Economic Reforms and R&D Expenditure in Industrial Firms in India

B.N. Goldar
V.S. Renganathan

No. 1 January 1997

Abstract

In this paper, an analysis of R&D intensities of industrial firms in India has been undertaken making a comparison between pre and post-reform periods. We analyse the data for 56 large companies of which 39 belong to the private corporate sector and 17 to the public sector. The data relate to 1989-90 and 1994-95. It is found from a comparative analysis of R&D intensities of industrial firms that in the post-reform period, contrary to expectations, there has been no general increase in the R&D intensity of industrial firms and the average R&D intensity in 1994-95 was no higher than that in 1989-90.

Inter-firm differences in R&D intensity have been explained in the framework of multiple regression analysis, carried out for pre and post-reform periods. Of the determinants of R&D intensity, the relationship between profits and R&D intensity, capital-output ratio and R&D intensity, and the degree of vertical integration and R&D intensity has become weaker, while that between the age of the firm and R&D expenditure has become stronger in the post-reform period as compared to the pre-reform period. The other important determinants of R&D intensity in both pre and post-reform periods are firm size, rate of excise duty, whether the firm is in the public sector and the extent of foreign ownership.

Economic Reforms and R&D Expenditure in Industrial Firms in India

B.N. Goldar [1]
V.S.Renganathan [2]

I. Introduction

Despite being better endowed with scientific man-power and skill, India has lagged behind the Asian Tigers and some other countries of Asia in terms of technology standards and industrial productivity. This could be attributed to the fact that India has been slow in developing local R&D (research and development) in the industrial sector and also in adopting and assimilating imported technology developed elsewhere to her advantage. Though in-house R&D of Indian R&D institutions have led to the development of some technologies, these have remained mostly non-marketable, not being found suitable for commercial use in the country. As a result, the Indian economy has not been able to reap the benefits of the investments made in the development of scientific skills and manpower in the country.

---

[1] Professor, Institute of Economic Growth, Delhi-7

[2] Economist, National Institute of Public Finance and Policy, New Delhi-110067.

This paper is prepared under the Macro-Economic and Industrial Policy Research Programme sponsored by the Ford Foundation at the National Institute of Public Finance and Policy, New Delhi.

We have benefited greatly from the comments of Dr. Charu C. Garg on an earlier version of this paper. We gratefully acknowledge the help we received from Shri Sathish Kamath of the NIPFP for computer programming.

With the economic reforms programme initiated in 1991, the situation may be expected to change substantially because the Indian industry would require, in the new economic policy regime, a significant technology up-gradation and efficiency improvement to meet the challenges of competition and globalisation. Clearly, a marked increase in indigenous R&D efforts is crucial for the successful implementation of the economic reforms. The need for a suitable science and technology policy has been underlined in the Indian Science Congress held at Calcutta in 1995. R&D has acquired added urgency in the post-GATT period. For the successful integration of Indian industry with the global economy, it is very important that proper linkages be created among the R&D establishments, the Universities, and Research Institutions, and close coordination be developed between R&D establishments and manufacturing firms.

In this context, it would be useful and interesting to study whether in the last few years there has been a significant increase in the R&D intensity of industrial firms in India in response to the economic policy changes. Some important questions to be investigated are whether there has been a general increase in the R&D intensity of industrial firms in the post-reform period or was the increase confined to only a small section of the industry. Also, in terms of the R & D behaviour of firms, as reflected in the determinants of R&D expenditure, has there been a change in the post-reform period. The present paper is concerned with these questions.

II. Response of the Industry

In regard to technology upgradation efforts, the initial response of the industry to reform measures has been quite encouraging. This is evident from the number of collaborations that the Indian companies have, in recent years, entered into with foreign companies[3]. There has been a marked increase in foreign collaborations in the post-reform period. Between August 1991 to August 1995 there were 6959 foreign collaborations approved by the Government of India, of which 3378 were technical collaborations[4]. According to one estimate[5], the payment on account of technology imports has been rising in the post-reform period. In 1991-92 the payment was of the order of Rs. 655 crore which increased to Rs. 1214 crore in 1993-94, and further to Rs. 1420 crore in 1994-95. By contrast, the response of the Indian industry to economic reforms in terms of indigenous R&D efforts has been sluggish. R&D expenditures in the public sector and private sector industrial enterprises together as a percentage of GNP was 0.22 per cent in 1989-90 and remained almost the same in 1992-93. Between these two years, R&D expenditure of public and private sector industry increased from

---

[3] Total approved financial collaboration in the post-reform period (Aug. 1991 to Sept. 1995) amounted to Rs. 33060 crore. (Economic Survey, 1995-96, p 119).

[4] In the 1980s, the average number of collaborations approved per year was around 700. For the year 1992 to 1995, the comparable figure was about 1500.

