Efficiency Analysis of Indian Pharmaceutical Companies in the Post-TRIPS and Post Product Patent Regime using Stochastic Frontier Approach

Aas Mohammad[1]
Bandi Kamaiah [2]

This paper analyses the technical efficiency of Indian pharmaceutical industry using the parametric technique; stochastic frontier analysis (SFA) for the period of 1997-2011 which covers both post TRIPS and post product patent period. The results of the study indicate the dominance of raw material in producing the firms' outputs. Labour as an input variable has emerged as the most significant variable influencing the profit of the firms. There are considerable evidences that the observed outputs are less than their respective potential outputs due to technical inefficiency of firms. The results of the study are very important for the companies to realize their potential output and in dictating their survival and growth in the industry.

Keywords: stochastic frontier analysis, technical efficiency, post TRIPS, product patent regime.

[1] **Aas Mohammad,** Post-doctoral Fellow, School of Economics, University of Hyderabad, Hyderabad, India , e-mail: aasmohammad.amu@gmail.com
[2] **Bandi Kamaiah,** Dean & Professor, School of Economics, University of Hyderabad, Hyderabad, India, e-mail: deanseuh@gmail.com

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Introduction:

The Indian Pharmaceutical Industry (hereafter, IPI) is one of the largest and most advanced among the developing countries. The IPI today is the fourth largest producer of the world, after USA, Japan and Germany, with 8% share of global production in volume and ranks 13th in terms of value, constituting around 1.5%. The Indian pharmaceutical market reached US$ 10.04 billion in size in July 2010 of which the share of export is 40% (AR 2011-12). The industry 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. 70% of the India's domestic requirement of the bulk drugs (the active pharmaceutical ingredients) and almost 100% of the formulations (the end products) are being procured by the IPI (Pradhan, 2006). The industry today possesses the largest number of US Food and Drug Administration (FDA) approved manufacturing facilities outside the USA.

The IPI has transformed itself over the period of time, being almost none existing till 1970's, to now being a prominent provider of pharmaceutical products. Up to 1970, the IPI was dominated by MNCs which imported most of the bulk drugs, from their parent companies abroad and sold the formulations at unaffordable prices. This led to revision of Government of India's (GOI) policy stand towards the industry in 1972 allowing Indian firms to reverse engineer the patented drugs and produce them using a different process that was not under the patent. The policy measures taken by GOI provided conducive environment which laid foundations to a strong manufacturing base for bulk drugs and formulations and accelerated the growth in the IPI. In 1995, when the World Trade Organisation(WTO) came into being, India being one of its founder members automatically became a signatory of the Trade-Related Intellectual Property Rights (TRIPS) agreement and introduce the product patent regime by 2005 (EXIM, 2007). The amendment of 2005 extended full TRIPS coverage to food, drugs and medicines. Thus, post-2005, the importance of research and development (R&D) activities for the Indian pharmaceutical industry has gone up, with a number of firms setting up their own R&D units (Jha 2007), and collaborating with research laboratories (FICCI, 2005).During 2003-04 to 2007-08, the pharmaceutical industry of India has been identified as one of the main drivers of the high export-led growth of India (GOI, 2008) and an employment generator, possessing enormous positive externalities (GOI, 2009).

The changes in various policies related to trade and entry of multinational companies in IPI have started during early seventies. However, the pace of growth of this industry has shown a remarkable upswing only after 1991 and it shows a major jump after 2005. The introduction of pharmaceutical product patents brings new business opportunities to the IPI. On the other hand the competitive pressure has possibly made the exit of small and inefficient firms. In this backdrop it is necessary to assess the performances of pharmaceutical industry during the recent years and to find out the factors responsible behind the variation of industry's efficiency. This can be studied by undertaking an efficiency analysis. The efficiencies of the firms play a major role in dictating the survival and growth of companies in various segments of pharmaceutical industry, particularly at the time when the industry is witnessing a dynamic structural transformation owing to external changes. In the present study we have employed stochastic frontier analysis (SFA) for analyzing the technical efficiency of Indian pharmaceutical firms during the period 1997-2011 covering the post-TRIPS (1995) and post Indian Patent Act Amendment (2005) period.

