RD strategy of small and medium enterprises in India: Trends and determinants

Pradhan, Jaya Prakash

Sardar Patel Institute of Economic Social Research

24 February 2010

R&D Strategy of Small and Medium Enterprises in India
Trends and Determinants

Jaya Prakash Pradhan

Version 1.0: 24th February 2010.

Sardar Patel Institute of Economic & Social Research (SPIESR)
Thaltej Road, Near Doordarshan Tower,
Ahmedabad, 380 054, Gujarat.
Phones: (079) 26850598, 26851428.
Fax: (079) 26851714
E-mail: pradhanjayaprakash@gmail.com

Acknowledgement: The author is thankful to Geir W. Gustavsen, Sachin Chintawar, Thorsten Doherr and Neelam Singh for their useful discussions and interactions while conducting this study. However, the usual disclaimer applies.

Contents

List of Tables

List of Figures

R&D Strategy of Small and Medium Enterprises in India
Trends and Determinants

Abstract: The liberalization of economic policies in the last two decades and intensifying market competition tends to be a cause of policy concern for the survival of SMEs in emerging economies like India as these firms accounts for the largest chunk of industrial units and employment. Given their limited financial and intangible resources, the promotion of R&D among SMEs has become a very important policy parameter. The aim of this paper is to contribute to the literature on Indian R&D by analyzing the trends and patterns of R&D investment by Indian manufacturing SMEs during the period 1991−2008 and exploring various factors that determine their R&D behaviour. The results show that Indian SMEs have lowest incidence of doing in-house R&D and their R&D intensities have fallen in the last decade. A number of factors that play important role in determining SME R&D have been identified based on the three steps Censored Quantile Regression and some useful policy implications are suggested for enhancing R&D activities of small firms.

Key Words: SMEs; R&D; Business Groups; Foreign Firms.
JEL Classification: L11; 031; 032; L22; F23.

1. Introduction

In the ongoing globalization process of national markets, the role of technological capabilities becomes critical for firms' survival and growth. The disappearance of inward FDI and import barriers that once protected national markets and the introduction of product patent regime recently have vastly expanded the strategic role of technology in the evolving competitive environment of national markets. While the large firms are well positioned to face these globalizing competitive challenges with their better strategic asset bundle, the resource-starved small and medium enterprises (SMEs) are expected to be at greater risks (Etemad, 2004; Pradhan and Sahu, 2008).

It is no longer feasible for SMEs in emerging economies like India to use the competitive strategy of reverse engineering and innovative cost-effective processes to survive under the new technology policy regime. They also cannot take refuge in policy protection as current economic openness policies saw the removal of special treatment to SMEs in industrial policies like exemption from price controls, product reservation, preference in government procurement, etc. Therefore SMEs are required to develop or acquire necessary competitive resources like new technologies to compete with large national firms, foreign firms and cheap imports. Rapidly changing consumer preferences, shorter product life cycle and growing quality consciousness clearly call for SMEs to upgrade their technological assets.

In the above background this study concentrates on the in-house R&D activities of Indian manufacturing SMEs during the period 1991−2008. Since R&D is required not only to develop distinctive technological competencies but also to successfully absorb external technologies, the analysis of their trends and patterns will be helpful in drawing policy implications for strengthening the vital SME sector. The existing firm-level studies on industrial R&D patterns in India rarely differentiated between large firms and SMEs because the latter group did negligible R&D in the past coupled with problem of unavailability of required data and lack of definition on medium firms hitherto October

2006. In most cases while discussing the issue of firm size the empirical literature concentrated on identifying the linear or non-liner relationship between firm size and R&D intensity among relatively large Indian firms (e.g. Lall, 1983; Katrak, 1985; Siddharthan, 1988, 1992; Basant, 1997; Pradhan, 2002; Kumar and Aggarwal, 2005, Kathuria, 2008). There are, of course, a few exploratory and survey based studies on innovation issues by Indian SMEs (Sikka, 1999; Kharbanda, 2001; Kacker, 2005; Sahu, 2008) and one statistical study at the sectoral level (Bala Subrahmanya, 2006).

This paper depart from existing studies in that it estimate the size and intensity of R&D investment of Indian manufacturing SMEs across different sectors and undertake quantitative analysis of the factors that determine R&D intensity variation of Indian manufacturing SMEs.