[5] The Economic Times, 12th October, 1995

Rs 904 crore to Rs 1359 crore[6]. Although comparable figures on expenditures on R&D and technology imports are not available, it appears that in recent years growth in R&D expenditure has been slower than that in payments for technology imports.[7]

It would be interesting to find out how the real R&D expenditure and R&D intensities (ratio of R&D expenditure to sales) of leading industrial groups[8] have changed in recent years. Such information is available in the publications of the Department of Science and Technology (Government of India); but the latest figures available are for 1992-93. Table 1 presents a comparison of deflated R&D expenditure of the leading industrial groups for 1989-90 and 1992-93. It is remarkable to find that in most case there has been a decline or only a marginal increase in real R&D expenditure between these two years. A comparison of R&D intensity of leading industrial groups for 1989-90 and 1992-93 is shown in Table 2. It is seen that R&D intensity of the defence industries increased sharply from 4.85 per cent in 1989-90 to 12.63 per cent in 1992-93 (not due to higher R&D expenditure, but due to lower sales). There has been a modest increase in the R&D intensity of

---

6 Department of Science and Technology, Science and Technology Pocket Data Book, 1993.

7 Average annual growth rate of R&D expenditure (at constant prices) of public sector industry was 6.71 per cent during 1985-86 to 1990-91. It declined to 6.16 per cent during 1990-91 to 1992-93. For private sector industry, the decline has been from 7.25 per cent to 5.90 per cent.

8 In 1989-90, these groups accounted for 65 per cent of total industrial R&D expenditure.

transportation industry group. But, in the other industry groups, the R&D intensity has declined. Thus in electrical and electronics industrial groups, the R&D intensity has declined from 1.1 per cent in 1989-90 to 0.74 per cent in 1992-93, in metallurgical industries from 0.37 per cent to 0.28 per cent, and in chemical industries (except fertilizers) from 0.88 per cent to 0.65 per cent. Considering the trends in real R&D expenditure and R&D intensities of leading industrial groups, it see therefore that in the post-reform period there has not been any substantial increase in the R&D efforts of Indian industrial firms.

III. Object of the Study, Research Methodology and Data Sources

The object of this study is to analyze the differences in the R&D behaviour of Indian industrial firms in the pre and post-reform periods. The analysis is carried out using data for a sample of large industrial firms. The average levels of R&D intensity and the frequency distributions of firms according to R&D intensity are compared between pre and post-reform periods. Multiple regression equations are estimated for analysing the determinants of R&D intensity. The equations are estimated from cross-section data separately for two years, one in the pre-reform and one in the post-reform period. The results of the regression analysis are then compared to bring out the differences in R&D behaviour.

The basic data for the analysis have been drawn from a

publication (regular) of the CII (Confederation of Indian Industries) entitled Top 100 Companies. This source provides firm-level data on R&D expenditure and sales, from which the R&D intensities have been computed. Such data have been collected for two years 1989-90 and 1994-95 (one year before the economic reforms and one year in the post-reform period).

Since, in our analysis, we estimate regression equations to relate R&D intensity to various characteristics of the firms, data on various variables representing the firms' characteristics have been collected. For some of these variables, the CII source mentioned above has been used. Other sources of data have also been utilized. Thus, for some of the variables, we could get the required information from the data compiled by the Institute for Studies in Industrial Development (ISID), New Delhi and from the records of the Director of Industrial Research, Department of Science and Technology, Government of India, New Delhi. For the details on the product profile of the companies, we have used the CMIE (Centre for monitoring Indian economy) publication Statistical Profile of 500 Corporate Giants. The details regarding payment of Technical Fee and Royalty by public sector enterprises in the sample have been taken from their respective Annual Reports available in the Library of Standing Conference of Public Sector Enterprises(SCOPE) New Delhi.

Although the CII publication covers Top 100 firms, by sales, we could get comparable data on all the variables used in the study only for 56 firms which constitute our sample. These are

mostly large engineering firms. In our sample, there are 39 companies in the private sector and 17 in the public sector.

IV. Empirical Results

a) Changes in R&D Intensity

Frequency distribution of firms according to the R&D intensity (R&D expenditure by sales turnover of the firm) is presented for 1989-90 and 1994-95 in Table 3. As many as 20 companies are in the class interval of 0.00 - 0.15 per cent R&D intensity for 1989-90; the figure for 1994-95 is slightly lower at 18. The number of firms spending a very low proportion of sales revenue on R&D has thus not changed significantly between the two years. The remaining firms are in the different ranges of R&D intensity. There are around 25 companies in respect of both years in the range of 0.16 per cent to 1.00 per cent. In the higher ranges of R&D intensity of 1.00 - 2.00 per cent there were only six companies in 1989-90 and this increased to ten in 1994-95. In the still higher class interval of 2.00 - 5.00 per cent there were four companies in 1989-90 but number decreased to three in 1994-95. Though there are some small changes, it is evident that in terms of frequency distribution of firms according to R&D intensity, there has been no substantial change between the years 1989-90 and 1994-95.