The rest of the paper is organized as follows: Section 2 provides a brief overview of relevant literature, followed by a brief description of the SFA methodology used for the current empirical analysis in

Section 3. Section 4 discusses classification of firms into various groups. Section 5 explains the empirical results and finally conclusion in Section 6.

Literature Review

There are many studies that have employed SFA technique and data envelopment analysis (DEA) for measuring the efficiency related issues for various industries. However in case of pharmaceutical industry, few studies so far have examined the efficiency issues. Internationally there are some studies carried out regarding the efficiency issues such as Majumder and Rahman (2011) analyzed the financial performance of the pharmaceutical industry in Bangladesh, Vernon and Gusen (1974) analysed the elasticity of technical change with respect to firm size in case of US pharmaceutical firms. The results of the study indicated that larger pharmaceutical manufacturers appear to be advantageous over smaller ones in accomplishing technical change. Gonzalez and Gascon (2004) analyzed the productivity patterns for Spanish pharmaceutical laboratories; Shu-Chuan Yang (2011) analyzed the performance of Taiwan's pharmaceutical industry. The study aimed to investigate and build the complex system of Taiwan's pharmaceutical industry; then, amend the policy direction to enhance its performance. The results of the simulation analysis revealed that the policy of drug-cutting prices rate results in the obvious slow-down of the domestic pharmaceutical market. The study indicates that the R&D funding is the best effective driving force for the increasing R&D capability and new drugs appear in the market. Hashimoto and Haneda (2008) analyzed the change in R&D efficiency at both firm and industry levels for Japanese pharmaceutical industry.

Chaudhari and Das (2006) estimated efficiency of the IPI using parametric frontier approach for the period 1990 to 2001. The study concluded that large sized firms and firms exporting more of their product in the international market have reduced their inefficiency. Fujimori et al. (2010), who estimated the efficiency and productivity of small scale Indian pharmaceutical industry (SSPI), found that the small scale pharmaceutical industry has inefficiency in their production activity. Neogi et al (2012) assessed the performance of Indian pharmaceutical industry during the period of 2000 to 2005 and tried to find out the factors responsible behind the variation of industry's efficiency and productivity using Stochastic Frontier Analysis (SFA). Total factor productivity also has been estimated using the same data. They found that technical efficiencies and total factor productivity of the firms are increasing over the years but not without fluctuation. However, the level and growth of efficiencies differs in a considerable ways among the type of ownerships of firms. The study further found that the private players are doing significantly better compared to other type of ownerships. A positive association was found between the size of firms and their technical efficiencies and the total factor productivity. So the study concluded that scale of economies is prevailed in the pharmaceutical industries in India.

Pattnayak et al (2013) estimated the technical efficiency using the stochastic frontier production function for 76 Indian pharmaceutical firms during 1991-2003 in the light of policy changes in the international and domestic environment since 1995. The results of the analysis revealed that for the industry as a whole, there is evidence of time-varying technical efficiency for the sample firms and the overall technical efficiency has improved over the period 1991 to 2003. Pradhan (2003) attempted to empirically verify the impact of economic liberalization on the R&D behaviour of Indian pharmaceutical firms controlling for the effects of several firm specific characteristics including firm size. The results from the Tobit analysis for a sample of firms over the period 1989-90 to 2000-01 indicated that competitive pressure generated by liberalization has worked effectively in pushing Indian pharmaceutical firms into R&D activities.

A host of firm characteristics like firm age, size, profitability, intangible assets, export orientation and outward foreign direct investment have been found to be important determinants of innovative activity in the industry.

