
Munich Personal RePEc Archive

RD and productivity in the Indian pharmaceutical firms

Sharma, Chandan

Department of Economics, National Institute of Financial Management, Faridabad

12 February 2011

Online at https://mpra.ub.uni-muenchen.de/31681/
MPRA Paper No. 31681, posted 18 Jun 2011 15:39 UTC

R&D and Productivity in the Indian Pharmaceutical Firms

Chandan Sharma*

Abstract

Recent researches for developing countries suggest knowledge generating activates is no silver bullet for productivity growth. In this context, this paper examines the impact of R&D activities on firms' performance for the Indian pharmaceutical industry by utilizing the data of the post reform period (1994-2006). The empirical analysis is performed in two stages. In first stage, we examine the relative productivity performance of R&D vis-à-vis non- R&D. Subsequently, we construct two empirical frameworks, namely, growth accounting and production function. Results of analysis indicate that R&D firms have productivity edge over non- R&D firms. Regression results based on the growth accounting framework suggest that R&D intensity has a positive and significant effect (15%) on TFP. The results also confirm that the performance of foreign firms operating in the industry is more sensitive towards R&D than the local firms. Furthermore, the estimation results of the production function approach indicate that the output elasticity to R&D capital varies from 10% to 13%. Therefore, we support the argument that 'manna from heaven' impact is large and significant.

JEL classification: O30, D24

Keywords: Productivity; R&D; Indian Pharmaceutical

* Assistant Professor, Department of Economics, National Institute of Financial Management, Faridabad-121 001, Haryana, India.
Address for communication:
National Institute of Financial Management, Sector 48, Faridabad 121 001, Haryana, India
Telephone:+91-129-2465268, Fax: +91-0129-2418867, E-mail- chandanieg@gmail.com

1. Introduction

The pharmaceutical industry in India has completely transformed itself since around the mid-1990s when Trade-Related Aspects of Intellectual Property Rights (TRIPS) came into effect. It is not only that the amount of research and development (R&D) expenditure has increased substantially, but also a sharp change in the structure of R&D activities has been witnessed in the industry. While in the past, the firms were mainly focused on development of new processes for manufacturing drugs, now they are also engaging aggressively in R&D for new chemical entities (NCEs) and modification of existing chemical entities to develop new formulations and compositions. Furthermore, the fiscal incentives for doing R&D have also grown significantly in the recent years. In this context, this study attempts to answer a question that how firms' in-house R&D affects their performance indirectly through total factor productivity (TFP) and directly on output in the Indian pharmaceutical manufacturing? The question that we deal in this paper is relevant and one would like to have an answer for.

In a pioneer study Solow (1957) recognized that technological change is one of the key driving factors of productivity growth. Proponents of recently developed endogenous growth theories have also recognized its role, however, they considered it endogenous which is driven by the

deliberate investment of resources by profit-seeking firms (Grossman and Helpman, 1990; Smolny, 2000). The theory also accepts the fact that a firm's innovation activity is crucial to its technological progress and productivity growth. Klette and Grilliches (1996) extended the edogenous growth theory for R&D and productivity linkage in the context of firm and presented the quality ladder model in a partial equilibrium framework. The model explains that R&D investment and innovations are the engine of growth. Thus, the theortical linkage between R&D activities and productivity of firms is well established in the literature.

In the empirical literature too, there is no dearth of study on R&D and firm's or plant's performance. Most of these studies are invariably found to have a significant and positive effect of R&D on the performance of firm. However, the estimated elasticity of productivity or output with respect to R&D varies widely in these studies (e.g. see Griliches, 1979, 1986, Griliches and Mairesse, 1990, Jaffe, 1986, and Griffith et al., 2006).[1] Some recent studies for the developed countries, for example, O'Mahony and Vecchi, (2009) suggested that knowledge generating activates is no silver bullet for productivity growth and 'manna from heaven' impact is very small. A closer look on the related empirical literature reveals several reasons for a wide variation in the elasticity estimation. First, these results are observed to vary to the type of industry in consideration as in R&D intensive industries, by and large, elasticity is found to be larger. Second, the choice of the estimation technique is another source of the divergence. In several studies, application of different econometric techniques has yielded wide variation in the results on the same data (e.g. see O'Mahony and Vecchi, 2009). Third, it is also observed that a vast variation exists in results between firm-level and industry-level data.[2] Finally, the size of elasticity also depends heavily on the choice of the indicator of firm's performance (on the dependent variable) i.e. output, labor productivity, TFP and profit.

[1] Considering the example from firm-level studies, Griliches (1979, 1986) found that the elasticity to R&D in the US manufacturing was around 0.07. In France, it was found that the elasticity was larger than in the US and it ranged between 0.09 and 0.33 (Cuneo and Mairesse, 1984; Mairesse and Cuneo, 1985). For USA, Jaffe (1986) estimated the elasticity around 0.20. For the same country, Griliches and Mairesse (1990) found it is ranging between 0.25 to 0.45, while in the same study, for Japanese manufacturing it was found to be ranging between 0.20 to 0.50. However, for Taiwanese manufacturing firms, Wang and Tsai's (2003) estimation suggested it as 0.19. In a recent paper, Griffith et al. (2006) for the UK manufacturing firms found the size of the elasticity too low (ranging from 0.012 to 0.029). In the case of India, the elasticity with respect to value added was calculated to be 0.064 in the heavy industries, 0.357 in the light industries and 0.101 in the overall industries (Raut, 1995).