Table 4 shows the average levels of R&D intensity taking all the 56 firms together. The average R&D intensity is found to be

0.63 per cent for 1989-90 and 0.62 per cent for 1994-95. Thus, the average level has not increased between the two years (even after four years since the reforms were initiated). However, when firms are grouped according to their R&D intensities in 1989-90 and the average R&D intensity of the firms so classified are compared for the two years, an interesting pattern is observed. It is interesting to note that 20 firms had R&D intensity in the range of 0-0.15 per cent in 1989-90 and the average R&D intensity of those 20 firms increased from 0.04 per cent in 1989-90 to 0.22 per cent in 1994-95. Evidently, a number of firms of this group significantly increased their R&D intensity in 1994-95. An increase in average R & D intensity is observed also for firms in the R&D intensity ranges of 0.16 - 0.50 per cent and 0.51 - 1.00 per cent. On the other hand, no such increase in R&D intensity is observed for the ten firms which topped the list in terms of R&D intensity in 1989-90. Rather the average R&D intensity of these firms declined from 2.27 per cent in 1989-90 to 1.78 per cent in 1994-95. As a result of these changes in R&D intensity, the degree of inter-firm dispersion in R&D intensity has come down and the standard deviation declined from 0.95 to 0.89.

Our findings that the average level of R&D intensity has not increased in the post-reform period is remarkable, since an increase is expected considering the policy changes introduced since July 1991 and taking account of the general impression that corporate sector industry has responded well to the economic reforms. One may argue here that the observed stagnancy in R&D

intensity on average is not due to a slow increase in R&D expenditure but a faster increase in sales in this period. Table 5 shows the distribution of firms according to the ratio of R&D expenditure (at constant prices) in 1994-95 to that in 1989-90. In 35 cases (62.5 per cent of the sample), the ratio is less than one i.e. we find a decline in real R&D expenditure. In 12 cases, there is an increase, upto 100 per cent, and, in 9 cases, real R&D expenditure has more than doubled between 1989-90 and 1994-95. It is an evident that the majority of firms have not responded well to economic reforms in terms of their R&D efforts. But, there is a section of firms which did step up substantially their real R&D expenditure in the post-reform period.

b) Variables and Hypotheses

The key variable for the study is R&D intensity which is defined as the ratio of R&D expenditure to sales. The definition of R&D in this study is as adopted in the company balance sheets for the allocation of funds to R&D projects within the firms. The analysis of R&D behaviour is done by estimating a multiple regression equation that explains inter-firm variations in R&D intensity. A similar approach has been followed in a number of earlier studies. Some of the variables used in earlier studies for explaining R&D intensity are firm size, export intensity, capital and skill intensity, technology imports, foreign equity participation and vertical integration. In choosing the explanatory variables for the multiple regression analysis

carried out for this paper, we have been guided by the earlier studies on R&D behaviour undertaken for Indian industries (see Annexure). However, the data sources used for the study did constrain the choice of the explanatory variables for our study. The variables we have used in our analysis are explained below along with the nature of relationship hypothesized.

Size: Size of the firm is measured by sales. As the earlier studies have done, we take the logarithm of sales for measuring this variable. Turning to the nature of the relationship expected, it may be argued that larger firms are more diversified and technologically complex. Awareness of technological opportunities are relatively greater among the larger firms than among the smaller firms. Therefore, to remain competitive, large firms can afford to invest more on R&D and are more likely to do so. Further, in large industrial firms profits generate funds for R&D expenditure, in turn R&D expenditure via market capitalisation generate profit (Galbraith, 1972). Hence, the relationship of firm size with R&D expenditure as well as R&D intensity is expected to be positive.

Rate of Central Excise duty (ED): This is measured by the ratio of Central excise duty paid by the firms to their sales. There are reasons to expect a negative effect of excise duty on R&D expenditure. Inasmuch as higher payment of Central excise duty on production is likely to erode profit margin, it should have a negative relationship with firms' R&D outlay. But, when profit margin is included as an explanatory variable, this effect

will be captured by the profit margin variable itself. Therefore, the regression results may not show a negative relationship. A different argument is that high rates of excise duty may lower the expected returns from R&D investment and thereby reduce the incentive for R&D. This again should lead to a negative relationship between excise duty rate and R&D expenditure.

Export Intensity (XI): This is measured by the total value of exports of a firm as a proportion of the sales of the firm. Indian enterprises have been for a long time primarily inward oriented due to the policy of import substitution and for this reason the firms paid little attention to R&D. Thus, one would expect that the firms which have diversified into the international markets will have greater inclination to invest in R&D. Accordingly, we expect a positive relationship between R&D intensity and export intensity. Indeed, the study of Siddharthan and Agarwal (1992) has found a statistically significant, positive relationship between export-sales ratio and the probability of a firm deciding to invest funds in R&D.

Profit margin (PRM): This is taken as the ratio of profits before tax to sales. Higher the ratio, the higher should be the availability of funds to the firm for undertaking R&D and therefore the higher should be the allocation of resources for R&D.

Import Intensity (MI): This is defined as the ratio of the

value of imports by the firm to its total value of sales turnover. The relationship of this variable with R&D intensity is not clear. But, a negative relationship may be hypothesised on the ground that if the firm has greater access to imported inputs (including parts, components and capital goods), it is under less pressure to undertake R&D. Another point to be noted here is that under "phased manufacturing programmes" firms were under obligation to replace imported parts and components by domestically produced ones, and this became a major objective of R&D in industrial firms. This should give rise to a negative relationship between import intensity and R&D intensity.

