact on the efficiency of the firms[15].

We also hypothesize that the large sized firms have some advantage to sell their products in the international market. Consequently, we have also considered the interaction between the export intensity and the market share of the firms to examine the joint effect of the size of firms and its export earning on its efficiency.

Empirical evidence suggests that imported intermediary good is an important channel through which technological diffusion takes place (see, Tybout 2000). This may favorably affect the production and hence the efficiency of the firms.

Generally, Indian pharmaceutical firms re-engineer the imported technology and learn about new designs, product and process[16]. Such activities enable firms to build up its internal production capabilities, competency and may positively affect the efficiency of the firms. Imported technology is measured as the ratio of firm's expenditure on imported capital good to its total value of sales. Since once 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 percent as the rate of depreciation.

Structural Variables

[14] A number of studies have documented that because of various forms of entry barrier only the most productive firms self select for the global market.

[15] Instead of considering physical output, we have value of output, therefore price becomes a determining factor.

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

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

From the theoretical viewpoint the relationship between the size of firm and its efficiency is not clear (Audrestch, 1999). On the one hand it can be hypothesized large size firms will be more efficient because of the presence of threshold limit in production, scale economies and imperfection in capital market (Kumar, 2003). However, beyond a certain level larger firm size may also plague a firm with X-inefficiency (Leibenstein, 1976) which may lead to lower efficiency. The output share of a firm in the total industry (Kwoka, 1978) is taken as a proxy for its size. To capture the possible non-linear effect between the output efficiency and the size of the firms we have also included the square of the output-share in the regression analysis.

Capital-labor ratio[17] is a technological variable considered in our regression model. It is measured by the ratio of company's expenses for plant-machinery, building, and other fixed asset to its expenditure for wages and salaries and captures the degree of mechanization in the production process. We hypothesize that the degree of automation would increase efficiency.

With regard to product varieties three categories of firms are distinguished based on the product produced, viz., formulation companies which produce only the final product, bulk drug companies which produce the basic raw-material and bulk and formulation companies which produce both bulk and formulation products. Firms producing both bulk and formulation varieties are vertically integrated with raw-material industry and are expected to enjoy advantages of vertical integration (Coase, 1937; Hess, 1983; Williamson, 1981) compared to the other two categories. However, if there is internal co-ordination problem and control loss (Coase, 1937, Williamson, 1967) firms may also lose efficiency. Firms are differentiated based on product produced with dummies, treating the formulation companies as the benchmark for our analysis.

We also control for the age of the firm in our analysis. From the point of economic theory, the relationship between firm's age with its performance is again

[17] Capital –Labor Ratio =Expenditure on plant-Machinery, Building and other fixed Asset adjusted for historic prices by employing PIM / Expenses for salaries and wages.

ambiguous. Some authors suggest that older firms give superior performance since they are more experienced and enjoy the benefits of learning (Stinchcombe, 1965). Others have however argued that older firms are prone to inertia and less flexible to changed economic circumstances (Marshall, 1920). The age of a firm is calculated from the year of its incorporation.

Policy Related Variable

A time dummy has also been 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. The year 1995 is chosen because the first version of product patent was implemented in that year. The Drug and Cosmetic Act was also amended in 1995 to infuse competition for this sector. In other words important policy changes pertaining to this sector has taken place during this year.

The Model

Given the panel data, the OLS regression model is specified as

$$Ln(eff_{jt}) = x_{jt}\beta + \mu_{it} \tag{12}$$

where *j* represents the *jth* firm j (=1, 2,…, N); subscript *t* denotes time (that spans from 1991 to 2005). Utilizing a one-way error component model for the disturbance terms to account for the unobservable firm specific effect[18] we can re-write $\mu_{it} = \mu_i + v_{it}$, where μ_i, s is the unobservable firm specific effect that is independent of x_{jt} .

The independent variable in our model is x_{jt} which is a vector of k factors that explains the variations of the efficiency of the jth firms (=1-288) in the t-th time period (t=1991-2005). In our study, the data for all 288 firms are not available for all the years and we therefore have an unbalanced panel of 2437 firm-observations for 15 years. The relevant variables for our study are obtained from the Balance Sheets of the companies from the PROWESS database.

[18] The advantage of panel data is its ability to account for the unobservable firm specific individual effects like for example managerial skill, firm specific capabilities and others. Not accounting for the firm specific individual effects can actually lead to bias in the resulting estimates (see Baltagi, 2005).