[2] Firm based studies generally indicated for a greater role of R&D investment in production than industry level studies.

Against this backdrop, we are set to investigate the role of R&D on performance of firms in the Indian pharmaceutical industry. We take up the issue in an innovative way, and attempt to investigate the relationship for a very recent period (1994-2006). We take into consideration two important indicators of firms' performance, namely output and TFP, for the empirical analysis. This investigation is very relevant from a policy perspective, mainly, because contrary to the general perception that pharmaceutical industry in general is very sensitive to R&D activities, the Indian pharmaceutical industry is known for its low research intensity. Nevertheless, in recent years as regulatory environment has changed, firms are exposed to intense both in national and international market. This has encouraged firms (in some cases forced) to adopt the innovative activities as the key of the growth strategy. The recent data also validate that at least some large firms in this industry have started taking R&D activities a bit more seriously than earlier.

The remainder of this paper is structured methodically in sections, which are as follows: Section 2 discusses R&D issue in the Indian pharmaceutical industry. Sections 3 explain data related issues and estimates TFP of the sample firms. Section 4 compares productivity of R&D and non-R&D firms. Section 5 constructs empirical models and estimates the effects of R&D on Firms' Performance. The final section lays out concluding remarks and policy suggestions.

2. R&D and Indian Pharmaceutical Industry

During the postwar years and subsequently for a long period, the developing countries in general and India in particular had remained net users, rather than developers of R&D intensive pharmaceutical products. This was due to evident and obvious reasons of inadequate investment resources, lack of sufficient skill in medicinal chemistry and high risky uncertain nature of such investment and embryonic R&D infrastructure in most of these countries. Another question of developing countries adopting R&D and patent protection policy has been a debatable issue among the academia and the industry. For example, following the writings of Penrose (1951), Vaitsos (1972) and Greer (1973), it has been argued that developing countries lose by granting patent protection since the costs of patent protection outweighs its benefits and consumers suffer from higher drug prices resulting from patent monopolies. In India, for instance, many of the pharmaceutical multinational corporations (MNCs) operated through their subsidiaries and enjoyed product patent regime and high price. As a case of non-affordability of drugs by a large section of the population, the government abolished product patent protection in 1972 and drugs price control was introduced. Indian companies (along with MNCs subsidiaries) responded to

this situation by developing generics for our highly regulated market under the process patent protection of drugs.

Even when the 1994 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) which made mandatory product/process patent protection for World Trade Organization (WTO) member countries, it had again been initiated a debate that whether developing countries gain technologically from strong IPRs (patent regime). Empirical investigations show rather mixed results. For example, Sakakibara and Branstetter (2001) show that patent regime is not positively correlated with R&D activities in Japan. On the contrary, Mascus and Dougherty, (2005) in a recent study on China proclaim a positive relation between patents and R&D.

India signed the 1994 TRIPs Agreement and Indian companies established themselves as suppliers of active pharmaceutical ingredients (APIs) and intermediates to MNCs. Ever since the product patent regime was launched on 1 January 2005, domestic pharmaceutical companies have increased their allocation for R&D and their structure of R&D activities. At present, the Indian drug and pharmaceutical industry is ranked as the fourth largest in terms of volume and thirteenth in terms of value in the world. The industry accounts for about 8% of the total world's drug production (OPPI, 2008). By far, the Indian industry's forte remained in generic product market; and this has been propelled by reverse engineering skills and also low cost advantage. The pharmaceutical products price is ruled at relatively low level, both in the domestic as well as in export markets. Currently, Indian companies, on an average, spend about 5% turnover (OPPI, 2008) on R&D, which is much lower as compared to companies of most of the developed countries where this percentage varies between 15 to 20%. Traditionally, Western MNCs have dominated the pharmaceutical industry and their competitive edge has been in basic R&D, new drug discovery, new chemical entities (NCEs) and bio-technology supported by patent regime till end-2004. It is then no longer a surprise that these MNCs could invest massively in R&D, bear with high risk and long gestation period for new drug discovery and thereby reap monopoly profits.

Why Indian companies have hitherto invested very little in R&D for new drug discovery and NCEs? The industry circle possibly explains this phenomenon by two important factors. First, the industry lacks product patent protection regime, massive investment requirement and highly risky nature of such investment. Second, Indian price control regime also tended to squeeze the profit margin which served as a disincentive to spend on R&D.