Technology imports (MT): The impact of imported technology on R&D efforts has been an issue for debate for many years in India. Some held the opinion that foreign technology imports are a substitute for locally developed ones and hence argued that it is the major cause of low R&D efforts. This has been questioned in recent years. It has been argued that a complementary relation between R&D and technology imports should arise on the ground that firms would require R&D efforts and some minimum amount of technical skills for efficient use of foreign know-how and technology, to suit the production scale, to modify production process (if necessary), to use local raw materials, and change product characteristics to suit the local market or global markets. Some empirical studies in this area have found a positive relationship between technology imports and R&D.

The variable used for capturing this aspect is based on payments for imported technology which is defined to include payment of technical fee, lumpsum payment for technology imports, payment of royalty to the foreign collaborator firm for using their trade marks, brand names and reimbursement of expenditure by their technicians in India. The sum of all these is taken as a proportion to the value of production.

Vertical Integration (VI): Several researchers have hypothesized and empirically verified that the firms with higher degree of vertical integration are more inclined to allocate funds for R&D projects. Following these studies, we also hypothesize a similar relationship and expect that a vertically integrated firm will invest more in R&D and therefore the expected sign of the coefficient is positive. We have used the proportion of value added to the total value of production as a proxy to the degree of vertical integration.

Dividend paid in foreign exchange (FD): It is one of the variables used for capturing the effects of foreign ownership on R&D efforts of the companies. It is defined as the ratio of dividend paid in foreign exchange (foreign remittance) to the total dividend pay-out of the firm. One may argue that the equity participation of foreign companies in the Indian firm would not encourage local R&D, because the Indian firm need not incur such expenses as it will have access to the R&D centrally located with parent body abroad. This is evident in the cases of subsidiaries of the multinational companies. Accordingly, we

may expect the sign of the coefficient to be negative. On the other hand, one may argue that the outlook of foreign owned firms is often more progressive than Indian firms, and the foreign firms may be operating in those segments of the market where product quality is very important and significant amount of local R&D is required to make the product, developed abroad, suit the local market conditions. This would provide ground for a positive relationship between R&D intensity and the degree of foreign ownership.

Capital intensity (CI): Capital intensity is expected to have a positive coefficient in the regressions, since R&D intensity should be relatively higher in capital intensive firms (because capital intensity and technical complexity generally go hand in hand). This variable is measured as the ratio of total capital employed to total value of production.

Age of the firm (AG): As a measure of age, we take the number of years the firm has been in production. Following the results obtained by Lall (1983), Siddharthan (1992) and Kumar (1992) indicating that the firms having long span of years in production since its date of incorporation would incur relatively more expenditure on R&D compared to younger firms, we hypothesize a positive relationship between age and R&D intensity. As against that, it may be argued that new, upcoming firms would use better production technology and processes and would therefore spend more on R&D to get the competitive edge making for an inverse relationship between age and R&D intensity.

Ownership dummy (OWD): This variable takes value one for the public sector firms and zero for private sector. A positive relationship of this dummy variable with R&D intensity may be expected on the ground that public sector units are in most cases engaged in production of technologically complex products and therefore require much greater R&D efforts.

Consumer Goods Dummy (CGD): For firms producing consumer goods, this variable is assigned value one and for other firms it is assigned value zero. The coefficient of this dummy variable is expected to be positive as the manufacturers of consumer durable require supportive R&D base for designing their products to suit the consumers' changing taste and match the products coming out of their rival companies. It may be mentioned, however, that in Kumar's (1987) study, the coefficient of this variable has been found to be negative.

Foreign Ownership (FSD): We have used a dummy variable based on the level of foreign ownership in 1989-90. It takes the value one if 25 per cent or more of the firm's equity is held abroad and zero otherwise. The expected sign of the coefficient is negative as in the case of foreign dividend (FD) variable. Clearly, the foreign ownership dummy variable is related to the foreign dividend variable. But, these are not exactly the same.

C) Multiple Regression Results

Let us now turn to the results of multiple regression analysis of the determinants of R&D intensity. As mentioned

earlier, we have estimated regression equvations, for the years 1989-90 and 1994-95 (separately) using cross-section data for the same set of 56 firms for the two years.

To start the discussion of the results, it may be useful to take a look of simple correlation coefficients. Table 6 shows simple correlation coefficients between R&D intensity and the explanatory variables. In most cases, the correlation coefficients are found to be small. Confining attention to the cases where the correlation coefficients are relatively high, R&D intensity is found to have positive correlation with size, degree of foreign ownership, and the dummy variable for the public sector, and negative correlation with the rate of excise duty. The nature of relationships observed in respect of size, public sector dummy and excise duty are in conformity with our hypotheses. The observed positive correlation between R&D intensity and the degree of foreign ownership for both the years comes as a surprise, since a negative relationship was hypothesised.

It may be mentioned here that there is significant inter-correlation among some of the explanatory variables. In some cases, the correlation coefficients are about 0.5 or even higher (for example, between profitability and import intensity, between vertical integration and capital-output ratio and between the two measures of foreign ownership). This no doubt affects the results of multiple regression analysis and creates difficulties in choosing the variables to be included in the regression

equations. Two approaches have been taken in deciding about the variables to be included in the regression equations. In the first approach, we consider the variables for which the simple correlation coefficients between R&D intensity and the explanatory variables are about 0.1 or higher and estimate the regression equation using such variables. Then, the excluded variables are entered into the equation one at a time. If any substantial improvement occurs in the results, the variable is retained in the equation. Two equations estimated respectively for 1989-90 and 1994-95 using this approach are reported in Table 7.

