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# Impact of Innovation on the Performance of Indian Pharmaceutical Industry using Data Envelopment Analysis

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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 relative efficiency and productivity change and firm performance in 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. Using 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 and ability to attract contract manufacturing among Indian pharmaceutical companies. We also found that the sales growth is additionally driven by DEA efficiency, size, age which have a positive impact on productivity (sales). Export revenue is additionally driven by sales. Within the limitations of the model discussed, contract manufacturing was additionally driven by innovation, size and 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 is a new finding as there appears to be no previous investigation to explore this relationship.

*Keywords*: Data envelopment analysis, efficiency, Indian pharmaceutical industry, Malmquist index, productivity

## 1.0 Introduction

The Indian pharmaceutical industry (IPI) today is the 4th largest pharmaceutical producer of the world, after US, Japan and Germany, with 8% share of global production in volume. 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). The industry today possesses the largest number of US Food and Drug Administration (FDA) approved manufacturing facilities outside the USA.

The main activities of the Indian pharmaceutical industry can broadly be classified into production of (i) bulk drugs and (ii) 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 only on the formulation business. The IPI is highly fragmented, with around 280 players constituting the organized sector while more than 6,000 players present in the small-scale sector. Exports form a vital component of the growth strategy of most Indian pharmaceutical companies and the growth of exports over the last five years has been more than 20 percent (Saranga, 2007). 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. Indian pharmaceutical products are exported to over 65 countries across the world (Pradhan, 2006). A major share of Indian pharmaceutical exports is destined

to highly regulated markets of USA, Germany, UK, Netherlands and others. 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).

As a signatory of GATT (General Agreement on Trade and Tariffs), India revised the intellectual property protection (IPP) from a softer 'process patent' regime 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 are not clear yet. 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, most analysts seem to agree that a substantial restructuring is bound to occur. In the best scenarios many local generic firms would become intermediate product manufacturers or service providers to larger foreign companies or would continue as generics producers but with much higher costs linked to access to licenses, litigation, etc.

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

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 2009 ). However 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. Saranga (2007) analysed a sample of 44 Indian pharmaceutical companies and showed that the DEA models are sensitive to the selected inputs and outputs. Saranga (2007) showed that the DEA model can be used for efficient outsourcing and vendor selection in pharmaceutical products. Recently, 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. Hashimoto and Haneda (2008) used DEA to analyse R&D efficiency of Japanese pharmaceutical companies. Recently Chadha (2009) 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. So far there is no study available which explores the impact of Indian Patent Act Amendment (2005), which marks the final act of implementation of TRIPS Agreement in India on efficiency and productivity of Indian Pharmaceutical Industry. The earlier period has been covered from many different angles in the work of Saranga (2007) and Saranga and Phani (2008). To the best of our knowledge this will be the first study that attempts to capture the impact of full implementation of TRIPS on IPI as it covers this period, data set being from 1998 to 2007.

The main objective of this paper is to study the relative efficiency and productivity change of IPI and impact of innovation on industry performance using advanced DEA and econometric models 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 and ability to attract contract manufacturing of companies in IPI are proposed and tested in section 5. Conclusions are discussed in section 6.

## 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

[1] http://www.cmie.com
http://www.cmie.com/products/index.htm

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<br>Foreign owned – 9<br>Total – 39 firms | Domestic – 24.39 %<br>Foreign owned – 7.32 %<br>Total – 31.71 % |
| | Small (Total sales < 75 Million US dollars) | Domestic – 81<br>Foreign owned – 3<br>Total – 84 firms | Domestic – 65.85 %<br>Foreign owned – 2.44 %<br>Total – 68.29 % |
| Size by Plant & Machinery (2007) | Very large firms (> Rs. 100 cr.) | Domestic – 32<br>Foreign owned – 4 | Domestic – 26.02 %<br>Foreign owned – 3.25 %<br>Total – 29.27 % |
| | Large firms (Rs.10 to 100 cr.) | Domestic – 43<br>Foreign owned – 6 | Domestic – 34.96 %<br>Foreign owned – 4.88 %<br>Total – 39.84 % |
| | Medium firms (Rs.5 to 10 cr.) | Domestic – 15<br>Foreign owned - 0 | Domestic – 12.20 %<br>Foreign owned –0<br>Total – 12.20 % |
| | Small firms (Rs.0.25 to 5 cr.) | Domestic – 14<br>Foreign owned – 2 | Domestic – 11.38 %<br>Foreign owned – 1.63 %<br>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<br>Foreign owned -11<br>Total - 104 | Domestic – 75.61 %<br>Foreign owned – 8.94 %<br>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 |