The exact specification of the fitted model was:

$$\ln(eff)_{it} = \beta_0 + \beta_1(R\&D)_{it} + \beta_2(R\&D*MarketShare)_{it} + \beta_3(Export-\text{int}ensity)_{it} + \beta_4(Export\,\text{int}ensity*Marketshare)_{it} + \beta_5(\text{Imported technology})_{it} + \beta_7(\text{imported rawmaterial})_{it} + \beta_8(Marketshare)_{it} + \beta_7(Marketshare*Marketshare)_{it} + \beta_9(Capital/labor)_{it} + \beta_{10}(Dummybulkdrug)_{it} + \beta_{11}(DummyFormulation)_{it} + \beta_{12}(Age)_{it} + \beta_{13}(Age*Age) + \beta_{14}(TimeDummy)_{it} + \mu_i + v_{it}\,, \ldots\ldots\ldots\ldots\ldots..(3.1) \quad v_{it} \sim IID(0,\sigma_v^2)$$

Here 'μ_i' are unobserved firm specific effects (like, entrepreneurial or managerial skills, firm specific intrinsic skill and resources). 'v_{it}' are stochastic term which are assumed to be identically and independently distributed, IID(0, σ^2). It is assumed that the independent variables are independent of v_{it} for all *i* and *t*.

Following the standard practice in the literature, we performed Hausman's specification test for a choice between a fixed effect (FE) and a random effect (RE) model. The value of the relevant χ^2 test statistic was 130.93 with a p-value lower than 0.0001 under the null hypothesis of fixed effects. We therefore estimated the regression reported in Table 2 below.

It is evident from table 2 that most of the individual coefficients are statistically significant. The model as a whole is also significant, as indicated by the 'F' test statistic, which is significant at 1 per cent level. The R^2 square of the model is 0.42, which is quite high for a 2nd stage DEA regression model.

An important component of panel data model (Fixed effect model) is the presence of firm specific effects. The estimated 'F' statistic for the null hypothesis of no fixed effects was 26.43, which led to a rejection of the null implying that unobservable firm specific factors such as managerial capability did significantly influence the efficiency of the firms.

The Results

Structural Variables

Amongst the variables that capture the structure of a firm, its size is observed to have significant positive impact indicating that small sized firms can gain efficiency by merging. However, a negative coefficient for the square of the firm size also signifies the presence of diseconomies of scale in production beyond certain threshold limit. Simple calculation reveals that efficiency of the firms falls when it attains a production level of Rs .0830 in value

Table 2: Results from Fixed Effect Model

Number of observations: 2492, Number of groups: 289

Variables	Coefficients	t-values	Prob> │ t│>0
R&D/Sales	.0494315	0.63	0.529
R&D/Sales*firm size	40.2558**	2.10	0.036
Export/sales	-.2397499*	-3.32	0.001
Export/Sales*firm size	7.434762*	3.17	0.002
Imported raw-material	.2289138*	4.15	0.000
Imported Technology	.319771**	2.42	0.016
Firm size	9.789846*	11.15	0.000
Square Firm size	-49.77589*	-4.03	0.000
Capital –labor ratio	-.0000527**	-2.45	0.014
Bulk Drug	-.287102	-1.24	0.215
Bulk and Formulation	.0729986**	2.55	0.011
Age	-.0172499*	-8.58	0.000
Time dummy	-.1165368*	-7.92	0.000
Constant	.7006724*	19.50	0.000
R square (overall)	**0.4205***	F statistic	**17.29**

*, **, ***-Significant at one percent, five percent and ten percent level respectively

Our analysis also reveals that use of imported technology enhances efficiency as firms importing foreign technology also benefit from the training and knowledge transfer commonly imparted from the foreign seller. (see Clerides *et al.* 1998, World Bank Report, 1993, 1997).

Table 2 also indicates that firms producing both bulk and formulation products are more efficient compared to the firms that produce only bulk drug or formulation. Our results also implies that vertical mergers can a strategic option for firms to grow and gain from efficiency in production.

Age of the firm is statistically significant with a negative coefficient. This indicates that new entrants are more efficient. Generally, new firms tend to use advanced technology. This has resulted in higher efficiency.

The coefficient for the capital–labor ratio is negative and statistically significant which is consistent with the low input-specific efficiency for capital reported in Table 1. Most of the Indian pharmaceuticals have installed new plant and machinery recently possibly keeping future opportunities in view and presently these capitals are not fully utilized(Figure A.2 in the appendix indicate this).

Strategy Variables

While the R&D variable is not statistically significant, the interaction between the R&D and size of the firms is positively significant. This indicates that R&D is beneficial if it is done in large scale. We have argued that this may happen either due to the economies of scale and scope present in R&D activity or because of greater market reach and reputation of the large firms that help them to successfully launch their new product and earn much higher value of output for the same level of inputs employed.

