Indian Pharmaceutical Industry in transition: A study of Productivity, Efficiency and Innovation

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Abstract:
In this paper we have used data envelopment analysis (DEA) and econometric models to analyse the impact of research and development and innovation on efficiency and productivity change and firm (company) performance in the Indian pharmaceutical industry (IPI) between 1998 and 2007 which covers the post-TRIPS (1995) and post Indian Patent Act Amendment (2005) period. Output oriented BCC DEA model and Malmquist productivity index are used to estimate the relative efficiency and productivity change of Indian pharmaceutical companies over the 10 year period. We have identified efficiency and productivity leaders and laggards in the IPI. We observe that during the 10-year period of study, the productivity change shows an increasing trend and this increase is mainly due to the technical change.

Using econometric models, we have proposed and tested several hypotheses for the IPI and found a positive impact of innovation (represented by company's R&D investment and patents) on company performance (sales), market share, export revenue. We found that additionally DEA efficiency, size and age have a positive impact on company performance (sales). The company sales growth was found to be driven by export growth and DEA efficiency.

This paper makes a contribution to literature on DEA and innovation studies as there is a dearth of literature in DEA studies wherein company R&D expenditure is one of the inputs and company patents are one of the outputs. The DEA efficiency having a positive impact on sales and sales growth is a new finding as there appears to be no previous investigation to explore this relationship. Though further research is required as this research is limited to the IPI, our finding that innovation positively influences company sales, exports and market share is significant. We propose to add case studies of companies in the IPI to study this relationship in future. Without elaborating in this paper, we present a snapshot of one firm's innovation performance as well as DEA efficiency and productivity in a unified framework for case study research in future.

Keywords: DEA, Data envelopment analysis, efficiency, Indian pharmaceutical industry, Innovation, Malmquist index, productivity, research and development, econometric models, technical change, relative efficiency change, patents, market share, growth, exports, sales, company size, age, TRIPS (1995), Indian Patent Act Amendment (2005), contract manufacturing

1.0 Introduction

The Indian Pharmaceutical Industry (IPI) ranks 3rd in terms of volume with 10% share of global production in volume and is 14th in terms of value globally with 1.5% share. It has witnessed a rapid growth , from a turnover of approx. US$ 1 billion in 1990 to over US $ 20 billion in 2010 of which the export turnover is approximately US$ 8 billion. Globally, it ranks 4th in terms of generics production and 17th in terms of export value of bulk actives and dosage forms. Indian exports are destined to more than 200 countries around the globe including highly regulated markets of US, West Europe, Japan and Australia (Dept of Pharmaceuticals GOI, 2014). IPI is valued at US$ 25.87 billion at present, according to Care Ratings, is also expected to grow in the local market with aggressive rural penetration by drug makers, increased government spending on health, and growing health awareness among people (IBEF, 2014).

IPI is a high growth sector of the Indian economy with substantial international presence and has emerged as a technologically dynamic manufacturing industry in the recent years (Kumar and Pradhan, 2003). IPI has achieved a significant scale and level of technological capability for manufacturing modern drugs cost effectively to emerge as a major force in the pharmaceutical products in the world. IPI meets up to 70% of the India's domestic requirement of the bulk drugs and almost 100% of the formulations (Pradhan, 2006). Many experts believe that the Industry has the potential to grow at an accelerated 15 to 20% CAGR to reach between US$49 billion to US$74 billion in 2020 (PwC- CII 2010).

The Indian pharmaceutical industry is highly fragmented with about 24,000 players (330 in the organised sector). The top ten companies make up for more than a third of the market (IBEF, 2014). The main activities of the industry can broadly be classified into production of (i) bulk drugs (ii) formulations (iii) both bulk drugs and formulations. The bulk drug business is essentially a commodity business, whereas the formulation business is primarily a market driven and brand-oriented business. While the indigenous companies are present in bulk as well as formulation business, the multinational companies have continued to focus on the formulation business. The industry now produces bulk drugs belonging to all major therapeutic groups requiring complicated manufacturing technologies. Formulations in various dosage forms are being produced in GMP compliant facilities. Strong scientific and technical manpower and pioneering work done in process development have made this possible.

The Exports form a vital component of the growth strategy of most Indian pharmaceutical companies. India currently exports drug intermediates, Active Pharmaceutical Ingredients (APIs), Finished Dosage Formulations (FDFs), bio-pharmaceuticals, and clinical services across the globe. In terms of value, exports of Indian pharmaceutical products increased at a CAGR of 26.1 per cent to touch US$ 10.1 billion during FY06-13 (IBEF, 2014). The US is the largest export market for Indian pharmaceutical companies. Indian companies have a cost advantage that facilitates the production of drugs at much lower cost incurred by other developed economies (Pradhan, 2006). Some of the top Indian companies have export contribution of more than 50% in their sales. For example, Ranbaxy had an export share of

more than 75% (Aggarwal, 2004).). India is the only country with largest number of US-FDA compliant plants (more than 100) outside USA. There are 793 WHO-GMP approved Pharma Plants, 153 European Directorate of Quality Medicines (EDQM) approved plants with modern state of art technology (Dept of Pharmaceuticals GOI, 2014).
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As a signatory of GATT (General Agreement on Trade and Tariffs), India revised the intellectual property protection (IPP) from a softer 'process patent' regime (since Patent Act, 1970) to a stronger 'product patent' regime in 2005 in a phased manner starting from 1995. It is evident from Laforgia *et al* (2007) that significant research has been carried out that speculate on the effect of the aforementioned change in patent laws on the Indian Pharmaceutical Industry. The effects of TRIPS (Trade Related Intellectual Property Rights) patent protection on the Indian industry. However, the available evidence suggests that quite a few Indian companies are trying to enter the club of innovative firms, raising significantly their R&D intensity and patents, with mixed results so far. On the other hand, while evidence does not yet show any dramatic shake-out of local producers of generics. In fact with 72 per cent of market share (in terms of revenues), generic drugs form the largest segment of the Indian pharmaceutical sector, the balance market share being divided between OTCs (19%) and patented drugs (9%) (IBEF, 2014).
Henderson *et al* (2000) have concluded that institutional factors within the USA and UK have been major factors in producing new biopharmaceutical companies. The factors they cite do not explain the current emergence of the Indian pharmaceutical industry as an increasingly important global competitor. Chittoor and Ray (2007) analysed strategic variables associated with IPI that revealed significant variation in their internationalization strategies that exhibited different value creation potential. Bower and Sulej (2007) have analysed the strategies used by successful Indian pharmaceutical companies in western markets. It is evident from the literature that significant analysis exists on strategies used by IPI. The focus of this paper is on the impact of R&D, innovation, efficiency and productivity gains of indigenous and MNC companies over a period of 10 years covering both process and product patent regimes.

2.0 Literature Survey

There has been significant growth of literature on IPI both nationally and internationally since the TRIPS implementation began in mid-1990s. TRIPS literature reveals considerable concern both, pro-TRIPS relating to consequences to India and international pharmaceutical manufacturers of non-compliance by India and against TRIPS relating to the welfare aspects of denial of access to medicines to poor in India and third world countries as well as gloomy predictions of impact of TRIPS on IPI.
The actual picture that emerged post-TRIPS, turned out to be very different from the predictions in the literature. This was due to the following major reasons, which show the IPI being in transition, justifying the title of this paper :
(a) While India did enact the Patent Amendment Act in 2005 complying with the TRIPS obligations, some clauses relating novelty of the compound being patented (Section 3(d)) and compulsory licensing (which is permitted by TRIPS) did not find favour with the protagonists of TRIPS some of whom are now defending their interests in Indian courts.