## 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 $\tau$, 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,

$$\phi_{j\tau}^i = \phi^i(x_j^\tau, y_j^\tau) = \sup\{\phi^i : (x_j^\tau, \phi^i y_j^\tau) \in P^i\}. \quad (1)$$

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

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

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' = $\ln(\phi_{j0}^0) - \ln(\phi_{jt}^0)$ (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 $(\mathbf{x}_{j\tau}, \mathbf{y}_{j\tau})$, $\tau = 0, t$; j=1,..N be the observed sample of N pairs of input-output vectors. We estimate $\phi^0_{j0}$ and $\phi^t_{jt}$ (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 $\phi^t_{jt}$, we use the following linear program:

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

subject to the constraints

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

$$\sum_{k=1}^{N} \lambda^t_{kt}\mathbf{y}_{kt} \ge \hat{\phi}^t_{jt}\mathbf{y}_{jt}$$

$$\sum_{k=1}^{N} \lambda^t_{kt} = 1$$

$$\lambda^t_{kt} \ge 0, \qquad k = 1,2,\ldots, N \qquad (5)$$

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

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

subject to the constraints

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

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

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

$$\lambda^0_{k0} \geq 0, \qquad k = 1,2,..., N \tag{6}$$

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 $\hat{\theta}^0_{jt}$ may take a value less than 1 unlike the DEA estimator $\hat{\theta}^0_{j0}$ 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 $\hat{\theta}^0_{jt}$ 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:

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

## 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 1 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 3. 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 4. 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 |