Contrary to the general perception, we find that with the rise in export intensity the efficiency of the firms falls[19]. Export markets for the generic products are of three types viz., the highly regulated generic market (such as market in USA, European Unions, Australia and so on), the semi-regulated generic market (such as Russia, Ukraine, Portugal and so) and the unregulated generic market (such as Sri-Lanka, Arab Emirates and so on). Generally, most of the firms target either the regulated or the unregulated market whereas a moderate proportion of the firms (almost 40 percent) also target the semi-regulated market. Exporting in the global regulated market for both the bulk drug and formulation is risky given the stringent regulatory norm that a firm has to follow to sell its product (Chaudhuri, 2005, pp 188-195). If the value of output from such markets is not high enough to compensate for the expenditure incurred to comply with the regulatory barriers it leads to a fall in its efficiency (as output efficiency is measured here

[19] An interesting point to mention here is that a large number of pharmaceutical firms still sell their product in the domestic market. Though not reported we have differentiated the firms that sell their product in the domestic market from the firms that sell their product in the international using dummy variable. The result of our analysis confirms that firms targeting the international market are always better off.

in terms of value of output as against total expenditure on inputs). Although the regulated markets account for about 38.5% of India's total export and 50% of the bulk drug export in 2005, only a handful of Indian firms has benefited from the regulated market because of high cost of regulation[20]. In the unregulated market, there is no entry barrier, but the competition is intense and the value of output is less. On the other hand, in the semi-regulated, the entry barrier is less compared to the regulated market and the benefit is more in comparison to the unregulated market. Few firms however target the semi-regulated market and almost all the small sized firms target the unregulated market. We therefore find that efficiency falls with rise in export intensity.

However, the interaction between the size of the firms and its export intensity is significant with positive coefficient. This implies firms that are large and also exports more in the international market are better off. Generally, large sized firms have a better portfolio of products that they sell evenly across the regulated and semi-regulated markets. Thus, they can compensate for a loss of revenue in one market with the gain in another. In addition, large sized firms have better marketing network that also assist them to sell their product successfully.

Policy Related Variables

The coefficient of time dummy takes a negative value for the efficiency of the firms. This may happen due to two reasons. First, on an average the efficiency of the firms has deteriorated due to policy changes. Another possibility is that with liberalization and increased competition it is plausible 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 rest of the firms. Consequently, we find that there has been a fall in the average efficiency for the sector. The Malmquist analysis done by Majumdar and Rajeev (2008) shows that the sector has indeed experienced technological progress for a considerable period leading to an outward shift of the frontier and a fall in the efficiency of the firms.

[20] Even the largest company of India Ranbaxy incurred huge loss in 2008 by exporting in the US market because it failed to fulfill the US Food and Drug Administration (FDA) regulatory requirement (see Mint, June 6, 2009). Similar was the plight for Dr Reddys Lab and Cipla

5. Conclusion

The present analysis attempts to examine the firm heterogeneity in the Indian Pharmaceutical industry by measuring their input and output efficiency. Based on our analysis we can conclude that with policy changes the output efficiency of the Indian pharmaceutical sector has declined. It appears that few large firms have been able to take the benefit of a liberalized regime, but rest of the large number of small firms in the industry lagged behind. Further, analysis of the input and output efficiency reveals that even though firms have been able to use their inputs efficiently there has been a persistent decline in the output efficiency of the firms. We argue that such circumstance arises because of the 'economies of scale in production and the presence of large number of small firms that lie in the IRS zone of the empirically constructed production possibility set. Thus, one possible route to improve their efficiency will be to encourage merger to reap the benefit of economies of scale.

Our analysis also reveals the importance of firm specific characteristics to achieve higher efficiency. We find that increased investment in R&D will be a beneficial strategy for large sized firms. Thus, one possible way to encourage the firms to do more of R&D will be to involve in more of private–public partnership in R&D. It is noticed that in the context of the developed nation public support played a very important role to boost the R&D climate of the country see National Institute for Health Care Management Research and Educational Foundation (NICHM) (2000). However, in India, public-private co-operation is currently not significant and it is necessary to improve such cooperation for the development of the industry (see also Chaudhuri, 2005). Firms that are able to successfully market their product in the regulated market has to be technologically competent and this is seen through their efficiency scores as well. Small firms that cater mainly to the unregulated international or domestic market need to improve their efficiency to remain competitive in the long run and one way to do so is through merger. In this context our study indicates that vertical merger is better than horizontal merger. Therefore, firms producing only formulation or final product should merge with firms that produce the raw material or the bulk drug for the industry. Finally, the increased inefficiency levels depicted over time indicate that unless the inefficient firms internalized the changed market scenario and take up appropriate measures, it will be difficult to survive in a globally competitive market as they did in a protected market in the past.