2. R&D Investments by Indian Manufacturing SMEs

In India the official source for industrial R&D statistics is the Department of Science and Technology (DST). However, this source of information is known to hugely underestimate the actual R&D investment as the primary survey is limited to just R&D units recognized by the DSIR (Department of Scientific and Industrial Research) (Alagh, 1998). Many Indian firms, especially SMEs stay away from obtaining such recognition as it involves a fixed cost associated with application, officials' visits to the in-house R&D unit, maintenance of distinct identity of the unit with separate R&D account and that also for a recognition that is valid for a very short period ranging 1 to 3 years. For example, Bhattacharya et al. (2007) could identify as many as 1208 R&D incurring public limited firms that were not part of the official survey in 2002−2003 because these firms' R&D units are not recognized by the DSIR. Moreover, this source do not segregate private sector R&D by firm size.

Given the above limitation of the official source, the present study draws upon the recently updated Prowess database of the Centre for Monitoring Indian Economy (2009). This dataset contains financial information on over 9200 manufacturing firms, of which a set of 4071 Indian manufacturing SMEs could be identified. As per the Micro, Small and Medium Enterprise Development (MSMED) Act, 2006, a manufacturing enterprise with an investment in plant and machinery up to Rs. 5 crore is defined as small firm; an investment of above Rs. 5 crore and up to Rs. 10 crore is defined as medium size firm; and an investment above Rs. 10 crore is taken as large firm. Since the dataset has an unbalanced panel structure providing for entry and exit of firms during 1991−2008, firm-specific latest year data on cumulative investment in plant and machinery has been used.

2.1. Overall Trends

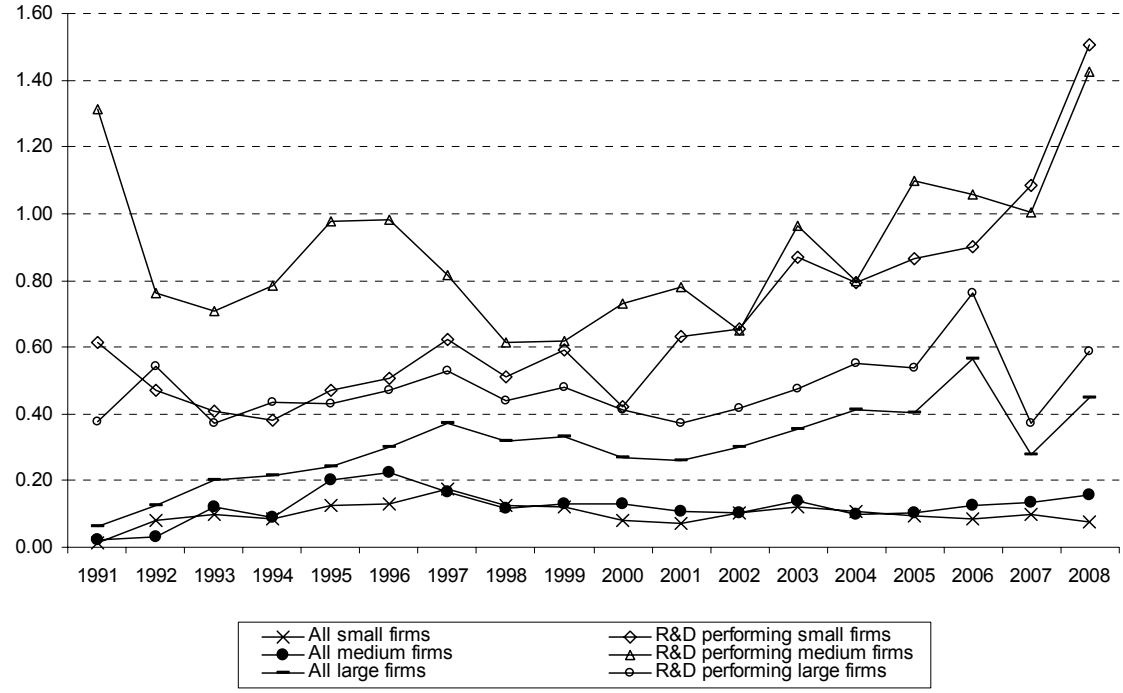
The trends of R&D performance of Indian manufacturing firms across different sizes have been presented in Figure-1 and Table-1. It is apparent that Indian manufacturing firms in general are characterized by a very low incident of incurring in-house R&D and where they spend, the intensity of such activities is very weak. For instance, just about 38 per cent of the total number of large firms in the sample reported R&D expenses for at

least single year during 1991−2008. This share slides to 16 per cent and 8.5 per cent for medium firms and small firms respectively. The period average R&D intensity — R&D as a per cent of sales — for these groups of firms falls below even 0.5 per cent.