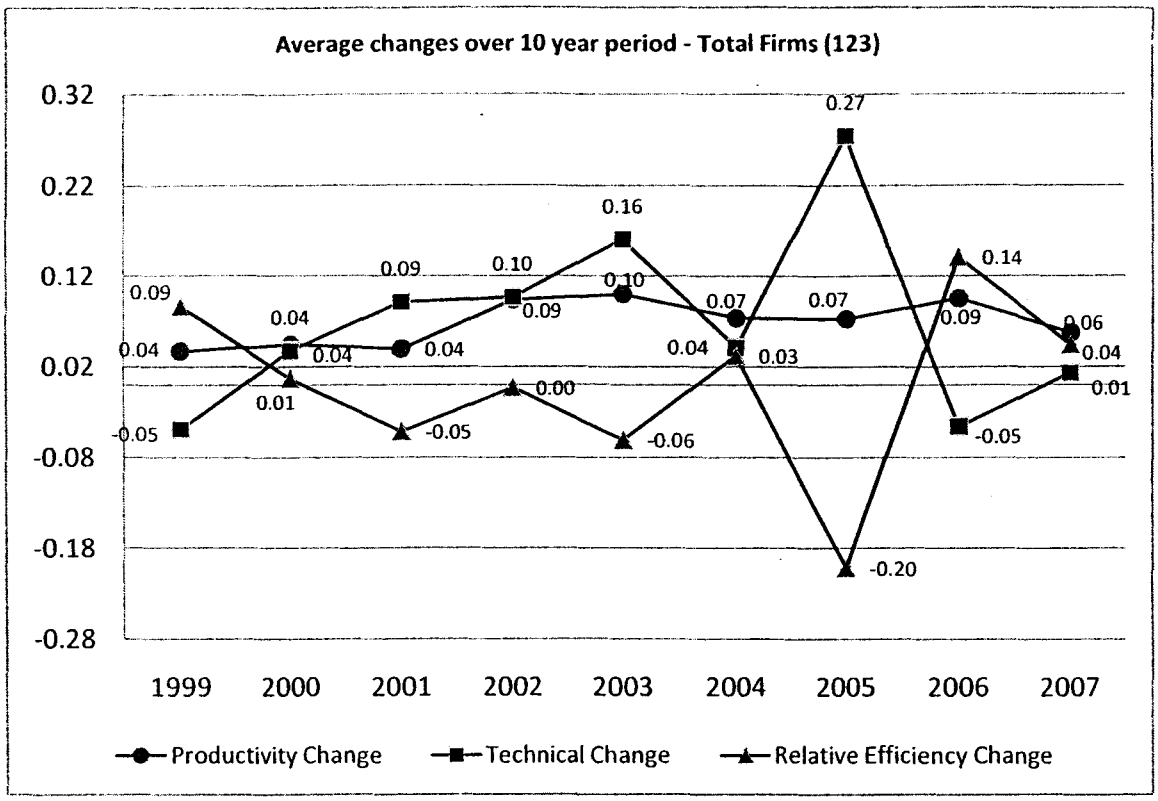


Figure 1. Productivity, relative efficiency and technical change over a period of 10 years

One of the objectives of this research is to study the impact of TRIPS Agreement (1995) and Indian Patent Act Amendment (2005) on the Indian pharmaceutical industry. We therefore 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. 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. The following five hypotheses were proposed and checked using appropriate statistical tests:

**Hypothesis 1:**

The productivity of pharmaceutical companies does not increase as their intensity of innovation increases. The intensity of innovation will be measured through the company's investment in R & D, R & D Intensity (R & D Investment/Sales%), number of patents obtained.

In this hypothesis, we have used sales as a measure of productivity. The use of sales to measure productivity is very common among researchers.

**Hypothesis 2:**

Innovation does not increase the market share of pharmaceutical companies.

**Hypothesis 3:**

Innovative companies' revenue through export is not higher than that of the companies without any expenditure on R & D.

**Hypothesis 4:**

Innovative pharmaceutical companies are not able to attract contract manufacturing and contract product development from multi-national pharmaceutical companies.

**Hypothesis 5:**

The growth of innovative companies is not higher than that of the non-innovative companies.

To test the hypotheses listed above, we developed the following regression models using SAS software. The results of the regression analysis are shown in Tables 5 to 9 (a & b). These are followed by a discussion of Robustness checks for OLS regression for hypotheses 1, 2, 3 and 5 for which details are given in Table 10. Robustness checks for hypothesis 4 for which logistic regression was used are included along with discussion of the logistic regression model. 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 OLS viz. multicollinearity, heteroscedasticity, normality and independence. In the following paragraphs regression results and interpretation for all five hypotheses are discussed.

**Regression model for hypothesis 1:**

Dependent variable: lnS

Independent variables: I_D, AG, 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

**Table 5a:**

Ordinary least square regression: Model summary (Stepwise regression)

| Step | Variable Entered | Number Vars In | Partial R-Square | Model R-Square | C(p) | F Value | Pr > F |
|---|---|---|---|---|---|---|---|

| Step | Variable Entered | Number Vars In | Partial R-Square | Model R-Square | C(p) | F Value | Pr > F |
|---|---|---|---|---|---|---|---|
| 1 | lnSize | 1 | 0.6585 | 0.6585 | 690.086 | 2367.69 | <.0001 |
| 2 | AG | 2 | 0.0645 | 0.7230 | 330.317 | 285.59 | <.0001 |
| 3 | lnEY | 3 | 0.0294 | 0.7523 | 167.554 | 145.37 | <.0001 |
| 4 | lnRDI | 4 | 0.0230 | 0.7753 | 40.6978 | 125.21 | <.0001 |
| 5 | I_D | 5 | 0.0061 | 0.7813 | 8.7510 | 33.87 | <.0001 |
| 6 | lnP | 6 | 0.0007 | 0.7820 | 7.0000 | 3.75 | 0.0530 |

Other statistics related to regression model including parameter (coefficients), standard error of estimates and other relevant statistics along with level of significance are exhibited in table 5b.