(b) In the period following 2005, there have been billions of US$ worth of patent expiries resulting in patented medicines becoming generic with consequent export opportunities for low-cost Indian manufacturers to US and European and other international markets. Hence instead of a fall in fortunes of IPI, there was a surge of growth which still continues. Simultaneously there was a shift in preferences of consumers and health-care providers in western countries towards cheaper generic medicines. Furthermore during this period, the patent pipeline of NCEs (New Chemical Entities) of pharma MNCs started drying up due to steep fall in productivity of R&D leading to "patent cliff" and resultant financial impact.
(c) In the years leading to the Patent Act Amendment, 2005, the major players in IPI, apprehending loss of market-share and revenue to NCEs of pharma MNCs post-TRIPS , made a strategic shift towards in-house R&D which resulted in innovations leading to Indian, US and international patents. They also became active in the US market securing ANDAs. In order to have stronger presence in the US and international markets, some of the firms resorted to merger and acquisition activity in US and other countries.
In case of both (b) and (c) above, economic liberalization of India in 1990s also played an important role as it removed the rigidities imposed on firms by laws, rules and regulations and enabled them to seize opportunities.
The foregoing events have influenced the evolution of literature on IPI. We discern the following strands in literature:
(a) Impact of TRIPS on different facets of IPI
Much of this literature is prior to 2005. Post-2005, significant research has been carried out on the strategies of IPI and the likely impact of TRIPS and Indian Patent Act on the IPI (Chittoor and Ray 2007, Chadha 2009a). Athreye et al (2008) study the strategy and dynamic capabilities in IPI using the case study approach. Chadha (2009b) analysed the export performance of IPI using a sample of 131 firms using econometric models and found significant impact on export performance and foreign patents. Vyas et al (2012) use a logit model to study the determinants of M&A in IPI. *(More papers to be added)*

(b) Productivity Studies
Even internationally there are only a few empirical studies relating to productivity changes in this industry. Fare *et al* (1995) have analysed Swedish pharmaceutical companies by decomposing Malmquist productivity change into three categories, namely, quality change, technical change and efficiency change. Carolis (2003) analysed the impact of technological competence on firm performance of global pharmaceutical companies. Danzon *et al* (2005) analysed productivity in pharmaceutical industry using various econometric models to analyse the impact of experience and alliances in their success. Gonzalez and Gascon (2004) analysed Spanish pharmaceutical industry using DEA BCC model and found significant contribution of technical efficiency to productivity growth. They also note that the impact of technical efficiency on productivity change was different in case of large, medium and small companies. Hashimoto and Haneda (2008) used DEA to analyse R&D efficiency of Japanese pharmaceutical companies.
In the IPI use of DEA for productivity studies was pioneered by Saranga. Saranga (2007a) analysed a sample of 44 Indian pharmaceutical companies and showed that the DEA models are sensitive to the selected inputs and outputs. Saranga (2007b) showed that the DEA model can be used for efficient outsourcing and vendor selection in pharmaceutical products. Saranga and Phani (2008) using CCR and BCC DEA models established that firms

with higher levels of R&D investments and older establishments are associated with higher efficiencies when compared to their less R&D intensive and younger counterparts. Saranga and Banker (2007) analysed the technical and productivity changes in Indian pharmaceutical industry post liberalization using DEA models.
Mazumdar et.al. (2010) used DEA efficiency score of a firm which provides an assessment of its performance based on measurement of output and input efficiencies for Indian pharmaceutical firms.

Gap in literature

From the foregoing, it would be seen that there is a dearth of studies relating to productivity and efficiency movements in the IPI particularly the post-TRIPS period. Furthermore, though R&D and innovation has become an important feature of IPI, to the best of our knowledge there are no papers which capture their impact by internalizing R&D and innovation in the DEA model with the exception of following papers written by the authors.
Pannu , Kumar and Farooquie (2011), first two being the authors of this paper, studied the total, technical and relative efficiency and productivity of a balanced panel of 146 IPI firms data for 10 years (1998-2007 which covers the period before and after patent act amendment, 2005) using OLS with pooled data. An increase in productivity over the period was found on account of technical change; efficiency and productivity leaders were identified. Hypotheses were tested for comparison of indigenous and multinational companies, effect of firm size over several performance measures was studied. Importantly, exploring the relationship between DEA efficiency and innovation, it was found that innovative firms with R&D and patents have higher efficiency than non-innovative firms.
Pannu , Kumar and Farooquie (2010), first two being the authors of this paper, studied the total, technical and relative efficiency and productivity of a balanced panel of 123 IPI firms data for 10 years (1998-2007). Using DEA with R&D cost as one of the inputs and Patents as one of the outputs to analyse the impact of research and development and innovation on relative efficiency and productivity changeof IPI. Using OLS with pooled data econometric models, we have proposed and tested several hypotheses for the IPI and found a positive impact of innovation represented by R&D investment and patents on productivity (sales), market share, exports. We also found that the sales are additionally driven by DEA efficiency, size, age which have a positive impact on productivity (sales). Export revenue is additionally driven by sales. The company sales growth was additionally driven by export growth and DEA efficiency. The DEA efficiency having a positive impact on sales and sales growth was a new finding as there appears to be no previous investigation to explore this relationship.

The main objective of this paper is to carry forward the work in Pannu , Kumar and Farooquie (2010), the first two being authors of this paper using the same DEA data, and then study impact of innovation on industry performance using panel data model instead of pooled OLS model during the period 1998 to 2007. The rest of the paper is organized as follows. In section 3 we have described the data source and descriptive statistics related to the sample along with DEA inputs and outputs. In section 4 the DEA methodology for estimation of technical and relative efficiency change is discussed. The results of the DEA models are analysed in section 5. Several hypotheses on productivity (sales), growth, market share, export of companies in IPI are proposed and tested in section 6. In our

further research we intend to discuss the DEA results with reference to case studies of R&D and innovation by representative IPI firms. In Section 7, we give a snapshot for on company of the unified framework we intend to research . This is very rare in IPI (except for papers which rely only on case studies). Conclusions are discussed in section 8.

3.0 Description of the IPI Data

We obtained the relevant data from the Prowess Database which is one of the many databases provided by the Center for Monitoring Indian Economy (CMIE)[1]. Centre for Monitoring Indian Economy Pvt. Ltd was established in 1976 and has grown into India's leading private sector economic research institution headquartered at Mumbai, India. Prowess is a database of over 10,000 Indian companies. It contains detailed normalized data culled from the audited annual accounts, stock exchanges, company announcements, etc. It has over ten years of time-series data and is updated with the latest data on a daily basis. Our sample consists of data relating to financial statement for 123 companies of pharmaceutical sector for which data for all the ten years was available in the Prowess database. However, for 5 firms, the data was incomplete for two years and for 22 firms the data was incomplete for one year. These cases were also included in the sample by extrapolating values for the missing years by projecting the growth rates using data of two successive adjacent years or calculating an average value where data was available for both the preceding year and the succeeding year. Further details of the sample pharmaceutical companies used in this analysis are shown in Table 1. The inputs and outputs chosen for DEA model play an important role in deciding the efficiency of the DMUs. Selection of appropriate DEA models, especially the inputs and outputs has been a focus of DEA research for many years (Banker and Morey 1986, Norman and Stocker 1991, Pastor *et al* 2002). Pastor *et al* (2002) used the concept of efficiency contribution measure (ECM) that compares the efficiency scores of two DEA models differing in either one input or output. The data in the financial statement were combined as follows:

Inputs - The major cost elements are chosen as inputs for the application of DEA in the current paper: (i) Cost of Material (ii) Cost of Manpower (iii) Capital cost (Capital cost = Cost of Production & selling - Raw materials, stores & spares - Compensation to employees) and (iv) Research and Development investment.

Output – consisted of (i) Sales and (ii) Patents data.

The entire data set was deflated to 1998 prices. Summary statistics related to inputs and outputs for years 1998 and 2007 are shown in Table 2.

Table 1. Details of pharmaceutical companies used in this study

Metric	Category	Number of Firms	% of each category in the sample
Ownership	Domestic firms	111 firms	90.24 %
	Foreign owned Indian firms	12 firms	9.76 %
Product	Bulk & Formulations	67	54.47 %
	Only Formulations	47	38.21 %
	Medical Equipment	9	7.32 %
	No. of firms out of the total sample of 123 firms engaged additionally in Contract/Job work/ Royalties/Services etc.	57	46.34 %
Size by Sales (Turnover for 2007 and conversion rate of 1 USD=Rs.43.59)	Big (Total sales > 75 Million US dollars)	Domestic – 30 Foreign owned – 9 Total – 39 firms	Domestic – 24.39 % Foreign owned – 7.32 % Total – 31.71 %
	Small (Total sales < 75 Million US dollars)	Domestic – 81 Foreign owned – 3 Total – 84 firms	Domestic – 65.85 % Foreign owned – 2.44 % Total – 68.29 %
Size by Plant & Machinery (2007)	Very large firms (> Rs. 100 cr.)	Domestic – 32 Foreign owned – 4	Domestic – 26.02 % Foreign owned – 3.25 % Total – 29.27 %
	Large firms (Rs.10 to 100 cr.)	Domestic – 43 Foreign owned – 6	Domestic – 34.96 % Foreign owned – 4.88 % Total – 39.84 %
	Medium firms (Rs.5 to 10 cr.)	Domestic – 15 Foreign owned - 0	Domestic – 12.20 % Foreign owned –0 Total – 12.20 %
	Small firms (Rs.0.25 to 5 cr.)	Domestic – 14 Foreign owned – 2	Domestic – 11.38 % Foreign owned – 1.63 % Total – 13.1 %
	Plant & Machinery data not available for 7 domestic firms		
Importance of firms in sample	104 out of 123 firms in the sample are listed in the BSE.	Domestic –93 Foreign owned -11 Total - 104	Domestic – 75.61 % Foreign owned – 8.94 % Total – 84.55 %

Table 2. Descriptive Statistics of Input and Output variables for the years 1998 and 2007 for the sample of 123 firms