Nevertheless, in the recent years, the outlook of the industry has changed considerably and firms in India have started taking R&D activities more seriously and more money is being invested now in these activities (see Figure 1). There can be many reasons behind this change in the attitude of Indian firms relating to the R&D activities. First, fiscal incentives and government support has encouraged firms for R&D. Recently the government has started many new tax exemptions schemes and most of the old such schemes are extended.[3] At second place, new patent regime has also encouraged and forced Indian firms to take up the R&D activities more seriously, if they have to survive in the market. As a result investment in R&D for developing new drugs has surged since TRIPS came into effect (since 2005). According to the current estimates there are at least 10 to 15 domestic Indian pharmaceutical companies that are active in drug research and have research centers across the country. Table 1 presents the share of pay-out on R&D by 10 large firms of the pharmaceutical industry, which demonstrates clearly that in recent years these firms have increased their pay-out on the innovation activity sufficiently. Major domestic companies such as Dr Reddy's Lab, Ranbaxy, Wockhardt, Lupin and Cipla have realized that R&D is the key to success for their growth and expansion plans in this industry. Consequently, they have started demonstrating change in the structure of their R&D activities. These companies have comparative advantage in undertaking R&D activities locally as i) R&D expenditure in India is far lower than in developed countries and cost differentials are reflected in lower costs of machinery, equipment and intellectual capital; ii) India's large population base facilitates clinical trials (CTs) for diseases prevalent in tropical countries; iii) Many of the Indian pharmaceutical firms have been accredited by regulatory agencies such as World Health Organization (WHO) and United State Food and Drug Administrator (US-FDA) and they have turned to contract research and manufacturing.

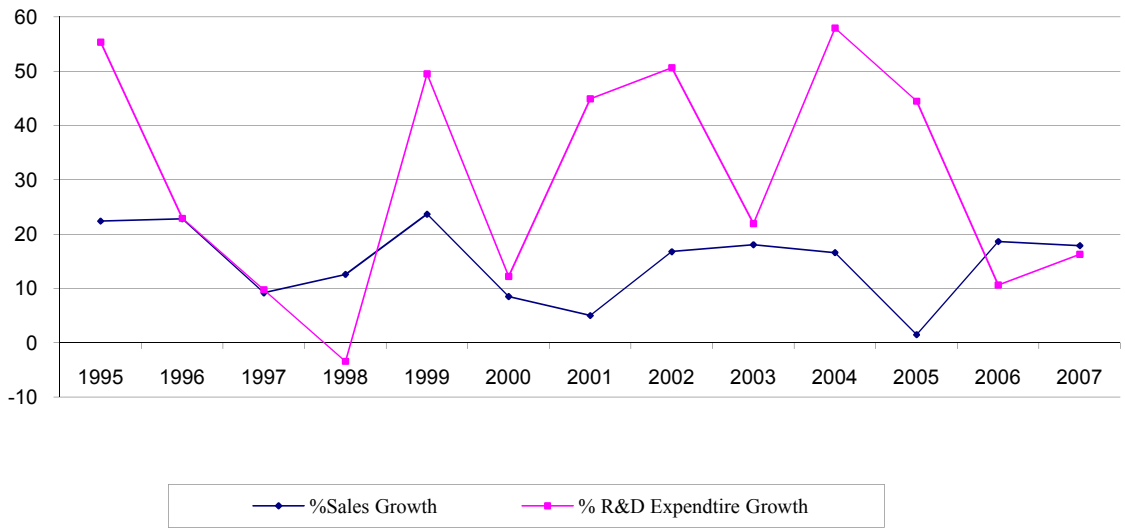
More recently, growth through overseas acquisitions has been one of the stated strategies of large pharmaceutical companies to undertake risky R&D investments and, enhance the skill levels of

[3] Some of important fiscal benefits are as follows:
a) The benefit of weighted exemption on the income tax has been till 31st March, 2015.b) Deduction is given on tax to depreciation on investment made in land and building for dedicated research facilities, expenditure incurred on clinical trials and expenditure incurred for obtaining regulatory approvals. c) Reference Standard (sample under test) is exempted from import duty. e) Reference books to be imported for R&D are exempted from import duty. f) On the basis of recommendations of The Pharmaceutical Research and Development Committee, the government provides some extra fiscal incentives to R&D Intensive Companies (Gold Standard Companies). g) To fund the R&D initiatives of Institutions and industry, the Pharmaceutical research and Development Support Fund (PRDSF) has a corpus of INR 1500 million) to utilize.

their employees by networking and leveraging their assets. The R&D focus of these companies has been on biopharmaceuticals, new chemical entities (NCEs), and novel drug delivery systems (NDDSs).

In this changing scenario and backdrop of findings of recent empirical literature, it becomes relevant to test the role of in-house knowledge activities on firms' performance in the Indian pharmaceutical industry.

Figure: 1
Growth of Sales and R&D Expenditure in the Indian Pharmaceutical Industry



(Source: Prowess Database, CMIE, 2008)

Table: 1

Percentage of R&D Expenditure to Sales of Large Firms of Indian Pharmaceutical Industry

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Aurobindo Pharma Ltd.	1.92	0.86	1.25	1.85	3.65	4.67	4.39	4.86	4.88
Cadila Healthcare Ltd.	4.74	8.32	7.50	3.88	7.76	8.96	8.86	10.14	9.20
Cipla Ltd.	3.89	3.85	3.34	0.00	2.75	4.10	5.01	4.80	5.41
Dr. Reddy'S Lab Ltd.	2.68	4.17	6.32	10.17	12.88	18.18	11.79	6.98	9.22
Glaxosmithkline P. Ltd.	0.43	0.35	0.33	0.29	0.30	0.28	0.36	0.33	0.70
Glenmark Pharma Ltd.	3.58	11.98	4.66	9.17	9.75	9.05	5.32	6.12	4.68
Lupin Ltd.	0.74	5.45	6.10	3.57	3.84	6.86	6.29	6.93	7.27
Orchid C & P Ltd.	1.26	3.79	4.12	5.13	5.56	7.57	6.95	6.74	5.67