**Table 5b:**

Ordinary least square regression results

| Variable | Parameter Estimate | Standard Error | F Value | Pr > F |
|---|---|---|---|---|
| *Intercept* | *3.49643* | *0.21207* | *271.83* | *<.0001* |
| I_D | 0.38115 | 0.06347 | 36.07 | <.0001 |
| AG | 0.02160 | 0.00118 | 337.73 | <.0001 |
| lnEY | -2.47895 | 0.16489 | 226.02 | <.0001 |
| lnP | 0.07591 | 0.03919 | 3.75 | <.0530 |
| lnSize | 0.54097 | 0.01692 | 1022.19 | <.0001 |
| lnRDI | 0.47460 | 0.05970 | 63.19 | <.0001 |

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

$$\text{Sales} = 3.496 + 0.381 \times \textit{Innovation}\ \text{Dumay (I\_D)} + 0.022 \times \text{Age} - 2.479 \times \text{DEA Efficiency (lnEY)} + 0.076 \times \text{No of patents (lnP)} + 0.541 \times \textit{Size}\ \text{(lnSize)} + 0.475 \times \textit{R \& D}\ \text{Intensity (lnRDI\_PCT)} \quad (8)$$

The response variable in hypothesis 1 is Sales, which is used as a measure of productivity. 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 5b that all the variables included in the model are significant at 95% confidence level. $R^2$ to predict dependent variable (lnS) on the basis of six independent variables (lnSize, AG, lnEY, lnRDI, I_D, lnP) was found to be 0.78, which is quite high. Since coefficients βs > 0, Innovation Dummy, No. of patents and R&D intensity of the companies have a positive impact on productivity (sales). Therefore, we establish that the innovative companies have higher productivity (sales) than non-innovative companies. Furthermore, since βs are > 0, company size, age, DEA efficiency also have a positive impact on productivity (sales). It may be noted that in the output oriented VRS BCC Model for DEA used in this paper, the best value of DEA Efficiency=1 and all other values being worse are higher resulting in negative sign for the DEA Efficiency (lnEY) variable in equation (8).

**Regression model for hypothesis 2:**

Dependent variable: lnMS

Independent variables: I_D lnRD lnP

Where, MS = Market share; RD = R&D investment; I_DUM = Innovation Dummy; P = Number of patents

**Table 6a:**

Ordinary least square regression: Model summary (Stepwise regression)

| Step | Variable Entered | Number Vars In | Partial R-Square | Model R-Square | C(p) | F Value | Pr > F |
|---|---|---|---|---|---|---|---|
| 1 | lnRD | 1 | 0.6406 | 0.6406 | 40.9459 | 2188.54 | <.0001 |
| 2 | I_D | 2 | 0.0115 | 0.6521 | 2.2618 | 40.71 | <.0001 |

Other statistics related to regression model including parameter (coefficients), standard error of estimates and other relevant statistics along with level of significance are exhibited in table 6b.

**Table 6b:**

Ordinary least square regression results

| Variable | Parameter Estimate | Standard Error | F Value | Pr > F |
|---|---|---|---|---|
| *Intercept* | *0.55112* | *0.01304* | *1786.38* | *<.0001* |
| I_D | 0.09220 | 0.01445 | 40.71 | <.0001 |
| lnRD | 0.27852 | 0.00640 | 1895.42 | <.0001 |

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

$$\text{Market Share} = 0.551 + 0.092 \times \text{Innovation Dummy(I\_DUM)} + 0.279 \times \text{R \& D investment (lnRD)} \quad (9)$$

In the above regression model, the market share is estimated by calculating the ratio of the sales of the company to the overall sales. The step-wise regression output from SAS is shown in table 6b. It is evident from the table that all the variables included in the model are significant. $R^2$ to predict dependent variable (lnMS) on the basis of two independent variables (I_D and lnRD) was found to be 0.65which 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 ($\beta$s are > 0).