(Figures in crores (10 million) of rupees – deflated to 1998 price; 1 crore = Rs.10 million)

Variables	Year	Mean	Standard deviation	Minimum	Maximum	Lower Quartile	Median	Upper Quartile
Raw materials, stores & spares	1998	39.88	56.20	0.11	363.64	5.91	18.64	47.65
	2007	64.48	109.49	0.20	623.96	4.84	18.85	75.09
Compensation to employees	1998	9.64	16.33	0.11	81.67	0.69	2.55	10.47
	2007	22.33	39.42	0.13	274.92	1.83	6.95	22.77
Capital Cost	1998	17.03	29.27	0.19	181.99	1.72	4.59	20.11
	2007	30.91	60.88	0.19	392.54	2.55	9.60	28.80
Sales	1998	114.40	175.39	0.44	1129.65	13.47	37.95	134.98
	2007	201.06	356.38	0.56	2142.26	15.96	74.15	236.80
R&D Expenses	1998	1.61	5.03	0.00	45.64	0.00	0.00	1.13
	2007	11.31	30.57	0.00	235.07	0.00	0.22	5.65
Export Earning	1998	25.72	63.45	0.00	441.00	0.36	2.40	19.35
	2007	79.22	216.38	0.00	1558.77	0.57	6.47	50.34
Assets	1998	122.09	247.82	2.35	2180.97	15.32	34.35	127.82
	2007	298.83	594.71	1.06	4061.73	19.00	79.84	263.68
R&D/Sales(%)	1998	0.71	1.32	0.00	7.79	0.00	0.00	0.76
	2007	2.43	4.05	0.00	23.94	0.00	0.47	3.22
Market Share(%)	1998	0.81	1.25	0.00	8.03	0.10	0.27	0.96
	2007	0.81	1.44	0.00	8.66	0.06	0.30	0.96
Indian Patents	1998	10	19	1	58	1	2	8
	2007	18	30	1	132	2	7	20
Sales CAGR(%)	1998-2007	4.36	11.43	-27.06	34.48	-2.79	4.62	11.22

3.1 innovative activity of IPI companies
Table 3 lists the innovative activity of IPI companies.

Table 3 **R&D, SALES & INDIAN PATENTS - 10 YEARS (DEFLATED)**

S.No.		TOTAL (10 YRS) R&D expenses	R&D/Sales	Indian Patents (Ekaswa, IP, BP)	TOTAL (10 YRS) US Patents (Engg. Village)	DMFs (USFDA)	ANDAs (Orange Book)
1	Astrazeneca Pharma India Ltd.(0)	17.65	1.59	2	13	0	0
2	Strides Arcolab Ltd.(0)	69.94	4.64	16	7	0	0
3	Matrix Laboratories Ltd.(0)	110.09	5.50	69	2	79	1
4	Medi-Caps Ltd.	0.00	0.00	1	0	1	0
5	Albert David Ltd.	0.39	0.06	1	0	0	0
6	Arvind Remedies Ltd.	0.81	0.13	1	0	0	0
7	Nectar Lifesciences Ltd.	3.96	0.37	1	0	2	0
8	Jagsonpal Pharmaceuticals Ltd.	4.57	0.45	1	0	1	0
9	Anuh Pharma Ltd.	0.00	0.00	2	0	1	0
10	Mercury Laboratories Ltd.	0.00	0.00	2	0	0	0
11	Shree Dhootapapeshwar Ltd.	0.88	1.53	2	0	0	0
12	Marksans Pharma Ltd.	8.23	1.28	2	0	1	0
13	Gufic Biosciences Ltd.	0.00	0.00	3	0	4	0
14	Ankur Drugs & Pharma Ltd.	0.00	0.00	4	0	0	0
15	Zenotech Laboratories Ltd.	5.72	24.02	4	0	0	0
16	Shilpa Medicare Ltd.	0.00	0.00	5	0	0	0
17	Wanbury Ltd.	12.67	4.52	5	0	15	0
18	Neuland Laboratories Ltd.	21.99	3.04	5	0	24	0
19	Indoco Remedies Ltd.	26.76	2.57	5	0	0	0
20	Auro Laboratories Ltd.	0.00	0.00	6	0	1	0
21	Span Diagnostics Ltd.	0.94	0.50	6	0	0	0
22	Ind-Swift Ltd.	11.74	1.15	6	1	0	0
23	S M S Pharmaceuticals Ltd.	7.68	1.38	7	0	7	0
24	Aarti Drugs Ltd.	13.22	1.06	7	0	5	0
25	Divi'S Laboratories Ltd.	38.55	2.29	7	3	28	0
26	Macleods Pharmaceuticals Ltd.	34.69	2.98	8	0	0	0
27	Lincoln Pharmaceuticals Ltd.	0.00	0.00	9	0	0	0

28	Tonira Pharma Ltd.	3.39	2.23	11	1	2	0
29	Elder Pharmaceuticals Ltd.	8.36	0.56	11	0	0	0
30	Shasun Chemicals & Drugs Ltd.	70.83	4.45	13	3	18	0
31	Lyka Labs Ltd.	4.29	0.41	14	0	0	0
32	F D C Ltd.	22.41	1.46	14	0	4	0
33	Morepen Laboratories Ltd.	12.34	0.59	15	0	5	0
34	Themis Medicare Ltd.	4.58	1.03	21	3	0	0
35	Natural Capsules Ltd.	0.00	0.00	22	1	3	0
36	Ind-Swift Laboratories Ltd.	81.98	8.94	23	0	0	0
37	Kopran Ltd.	3.93	0.33	34	6	0	0
38	Piramal Healthcare Ltd.	256.47	4.14	34	12	5	0
39	Suven Life Sciences Ltd.	37.96	11.45	38	7	7	0
40	Unichem Laboratories Ltd.	56.61	2.82	38	0	10	1
41	Ajanta Pharma Ltd.	28.19	3.10	42	1	1	0
42	J B Chemicals & Pharmaceuticals Ltd.	27.23	1.44	48	11	0	0
43	U S V Ltd.	128.86	5.33	56	12	19	0
44	Ipca Laboratories Ltd.	98.70	2.88	76	4	21	0
45	Torrent Pharmaceuticals Ltd.	237.83	7.61	102	21	5	3
46	Glenmark Pharmaceuticals Ltd.	139.07	6.77	110	48	24	5
47	Alembic Ltd.	89.60	2.53	112	26	17	0
48	Panacea Biotec Ltd.	133.08	7.00	112	21	0	0
49	Natco Pharma Ltd.	29.76	2.16	113	5	11	0
50	Aurobindo Pharma Ltd.	182.94	2.80	122	11	107	13
51	Lupin Ltd.	294.75	5.52	148	47	54	17
52	Cipla Ltd.	380.06	3.72	176	24	88	0
53	Orchid Chemicals & Pharmaceuticals Ltd.	167.07	4.98	208	69	41	0
54	Sun Pharmaceutical Inds. Ltd.	425.54	8.71	224	39	56	0
55	Wockhardt Ltd.	384.43	7.65	225	42	45	18
56	Cadila Healthcare Ltd.	361.49	7.24	284	12	55	0
57	Dr. Reddy'S Laboratories Ltd.	812.18	9.11	438	155	49	29
58	Ranbaxy Laboratories Ltd.	1588.73	9.23	592	74	82	78