There are some studies carried out using the non-parametric approach DEA in case of efficiency analysis of pharmaceutical industry. Mazumdar et al. (2009) estimated the technical efficiency of IPI for the period 1991 to 2005 using DEA. The analysis established that even though the output efficiency levels of firms reveal a declining trend, firms have been able to make efficient use of labour and raw material. In contrast to popular belief, the analysis reveals that neither R&D and export expenditure nor the use of imported technology improve the technical efficiency of firms. Saranga and Phani (2004) using DEA technique analyzed the efficiency of IPI for the period 1992- 2002 and found that the size of a company does not dictate the internal efficiency ratings; however indigenous firms, which are in the business of both bulk and formulations, have an edge over MNCs and firms with only formulations business. The comparative analysis between efficiency scores and growth ratings of all the companies established the fact that there is a direct relationship between internal efficiencies and higher growth. In a recent study, Pannu et al. (2011) analyzed the relative efficiency and productivity change of IPI between 1998 and 2007. They found that innovative firms with R&D and patents have higher efficiency than non-innovative firms. Saranga and Banker (2010) studied the productivity change and factors driving this change in the IPI during 1994–2003 by using DEA. They found that higher R&D investments and switching to higher value-added products by few innovative firms pushed the production frontier upwards with increasing technical and productivity gains.

From the above review, it is clear that there is no study till date in our knowledge which has covered the whole post product patent period to measure the performance of the IPI. The present study is an attempt to fill the gap.

Research Methodology

The study utilises the parametric technique SFA technique to estimate a production frontier which serves as a benchmark to estimate the technical efficiency of the IPI. The SFA, developed by Anger, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), is a parametric technique that generates an efficiency frontier for the sample firms. The efficiency of each decision making unit (in the present case a firm) is then measured as the distance of its output to the frontier. This involves estimation of stochastic frontier production function, where the output of a firm is expressed as a function of a set of inputs, inefficiency and random error. The SFA treats the observed inefficiency of a firm as a combination of the inefficiency specific to the firm and a random error and tries to disentangle the two components by making explicit assumptions about the underlying inefficiency process.

The original specification of SFA involved estimation of production function for cross-sectional data, which had an error term having two components, one accounting for random factors and another for technical [in]efficiency. Formally, the model may be specified as,

$$Q_i = x_i\beta + (v_i - u_i), \quad i = 1, 2, 3, \ldots, n \qquad \ldots (1)$$

Where Q_i represents the actual output for the sample firm i ;

x_i is a $k \times 1$ vector of inputs of the i-th firm;

β is a vector of unknown parameters that describe the transformation process;

v_i are random variables which are assumed to be iid $N(0, \sigma^2)$, and independent of the u_i which are one-sided (non-negative) random variables assumed to account for technical efficiency in production and generally assumed to be iid $N(0,\sigma_u{}^2)$. If the operation of a firm is inefficient (efficient), its actual output is less than (equal to) the potential output. Therefore, one can treat the ratio of the actual output to potential output as a measure of TE of a firm during the time period. The residual term u_i is zero when the firm produces the potential output (full TE) and is greater than zero when production is below the frontier (less than full TE).

Later the original specification has been altered and extended, to incorporate more general distribution assumptions for the u_i, such as truncated normal or two-parameter gamma distributions' for the consideration of panel data and time-varying technical efficiencies.In the present study, we have adopted the specification of stochastic frontier production developed by Battese and Coelli (1992) specification for panel data which has firm effects and assumed to be distributed as truncated normal random variables, which may also vary systematically with time i.e. it capture time varying technical efficiency (TE). This may be expressed as,

$$Q_{it} = x_{it}\beta + (v_{it} - u_{it}) \quad i = 1, 2, 3, \ldots, n; \quad t = 1, 2, 3, ..T; \quad \ldots (2)$$

Where Q_{it} represents the actual output for the sample firm i in period t;

x_{it} is a $k \times 1$ vector of inputs of the sample firm i in period t ;

β is a vector of unknown parameters that describe the transformation process;

v_{it} are random variables which are assumed to be $N(0,\sigma^2)$, and independent of the u_{it}