In the second approach, we start by including all the explanatory variables in the regression equation. Then, the variables with low t-ratios are excluded one by one, till we get an equation in which all the explanatory variables have t-ratios above one. The results obtained by the approach are reported in Table 8.

The regression equations presented in Tables 7 and 8 are based on a linear specification and have been estimated by the Ordinary Least Squares (OLS) method. For the estimated equations, tests of heteroscedasticity (based on Breusch-Pagan Chi-Square) were carried out and the problem of heteroscedasticity was detected. Accordingly, the variance-covariance matrix has been corrected for heteroscedasticity.

In the the results presented in Table 7, the coefficient of

the size variable is found to be significant and positive for both 1989-90 and 1994-95. This indicates that the R & D intensity is higher in bigger firms, as we hypothesized. Our results, confirm the results obtained by Braga, et.al (1991) for Brazil and Lall (1983), Siddharthan (1988) and Siddharthan and Aggrawal (1992) for India.

For the excise duty variable, the coefficient is negative and statistically significant for both years. For the public sector dummy variable, the coefficient is positive and statistically significant for both years. These results are in accordance with our hypotheses.

It is interesting to note from the table that the foreign dividend remittance variable (representing the degree of foreign ownership) is a very important determinant of R&D intensity and it bears a positive relationship. This goes against what was hypothesized based on some past econometric research and calls into question the conclusions reached in such studies.

Degree of vertical integration and capital-output ratio are found to be important determinants of R&D intensity (with expected sign of coefficients) in the results for 1989-90. But, these variables had insignificant coefficients when these were included in the equation estimated for 1994-95. It would appear therefore that the importance of these variables as determinants of R&D intensity has declined in the post-reform period.

A negative relationship is found between import intensity and R&D intensity in the results for 1989-90, as hypothesized. The coefficient is, however, not statistically significant. In the equation estimated for 1994-95, this variable was tried, but the results were found to be poor. On the other hand, the age of the firm is found to have a significant positive effect on R&D intensity for 1994-95, but not for 1989-90.

Export intensity, technology import variable, and dummy variables for consumer goods and foreign ownership were tried in the regression equations but none of them were found to have a significant effect on R&D intensity. The dummy variable for foreign equity participation did not work, even when the foreign dividend remittance variable was excluded from the equation to take care of possible multicollinearity.

Turning to Table 8, which reports results based on the second approach discussed above, we find that six variables are common to the two sets of results. These are size, excise duty rate, technology imports, degree of foreign ownership, age and public sector dummy.

The coefficients of size, dividend foreign remittance and public sector dummy are positive and significant in both the years and this is in conformity with our earlier results presented in Table 7. The other three variables viz., excise duty rate, technology imports and age have significant coefficient for one year, but not for the other. In the equation estimated for

1989-90, ratio of Profit before tax to Sales, ratio of value added to production and ratio of total capital employed to value of production are included as explanatory variables. All of them have significant coefficients. But, these variables do not get included in the results for 1994-95 as their respective "t" values were found to be less than 1.0.

One interesting point that emerges from the regression results is that even if a model works quite well for a cross-section of firms for one year, it may not work so well for another year. Although the same model is estimated with variables obtained from the same data sources and defined in the same way, the results of the multiple regression analysis give much better fit for 1989-90, while the fit is relatively poor for the data for 1994-95, as is evident from the value of R^2 and "t" ratios of the coefficients (Tables 7 and 8).

Turning to the differences between the results for the two years, important differences are found in respect of technology imports, profitability, vertical integration and capital intensity. While higher profitability is found to be associated with higher R&D intensity in the results for 1989-90, there is no such relationship in the results for 1994-95. Technology import intensity and R&D intensity are found to be significantly negatively related in the results for 1989-90, but not in the results for 1994-95. Another difference is about the capital intensity variable. A negative relationship is found for 1989-90 but not for 1994-95. Again the coefficient of the vertical

integration variable is significant and positive for 1989-90; but for 1994-95, no such relationship is found.

The differences in results of regression analysis indicate that there have been some important changes in the R&D behaviour of firms in the post-reform period. It is difficult to provide an explanation for the changes in R&D behaviour except to note that the business environment may be changing significantly.

As regards the profit margin being an important determinant factor of R & D in 1989-90 but not so in 1994-95, one possible explanation could be that the investment outlay for R&D projects out of the retained earnings are found to be "risky". In the absence of good and sound venture capital market, the entrepreneurs may prefer to import off-the-shelf technologies from the suppliers abroad. Since, the rules and regulations have been relaxed, they may find it easy and more attractive to import technologies rather than investing on R & D from the retained profit. In short, it is the easier access to foreign technology which has made the relation between profitability and R & D expenditure weaker.

A different line of argument is that in the pre-reform period, R & D was not so crucial for firms' competitiveness and therefore allocation for R & D was dependent mostly on the availability of funds. High profits provided funds for the R & D and the positive relationship between profit margin and R & D expenditure is evident in the analysis. In the post-reform

period with the opening up of the economy, R & D has become more important for the competitiveness of firms, for entering the international market as well as meeting successfully competition from foreign firms in domestic markets. As a result, R & D expenditure becomes necessary for firms and they may be compelled to invest on R & D whether or not they have high profits since profit need not be the only source for R & D expenditure.