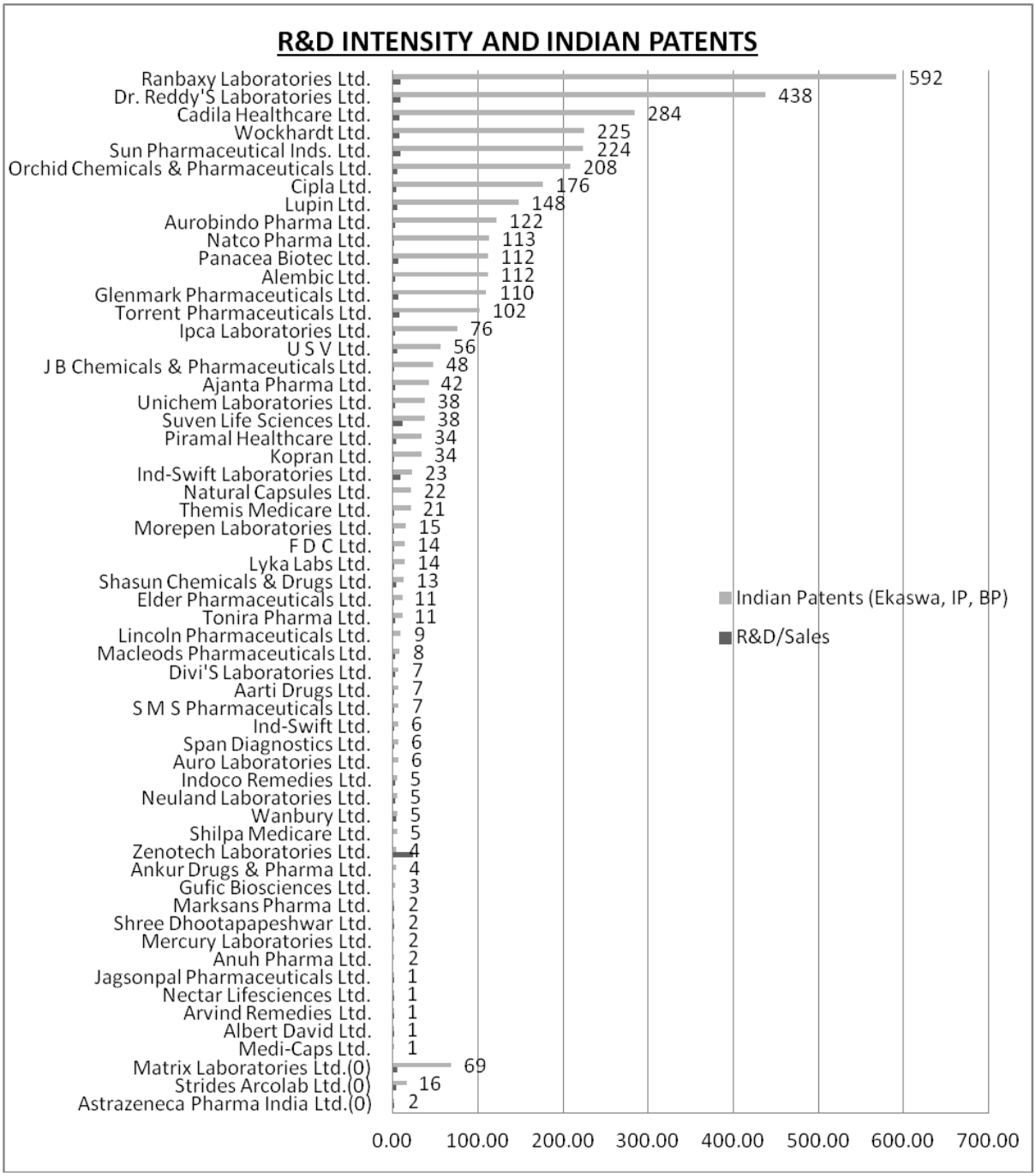


Figure 1 R&D Intensity And Indian Patents

4.0 DEA Methodology for estimation of productivity, technical and relative efficiency change

We follow the methods developed by Banker *et al* (2005) to compute the productivity, technical and relative efficiency changes. We denote the base period by the superscript '0' and a subsequent period 't'. The production set is defined for period i = 0, t as

$P^i = \{(x,y)$: x can produce y at time i$\}$.

The production set P^i, i = 0, t, is assumed to be monotone increasing and convex. The inefficiency measure for an output-input combination $(\mathbf{y}_j^\tau, \mathbf{x}_j^\tau)$ for observation j at time τ,

relative to technology P^i from the period i, is measured radially by the reciprocal of Shephard's (1970) output distance function and is given as,

$$\phi^i_{j\tau} = \phi^i(x^\tau_j, y^\tau_j) = \sup\{\phi^i : (x^\tau_j, \phi^i y^\tau_j) \in P^i\}. \quad (1)$$

The productivity index introduced by Caves, Christensen and Diewert, (1982), based on Malmquist (1953), for comparison between the base period and period t, with the frontier technology from the base period as reference, is

$$P_j(0,t) = \frac{y_0}{\phi^0(x_0)} \Big/ \frac{y_t}{\phi^0(x_t)} = \frac{\phi^0_{j0}}{\phi^0_{jt}} \quad (2)$$

If this index is greater than 1 it indicates that the firm j is more productive in period 1 than in the base period 0. Taking logarithms on both sides of (2) we can express the change in productivity as:

Productivity change for firm j, from period '0' to period 't' = $\ln(\phi^0_{j0}) - \ln(\phi^0_{jt})$ (3)

In order to divide the productivity change into its technical component and relative efficiency component, the term $\ln(\phi^t_{jt})$ is added and subtracted from equation (3) to give the following equation:

$$\begin{aligned} \text{Productivity change} &\equiv \ln(\phi^t_{jt}/\phi^0_{jt}) + \ln(\phi^0_{j0}/\phi^t_{jt}) \\ &\equiv \{\ln(\phi^t_{jt}) - \ln(\phi^0_{jt})\} + \{\ln(\phi^0_{j0}) - \ln(\phi^t_{jt})\} \\ &\equiv \text{Technical change + Relative efficiency change.} \quad (4) \end{aligned}$$

Let $(x_{j\tau}, y_{j\tau})$, $\tau = 0, t$; j=1,..N be the observed sample of N pairs of input-output vectors. We estimate ϕ^0_{j0} and ϕ^t_{jt} (denoted by $\hat{\phi}^0_{j0}$ and $\hat{\phi}^t_{jt}$ respectively), as well as, the inefficiency values for the j^{th} firm corresponding to base period and period t input-output vectors using the BCC linear program model (Banker, Charnes and Cooper 1984). For estimating ϕ^t_{jt}, we use the following linear program:

$$\text{Max}\hat{\phi}^t_{jt}$$

subject to the constraints

$$\begin{aligned} &\sum_{k=1}^{N} \lambda^t_{kt}\mathbf{x}_{kt} \le \mathbf{x}_{jt} \\ &\sum_{k=1}^{N} \lambda^t_{kt}\mathbf{y}_{kt} \ge \hat{\phi}^t_{jt}\mathbf{y}_{jt} \\ &\sum_{k=1}^{N} \lambda^t_{kt} = 1 \\ &\lambda^t_{kt} \ge 0, \qquad k = 1,2,\ldots,N \end{aligned} \quad (5)$$

We estimate ϕ^0_{j0} similar to the above estimation of ϕ^t_{jt} in (5), with period 't' replaced by period '0'. We then estimate ϕ^0_{jt}, the inefficiency of firm j's period t input-output vector relative to the base period production possibility set, using the following linear program.

$$\text{Max } \hat{\phi}^0_{jt}$$

subject to the constraints

$$\sum_{k=1}^{N} \lambda^0_{k0}\mathbf{x}_{k0} \le \mathbf{x}_{jt}$$

$$\sum_{k=1}^{N} \lambda_{k0}^{0} \mathbf{y}_{k0} \geq \hat{\phi}_{jt}^{0} \mathbf{y}_{jt}$$

$$\sum_{k=1}^{N} \lambda_{k0}^{0} = 1$$

$$\lambda_{k0}^{0} \geq 0, \qquad k = 1,2,\ldots,N \tag{6}$$

The difference between the two models (5) and (6) is that the observation under evaluation (period t input/output) is not included in the reference set of period 0 observations for the constraints in (6). However, the observation's period 0 input/output values are considered in the reference set instead.

The goal is to compare the maximal output achievable with period t input and base period 0 production technology with the actual output achieved in period t. This is similar to the super efficiency model (Banker, Das and Datar 1989), so the DEA inefficiency estimator $\hat{\theta}_{jt}^{0}$ may take a value less than 1 unlike the DEA estimator $\hat{\theta}_{j0}^{0}$ which is always greater than or equal to 1. Also, if the input-output vector for the observation under evaluation is outside the range of the input-output vectors contained in the reference set, it is not feasible to solve the program in (6), hence the value of $\hat{\theta}_{jt}^{0}$ is set equal to 1.

Firm specific estimators $\hat{\mathbf{p}}_j$, $\hat{\mathbf{t}}_j$ and $\hat{\mathbf{e}}_j$ of productivity change, technical change and relative efficiency change, respectively, are then determined as functions of the various inefficiency estimators as follows:

$$\hat{p}_j = \ln\left(\frac{\hat{\phi}_{j0}^{0}}{\hat{\phi}_{jt}^{0}}\right), \hat{t}_j = \ln\left(\frac{\hat{\phi}_{jt}^{t}}{\hat{\phi}_{jt}^{0}}\right), \text{ and } \hat{e}_j = \ln\left(\frac{\hat{\phi}_{j0}^{0}}{\hat{\phi}_{jt}^{t}}\right) \tag{7}$$

5.0 Analysis of the DEA results and regression models for impact of research and development and innovation

In the above DEA model used by us, the value of efficiency=1 represents the best practice, i.e. the companies on the efficient frontier and the values of efficiency >1 and increasingly greater than 1 represent companies away from the frontier and worsening of company efficiency. Using BCC VRS model, the efficiency and productivity leaders and laggards have been identified. Efficiency leaders and laggards based on BCC VRS output model over 10 year period along with their average efficiency scores are shown in table 3. Among efficiency leaders, we found that Amol Drug Pharma Ltd., Cipla Ltd, Ranbaxy laboratories Ltd., Vista pharmaceutical Ltd., Abbott India Ltd., Fulford (India) Ltd., Glaxosmithkline Pharmaceuticals Ltd. and Novartis India Ltd. were efficient throughout the 10 year period. Among efficiency laggards Resonance Specialties Ltd., Capsugel Healthcare Ltd., Dey's Medical Stores Mfg. Ltd., Kerala Ayurveda Ltd., Godavari Drugs Ltd., Biochemical & Synthetic Products Ltd., Wintac Ltd., Shree Dhootapapeshwar Ltd. and Alta Laboratories Ltd. were inefficient during all 10 years.