**Regression model for hypothesis 3:**

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

**Table 7a:**

Ordinary least square regression: Model summary (Stepwise regression)

| Step | Variable Entered | Number Vars In | Partial R-Square | Model R-Square | C(p) | F Value | Pr > F |
|---|---|---|---|---|---|---|---|
| 1 | lnS | 1 | 0.5745 | 0.5745 | 371.090 | 1657.85 | <.0001 |
| 2 | lnRD | 2 | 0.0835 | 0.6579 | 59.8684 | 299.35 | <.0001 |
| 3 | lnP | 3 | 0.0131 | 0.6710 | 12.8694 | 48.65 | <.0001 |
| 4 | I_D | 4 | 0.0026 | 0.6736 | 5.0000 | 9.87 | <.0017 |

Other statistics related to regression model including parameter (coefficients), standard error of estimates and other relevant statistics along with level of significance are exhibited in table 7b.

**Table 7b:**

Ordinary least square regression results

| Variable | Parameter Estimate | Standard Error | F Value | Pr > F |
|---|---|---|---|---|
| *Intercept* | *-0.45880* | *0.07061* | *42.21* | *<.0001* |
| I_D | 0.22567 | 0.07183 | 9.87 | <.0017 |
| lnRD | 0.43473 | 0.05233 | 69.00 | <.0001 |
| lnS | 0.44161 | 0.02352 | 352.45 | <.0001 |
| lnP | 0.36403 | 0.05264 | 47.83 | <.0001 |

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

$$\text{Export Revenue} = -0.459 + 0.226 \times \text{Innovation Dummy(I\_DUM)} + 0.435 \times \text{R \& D investment (lnRD)} + 0.442 \times \text{Sales (lnS)} + 0.364 \times \text{No. of Patents (lnP)} \quad (10)$$

The stepwise regression output from SAS is shown in Table 7b. It is evident from the Table 7b that all the variables included in the model are significant. $R^2$ to predict dependent variable export revenue (lnXE) on the basis of four independent variables (I_D, lnRD, lnS

and lnP) was found to be 0.67, which is 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, R&D investment and sales also have a positive impact on export earnings.

**Logistic Regression model for hypothesis 4:**

To test hypothesis 4, logistic regression was used, as dependent variable was binary in nature. Moreover, the logistic regression model is non-linear in characteristics.

Dependent Variable: CM_D = Contract manufacturing Dummy

Binary Variable (0= Firm is not a contract manufacturer, 1= Firm is a contract manufacturer)

Independent Variables: S = Sales, I_DUM = Innovation Dummy and Size=Investment in P&M

Here we will consider another multivariate technique for estimating the probability that an event occurs: the binary logit regression model, which is based on Fisher's scoring optimization technique. In logistic regression, we directly estimate the probability of an event occurring (firm being a contract manufacturer). Probability modeled is CM_D=1 (Firm is a contract manufacturer). Stepwise selection procedure was used to accept the variables into the model. For this case the logistic regression model can be written as:

$$\Pr ob(event) = \frac{1}{1+e^{-(\beta 0+\beta 1X1+.....+\beta nXn)}} \quad \text{or} \quad \Pr ob(event) = \frac{1}{1+e^{-z}} \qquad (11)$$

Where, $\beta_0$ and $\beta_{1.....}\beta_n$ are coefficients estimated from the data, $X_1 ... X_n$ are the independent variables, and 'e' is the base of the natural logarithms, approximately equal to 2.718.