Before concluding this section, attention may be drawn to two limitations of the econometric analysis presented above. First, there may be some degree of simultaneity between R&D intensity and some of the explanatory variables (for example, profitability) because of which the OLS results may be biased. Secondly, for a sizeable proportion of firms, the R&D intensity is zero or negligible. This gives rise to an estimation problem because the dependent variable has a lower bound. We have not made any attempt to take care of these econometric estimation problems. It seems to us, however, that even if we had used instrumental variables method or TOBIT model, the results would not have been substantially different.

V. Conclusions

In this paper, an analysis of R&D behaviour of Indian Industrial firms has been undertaken, and a comparison has been made between the pre and post-reform periods. The main conclusions of the study are as follows:

1. It is found from a comparative analysis of R&D intensities of industrial firms that in the post-reform period, contrary to expectations, there has been no general increase in the R&D intensity of industrial firms and the average R&D intensity has not gone up.

2. Firms whose R&D intensity was very low in the pre-reform period have in many cases raised their R&D intensity while the firms which were already spending more than one per cent of their sales on R&D have reduced their R&D intensity on average in the post-reform period. This seems to be reflecting two opposing tendencies - the forces of competition and globalisation inducing firms to undertake more R & D efforts while the easier availability of foreign technology inducing firms to import technology rather than depend on local R&D.

3. Growth of R&D expenditure in the post-reform period has in general been sluggish, and in many cases there has been a decline in real R&D expenditure. But, a small section of industrial firms have responded well to the economic reforms in terms of increased R&D outlay.

4. The analysis of determinants of R&D expenditure has brought out that size and foreign ownership are important determinants of R&D intensity of Indian industrial firms. The results indicate that higher excise duty rate is associated with lower R&D intensity. A negative

relationship is found between technology imports and R&D efforts of the firm. Also, it is found that foreign equity participation in Indian firms encourages R&D expenditure.

5. Comparing the results of regression analysis between pre and post-reform periods, it is found that the relationship between profits and R&D has become weaker in the post-reform period as compared to the pre-reform period. It seems that in the new, emerging situation, the availability of funds is becoming a relatively minor factor in influencing the decision of firms regarding R&D expenditure.

Table 1
Industrial Sector R & D Expenditure by leading industry Groups, 1989-90 and 1992-93

(at 1980-81 prices)

Year/Industry Group	1989-90 (Rs.crore)	1992-93 (Rs.crore)
Electricals and Electronics	68.41	62.55
Defence	63.08	64.93
Metallurgical Industries	38.08	30.86
Drugs and Pharmaceuticals	31.16	38.05
Transportation	27.30	41.82
Fuels	22.36	22.88
Chemicals (other than fertilisers)	40.66	43.17

Source:- Government of India, Department of Science and Technology, *Science & Technology Pocket Data Book*, 1992 & 1993.

Table 2

R & D Intensity of the Leading Industry Groups 1989-90 and 1992-93

Year/Industry Groups	1989-90	1992-93
Electricals & Electronics	1.10	0.74
Defence Industries	4.85	12.63
Metallurgical Industries	0.37	0.28
Drugs and Pharmaceutical	1.45	1.10
Transportation	0.57	0.84
Fuels	0.14	0.11
Chemicals (other than fertilisers)	0.88	0.65

Source:- Same as for the Table 1.
R & D intensity = R&D expenditure as a per cent of sales turnover

Table 3
R & D Intensity of Industrial Firms 1989-90 and 1994-95
(number of firms in different ranges)

Range (per cent)	1989-90	1994-95
0.00 - 0.15	20	18
0.16 - 0.30	12	12
0.31 - 1.00	14	13
1.01 - 2.00	6	10
2.01 - 5.00	4	3
Total firms	56	56

R & D intensity = R & D expenditure as a percent of sales turnover
Note: firms selected among Top 100 firms

Table 4

Changes in R&D Intensity between 1989-90 & 1994-95

Range (%) (as in 1989-90)	Number of firms	Average R&D intensity in 1989-90	Average R&D intensity in 1994-95
0.00 - 0.15	20	0.04	0.22
0.16 - 0.50	14	0.25	0.28
0.51 - 1.00	12	0.69	0.74
1.01 & above	10	2.27	1.78
all firms	56	0.63 (0.95)	0.62 (0.89)

Note: (1) Standard deviations in parentheses
(2) Firms are classified according to their R & D intensity in 1989-90. For the same set of firms average R & D intensity is computed for 1989-90 and 1994-95.

Table 5

Increase in Real R&D Expenditure in Industrial Firms Between 1989-90 and 1994-95

Ratio of R & D expenditure in 1994-95 to that in 1989-90	Number of firms
Below 1.00	35
1.00 to 2.00	12
2.01 to 3.00	4
3.1 & above	5
Total	56

Note: R & D Expenditures have been deflated to bring them at 1980-81 prices.