Appendix A

Figure A.1: Growth rate in Inputs and Output

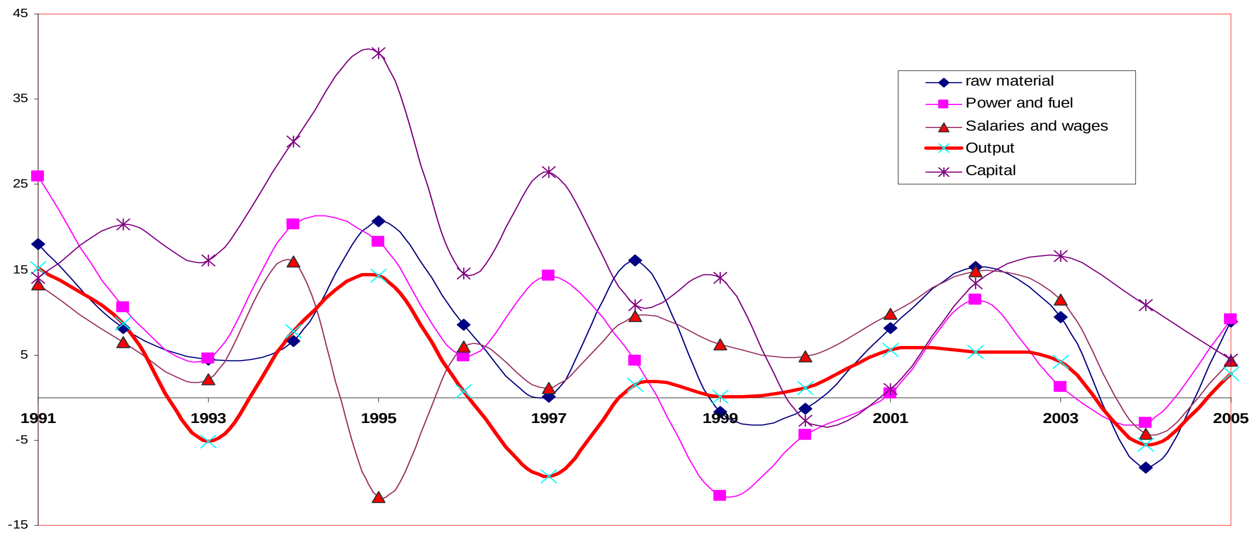

Figure A.2 Growth rates of output and Capital

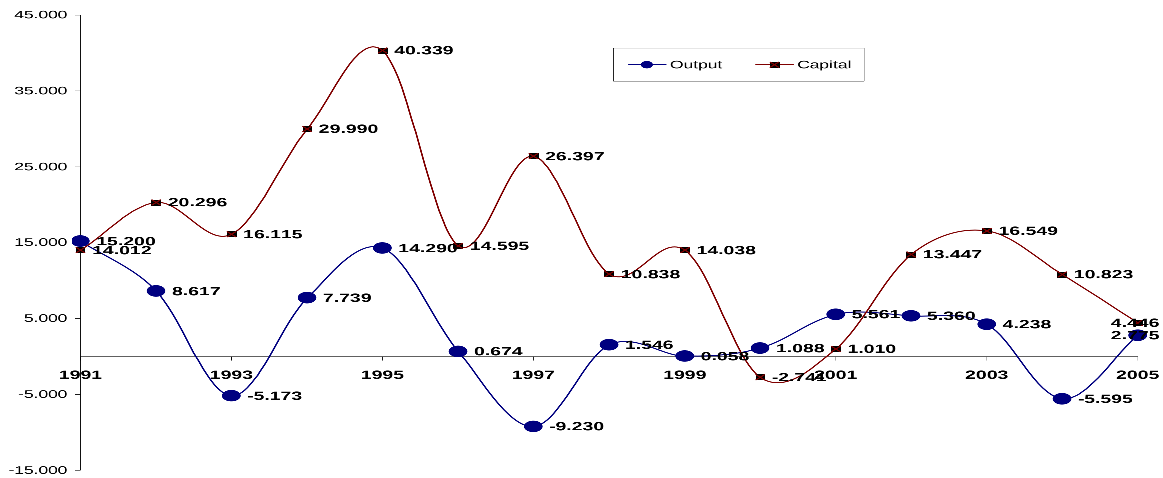

Table A.1: Distribution of Firms based on their Size and Efficiency scores

Size Distribution of Firms (In percent)*						
Year	Large Firms	Inefficient** Large Firms	Medium Firms	Inefficient Medium Firms	Small Firms	Inefficient Small Firms
1991-1995	27.5	15	24	20	48.5	34
1996-2000	16.5	20	12.3	32	71.0	47
2001-2005	13.5	22	11.8	40	75.0	60

*The Classification of firms as small, medium and large is arrived by dividing the output distribution into three groups: firms with 50 the value of output up to 50^{th} percentile are considered as small firms, firms having sales greater than 25 percentile and up to 50^{th} percentile are classified as medium firms and the rest as large firms .**Firms with an efficiency score of 1 to .95 are defined as efficient firms and the rest inefficient firms

Source: Authors Own Calculation

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