**Logistic Regression Coefficients**

The table 8a shows the estimated coefficients and related statistics from the logistic regression model that predicts firm (contract manufacturer/ not a contract manufacturer) from a constant and the independent variables. R statistic is used to look at the partial correlation between the dependent variable and each of the independent variables, as shown in the last column of the table 8a. R can range in value from -1 to +1. A positive value indicates that as the variable increases in value, so does the likelihood of the event occurring. If R is negative, the opposite is true.

**Table 8a**
Logistic regression coefficients and other statistics

**Analysis of Maximum Likelihood Estimates**

| Parameter | Analysis of Maximum Likelihood Estimates | | | |
|---|---|---|---|---|
| | DF | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq |
| Intercept | 1 | -0.26180 | 0.0779 | 11.2953 | <.0008 |
| Size | 1 | 0.00191 | 0.000457 | 17.4612 | <.0001 |
| S | 1 | 0.00143 | 0.000496 | 8.3231 | <.0039 |
| I_D | 1 | 0.51850 | 0.0755 | 47.2291 | <.0001 |

The logistic regression equation can be written as:

$$\Pr ob(event) = \frac{1}{1+e^{-z}} \tag{12}$$

Where, z= -0.2618+ 0.5185× Innovation Dummy (I_D) + 0.00143× Sales (S) + 0.00191× Investment in P&M (Size)

**Table 8b**

Odds ratio estimates

| Effect | Odds Ratio Estimates | | |
|---|---|---|---|
| | Point Estimate | 95% Wald Confidence Limits | |
| Size | 1.002 | 1.001 | 1.003 |
| S | 1.001 | 1.000 | 1.002 |
| I_D (0.00 vs 1.00) | 2.821 | 2.099 | 3.792 |

The Variables in the Equation output also gives us the point estimates of Table 8b. This is the odds ratio predicted by the model. This odds ratio can be computed by raising the base of the natural log to the $b^{th}$ power, where b is the slope from our logistic regression equation. As in other multivariate statistical techniques, we may want to identify subsets of independent variables that are good predictors of the dependent variable. Independent variables I_D, S and Size variables emerged as the best predictors and passed on the criteria to classify the

observations in dependent binary groups. Table 8c shows association of predicted probabilities and observed responses. It is therefore, established that (since all βs > 0) the whether the company is a contract manufacturer is true for innovative (I_D), export oriented (XI), high efficiency (EY) companies with high sales and larger size.

**Table 8c**

Association of Predicted Probabilities and Observed Responses

| | | | |
|---|---|---|---|
| Percent Concordant | 63.2 | Somers' D | 0.264 |
| Percent Discordant | 36.8 | Gamma | 0.264 |
| Percent Tied | 0.0 | Tau-a | 0.132 |
| Pairs | 376200 | c | 0.632 |

Somer's D is used to determine the strength and direction of relation between pairs of variables. Its values range from -1.0 (all pairs disagree) to 1.0 (all pairs agree). It is defined as (nc-nd)/t where nc is the number of pairs that are concordant, and nd the number of pairs that are discordant, and t is the number of total number of pairs with different responses. Whereas, c is the correct percent of classification of cases in respective groups and is to the analog of R-square in case of OLS estimation.

The results of our logistic regression can be used to classify companies with respect to what decision we think they will make. If the probability of the event is greater than or equal to some threshold, we shall predict that the event will take place. By default, the theory sets this threshold to 0.50. While that seems reasonable, in many cases we may want to set it higher or lower than 0.50. Using the default threshold, SAS will classify a company into the "Firm is a contract manufacturer" category if the estimated probability is 0.50 or more, which it is for every firm. SAS will classify into the Firm is not a contract manufacturer" category if the estimated probability is less than 0.50. Table 8d shows classification of companies in respective groups.

**Table 8d**

Classification Table

| Prob Level | Correct | | Incorrect | | Percentages | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Event | Non-Event | Event | Non-Event | Correct | Sensitivity | Specificity | False POS | False NEG |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.500 | 284 | 499 | 161 | 286 | 63.7 | 49.8 | 75.6 | 36.2 | 36.4 |

Table 8d can be reproduced to read classification table in more meaningful way as is given in Table 8e.