Following Battese and Coelli (1992), we can write:

$$u_{it} = u_i \exp\{-\eta(t - T_i)\}; \quad \mathrm{i} = 1, \ldots\ldots, n, t \in g(i) \quad \ldots (3)$$

where u_i's are non-negative random variables, assumed to be independently and identically distributed as truncated normal with mean μ and variance σ_u^2, η is an unknown parameter to be estimated and $g(i)$ is the set of T_i time periods for which observations for firm i are available. Hence, the TE effect of firm i in period t(*i.e.* u_{it}) depends on η and number of remaining periods $(t-T_i)$. When $t=T_i$, u_{it} equals u_i which can be treated as the TE effect of firm *i* in the last period T_i. From Equation (3), one can show that as *t* increases, u_{it} decreases, remains constant, or increases, depending on whether η is greater than, equal to, or less than zero. Therefore, a firm's TE increases, remains the same, or decreases over time, according to weather η is positive, zero, or negative. Following the model specified in Equations (2) and (3), the conditional expectation of $\exp(-u_{it})$, given the composite error term $\varepsilon_{it}(=v_{it}-u_{it})$, that is $E[\exp(-\eta_{it}u_{it})/\varepsilon_{it}]$ would provide the measure of TE of firm *i* in period *t*.

The model given in equations (2) and (3) can be estimated by the maximum likelihood (ML) method. Various parametric restrictions in the model would lead to a number of interesting cases. Setting μ=0 reduces the model to the traditional half-normal distribution model. If $\eta=0$, then TE is time-invariant (i.e. firms never improve their TE). The value of $\gamma=\sigma_u^2/\sigma^2$ ($where\ \sigma^2=\sigma_u^2+\sigma_v^2$) will lie between 0 and 1. In the event that $u_i=0$ i.e., firms are fully efficient, then γ equals to zero and deviations from the frontier are entirely due to noise v_{it}. In this case, the OLS estimates of the remaining parameters are also ML estimates. When $\gamma=1$, all deviations from the frontier are entirely due to technical inefficiency (in this case $\sigma_v^2=0$). One can test the null hypothesis that $\gamma=\eta=\mu=0$ using the generalized likelihood-ratio test statistic, which equals twice the difference between the logarithmic likelihood values of the unrestricted and restricted $(\gamma=\eta=\mu=0)$ ML estimates. The test statistic is a mixed χ^2 (with degrees of freedom equal to 3). If the null is not rejected, it implies that the firms are fully technically efficient; do not exhibit changes in technical efficiency over time, and the error associated with the frontier being half normal distribution.

Data and Model Specifications

The firm level data has been collected from the financial balance sheets of the companies provided by the prowess data source of the Centre for Monitoring of Indian Economy (CMIE) for the period 1997 to 2011. The number of firms in the sample varies from 29 to 183 over the years and in total there is an unbalanced panel of 2069 firms for 15 years. The study has conceptualised a 3-output, 4-input production technology. Considering the goals of Indian pharmaceutical industry and previous studies, the outputs considered in the model are (i) total sales (Y_1) (ii) total foreign exchange earnings (Y_2), (iii) and profit after tax (Y_3). The inputs in the model are (i) labour (L) (ii) material inputs (R), (iii) energy input (P) and (iv) capital (K). For the estimation of stochastic frontier production function, functional form should be specified. In the present study we have employed the Cobb–Douglas functional form (as it is known to provides the best fit and the same having been applied in the literature extensively). More specifically the production frontier is specified as

$$\ln Q_{it} = \beta_{0t} + \beta_{1t} \ln R_{it} + \beta_{2t} \ln P_{it} + \beta_{3t} \ln L_{it} + \beta_{4t} \ln K_{it} + v_{it} - \eta_{it} u_i \qquad \ldots(3)$$

Table 1

Summary of Basic Statistics

Variables	Mean	Std. Dev	Min	Max
Total Sales	3008.752	5953.942	6.4	63796.6
Total Foreign exchange Earnings	1168.56	3496.1	0.1	37866.5
Profit	361.8755	1204.487	-10448	13838
Raw Materials	1012.818	1975.878	1	23150.4
Energy input	80.45573	168.0285	0.1	1968.3
Labour	224.4633	496.6863	0.3	6850.5
Capital	996.3226	2085.393	2.4	27974.9

Note: values are given in Rs million.