Productivity leaders and laggards are shown in table 4. Among productivity leaders, Fulford (India) Ltd., Abbott India Ltd, Ranbaxy laboratories Ltd., Novartis India Ltd., Glaxosmithkline Pharmaceuticals Ltd. and Cipla Ltd. were also efficient leaders. Among the productivity laggards, Capsugel Healthcare Ltd., Godavari Drugs Ltd. and Shree Dhootapapeshwar Ltd. were also efficiency laggards.

We have decomposed productivity change into its technical component and relative efficiency component as in equation 4 above. Figure 2 shows the average productivity, technical and relative efficiency change over the period of study. It can be observed that the productivity change shows an increasing trend and this increase is mainly due to the technical change.

Table 4. Efficiency leaders and laggards over 10 year period

Efficiency Leaders			Efficiency Laggards		
DMU Name	Average Efficiency over 10 years	Number of years efficient over 10 year period	DMU Name	Average Efficiency over 10 years	Number of years inefficient over 10 year period
Amol Drug Pharma Ltd.	1.000	10	Resonance Specialties Ltd.	2.045	10
Cipla Ltd.	1.000	10	Capsugel Healthcare Ltd.	2.086	10
Ranbaxy Laboratories Ltd.	1.000	10	Dey's Medical Stores Mfg. Ltd.	2.111	10
Vista Pharmaceuticals Ltd.	1.000	10	Kerala Ayurveda Ltd.	2.221	10
Abbott India Ltd.	1.000	10	Godavari Drugs Ltd.	2.238	10
Fulford (India) Ltd.	1.000	10	Biochemical & Synthetic Products Ltd.	2.246	10
Glaxosmithkline Pharmaceuticals Ltd.	1.000	10	Wintac Ltd.	2.272	10
Novartis India Ltd.	1.000	10	Shree Dhootapapeshwar Ltd.	2.457	10
Aurobindo Pharma Ltd.	1.005	9	Caplin Point Laboratories Ltd.	2.461	8
Arvind Remedies Ltd.	1.005	8	Alta Laboratories Ltd.	2.670	10

Table 5 Productivity leaders and laggards

Productivity Leaders		Productivity Laggards	
DMU Name	Productivity over 10 years	DMU	Productivity over 10 years
Samrat Pharmachem Ltd.	0.90	Krebs Biochemicals & Inds. Ltd.	-0.06
Fulford (India) Ltd.	0.72	Capsugel Healthcare Ltd.	-0.06
Abbott India Ltd.	0.62	J B Chemicals & Pharmaceuticals Ltd.	-0.06
Ranbaxy Laboratories Ltd.	0.59	Tonira Pharma Ltd.	-0.07
Marksans Pharma Ltd.	0.52	Ambalal Sarabhai Enterprises Ltd.	-0.07
Novartis India Ltd.	0.51	Kamron Laboratories Ltd.	-0.07
Phaarmasia Ltd.	0.51	Natural Capsules Ltd.	-0.09
Glaxosmithkline Pharmaceuticals Ltd.	0.48	S S Organics Ltd.	-0.09
Cipla Ltd.	0.46	Shree Dhootapapeshwar Ltd.	-0.11
Sanjivani Paranteral Ltd.	0.42	Godavari Drugs Ltd.	-0.14

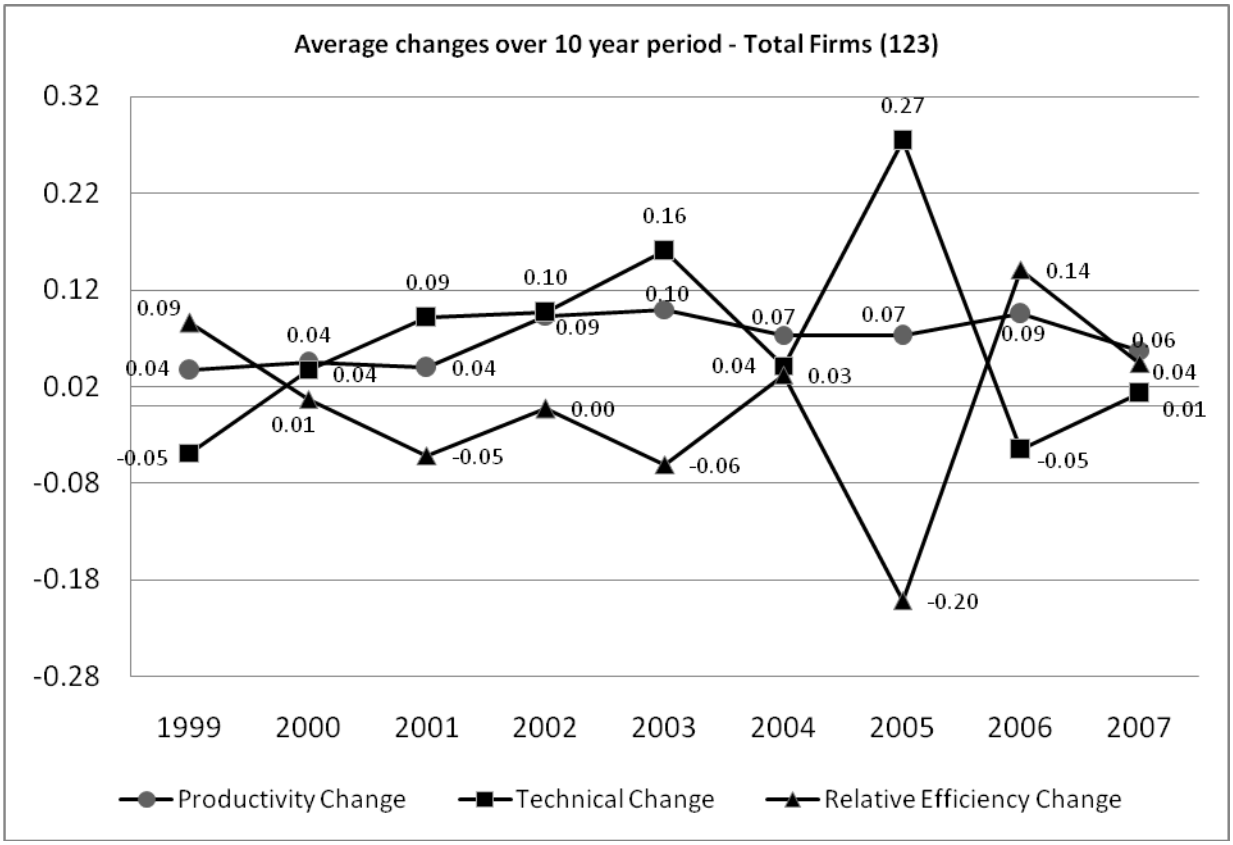


Figure 2. Productivity, relative efficiency and technical change over a period of 10 years

We analyse the data for the IPI between 1998 and 2007 which covers the post-TRIPS (1995) and post Indian Patent Act Amendment (2005) period. Our data shows that this period has been characterized by a sharp increase in R&D investment and patents by the companies. We have studied above, the changes in efficiency and productivity of indigenous and multi-national companies (MNCs) for this period. Using regression models, we also analyse the impact of research and development, innovation and DEA efficiency on the performance of IPI companies. As appropriate in different contexts, we use one or more of the following variables to represent the innovative activity of individual companies: R&D investment, R&D Intensity (R&D investment as a percentage of sales), R&D Investment 10-year CAGR, the number of Indian patents for companies and an Innovation Dummy I_D (Value=1 representing the Innovative companies and Value=0 representing the Non-Innovative companies). Here, by non-innovative companies, we mean those companies which do not invest in R & D and do not have any patents in any of the years, rest of the companies in the sample being Innovative. In this study we also introduce where appropriate, additional predictor variables: DEA efficiency of the foregoing analysis, age of the company measured from year of incorporation to the year of rest of the company data and company size measured by company's investment in plant & machinery.

5.1 It may be pointed out that in the regression analysis the coefficient (β) for DEA efficiency would be negative for a positive impact on innovation since, as mentioned in foregoing, the value of efficiency=1 represents the best practice, i.e. the companies on the efficient frontier and the values of efficiency >1 and increasingly greater than 1 represent companies away from the frontier and worsening of company efficiency.

6.0 Hypotheses and Tests using Panel Data and OLS Regression Models

The following four hypotheses relating to innovation are proposed for testing using appropriate statistical tests.