Piramal Healthcare Ltd.	1.89	1.78	2.12	1.60	3.87	8.28	6.04	6.29	1.76
Sun Pharma Inds. Ltd.	3.94	4.47	4.84	8.33	12.06	11.11	11.94	10.93	5.95

(Source: Prowess Database, CMIE, 2008)

3.Data and TFP Estimation Technique

3.1. Data

Firms' data of the Indian Drug and Pharmaceutical industry are mainly obtained from the Prowess[4] database provided by Center for Monitoring Indian Economy (CMIE). The analysis includes only firms (358 firms) which have consistent data in the study period (1994 to 2006). Details of variables, their definitions and sources are discussed in Table 1. A descriptive statistics of data series is reported in Table 1A of Appendix.

Table 2: Variables Definition and their Source, 1994-2006

Variable	Definition	Data source
Output(Y)	Gross value added of the firms	Prowess
Labour input (N)	Number of workers	Prowess
Physical capital (K)	Computed as follows: $K_t = (1-\delta)K_{t-1} + I_t$ where K is the capital stock, I is deflated gross investment, and δ is the rate of depreciation taken at 7%.	Prowess
*R&D Intensity(*R&DInt)	R&D expenditure of firms divided by their sales	Prowess
*R&D Capital(*R&DCap)	Annual expenditure on R&D of firms	Prowess
*Export intensity (*Export)	Export of firms divided by their sales	Prowess

[4] Prowess Database is online database provided by the Centre for Monitoring Indian Economy (CMIE). The database covers financial data for over 23000 companies operating in India. Most of the companies covered in the Database are listed on stock exchanges, and the financial data includes all those information that operating companies are required to disclose in their annual reports. The accepted disclosure norms under the Indian Companies Act, 1956, makes compulsory for companies to report all heads of income and expenditure, which accounts for more than 1% of their turnover.

*Import intensity (*Import)	Total import (raw material and finished goods) of firms divided by their sales.	Prowess
Raw materials	Expenditure on raw materials of firms	Prowess
Power&fuel	Expenditure on power and fuel of firms.	Prowess
Size	Value of sales of firms	Prowess

Note: all series are deflated with appropriate deflator before any econometrics treatment.

3.2. TFP estimation

In order to examine the role of R&D on firms' performance, firstly we need to estimate TFP of our sample firms. In this process, the OLS approach of measuring TFP of firms as the difference between actual and predicted output may lead to omitted variable bias since the firm's choice of inputs is potentially correlated with unobserved productivity shocks. To overcome this problem we use the Levinsohn-Petrin (2003) technique. This procedure utilizes firms' intermediate inputs as proxies to correct for the part of the unobserved productivity shock correlated with firms' inputs. Following this approach, we estimate a Cobb Douglas production function in following form:

$$Ln(Y_{it}) = \alpha_0 + \alpha_1 Ln(N_{it}) + \alpha_2 Ln(K_{it}) + \omega_{it} + \eta_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

where Y, N and K denote value added, labor and capital, respectively of firm i in year t. Ln indicate that series are transformed in logarithm before any econometric treatment. In this model (equation 1) the error has two parts: first is ω, which represents the transmitted productivity component, while η is an error term that is not correlated with inputs. ω is affected by firms' policy, and it is unobserved (for details of this methodology, see Levinsohn-Petrin, 2003, and Sharma, 2010). Results of the estimated production function are reported in Table 3, which suggests that both inputs have significant impact on output of firms. On the basis of this estimation, TFP of our sample firms is predicted for further analysis.

Table: 3

Cobb- Douglas Production Function Estimation using Levinsohn-Petrin Productivity Estimator

(Dependent Variable: LY)

Variables	Coefficient	Z-value
Ln(K)	0.26801*	2.50
Ln(N)	0.60809*	13.33
Wald test (P-Value)	0.1667	

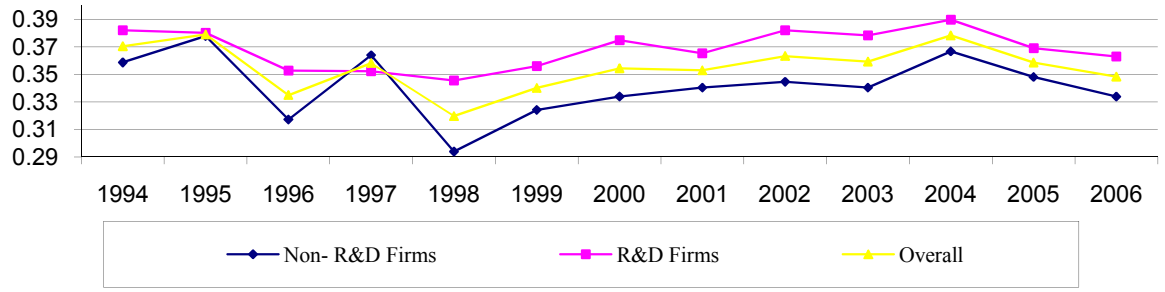
Notes:

1. Wald test of constant returns to scale.
2. Proxy variables: Power and fuel expenses; and Raw material expenses.
3. * indicate statistical significance at the 5%.