For the small firms as a group, the R&D performance has been very poor. The number of R&D doing small firms is not responsive to the increase in the total number of small firms in the sample. In fact, the elasticity of the number of R&D doing firms to total number of firms in the case of small firms has fallen from 0.082 in 1991−99 to 0.045 in 2000−08. As a result of large number of small firms not doing R&D, the overall intensity of all small firms is very small at 0.1 per cent. The elasticity of R&D expenses to total sales of these small firms, which was 2.53 in 1990s, fell to 0.94 in 2000s. The R&D intensity of small firms as a group declined in 2000s following a period of consistent growth from 1991 to 1997 (Figure-1). The average R&D intensity of small firms experienced a 21 per cent fall from 0.12 per cent in 1991−99 to 0.09 per cent in 2000−08. This falling R&D intensity of small firms is a clear concern for policy makers interested in strengthening the capacities of small firms to meet the globalization process.

Figure-1 R&D Intensity of Indian Manufacturing Firms, 1991−2008

(Percent)



Source: Same as Table-1.

Table-1 R&D Performance of Indian Manufacturing Firms over Sizes, 1991−2008

(Number, Percent)

Year	Small Firms					Medium Firms					Large Firms				
	Number			R&D Intensity (%)		Number			R&D Intensity (%)		Number			R&D Intensity (%)	
	All	R&D-doing	% share of R&D firms	All	R&D-doing	All	R&D-doing	% share of R&D firms	All	R&D-doing	All	R&D-doing	% share of R&D firms	All	R&D-doing
1991	426	10	2.35	0.01	0.61	234	6	2.56	0.02	1.31	1,436	52	3.62	0.064	0.375
1992	512	30	5.86	0.08	0.47	278	13	4.68	0.03	0.76	1,582	173	10.94	0.126	0.544
1993	701	51	7.28	0.10	0.41	357	33	9.24	0.12	0.71	1,799	361	20.07	0.201	0.374
1994	1013	57	5.63	0.09	0.38	481	36	7.48	0.09	0.78	2,150	449	20.88	0.217	0.436
1995	1367	94	6.88	0.13	0.47	584	69	11.82	0.20	0.98	2,347	579	24.67	0.241	0.431
1996	1419	108	7.61	0.13	0.51	592	71	11.99	0.23	0.98	2,341	629	26.87	0.301	0.471
1997	1265	102	8.06	0.17	0.62	547	67	12.25	0.17	0.82	2,310	730	31.60	0.374	0.527
1998	1264	90	7.12	0.13	0.51	535	60	11.21	0.11	0.61	2,381	735	30.87	0.317	0.438
1999	1455	88	6.05	0.12	0.59	583	68	11.66	0.13	0.62	2,596	737	28.39	0.333	0.477
2000	1514	83	5.48	0.08	0.42	611	72	11.78	0.13	0.73	2,682	704	26.25	0.268	0.411
2001	1472	74	5.03	0.07	0.63	603	61	10.12	0.11	0.78	2,669	693	25.96	0.260	0.371
2002	1558	96	6.16	0.10	0.66	603	64	10.61	0.10	0.65	2,691	816	30.32	0.302	0.417
2003	1898	102	5.37	0.12	0.87	676	72	10.65	0.14	0.96	2,871	855	29.78	0.353	0.475
2004	2121	98	4.62	0.11	0.79	667	67	10.04	0.10	0.80	2,830	853	30.14	0.413	0.553
2005	2063	82	3.97	0.10	0.87	615	50	8.13	0.10	1.10	2,709	804	29.68	0.403	0.539
2006	1704	66	3.87	0.09	0.90	553	47	8.50	0.13	1.06	2,602	784	30.13	0.563	0.762
2007	1308	56	4.28	0.10	1.08	445	47	10.56	0.14	1.00	2,414	773	32.02	0.278	0.372
2008	1116	43	3.85	0.08	1.51	394	41	10.41	0.16	1.42	2,244	747	33.29	0.449	0.585
All years	4006	339	8.46	0.10	0.65	1231	199	16.17	0.13	0.90	4,006	1512	37.74	0.358	0.508

Note: For all years, the figure for number of firms is obtained by single counting of a firm during 1991−2008 (i.e. eliminating its multiple entries over different years) and the figure for R&D firms is arrived at by single counting of a firm even if it has done R&D for just one year.

Source: Estimation based on Prowess Database (2009), CMIE.