Table 6

Correlation Coefficients between R&D intensity and Explanatory Variables

Explanatory variables	for 1989-90	for 1994-95
Size (Sales)	0.203	0.226
Central Excise Duty to Sales	-0.138	-0.094
Value of Exports to Sales	0.037	-0.020
Value of Imports to Sales	-0.110	-0.032
Profit before Tax to sales	-0.038	-0.015
Payments of Technical Fee, and Royalty, etc., to sales	0.051	-0.065
Value added to value of production	0.100	0.050
Dividend Foreign remittance to total dividend pay-out	0.248	0.015
Total capital employed to value of production	-0.097	-0.031
Age	-0.017	0.122
Dummy variable Ownership (Public Sector)	0.153	0.157
Consumer goods	-0.025	0.039
Foreign Equity Participation	0.156	0.038

Table 7
Regression Results: Determinants of R&D Intensity in Indian Industries

n = 56

Explanatory variables	Estimated Equation for 1989-90	for 1994-95
Size (Sales)	0.267(b) (2.335)	0.489(b) (2.244)
Central Excise Duty to Sales	-0.031(c) (-1.896)	-0.021(c) (-1.684)
Value of Export to Sales		
Value of Imports to Sales	-0.016 (-1.153)	
Profit before Tax to Sales	0.021(c) (1.931)	
Payments of Technical Fee, Royalty etc. to Sales		
Value added to value of production	0.044(a) (2.596)	
Dividend Foreign remittance to Total Dividend pay-out	2.741(a) (4.125)	2.493(a) (4.653)
Total capital employed to value of production	-0.011(a) (-3.180)	
Age - Number of years in production from the date of incorporation		0.011(c) (1.706)
Dummy variables Ownership (Public Sector)	0.566(b) (2.207)	0.545(c) (1.642)
Consumer goods		
Foreign Equity Participation		
Constant	-0.957	-1.288
R^2	0.326	0.172
F	2.835	2.087

Note "t" statistics are in parentheses, superscript indicates the level of significance

a = 1 per cent
b = 5 per cent
c = 10 per cent

Variance-Covariance matrix has been corrected for heteroscedasticity

Table 8

Regression Results: Determinants of R&D Intensity in Indian Industries

n = 56

Explanatory variables	Estimated Equation	
	for 1989-90	for 1994-95
Size (Sales)	0.342(a) (2.771)	0.495(b) (2.313)
Central Excise Duty to Sales	-0.034(b) (-1.969)	-0.020 (-1.592)
Value of Export to Sales		
Value of Imports to Sales		
Profit before Tax to Sales	0.013(b) (1.975)	
Payments of Technical Fee, Royalty etc. to Sales	-0.355(b) (-2.024)	-0.164 (-1.298)
Value added to value of production	0.048(b) (2.523)	
Dividend Foreign remittance to Total Dividend pay-out	3.023(a) (4.316)	2.578(a) (4.848)
Total capital employed to value of production	-0.012(a) (-3.095)	
Age - Number of years in production from the date of incorporation	-0.006 (-1.113)	0.011(c) (1.680)
Dummy variables Ownership (Public Sector)	0.479(b) (2.262)	0.554(c) (1.659)
Consumer goods		
Foreign Equity Participation		
Constant	-1.072	-1.266
R2	0.333	0.180
F	2.550	1.796

Note "t" statistics are in parentheses, superscript indicates the level of significance

a = 1 per cent
b = 5 per cent
c = 10 per cent
Variance-Covariance matrix has been corrected for heteroscedasticity.

Summary of the Results of the Earlier Studies

There have been a number of econometric studies on the determinants of R&D expenditure of the industrial firms in India. The earliest work in this area was done by Lall (1983). Lall used R&D intensities of firms (ratio of R&D expenditure to sales) as the dependent variable. Among the explanatory variables, he included firm size, age of the firm, foreign equity participation, number of foreign licensing agreements entered into by the firm, royalties and lumpsum payment made and export intensity. The regression results of the study indicated a significant positive relationship between R&D intensity and firm size and technology imports, However, a negative relationship was found between R&D intensity and export intensity contrary to what the author postulated.

Katrak (1985 and 1989) examined the influence of imported technology and firm size on R&D activity of industrial firms in India. The result indicated a positive relationship between size of the firm and R&D efforts and also between imports of technology and R&D efforts. The coefficient of the size variable indicates that the R&D intensity increases with increase in firm's size, in conformity with the findings of Lall(1983).

Katrak (1990) in his paper has emphasised the point from his results that the technology imports and R&D intensity are related positively if the firm is export oriented, otherwise

relationship is negative. Conditional acceptance of foreign know-how only for producing domestic market according to his results is not conducive to the growth of technological knowledge in the importing firms.

Kumar (1987) in his study points out that the technology imports via foreign direct investment has negative influence on R & D efforts (substitution effect), while the licensing mode of technology imports has a significant positive influence (complementary) on R&D intensity. Kumar and Saquib (1992) have used the probit and tobit model to study the inter-firm differences in R&D intensity. The reported results are somewhat different from those of Siddharthan and Aggarwal, (1992). They found that the probability of a firm undertaking R&D activity increase with a firm size to a threshold level beyond which it declines. The extent of export orientation is found to influence firm's decision favourably to set up R&D units.