4. Are R&D Firms more productive than Non- R&D Firms?

In order to examine the role of R&D, we ask an important question 'Are R&D Firms more productive than Non- R&D Firms?' To answer this question, we begin the investigation comparing R&D firms and non- R&D firms, by plotting their average annual estimated TFP, which is presented in Figure 2. The comparison of the groups of firms reveals that firms those firms which have in-house R&D facilities are more productive than non-R&D firms on an average. Further, a closer look also reflects that before the year 2000, the difference between the groups was fluctuating, however, after this period the gap is consistently maintained. This is the first indication we receive about the R&D's role, which is quite positive and encouraging.

Figure 2
Average Estimated TFP, R&D vis-à-vis Non- R&D Firms



(Source: Author's calculation)

Taking forward our investigation at the next level, we compare the distribution of TFP of both types of firms. We conduct a two-sided non-parametric Kolmogorov-Smirnov test (KS-test) to determine whether the TFP distributions between the two groups differ significantly. The KS-test

calculates the largest difference between the observed and expected cumulative frequencies, which is called D-statistics. These statistics are compared against the critical D-statistic for the sample size. For this purpose, we consider three important years of the sample period: 1994, 2003 and 2006.[5] The results of the two-sided KS-test are shown in Table 4, which reveal the TFP distribution of R&D firms stochastically dominates those of non- R&D firms at least in the late reform years, i.e. 2003 and 2006. However, in the initial year (1994), the difference is not found to be statistically significant at any reasonable level. At this stage, we can also conclude that the evidence supports the hypothesis that in the whole sample of firms R&D firms stochastically dominate non- R&D firms at least in the recent years.

Test 4: Kolmogorov-Smirnov tests for R&D vis-à-vis Non- R&D, 1994-2006

Serial No.	Group	Largest Difference (D)		
		1994	2003	2006
1	$H_0 : R\ \&\ D - NonR\ \&\ D \leq 0$	0.2049 (0.256)	0.3314** (0.032)	0.3282* (0.097)
2	$H_0 : NonR\ \&\ D - R\ \&\ D \leq 0$	-0.1954 (0.290)	-0.0714 (0.852)	-0.0051 (0.999)
3	Combined K-S	0.2049 (0.205)	0.3314* (0.064)	0.3282 (0.194)

Notes:

1. *P*-values based on the bootstrap approximation are in parentheses.

2. ** and * denote for statistically significant at 5% and 10%, respectively.

5. Estimating the Effects of R&D on Firms' Performance

Now we investigate the impact of R&D on TFP and output of the sample firms. Our study constructs two frameworks. The first is a growth accounting framework, which allows an indirect impact of R&D on productivity through TFP, within the endogenous growth framework.

[5] 1994 and 2006 are our starting and ending points, respectively, while 2003 is important because this year is a turning point for the Indian manufacturing from recession to boom. We also test other years (but do not report) of the sample and the results are almost similar.

This framework is followed by a production function approach, in which R&D capital directly enters in the aggregate production function as an input.

5.1. Effects of R&D on TFP

We start our empirical modeling with the growth accounting framework. Under this approach we broadly follow Coe and Helpman (1995) and Atella and Quintieri (2001) and test R&D intensity (*R&D int*) on the estimated TFP of firms. Therefore, our baseline empirical model to be estimated is as follows:

$$TFP_{it} = \alpha + \gamma Ln(\text{R \& D int}_{it}) + \beta X_{it} + u_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

where TFP and *R&Dint* are the level of TFP and R&D intensity, respectively of firm *i* in period *t.* R&D intensity is measured by the ratio of R&D expenditure to sale of firms. In the equation, X is a vector of firm characteristics, u is error term and α, γ and β are parameters to be estimated. Ln indicates for logarithm transformation of the variables.

We estimate equation 2 in four alternative ways and their results are reported in Table 5. Column 1 of the table presents results of the model in which only R&D intensity is the explanatory variable. Columns 2, 3 and 4 include firm-specific characteristics (control variables), i.e. size, export intensity (export) and import intensity (import).[6] Column 3 also includes a dummy for foreign firms (FD) (if foreign firm, FD=1, otherwise 0), while column 4 includes an interaction variable of foreign firm dummy and R&D intensity. One previous year's lag of dependent variable is included in columns 2, 3 and 4, to tackle the potential endogeneity. The results show that the R&D intensity elasticity to the productivity is positive and varies from 0.15 to 0.19. This implies that 1% increase in R&D intensity leads to 0.15% to 0.19% increase in TFP. This estimate is relatively lower than the findings for France (Cuneo and Mairesse, 1984 and Hall and

[6] To capture the export intensity of firms, we use ratio of export to value of sales of firms. Theoretically exporting firms make themselves more productive and efficient to compete in foreign markets, therefore we expect a positive impact of this variable. On the other side, the import intensity of firms is captured by total import (imports of both raw material and finished goods) to value of sales of firms (for detailed discussion on this issue, see Ben-David, 1993; Sachs and Warner, 1995; Wagner, 2002; Aw et al., 2000; and Bernard and Bradford, 2004). Importing firms may receive technological as well as better inputs, which can potentially help firms to enhance their productivity performance. Size of firms is accommodated in the model by using logged value of sales of firms. Theoretically, because of economies of scale, a larger size and increasing output should have a positive influence on the productivity of firms. Therefore, we expect positive sign of this variable as well.