Table 2

Description of Variables

Total Sales	Gross sales for a period before making any deductions for discounts, returns transportation, and some other expenses.
Foreign Exchange Earnings	Proceeds from the export of goods and services of a country, and the returns from its foreign investments.
Profit	Net profit earned by the company after deducting all expenses like interest, depreciation and tax.
Raw material	It is measured in terms of the companies' expenditure for raw material.
Labour	It is measured in terms of wages and salaries for the workers.
Energy input	It is measured in terms of the expenditure on power and fuel.
Capital	The book value for plant and machinery, land and building.

Results and Discussion

In tables, the first column shows input variables and parameters of stochastic frontier function, whereas first row shows the different outputs. In the tables, σ^2, γ, μ and η are parameters of stochastic frontier function. Where σ^2 is variance of composite error term i.e. u_{it} and v_{it}, if it is significant, then one can infer that the difference between actual output and frontier output is because of the factors which are in control of firms. u_{it} measures the technical effect of the firms and v_{it} (iid normal with mean 0 and variance σ^2v) captures the effects of omitted variables/ measurement errors. The term γ is ratio of σ^2u and σ^2, which measures that how much of the difference between actual output and frontier output is because of technical inefficiency. μ is the mean of the distribution of the u_{it}, assuming that error term follow truncated normal distribution. If the μ is not significant then error term will follow half normal distribution. The parameter η show whether the TE is time varying or not. If it is significant, TE of the firm will be time varying otherwise it will time invariant. Log likelihood and χ^2 are the test statistic of the assumption that γ, μ and η are equal to zero.

Tables 3 present the ML estimates of stochastic frontier function of all the firms taken together. The estimates refer to the panel frontier. First we have estimated the model with μ and η unrestricted. Since the asymptotic t value of the estimated value of μ is not statistically significant at 5% level, it indicates that the error term of the frontier does not follow truncated normal distribution rather it follows half normal distribution. Subsequently, we have imposed a restriction μ=0 then re-estimated the equations.

Table 3

ML Estimates of Stochastic Frontier Function for All Firms

	Total Sales(Y1)	Foreign exchange Earnings(Y2)	Profit (Y3)
Constant	1.82***	-1.24***	-1.76***
Log R	0.56***	0.71***	0.27***
Log L	0.50***	0.06**	0.60***
Log P	0.01	0.36***	0.02
Log K	0.03***	0.23***	0.33***
σ^2	0.12***	2.06***	1.35***
γ	0.05**	0.02*	0.02
μ	0.16***		0.38***
η	-0.16***	0.11*	-0.12***

Log Likelihood	-725.83	-3674.39	-3243.91
χ^2	36.56	12.15	13.84
Iterations	14	16	15

Note: ***, ** and * denote 1%, 5% and 10% level of significance respectively; σ^2 is error variance of frontier function; μ-is decision parameter concerning distribution of error term. Variables are in logarithm form.

The ML Estimates of Stochastic Frontier Function for all firms is presented in table 3. In case of total sales, all input variables are positive and significant except capital and energy which are having negative impact on the total sales. In case of foreign exchange earnings all inputs have positive effect and significant at 1% level except labour as its coefficient is negative and statistically significant at 5% level. Raw material is dominant input in determining the total sales and foreign exchange earnings while labour has most determining effect on the profit output. The likelihood ratio test rejects the null hypothesis of $\gamma = \mu = \eta = 0$ in all cases.