**Table 8e**

Classification of observations in respective groups

| Observed | Predicted | | Percent correctly classified |
|---|---|---|---|
| | Not a Contract manufacturer (cm_dummy=0) | Contract manufacturer (cm_dummy=1) | |
| Not a contract manufacturer (cm_dummy=0) | 499 | 161 | 75.60 |
| Contract manufacturer (cm_dummy=1) | 286 | 284 | 49.80 |
| Overall | | | 63.70 |

Overall our predictions were correct in case of 783 out of 1230 observations, for an overall success rate of 63.70%.

**Goodness of Fit with all predictor variables**

As can be seen from equation 12 and Table 8a, the predictor variables for probability of a firm being a contract manufacturer i.e. CM_D , the Contract Manufacturing Dummy = 1 are: Innovation Dummy (I_D), Sales (S), Investment in Plant & Machinery (Size). As the innovation dummy is present in the model, we may conclude that innovative pharmaceutical companies are able to attract contract manufacturing and contract product development from multi-national pharmaceutical companies.

The Hosmer-Lemeshow tests the null hypothesis that there is a linear relationship between the change independent variables and the log odds of the dependent variable. Cases are arranged in order by their predicted probability on the criterion variable. A chi-square statistic is computed comparing the observed frequencies with those expected under the linear model. The chi-square value was found to be 90.3905 ($p<0.0001$). A significant chi-square indicates that the data does not fit the model well. The low p value is of indicative that there are other variables which may help in predicting the binary dependent variable well. Some deficiency of the test has been reported (Hosmer et al. 1997).

We also looked at the graph of residual versus predicted values, which do not show any particular pattern implying thereby that the logistic regression assumption for robustness is satisfied by the sample data. However, keeping in view the low value of p in Hosmer-Lemeshow test, it is not possible to be confident of the robustness of this model. On the other hand keeping in view the success rate of correct predictions at 63.7% brought out above is found to be quite high, confirming the fitness of the model. Further, improvement in the robustness of model would require considerable in depth research, which is beyond the scope of the present research and can be a subject for future research as we face a limitation of adequate data and information on contract manufacturing in the CMIE PROWESS database used by us

**Regression model for hypothesis 5:**
To test the hypothesis on relationship between growth and innovation, we used sales CAGR as the response variable and CAGR for sales, exports and R&D; all CAGR's were calculated for the 10 year period. The model used for testing the hypothesis is shown in equation (13).

Dependent variable: SCAGR

Independent variables: RDCAGR, XCAGR, EY, PRODCHNG, P, I_D

Where, SCAGR = Sales CAGR; RDCAGR= R&D Investment CAGR; XCAGR= Export Revenue CAGR; EY= DEA Efficiency

**Table 9a**

Ordinary least square regression: Model summary (Stepwise regression)

| Step | Variable Entered | Number Vars In | Partial R-Square | Model R-Square | C(p) | F Value | Pr > F |
|---|---|---|---|---|---|---|---|
| 1 | XCAGR | 1 | 0.4020 | 0.4020 | 10.9740 | 81.34 | <.0001 |
| 2 | EY | 2 | 0.0344 | 0.4364 | 5.4951 | 7.33 | 0.0078 |
| 3 | RDCAGR | 3 | 0.0284 | 0.4648 | 1.3201 | 6.32 | 0.0133 |

Other statistics related to regression model including parameter (coefficients), standard error of estimates and other relevant statistics along with level of significance are exhibited in Table 9b.