Mairesse, 1995) and for Taiwan (Wang and Tsai, 2003). However, it is larger than that of US (Mairesse and Hall, 1996), UK (Kafouros, 2005) and Japan (Sassenou, 1988). The impact of foreign firm dummy is also found to be significant and positive on TFP (see column 3), which suggests that foreign firms are more productive than the local firms in the industry. Surprisingly, the estimated coefficient of the interaction variable of R&D to foreign firm dummy is found to be sizably large (0.36) (see column 3 of Table 5). This can be interpreted as 1% increase in R&D intensity of foreign firms' leads to 0.36% increase in their TFP, which is one of the largest findings in a comparison with that of related literature. Further, the results regarding the trade variables i.e. export and import intensities are not found to have any significant effect on the productivity. However, size of firm (which measures economies of scale) seems to be crucial as coefficient of this variable found to be sizable, positive and statistically significant on the productivity.

Table 5: Effects of R&D on TFP, 1994-2006

	1	2	3	4
Ln(R&Dint)	0.1925* (1.943)	0.1516* (1.983)	0.1542* (1.994)	
Ln(Export)		-0.0093 (-0.999)	-0.3742 (-0.374)	-0.0034 (-0.384)
Ln(Import)		-0.0070 (-0.483)	-0.004 (-0.291)	-0.0096 (-0.673)
Ln(size)		0.1289* (13.391)	0.0096* (13.324)	0.1292* (13.401)
Foreign Firm Dummy (FD)			0.0157* (3.347)	
TFP(-1)		-0.1857* (-9.719)	0.0196* (-10.228)	-0.1814* (-9.691)
Ln(R&Dint) * FD				0.3632* (1.955)
Constant	0.3512 (41.33)	0.0601* (9.1159)	0.0617* (9.329)	0.0592* (9.018)
R^2	0.1630	0.34932	0.35838	0.3489

Notes:

1. t-values in parentheses.
2. * indicates statistical significance at 5% level.
3. Estimation technique is Random GLS.

5.2. Effects of R&D on Output

Next we shift our attention to estimate the impact of R&D capital on output of our sample firms. In so doing, a production function approach is utilized, *a la* Griliches (1980), Schankerman (1981) Bartelsman et al., (1996) and Branstetter and Chen (2006). Here our base-line specification is:

$$Ln(Y_{it}) = \alpha_0 + \alpha_1 Ln(K_{it}) + \alpha_2 Ln(N_{it}) + \alpha_3 Ln(R\ \&\ Dcap_{it}) + \varepsilon_{it} \quad \text{……..3}$$

where Y, N, K and R&Dcap represent value added, labor, physical capital and R&D capital, respectively. R&D capital is a measurement of the stock of knowledge possessed by a firm at a given point of time.[7] *Ln, i* and *t* denote logarithms of the variables, firm and year, respectively. α_1 , α_2 and α_3 are parameters to be estimated. We are especially interest in α_3, because this is the measure of output elasticity to R&D capital.

We estimate equation 3, by three estimators: fixed effect, random effect and system GMM. Estimating the model using Ordinary Least Squares (OLS) with fixed or random effect usually provides estimates that are generally consistent with *a priori* knowledge of factor shares and constant returns to scale (Griliches and Mairesse, 1995). However, the procedure may produce biased and inconsistent estimates in the presence of endogeneity (Griliches, 1979). Therefore, following O'Mahony and Vecchi (2009), we also apply system GMM. The technique significantly reduces the weak correlation problem, and has proved to give more reasonable and reliable results in the context of production function estimation (Blundell and Bond, 2000).

The estimated result of equation 3 is presented in Table 6. The system GMM estimator significantly reduces the size of parameters of labor and capital in comparison with estimate of fixed and random. However, the coefficient of our prime interest, R&D capital is almost

[7] It's important to note that two measures of R&D are used in the analysis. We have tested the R&D impact on TFP by using R&D intensity (a ratio of R&D expenditure to sale). While R&D capital is used as an input in the function therefore we use deflated expenditure on R&D activities and it is called R&D capital.

invariant to the use of the estimators. Results of the estimations suggest that the output elasticity to R&D capital varies from 10% to 13%, implies 1% increase in R&D capital leads to 0.10 to 0.13% growth in firms' output. This estimate is broadly in accordance with the estimates of Griliches (1979, 1984) for the U.S., larger however than that of Branstetter and Chen, (2006) for Taiwan, and O'Mahony and Vecchi, (2009) for three European countries. Also, our estimated elasticity is substantially larger than that of Raut (1995) for India, who finds it significant, however, a lower of the magnitude (0.016%).