As compared to small firms, medium firms have relatively better incidence of undertaking in-house R&D. The number of R&D doing firms accounted for 16 per cent of total number of firms for medium enterprise, double that of small firms. However, the number of R&D doing medium firms also emerged as not so reactive to the increasing number of medium firms in the sample[1]. Moreover, R&D intensity of medium firms as a group continued to be below 0.2 per cent in the overall period and it has gradually declined in the period 1996–2004 following a brief period of growth in the early 1990s (Figure-1). On a decadal basis medium firms' R&D intensity fell by 10 per cent in 2000–2008 to 0.13 per cent, from 0.14 per cent in 1991–1999.

In contrast, large firms' R&D intensity has generally been increased over 1991–2008. It has grown by 39 per cent from 0.27 per cent in 1990s to 0.38 per cent in 2000s. The R&D intensity of large firms not only exceeded that of SMEs throughout the study period, but the gap has only increased over time (Figure-1). Overall R&D intensity and proportion of R&D doing firms is greater for large firms.

These trends suggests that R&D activities of Indian SMEs, which went through a major push in 1991–1997 triggered by the competitive effects of economic openness policies, seems to have slowed down markedly in 2000s. Large firms continue to expand the intensity of their R&D activities while SMEs experience contraction in R&D intensity in the last decade. This shows that SMEs as a whole are not able to sustain their R&D activities unlike their large counterparts. Since a disproportionately larger proportion of SMEs doesn't do R&D and possess a very low level of R&D intensity, downward trends in their R&D intensities is likely to increase vulnerability of these firms to competitive pressure and further reduce their survivability in the long run.

As the proportion of R&D doing firms vary greatly over firm sizes, the overall R&D intensity is substantially depressed by higher proportion of firms not doing R&D for SMEs. Therefore, it will be interesting to analyze R&D behaviour of the sub-sample of R&D doing firms across different firm sizes. How R&D doing SMEs did as compared to R&D doing large firms? Unlike negative findings that emerged from the overall sample (that includes both R&D-doing SMEs and R&D not doing SMEs), this sub-sample analysis provides a different picture altogether.

In this sub-sample, R&D intensities of SMEs have consistently been higher than that of large firms, except for two years in the case of small firms. The R&D intensities of SMEs incurring R&D expenses have generally increased in 2000s to reach 1.5 per cent in 2008, nearly twice that of R&D doing large firms (Figure-1, Table-1). Especially since early 2000s, there is a general widening of the gap in R&D intensity of small firm (medium firms) incurring R&D and that of large firms. These trends along with previous findings obtained from the full sample provide a number of stylized facts about manufacturing R&D in India. They can be summarized as follows:

[1] The elasticity of the number of R&D doing firms to total number of firms for medium enterprises declined from in 0.178 in 1991−99 to 0.101 in 2000−08.

(i) Indian SMEs have a lower probability of doing R&D as compared to their large counterparts. A very small proportion of total SMEs undertake in-house R&D.

(ii) As a corollary of the above fact, SMEs as a group substantially lagged behind large firms in terms of allocating resources for R&D relative to sales. The R&D intensity goes down as one move from large firms to medium firms to small firms.

(iii) R&D doing SMEs are way ahead in R&D intensity than R&D doing large firms. Therefore, general belief that Indian SMEs lagged behind large firms in doing in-house R&D is valid at the overall group level but not at the sub-sample of R&D incurring firms. Indian SMEs have lower probability of incurring R&D but once they adopt R&D, they put more resources relative to their sales than well-endowed large firms. This fact is not unique to Indian SMEs but has been observed for SME R&D behaviour for many other countries (Freeman and Soete, 1997).

(iv) SME R&D in Indian manufacturing is increasingly getting concentrated among a small group of R&D doing SMEs in the last decade. This is reflected in facts like non-improving proportion of R&D incurring firms in the total number of SMEs and discouraging trend of their R&D intensity as a group while sub-sample of R&D incurring SMEs are aggressively pushing up their in-house R&D activities.

This low incidence of R&D among SMEs and growing concentration within them, therefore, don't corroborates the general expectation that large number of Indian SMEs will undertake R&D due to policy liberalization and heightened market competition.

2.2. SME Ownership and R&D

The patterns of R&D could vary widely by different types of SMEs based on ownership groups. A total of four types of SMEs can be distinguished — (i) domestic private-owned SMEs (promoted by standalone domestic investor), (ii) domestic private-owned group affiliated SMEs (owned by investors affiliated to large domestic business groups), (iii) foreign-owned SMEs (have foreign investors as promoters or controlling shareholders) and (iv) public-owned (having central government, state government, local bodies, joint or cooperative entities as shareholders).