Interestingly, σ^2 and γ are positive and statistically significant in all cases, revealing inefficient performance of the firms in producing these outputs. The μ is statistically significant at 1% level in case of total sales and profit, indicating that u follows a truncated normal distribution but insignificant in case of foreign exchange earning following half normal distribution. The η term is statistically significant in all cases indicates that the firm specific effects associated with TE are time varying. Over all, it is observed that in all firm, raw material is the most important determining factor (followed by labour) which positively influences the output. The energy input seems to have almost a negligible effect. Firm specific effects associated with technical efficiency (TE) are found to be time varying.

Mean Technical Efficiency Estimates for All Firms Output wise

Since we have seen that firm effects are time variant we have estimated time varying efficiency estimates. Technical efficiency estimates averages across the firms over the sample period are provided in the table 4. These measures indicate the average level of technical efficiency at a point of time (year in the present case) of firms which is time varying. These measures are provided output wise for each of the all pharmaceutical firms. These measures help to assess the average behaviour of the firms together, over a period of time, in respect of alternative output measures.

The mean TE for all firms has been depicted in table 4. The mean efficiency for raising some outputs has increased, for some other outputs decreased over the period of 1997 to 2011. The TE score in raising total sales has declined marginally from 91.82% in 1997 to 90.17% in 2011. With reference to the foreign exchange earnings, the study found a boost in TE from 65.48% in 1997 to 92.16% in 2011. TE for raising profit gradually tapered off continuously from 93.36% to 77.68% in 2011.

Table 4

Mean Efficiency of All Firms

Years	Total Sales	Foreign exchange Earning	Profit After Tax
1997	98.25	67.57	93.26
1998	97.96	70.65	92.47
1999	97.55	72.65	91.57
2000	97.12	74.80	90.51
2001	96.63	77.38	89.39
2002	96.04	79.68	88.13
2003	95.35	81.59	86.65
2004	94.58	83.25	85.07
2005	93.66	84.79	83.33
2006	92.60	86.24	81.36
2007	91.37	87.56	79.22

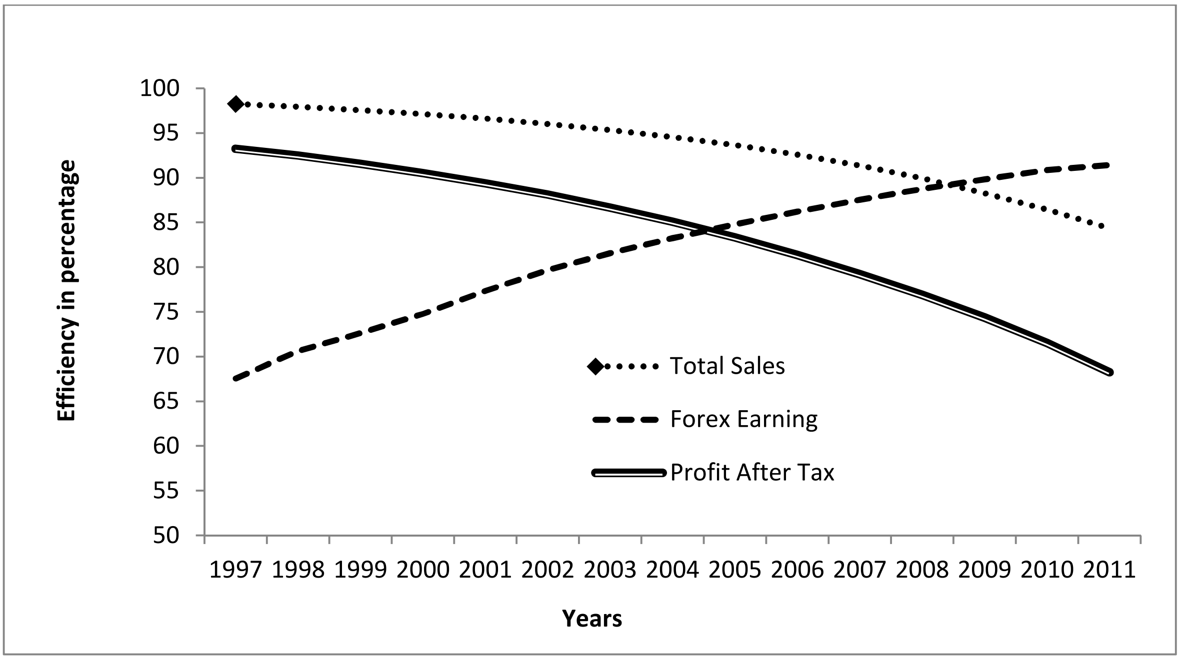
2008	89.94	88.76	76.89
2009	88.29	89.85	74.36
2010	86.45	90.87	71.51
2011	84.36	91.45	68.26