Table 6: Effects of R&D on Output of Firms, 1994-2006

Variables	(1)FE	(2)RE	(3)System GMM
Ln(K)	0.243* (5.74)	0.257* (7.71)	0.147* (2.58)
Ln(N)	0.489* (11.75)	0.553* (16.44)	0.381* (8.14)
Ln(R&DCap)	0.117* (5.34)	0.132* (6.57)	0.101* (3.53)
Sargan			0.171
R^2	0.9141	0.9147	

Notes:

1. t-values in parentheses.
2. * indicates statistical significance at 5% level.
3. Sargan is the p-value from the Sargan (1958) test of over-identifying restrictions, which test the overall validity of instruments for the GMM estimators.
4. FE and RE denote fixed effect and random GLS estimator, respectively.

6. Conclusion and Policy Suggestions

Findings of this study suggest that in-house R&D activities of firms are crucial determinates of productivity and output of the Indian pharmaceutical firms. The evidence clearly that suggests R&D firms are more efficient than non- R&D firms at least in the recent years. Furthermore, results of the regression analysis suggest that R&D intensity has a strong, positive and significant effect (15%) on TFP growth. This estimate is slightly larger than the findings of the international

studies. The results also confirm that foreign firms operating in the industry are more sensitive towards R&D activates than the local firms, as interaction of their dummy with the R&D variable yield elasticity to 0.36, which is meant that 1% increase in R&D intensity of foreign firms leads to 0.36% growth in their TFP. Finally, we investigate the effects of R&D capital on firms' output under the production function framework. The results indicate that the output elasticity to R&D capital varies from 0.10 to 0.13, implies 1% increase in R&D capital leads to 0.10 to 0.13% growth in firms' output. This finding is moderate in a comparison with the estimated elasticity for other countries. The estimated size of the elasticity in the Indian pharmaceutical in this study is equivalent to that of Griliches (1979, 1984) for the U.S., substantially larger however than that of Branstetter and Chen, (2006) for Taiwan, and O'Mahony and Vecchi, (2009) for three European countries. Therefore, we support the argument that 'manna from heaven' impact is large and significant.

Considering the findings of this study on the crucial role of R&D in stimulating output and productivity, it is a worrying factor that the Indian pharmaceutical is characterized by low R&D intensity. Thus, the policy suggestion is straightforward that the government should encourage firms for R&D activities through different ways which may include fiscal incentives, training and institutional collaboration. Moreover, foreign firms are found to be proactive in R&D activities, which will perhaps have a positive spillover effect for the others firms in the long run therefore flows of foreign direct investment in industry should also be encouraged. Finally, considering the findings in this study regarding the important role of in-house innovation activities of firms, we propose for further research in this area especially in developing countries using micro-level data.

Appendix

Table 1A. Descriptive Statistics on the Sample Firms, 1994-2006

Variable	Mean	Standard Deviation.	Minimum	Maximum
LY	0.946	0.844	-1.824	2.902
LK	1.1135	0.770	-1.076	2.986
LN	2.788	0.853	0.229	4.648
TFP	0.359	0.099	0.051	0.834

LExport	0.166	0.217	0	1
LImport	0.114	0.142	0	0.988
LR&DIntensity	0.014	0.032	0	0.588
LR&DCap	-.050	0.948	-2.117	2.554

References:

Atella, V., and Quintieri, B. (2001). Do R&D Expenditures Really Matter for TFP? *Applied Economics,* 33(11), 1385-89.

Aw, B. Y., Chung, S. and Roberts, M. J. (2000). Productivity and turnover in the export market: micro evidence from Taiwan and South Korea. *World Bank Economic Review,* 14 (1), 65-90.

Ben-David, D. (1993). Equalizing Exchange: Trade Liberalization and Income Convergence. *Quarterly Journal of Economics,* 108 (3), 653-79.

Bernard A. B. and Jensen, J. B. (1999). Exceptional Exporter Performance: Cause, Effect, or Both? *Journal of International Economics,* 47 (1), 1-25.

Bernard A. B. and Bradford, J. J. (2004). Exporting and Productivity in the US. *Oxford Review of Economic Policy,* 20(3), 343-357.

Blomström M. (1990). *Foreign Investment and Spillovers*. London: Routledge.

Blundell, R. and Bond, S. (2000). GMM Estimation with Persistent Panel Data: An Application to Production Functions, *Econometric Reviews,* 19, 321-340.

Branstetter, L. G., and Chen, J.R. (2006). The Impact of Technology Transfer and R&D on Productivity Growth in Taiwanese Industry: Microeconometric Analysis Using Plant and Firm-Level Data, *Journal of the Japanese and International Economies*, 20, 177-192.

Coe, D. T., and Helpman, E. (1995) International R&D spillovers, *European Economic Review*, 39(5), 859-887.

Cuneo, P. and Mairesse, J. (1984) Productivity and R&D at the firm level in French manufacturing. In: Griliches, Z. (Ed.), R&D, Patents and Productivity. University of Chicago Press, Chicago.

Greer, D. F. (197. The Case Against Patent Systems in Less-Developed Countries. *The Journal of International Law and Economics,* 8, 223-266.

Griffith, R., Huergo, E., Mairesse, J. and Peters, B. (2006). Innovation and Productivity Across Four European Countries, *Oxford Review of Economic Policy* 22(4), 483-498.