Hypothesis 1:
There is no influence of innovation on the performance of pharmaceutical companies.
Innovation shall be measured the presence of any of the following: company's investment in R & D or whether patents obtained (this being reflected in the Innovation Dummy, I_D=1; if no R&D investment or patents, I_D =0), R & D Intensity (R & D Investment/Sales %), number of patents obtained.
We also explore the influence of DEA efficiency, age and size on performance.
In this hypothesis, we have used sales as a measure of performance.

Hypothesis 2:
The market share of pharmaceutical companies is not influenced by innovation.
Hypothesis 3:
The export revenue of pharmaceutical companies is not influenced by innovation.
We also explore the influence of sales revenue on the export revenue of pharmaceutical companies
Hypothesis 4:
The growth of pharmaceutical companies is not influenced by innovation.
We also explore the influence of DEA efficiency, productivity change, export revenue growth on the growth of pharmaceutical companies

To test the above hypotheses, analysis was carried out using Stata Ver13 software, results for each hypothesis are given below. Panel data analysis was carried out for data for Hypotheses 1,2 and 3 as we have yearly data from 1998 to 2007 for a balanced panel of 123 firms of Indian Pharmaceutical Industry. OLS regression analysis was carried out Hypothesis 4, which has data for first year (1998) and final year (2007) for growth (CAGR) related variables and average values over 10-years for other variables. It would be seen that some of the variables have been transformed as logarithms, this being done to find the best combination that eliminates problems related to assumptions of analysis viz. multicollinearity, heteroscedasticity, normality and independence. The analysis results for all four hypotheses are discussed In the following paragraphs .

Panel Data Model for hypothesis 1:
There is no influence of innovation on the performance of pharmaceutical companies.
Dependent variable: lnS
Independent variables: I_D, lnAG, lnEY, lnP, lnSize, lnRDI
Where S= Sales; I_D= Innovation Dummy; Size= Investment in Plant &Machinery; P= Number of patents; EY= DEA efficiency, RDI_PCT= R&D intensity% and AG= Age of the company

Fixed or Random: Hausman test
To decide between fixed or random effects, Hausman test was used and the null hypothesis is that the preferred model is random effects vs. the alternative the fixed effects. It basically tests whether the unique errors (*ui*) are correlated with the regressors, the null hypothesis is they are not. The results are shown in Table 6.1.1 below.

Table 6.1.1
Hausman test

	Coefficients (b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
i_d	.3552499	.3448492	.0104007	.
ln_rdi	.3766782	.3808183	-.0041402	.0018885
ln_ey	-1.266711	-1.220666	-.0460442	.01092
ln_ag	.5767018	.5836688	-.006967	.0047679
ln_size	.5491689	.5486316	.0005374	.0003353
ln_p	.0189456	.0249819	-.0060364	.0024975

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 19.74
Prob>chi2 = 0.0031
(V_b-V_B is not positive definite)

The probability to reject the hypothesis is (χ^2=19.74, p<0.0031), it indicates that the fixed-effects panel regression model can be used to determine the percent of variance (R^2) explained sales (a measure of productivity) in pharmaceutical companies keeping in consideration: Innovation Dummy; Size (investment in Plant & Machinery); Number of patents; DEA efficiency, R&D intensity% and age of the company over the years. Fixed-effects panel regression model including parameter (coefficients), standard error of estimates, R-square and other relevant statistics along with level of significance are exhibited in Table 6.1.2 below.

Table 6.1.2

Fixed effects regression model and other related statistics

Fixed-effects (within) regression — Number of obs = 1228
Group variable: year — Number of groups = 10

R-sq: within = 0.7898 — Obs per group: min = 122
between = 0.3741 — avg = 122.8
overall = 0.7852 — max = 123

F(6,1212) = 758.93
corr(u_i, Xb) = -0.0160 — Prob > F = 0.0000

ln_s	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
i_d	.3552499	.0630018	5.64	0.000	.2316452	.4788546
ln_rdi	.3766782	.0425907	8.84	0.000	.2931185	.4602378
ln_ey	-1.266711	.0756571	-16.74	0.000	-1.415144	-1.118277
ln_ag	.5767018	.0318392	18.11	0.000	.5142357	.6391679
ln_size	.5491689	.0168627	32.57	0.000	.5160856	.5822523
ln_p	.0189456	.0301443	0.63	0.530	-.0401952	.0780863
_cons	.0410064	.1048396	0.39	0.696	-.1646808	.2466936
sigma_u	.14282185					
sigma_e	.75170174					
rho	.0348415	(fraction of variance due to u_i)				

F test that all u_i=0: F(9, 1212) = 4.17 — Prob > F = 0.0000

On the basis of above coefficients, the regression model equation in this case can be written as follows:

Sales (ln_s) = 0.0410 + 0.3552 × Innovation Dummy (I_d) + 0.3767 × R&D Intensity (ln_RDI) – 1.2667 × DEA Efficiency (ln_ey) + 0.5767 × Age (ln_ag) + 0.5492 × Size (ln_size) Equation (1)

The model is fit as (F=759.93, p< 0.001). This test helped to verify the assumption that all the coefficients in the model are different than zero.

The response variable in hypothesis 1 is Sales, which is used as a measure of firm performance. In the above regression model, size of the company is measured through its capital investment in plant and machinery. It is evident from the Table 6.1.2 that all the variables except number of patents (ln_p) are included in the model and significant at ($p<0.05$) level of significance. It may also be inferred that significant variables have influence on dependent (outcome) variable. R^2 to predict dependent variable Sales (lnS) on the basis of five independent variables: Innovation Dummy; Size; DEA efficiency; R&D intensity% and Age (I_D, lnSize, lnEY, , lnRDI, lnAG,) was found to be 0.79, which is quite high. Since coefficients, βs > 0, Innovation Dummy, R&D intensity of the companies, age of the company and size of the company have a positive impact on company performance (sales). Number of Patents (ln_p) was not included in the model as probability to reject the hypothesis ($p>0.05$). Therefore, it is established that innovative companies (Innovation Dummy; R&D intensity% being considered as proxies for innovative companies) have higher performance (sales) than non-innovative companies. It is also founnd that that the older, larger and efficient (DEA efficiency variable included, for significance of negative sign see para 5.1) impact company performance positively.
Rho (ρ=0.0348) is known as the interclass correlation and 3.8% of the variance is due to differences across panels observed.

Panel Data Model for hypothesis 2:
The market share of pharmaceutical companies is not influenced by innovation.
Dependent variable: lnMS
Independent variables: I_D, lnRD
Where, MS = Market share; RD = R&D investment; I_DUM = Innovation Dummy
The market share is estimated by calculating the ratio of the sales of the company to the overall sales.
Table 6.2.1
Random-Effects: Hausman test

	Coefficients (b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
i_d	1.136508	1.183558	-.0470494	.
ln_rd	.8975222	.8456344	.0518878	.

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= -236.55 chi2<0 ==> model fitted on these data fails to meet the asymptotic assumptions of the Hausman test; see suest for a generalized test

The Chi square (χ^2= - 236.55) is less than zero, model fitted on these data fails to meet the asymptotic assumptions of the Hausman test. The hypothesis, difference in coefficients is not systematic accepted. It indicates that the random-effects panel regression model can be used to determine the percent of variance (R^2) explained Market share of pharmaceutical companies through R&D investment and Innovation Dummy over the years. Random-effects panel regression model including parameter (coefficients), standard error of estimates, R-square and other relevant statistics along with level of significance are exhibited in Table 6.2.2

Table 6.2.2
Random-effects regression model and other related statistics

```
Random-effects GLS regression                   Number of obs      =      1230
Group variable: year                            Number of groups   =        10

R-sq:  within  = 0.5768                         Obs per group: min =       123
       between = 0.8046                                        avg =     123.0
       overall = 0.5508                                        max =       123

                                                Wald chi2(2)       =   1504.41
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

ln_ms	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
i_d	1.183558	.0809142	14.63	0.000	1.024969	1.342147
ln_rd	.8456344	.0289159	29.24	0.000	.7889603	.9023084
_cons	-2.867731	.067978	-42.19	0.000	-3.000965	-2.734496
sigma_u	0					
sigma_e	1.0657257					
rho	0	(fraction of variance due to u_i)				

On the basis of required parameters, the regression model equation in this case can be written as follows:

Market Share (ln_S) = -2.8677 + 1.1836 × Innovation Dummy (I_d) + 8456 ×R&D Investment (ln_RD)

Equation (2)

The model is fit as (Wald Chi Square = 1504.41, p< 0.001). This test helped to verify the assumption that all the coefficients in the model are different than zero.

In the above regression model, the market share is estimated by calculating the ratio of the sales of the company to the overall sales. It is evident from the table--- that all the variables included in the model are significant (p<0.001). R^2 to predict dependent variable market share (MS) on the basis of two independent variables: R&D investment and Innovation Dummy was found to be 0.58, which is quite high. Thus, we establish that the R&D investment and Innovation Dummy which together represent the innovative activity of Innovative companies have positive impact on market share (βs are > 0). *Rho* (ρ=0) is known as the interclass correlation and no variance is due to differences across panels observed.

Panel Data Model for hypothesis 3:
The export Revenue of pharmaceutical companies is not influenced by innovation.
Dependent variable: lnXE
Independent variables: lnRD, lnS, lnP, I_D
Where, XE = Export Earning; S= Sales, RD = R&D investment, P = Number of patents and I_DUM = Innovation Dummy

Random-Effects: Hausman test
The Chi square (χ^2= 0.98, p<0.91), model fitted on these data fails to meet the asymptotic assumptions of the Hausman test. The hypothesis, difference in coefficients is not systematic accepted. It indicates that the random-effects panel regression model can be used to determine the percent of variance (R^2) explained Export earning of pharmaceutical companies through sales, R&D investment, number of patents and innovation dummies over the years. Random-effects panel regression model including parameter (coefficients), standard error of estimates, R-square and other relevant statistics along with level of significance are exhibited in Table…..

Table 6.3.1
Random-effects regression model and other related statistics