Note: Mean Efficiency is given in percentage term.

The highest TE scores in 1997 have been registered in case of raising total sales followed by profit and foreign exchange earnings. In the year 2011, the TE for raising foreign exchange earnings ranks first followed by total sales and profit. In the following figure, the mean efficiency scores in percentage term are given on the vertical axis and the time period in terms of years on the horizontal axis.

Figure 1

Mean Efficiency of All Firms



On the whole it may be observed that in the entire pharmaceutical sector, the technical efficiency registered an increasing trend in rising foreign exchange earning while in case of total sales and profit TE shows declining trends over the study years 1997 to 2011.

Conclusions

The study has attempted to analyse the relative technical efficiency of the Indian pharmaceutical companies using the parametric approach i.e. stochastic frontier analysis for the period 1997 to 2011. The soft patent regime, prior to 2005, provided opportunities for this industry to witness significant growth, particularly in generics production and exports but results of the study reveal that the sector has been witnessing a gradual fall in its efficiency values and it has been accelerated after 2005 i.e. the post product patent regime. Our study also indicates that the industry has experienced rapid pace of technical progress opening up new production possibilities. However, most of the firms have failed to appropriate the benefits of such technological change. The study finds that the raw material as an input has emerged the most significant variable influencing the total sales and foreign exchange earnings in all the group of firms. Labour has been found the most significant input variable influencing the profit of firms. On the other hand, the energy input has been found to have marginal influence on firm's output. The firm specific effects associated with the technical efficiencies have been found to be time varying in almost all the firms.

Further the study reveals that the mean technical efficiency of output for all firms has registered a mixed trend. For some outputs it has increased over the study period and for some others over the same period has decreased. There are considerable evidences that the observed outputs are less than their respective potential outputs due to technical inefficiency of firms. The efficiency improvement is considerable in the case of foreign exchange earnings in all the firms.

Whereas the TE scores for raising the output of total sales and profit have shown a declining trend for all the firms. This study provides valuable suggestions to the firms in regard to adopt various strategies to achieve their objectives being profit maximization, sales maximization or targeting the foreign exchange earnings i.e. focusing on international market. The study also suggests that adopting capital-intensive techniques, importing advanced technology and investing more in R&D activities can ensure technological growth of the frontier firms in the industry.

References:

Annual Report (2011-12), Government of India, Ministry of Chemicals & Fertilizers, Department of Pharmaceuticals available at http://pharmaceuticals.gov.in/annualreport2012

Aigner, D.J., Lovell C.A.K. and Schmidt P. (1977) "*Formulation and Estimation of Stochastic Frontier Production Function Models*" Journal of Econometrics, Vol. 6, No.1, pp. 21-37.

Battesse, G.E. and Coelli T.J. (1992) "*Frontier Production Function, Technical Efficiency and Panel Data: With Application to Paddy farmers in India*" *Journal of Productivity Analysis,* Vol. 3, pp.153-169

Chaudhuri S. and Das S. (2006) "WTO, the TRIPS and Indian Pharmaceutical Industry", Journal of Quantitative Economics, Vol. 4, No.1, pp. 97-110.

Export-Import Bank of India (2007), "*Indian Pharmaceutical Industry: Surging Globally*", Occasional Paper No. 119, Published by Quest Publications.