Griliches, Z. (1986). Productivity, R&D, and Basic Research at the Firm Level in the 1970s, *American Economic Review,* 76 (1), 141–54.

Griliches, Z. (1979). Issues in Assessing the Contribution of R&D to Productivity. *Bell Journal of Economics*, 10, 92–116.

Griliches, Z., (1980). Returns to Research and Development Expenditures in the Private Sector," pp. 419-454 in Kendrick, J.W. and Vaccara, B. (Eds.), New Developments in Productivity Measurement, National Bureau of Economic Research, University of Chicago Press, Chicago, 1980.

Griliches, Z., and Mairesse, J. (1990) R&D and productivity growth: comparing Japanese and American manufacturing firms. In: Hulten, C. (ED.), Productivity Growth in Japan and the United States, NBER studies in income and wealth, Vol. 53, University of Chicago Press, pp. 317-348.

Grossman, G.M. and Helpman, E. (1991). *Innovation and Growth in the Global Economy*, MIT Press, Cambridge, MA.

Grossman, G. M. and Helpman. E. (1990). Product Development and International Trade, NBER Working Paper No. W2540.

Hall, B.H., and Mairesse. J. (1995). Exploring the Relationship between R&D and Productivity in French Manufacturing Firms. *Journal of Econometrics,* 65, 263–293.

Hill, H. (1988). *Foreign Investment and Industrialization in Indonesia*. Singapore: Oxford University Press.

Jaffe, A. B. (1986). Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value. *American Economic Review* 76(5), 984-1001.

Kafouros, M. I. (2005). The impact of the Internet on R&D efficiency: Theory and Evidence, *Technovation,* 26 (7), 827-835.

Klette, T. J. and Griliches, Z. (1996). The Inconsistency of Common Scale Estimators When Output Prices Are Unobserved and Engogenous, NBER Working Papers 4026.

Levinsohn, J., and Petrin, A. (2003). Estimating Production Functions Using Inputs to Control for Unobservable. *Review of Economic Studies* 70(2), 317–342.

Mairesse, J., and Hall, B. (1996). Estimating the Productivity of Research and Development in French and US Manufacturing Firms: An Exploration of Simultaneity Issues with GMM Methods. In Wagner, K. and Van Ark, B. (Eds) *International Productivity Differences and their Explanations*. Elsevier Science, pp. 285–315.

Maskus, K. E. and Dougherty, S. M. (2005). Intellectual property rights and economic development in China, in: Intellectual property and development: lessons from recent economic research/ed. by C. Fink and K.E. Maskus 295–331

O'Mahony, M., and Vecchi, M. (2009). R&D, Knowledge Spillovers and Company Productivity Performance, *Research Policy,* 38(1), 35-44.

OPPI, (2008). The Organisation of Pharmaceutical Producers of India (OPPI), 43rd Annual Report – 2008-09, Mumbai, India.

Penrose, E. (1951). *The Economics of the International Patent System.* Baltimore: Johns Hopkins University Press.

Raut, L. K., (1995). R & D spillover and Productivity Growth: Evidence from Indian Private Firms. *Journal of Development Economics,* 48(1), 1-23.

Sachs, J. D., and Warner, A. (1995). Economic Reform and the Process of Global Integration. *Brookings Papers on Economic Activity,* 1, 1-95.

Sakakibara, M. and Branstetter, L. (2001). Do Stronger Patents Induce more Innovation? Evidence for the 1988 Japanese Patent Law Reforms. *RAND Journal of Economics,* 32(1), 77–100.

Sassenou, M. (1988). Recherche-développement et productivité dans les enterprises japonaises: une étude econométrique sur données de panel, Doctoral dissertation, Ecole des Hautes Etudes en Sciences Sociales, Paris.

Schankerman, M. (1981). The Effect of Double-Counting and Expensing on the Measured Returns to R&D, *Review of Economics and Statistics,* 63(3), 454-58.

Sharma, C. (2010). Does Productivity Differ in Domestic and Foreign Firms? Evidence from the Indian Machinery Industry, *Indian Economic Review*, 45(1), 87-110.

Solow, R.M. (1957). Technical progress and the aggregate production function. *Review of Economics and Statistics,* 39, 312–320.

Sjöholm, F. (1998). Joint Ventures, Technology Transfer and Spillovers: Evidence from Indonesian Estblishment Data". in Economic Planning Agency, ed., *Foreign Direct Investment in Asia*, papers and proceedings of an international symposium, 22-23 October, Tokyo: Economic Planning Agency, 587-616.

Smolny, W. (2000). Endogenous Innovations and Knowledge Spillovers, Heidelberg and New York.

Vaitsos, C. (1972). Patents revisited: Their Function in Developing Countries, *Journal of Development Studies* (9)1: 71-97.

Wagner, J. (2002) The Causal Effects of Exports on Firm Size and Labor Productivity: First Evidence from a Matching Approach, *Economics Letters,* 77 (2), 287–292.

Wang, J., and Tsai, K. (2003). Productivity Growth and R&D Expenditure in Taiwan's Manufacturing Firms, NBER Working Papers No 9724.