```
Random-effects GLS regression                   Number of obs      =      1230
Group variable: year                            Number of groups   =        10

R-sq:  within  = 0.6538                         Obs per group: min =       123
       between = 0.9581                                        avg =     123.0
       overall = 0.6594                                        max =       123

                                                Wald chi2(4)       =   2371.99
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
```

ln_xe	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
i_d	.3470439	.0839527	4.13	0.000	.1824996	.5115881
ln_rd	.3450796	.0487081	7.08	0.000	.2496136	.4405456
ln_s	.5147619	.0282132	18.25	0.000	.459465	.5700587
ln_p	.3327161	.0461105	7.22	0.000	.2423412	.423091
_cons	-.6020473	.0909448	-6.62	0.000	-.7802958	-.4237989
sigma_u	0					
sigma_e	1.0522897					
rho	0	(fraction of variance due to u_i)				

On the basis of required parameters, the regression model equation in this case can be written as follows:
Export Earnings (ln_Xe)= -0.6020 + 0.3470 × Innovation Dummy (I_d) + 0.3451× R&D Investment (ln_RD) + 0.5148 × Sales (ln_s) + 0.3327 × No. of Patents (ln_p) Equation (3)

The model is fit as (F=2371.99, p< 0.001). This test helped to verify the assumption that all the coefficients in the model are different than zero.

It is evident from the table--- that all the variables included in the model are significant (p<0.001). R^2 to predict dependent variable Export earnings (Xe) on the basis of four independent variables: sales, R&D investment, number of patents and innovation dummies was found to be 0.65, which is quite high. Since coefficients βs > 0, Innovation Dummy and No. of patents of the companies have a positive impact on exports. Therefore, we establish that the innovative companies have higher export earnings than non-innovative companies. Furthermore, since βs are > 0, sales, R&D investment, number of patents and innovation dummies also has a positive impact on export earnings. *Rho* (ρ=0) is known as the interclass correlation and no variance is due to differences across panels observed.

OLS Regression model for hypothesis 4:
The growth of innovative companies is not influenced by innovation.

To test the hypothesis on relationship between growth and innovation, we used sales CAGR as the response variable and CAGR for exports and R&D; all CAGRs were calculated for the 10 year (1998-2007) period. The model used for testing the hypothesis is OLS regression and shown below:

Dependent variable: SCAGR
Independent variables: RDCAGR, XCAGR, EY, , P, I_D
Where, SCAGR = Sales CAGR; RDCAGR= R&D Investment CAGR; XCAGR= Export Revenue CAGR; EY=DEA Efficiency (Average over 10 years), PRODCHNG=Productivity Change(Average over 10 years), P = Number of patents and I_D=Innovation Dummy

Table 6.4.1
Ordinary least square regression results

Source	SS	df	MS		
Model	.651465623	6	.108577604	Number of obs =	112
Residual	.510377234	105	.004860736	F(6, 105) =	22.34
Total	1.16184286	111	.010467053	Prob > F =	0.0000
				R-squared =	0.5607
				Adj R-squared =	0.5356
				Root MSE =	.06972

ln_scagr	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
i_d	.0245365	.0180347	1.36	0.177	-.011223	.060296
ln_rdcag	.0257526	.044034	0.58	0.560	-.0615586	.1130639
ln_xcagr	.3081675	.0380844	8.09	0.000	.2326531	.3836818
ln_ey	-.077026	.0339601	-2.27	0.025	-.1443627	-.0096894
ln_prodc	.0180239	.0576063	0.31	0.755	-.0961987	.1322464
ln_p	.0040116	.0043615	0.92	0.360	-.0046365	.0126596
_cons	3.086884	.2110822	14.62	0.000	2.668347	3.505422

On the basis of required parameters, the regression model equation in this case can be written as follows:
Sales CAGR (ln_cagr) = 3.0869 + 0.3082 $\times$ *Export Revenue* (ln_xcagr) – 0.0770 $\times$ *DEA Efficiency* (ln_ey) Equation(4)

It is evident from Table 6.4 that only export revenue and DEA efficiency included in the model and are significant as probability to reject the hypothesis ($p<0.05$). R^2 to predict dependent variable (SCAGR) on the basis of two independent variables (XCAGR and EY) was found to be 0.56 which is moderately high. Innovation Dummy, R&D Investment CAGR and Productivity Change did not emerge as significant predictors as probability to reject the hypothesis was ($p>0.05$). We establish that export growth and DEA efficiency have positive impact on sales CAGR (since both βs are > 0 and that the growth of companies (CAGR) is not influenced by innovation.
Robustness checks for OLS Regression for hypothesis 4 carried out using SAS are given in Table 6.4.2 . Except for Heteroscedasticity, the results are robust.

Table 6.4.2
Summary of robustness checks for OLS Regression for hypotheses 4

R^2	Test of Robustness				Whether robustness verified