Basant (1993) in his working paper used the firm level data of 912 manufacturing firms compiled by Institute for Studies in Industrial Development (ISID), New Delhi from an annual reports of the public limited companies. For some of these firms, data are available for six years (1974-75 to 1979-80) and for others nine years (1974 to 1982-83). The overall sample has 6354 observations. The OLS estimates of regression equations with dependent variables as R&D expenditure show that the variables in respect of foreign technology licensing expenses and other variables such as capital goods imports dummy, other imports

dummy, R&D embodied domestic inputs are all negatively related to R&D expenditure of the firm and the coefficients are statistically significant. On the other hand, the variables relating to domestic technology spill-overs, multinational companies participation dummy and the industrial licensing policy of the Indian Government are all positively related to the R&D expenditure of the firm.

Siddharthan (1988) in his paper finds the complementary relation between import of technology and domestic R&D expenditure. Further his results indicate for smaller firm's R&D expenditure increases slower than the firm size but for very large firms (by Indian standard) R&D intensity increases faster than the increase in size of the firm.

Siddharthan and Aggarwal (1992) in their analysis, used the limited dependent variable model as used by Kumar and Saquib (1992) to study the determinants of R&D activity. Siddarthan and Aggarwal in their paper made distinction between the decision of a firm to start an R&D (a zero one decision) and the second decision regarding the amount to be spent on R&D. To analyse the first decision, they used probit model for a sample that included both firms having R&D units and firms not having one. To study the second decision, they considered only the former group of firms and applied multiple regression analysis.

From the result of the probit model, the authors found a positive influence of firm size on the probability of the Indian

firm investing in R&D but the results of the regression analysis brought out an inverse relationship between the size and R&D intensity indicating economies of scale advantages.

From the brief discussion on the results of the earlier studies, it is seen that there have been diverse findings on the relationship between firm size and R&D intensity. Some find positive, while some others find an inverse relationship between size and R&D intensity. Interestingly one finds the relationship to be "U" shaped.

Mention should be made here to certain econometric aspects of the studies. Though all the studies on the subject are based on the cross-sectional data the authors have paid scant attention to the problem of heteroscedasticity. It should be noted that for many firms the R&D ratio is negligible or zero. If such firms are involved in the sample to be considered for estimating the regression equation, then estimation problems are caused by the fact that the dependent variable has a lower bound. If such firms are excluded, then the results get affected by sample selection bias. An appropriate method to tackle this problem is to use a tobit model as has been done by Kumar and Saquib (1992).

REFERENCES

Basant R (1993) "R&D, Foreign Technology Purchase and Technology Spillovers in Indian Industry: Some Explorations UNU/INTECH, Working Paper No.8

Ghayur,Alam (1993) Research and Development by Indian Industry: A Study of the Determinants of its Size and Scope, Centre for Technology Studies, Mimeo.

Galbraith,J.K(1972) The New Industrial Estates(2ndEdn.) (London,1972)

Hay, A. Donald,et.al (1991) Industrial Economics and Organisation: Theory and Evidence (Oxford University Press)

Helson Braga and Larry Willmore (1991) "Technological Imports and Technological Effort: An Analysis of their determinants in Brazilan Firms", The Journal of Industrial Economics Volume xxxix, Number 4, (June)

Katrak,Homi (1985) "Imported Technology, Enterprise Size and R&D in a Newly Industrialising Country: The Indian Experience" Oxford Bulletin of Economics and Statistics. 47(3), 213-229

..... (1989) "Imported Technologies and R&D in a Newly Industrialising Country: The experience of Indian enterprises Journal of Development Economics, Vol. 31 (July); 123-139

..... (1990) "Imports of Technology and Technological Effort of Indian Enterprises" World Development 18, 317-81

Kathuria.S (1989) "Market Structure and Innovation - A Survey of Empirical Studies of Schumpeterian Hypotheses for Developed Countries and India" Economic & Political Weekly, August 26, Volume xxiv (34) M 113-25

Kumar,Nagesh (1987) "Technology Imports and Local Research and Development in Indian Manufacturing" The Developing Economies,25(3), 220-233

Kumar,Nagesh (1992) "Schumpeter, Opportunities for Adaptation and in-House R&D Activity in a Developing Country: The Indian Experience"- mimeo.

Lall, S (1983) "Determinants of R&D in a LDC: The Indian Engineering Industry" Economic Letters 13(4), 379-383

Raut, L.K. (1988) "R&D Behaviour of Indian Firms: A Stochastic Control Model" Indian Economic Review, XXIII No.2, 207-227

Siddharthan, N.S. (1988) "In-house R&D, Imported Technology Firm Size: Lessons from the Indian Experience", The Developing Economies xxvi-3 (September) 212-221

Siddharthan, N.S Agarwal, R.N. (1992) "Determinants of R&D Decisions: A Cross Section Study of Indian Private Corporate Firms" Economics of Innovation and New Technology, Volume 2, Number 2, 103-110

Other Publications

Confederation of Indian Industries (CII) Top Hundred Engineering Companies (1989 and 1994)

India Investment Centre (IIC) List of Foreign Collaborations Approved (1991, 1992 and 1993)

Government of India, Department of Science and Technology (DST) Science and Technology Pocket Data Book (1991, 1992 and 1993)

..... Research and Development in Industry (1992 and 1993)