**Table 9b**

Ordinary least square regression results

| Variable | Parameter Estimate | Standard Error | F Value | Pr > F |
|---|---|---|---|---|
| *Intercept* | *11.60592* | *3.13940* | *13.67* | *<.0003* |
| RDCAGR | 0.05966 | 0.02374 | 6.32 | <.0133 |
| XCAGR | 0.18393 | 0.02642 | 48.48 | <.0001 |
| EY | -5.70968 | 2.05701 | 7.70 | <.0064 |

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

$$\text{Sales CAGR (SCAGR)} = 11.606 + 0.060 \times \text{R \& D CAGR (RDCAGR)} + 0.184 \times \text{Export CAGR (XCAGR)} - 5.710 \times \text{DEA Efficieny (EY)} \quad (13)$$

We estimate the sales CAGR using above regression model in equation (13). The step-wise regression output from SAS is shown in Table 9b. It is evident from the Table 9b that all the variables included in the model are significant. $R^2$ to predict dependent variable (SCAGR) on the basis of three independent variables (RDCAGR, XCAGR and EY) was found to be 0.46 which is moderately high. Thus we establish that the R&D investment has a positive impact on sales CAGR (since all βs are > 0). Hence, the growth of innovative companies is higher than that of the non-innovative companies. Additionally, we establish that export growth and DEA efficiency also have positive impact on sales CAGR (since all three βs are > 0).

**Robustness checks**

Test of normality, multicollinearity, heteroscedasticity and independence for variables under treatment were verified. 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. Summary for all the relevant tests about all 5 hypotheses is given table 10.

**Table 10**

Summary of robustness checks for OLS Regression for hypotheses 1,2,3.5

| Hypothesis No. | Regression Methods | $R^2$ | Test for 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) | |
| 1 | OLS | 0.78 | Tol: 0.49 to 0.93 VIF: 1.06 to 2.03 | $\chi^2$=97.80, $p < 0.0001$ | Satisfied | DW = 1.802 | Yes |
| 2 | OLS | 0.65 | Tol: 0.91 to 0.91 VIF: 1.09 to 1.09 | $\chi^2$=102.69, $p < 0.0001$ | Satisfied | DW = 1.726 | Yes |
| 3 | OLS | 0.67 | Tol: 0.28 to 0.76 VIF: 1.31 to 3.56 | $\chi^2$=236.90, $p < 0.001$ | Satisfied | DW = 2.066 | Yes |
| 4 | Logistic | 0.64 | Not required as model is non-linear in nature | | | | |
| 5 | OLS | 0.46 | 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 |

As shown in Table 10 all the four assumptions required for OLS estimates in case of hypotheses 1, 2, 3 and 5 are satisfied. The assumption of Heteroscedasticity (White Test) in case of hypotheses 5 was not significant, indicating that the error distribution of the dependent variable has no constant variances. We also looked at the graph of residual versus predicted values, which do not show any particular pattern. Thus the multiple regression assumption for homoscedacity is moderately satisfied by the sample data.

## 6.0 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 1995. In this paper, we analysed a sample of 123 Indian pharmaceutical companies over 10 year period starting from 1998 to analyze the efficiency and 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 established that there is a strong positive relationship between productivity (sales), market share, export revenue and sales CAGR and the innovative activity of a company such as R&D Investment and patents. However, while we could find evidence to suggest that the ability to attract contract manufacturing is driven by the company's innovative activities, our model lacked robustness as we face a limitation of adequate data and information on contract manufacturing in the PROWESS database used by us. We also found that the sales growth is additionally driven by DEA efficiency, size, age which have a positive impact on productivity (sales). Export revenue is additionally driven by sales. Within the limitations of the model discussed, contract manufacturing was additionally driven by size and sales. The company sales growth was additionally driven by export growth and DEA efficiency. It can be seen that this study has found that DEA efficiency has a positive impact on sales and sales growth. This observation is a new finding as our literature survey could not reveal any previous reference to an investigation to explore this relationship.

As we have analysed the data for IPI between 1998 and 2007 which covers the post-TRIPS (1995) and post Indian Patent Act Amendment (2005) period, from the foregoing, we conclude that these events have led to an overall increase in the productivity of IPI manly due to increase in technical efficiency with the Innovative companies emerging as better performers with the company age (experience), size and DEA efficiency also playing a role.

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