	Multicollinearity Tolerance & VIF *(Range: Tol – 0-1, VIF- 1-9)*	Heteroscedasticity White Test *(Range: p < 0.05)*	Normality PP & QQ Plots	Independence Durbin – Watson *(Range: DW<3)*	
	(1)	(2)	(3)	(4)	
0.56	Tol: 0.80 to 0.96 VIF: 1.04 to 1.25	$\chi 2$=9.94, p < 0.36	Satisfied	DW = 1.802	Yes all 4 excluding 2

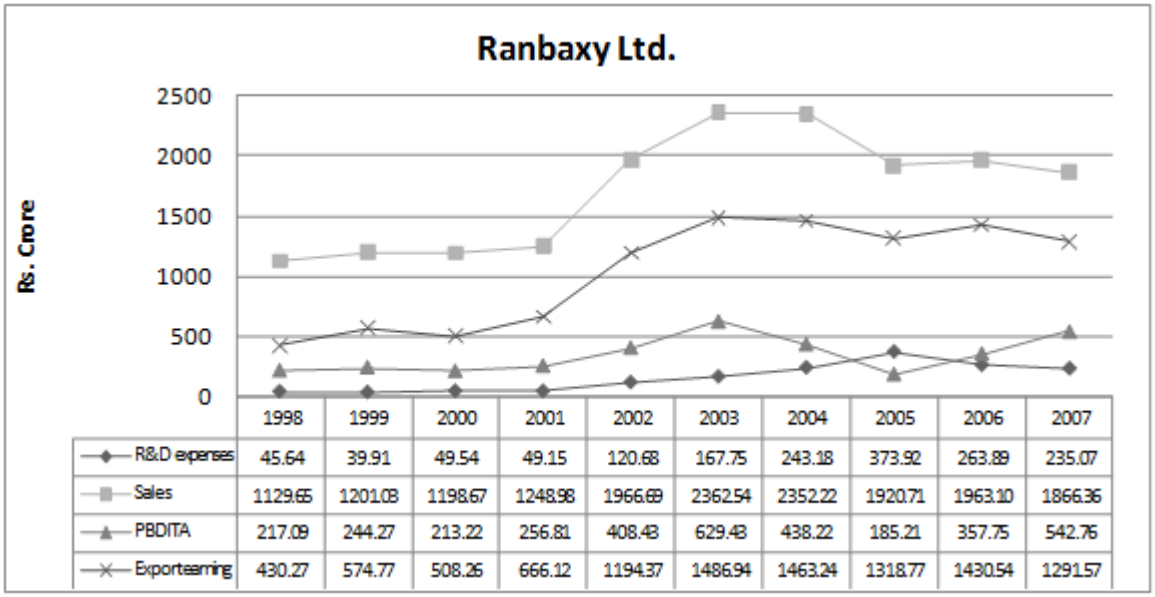
Robustness checks

Test of normality, multicollinearity, heteroscedasticity and independence for variables under treatment were verified. They all were in acceptable range and satisfied. These are sufficient conditions for the least-squares estimator to possess desirable properties. In particular, these assumptions imply that the parameter estimates will be unbiased, consistent and efficient in the class of linear unbiased estimators. Wherever, the variables showed high skewness, they were transformed using 'log natural' method.

7.0 Case Studies of Selected IPI firms

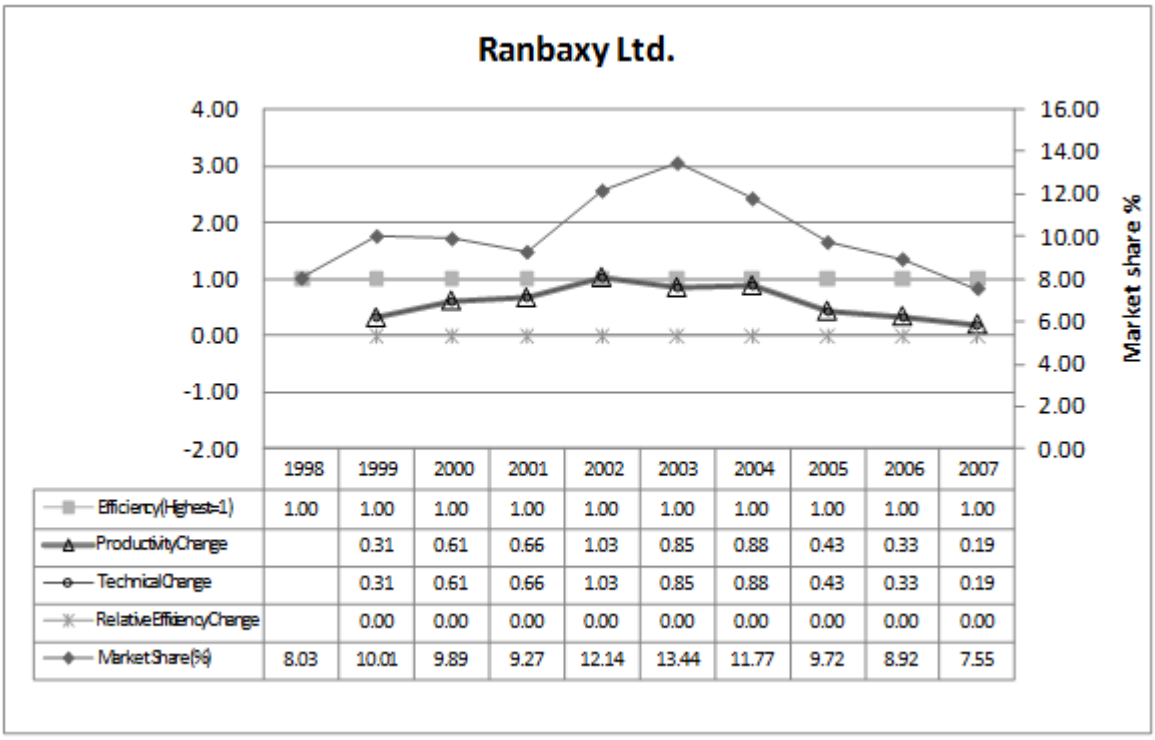
As a part of our future research, we propose to link and investigate our findings on company DEA efficiency, Malmquist productivity, innovation indices and company performance in a unified graphical framework. Without discussion, we present below in Figure 3 the graphs and data relating to Ranbaxy Laboratories Ltd.

Figure3 Case Study Graphical Data for Ranbaxy Laboratories Ltd
Figure3.1 Company Performance: Sales, PBDITA, Export Earnings, and R&D Expenses



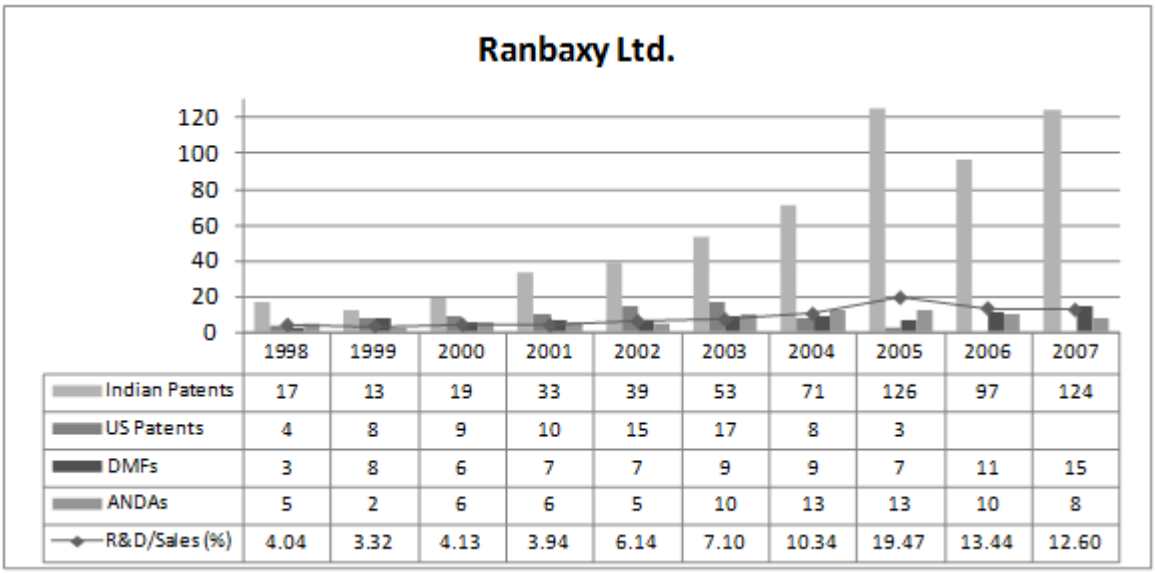
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
R&D expenses	45.64	39.91	49.54	49.15	120.68	167.75	243.18	373.92	263.89	235.07
Sales	1129.65	1201.03	1198.67	1248.98	1966.69	2362.54	2352.22	1920.71	1963.10	1866.36
PBDITA	217.09	244.27	213.22	256.81	408.43	629.43	438.22	185.21	357.75	542.76
Exportearning	430.27	574.77	508.26	666.12	1194.37	1486.94	1463.24	1318.77	1430.54	1291.57

Figure3.2 DEA efficiency, Malmquist Productivity & Market Share



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Efficiency(Highest=1)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ProductivityChange		0.31	0.61	0.66	1.03	0.85	0.88	0.43	0.33	0.19
TechnicalChange		0.31	0.61	0.66	1.03	0.85	0.88	0.43	0.33	0.19
RelativeEfficiencyChange		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MarketShare(%)	8.03	10.01	9.89	9.27	12.14	13.44	11.77	9.72	8.92	7.55

Figure3.2 Patents- Indian & US, ANDAs, DMFs, R&D Intensity



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Indian Patents	17	13	19	33	39	53	71	126	97	124
US Patents	4	8	9	10	15	17	8	3		
DMFs	3	8	6	7	7	9	9	7	11	15
ANDAs	5	2	6	6	5	10	13	13	10	8
R&D/Sales (%)	4.04	3.32	4.13	3.94	6.14	7.10	10.34	19.47	13.44	12.60

7.0 Conclusions

Indian pharmaceutical companies have gone a long way since the patent act in 1970 and the change of process patent to product patent in 2005. In this paper, we analysed a

sample of 123 Indian pharmaceutical companies over 10 year period starting from 1998 to 2007 which covers the post-TRIPS (1995) and post Indian Patent Act Amendment (2005) period to analyze the DEA efficiency and Malmquist productivity gains of these companies. Over all the average productivity change shows an increasing trend starting from 1998, interestingly this increase in productivity change is mainly due to the technical efficiency. We found the efficiency and productivity change leaders and laggards over 10 year period.
.
Using econometric models, we have proposed and tested four hypotheses for the IPI and found a positive impact of innovation (represented by company's R&D investment and patents) on company performance (sales), market share, export revenue. We found that additionally DEA efficiency, size and age have a positive impact on company performance (sales). The company sales growth was found to be driven by export growth and DEA efficiency and was not influenced by innovative behaviour of the companies.
This paper makes a contribution to literature on DEA and innovation studies as there is a dearth of literature in DEA studies wherein company R&D expenditure is one of the inputs and company patents are one of the outputs. The DEA efficiency having a positive impact on sales and sales growth is a new finding as there appears to be no previous investigation to explore this relationship. Though further research is required as this research is limited to the IPI, our finding that innovation positively influences company sales, exports and market share is significant. We propose to add case studies of companies in the IPI to study this relationship in future. Without elaborating in this paper, we present a snapshot of one firm's innovation performance as well as DEA efficiency and productivity in a unified graphical framework for case study research in future.

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