FICCI (2005), *Competitiveness of the Indian pharmaceutical industry in the new product patent regime,* Report for National Manufacturing Competitiveness Council, FICCI, New Delhi, India.

Fujimori, A., Kamiike A. and Sato T. (2010) "*Technical Efficiency of the Small-Scale Pharmaceutical Industry in India: Evidences from Firm-Level*

Survey", Kokumin Keizai Zasshi, Journal Of Economics & Business Administration, Kobe University, Japan.

Gonzalez, E. and Gascon F. (2004) "*Sources of Productivity growth in the Spanish Pharmaceutical Industry (1994–2000*)", Research Policy, Vol. 33, No. 5, pp.735–745.

Government of India (2008) *Strategy for Increasing Exports of Pharmaceutical Products: Report of the Task Force*, Department of Commerce, Ministry of Commerce and Industry, India.

Government of India (2009) *Third Round of Developments in the Pharmaceutical Sector: Department of Pharmaceuticals*, Ministry of Chemicals and Fertilisers, India.

Hashimoto, A. and Haneda S. (2008), "*Measuring the Change in R&D efficiency of the Japanese Pharmaceutical Industry",* Research Policy Vol. 37, pp.1829–1836.

Jha, R. (2007) "*Options for Indian Pharmaceutical Industry in the Changing Environment*", Economic and Political Weekly, Vol. 42, No. 39, pp. 3958-3967.

Mazumdar, M. and Rajeev M. (2009) *"A Comparative Analysis of Efficiency and Productivity of the Indian Pharmaceutical Firms: A Malmquist-Meta-Frontier Approach",* International Journal of Business and Economics, 8(2), 159-181

Majumder T.H. and Rahman M.M. (2011) "*Financial Analysis of Selected Pharmaceutical Companies in Bangladesh*", *Journal of Biology, Agriculture and Healthcare*, Vol. 1, No.2, pp. 25-49

Meeusen, W. and Van den Broeck J. (1977) "*Efficiency estimation from Cobb-Douglas production functions with composed error*", International economic review, Vol. 18, No. 2, pp. 435-444.

Neogi, C., A. Kamiike and T. Sato (2012), "*Identification of Factors Behind Performance of Pharmaceutical Industries in India"* (No. DP2012-23).

Pannu, H.S., Kumar U.D. and Farooquie J.A. (2011) "*Efficiency and productivity analysis of Indian pharmaceutical industry using data envelopment* *analysis"*, International Journal of Operational Research, 10(1), 121–136

Pattnayak, S. S. and Chadha A. (2013), "*Technical Efficiency of Indian Pharmaceutical Firms: A Stochastic Frontier Function Approach",* Productivity, 54(1), pp. 54

Pradhan, J.P. (2003), *"Liberalization, Firm Size and R&D performance: A Firm Level Study of Indian Pharmaceutical Industry*", Journal of Indian School of Political Economy, 14(4), pp. 647–666

Pradhan, J. P. (2006) "*Global competitiveness of Indian pharmaceutical industry: trends and strategies*" ISID Working Paper, No. 2006/05, available at SSRN: http://ssrn.com/abstract=1413728

Saranga, H. and R.D. Banker (2010) *"Productivity and Technical Changes in the Indian Pharmaceutical Industry"*, Journal of the Operational Research Society, 61, 1777–1788

Saranga H. and B.V. Phani (2004) "*The Indian Pharmaceutical Industry – An Overview of Internal Efficiencies using Data Envelopment Analysis",* available at- http://ssrn.com/abstract=544802 accessed on 28/3/2012

Shu-Chuan Yang (2011) "*Using Balanced Scorecard and System Dynamics in Exploring the Performance of Taiwan's Pharmaceutical Industry*" Technology Management in the Energy Smart World (PICMET), 2011 Proceedings of PICMET '11pp. 1-9.

Vernon J.M. and Gusen P. (1974) "*Technical Change and Firm Size: The Pharmaceutical Industry*" The Review of Economics and Statistics, Vol. 56, No. 3, pp. 294-302.