Theoretically, these SME groups are expected to have different R&D dynamics. SMEs affiliated to large business groups have access to a common pool of financial and non-financial resources, benefit from operational complementarities and leverage the inter-affiliate networks of information and knowledge. These SMEs have greater financial strength and access to complementary technological information from other affiliates within the group to have superior R&D performance. These benefits don't exist for standalone SMEs. Foreign investments in SMEs may or may not differentiate their R&D from those of SMEs without foreign investors. Since SMEs affiliated to foreign firms have access to parents' pool of technological assets and skills there is less need for in-house R&D. However, the successful transfer of technologies from foreign parent to Indian SMEs may still require adaptive R&D given the local factor and demand conditions. It is not clear though if such adaptive R&D of

foreign owned-SMEs will be greater than R&D undertaken by domestic-owned SMEs. The presence and absence of public ownership may also differentiate the R&D performance among Indian SMEs.

The structure and features of India SME R&D over these four ownership groups is summarized in Table-2. One of the key features is that the group affiliated firms have been the largest source of SME R&D in Indian manufacturing during the last two decades, contributing nearly half of the total. Roughly another 40 per cent of SME R&D has been conducted by standalone domestic SMEs, followed by 10 per cent share of SMEs with foreign investment. SMEs affiliated to public sector accounted for negligible proportion in the case of total R&D of small firms (0.15 per cent) and a low share of 3 per cent in the case of total R&D of medium firms.

The SME R&D has undergone shift in its structure during 1991−2008. There has been a significant rise in the R&D contribution form standalone domestic SMEs. The share of standalone firms in total R&D become more than doubled to 55 per cent in 2005−2008 from a low of 23 per cent in 1991−1994 for small firms. This share for medium firms increased from 27 per cent to 37 per cent between the corresponding periods. It can be seen that the shares of business group affiliated and foreign-owned firms have declined in SME R&D. These structural changes show that standalone Indian SMEs, which have no access to technological resources of business groups or foreign investors, are upgrading the scale of their R&D activities to meet the growing market competition. This has been particularly so for standalone medium firms.

Another aspect that is quite noticeable is the real jump in SME R&D came in the latter half of 1990s. The R&D expenses by Indian small manufacturing firms grew by 338 per cent between 1991−1994 and 1995−1999 from Rs. 325 million to Rs. 1426 million. This growth is higher for medium firms at 440 per cent. Since early 2000s, the trend in growth in SME R&D is negative.

The analysis of R&D intensities of different SME groups during 1991−2008 shows that SMEs with foreign investment tends to have highest R&D intensities (0.18 per cent and 0.32 per cent respectively for small firms and medium firms), followed by group affiliated SMEs (0.16 per cent and 0.24 per cent correspondingly). The R&D intensity of standalone private small firms is higher than that of public-owned small firms but standalone private medium firms did poorly as compared to public-owned medium firms. Among all the categories of firms, group affiliated medium firms have consistently pushed up their R&D intensities over different periods since early 1990s. All other domestic and privately owned SMEs have generally witnessed sharp rise in their R&D intensities only between the early and the late 1990s. It appears that the positive impact of implementation of economic reforms on Indian SMEs has been effective in the late 1990s but taper off in the subsequent periods.

Table-2 SME R&D by Ownership

(Rs. Million, Percent, Number)

A. R&D Expenses (Rs. Million)

Period	Domestic Private		Foreign-owned	Public sector	Total
	Standalone	Group Affiliated			
Small Firms					
1991−94	75	185	62	3	325
	(23.15)	(56.99)	(18.94)	(0.92)	(100)
1995−99	370	949	103	3	1426
	(25.97)	(66.54)	(7.25)	(0.24)	(100)
2000−04	679	610	98	0	1387
	(48.97)	(43.97)	(7.06)	(0.00)	(100)
2005−08	669	372	177	0	1217
	(54.95)	(30.55)	(14.50)	(0.00)	(100)
All years	1794	2116	439	6	4356
	(41.18)	(48.58)	(10.09)	(0.15)	(100)
Medium Firms					
1991−94	48	93	26	10	176
	(27.02)	(52.84)	(14.68)	(5.46)	(100)
1995−99	329	425	156	39	949
	(34.61)	(44.79)	(16.48)	(4.12)	(100)
2000−04	379	486	113	26	1005
	(37.70)	(48.42)	(11.29)	(2.59)	(100)
2005−08	545	706	97	29	1377
	(39.60)	(51.26)	(7.03)	(2.11)	(100)
All years	1300	1710	392	104	3506
	(37.07)	(48.78)	(11.19)	(2.96)	(100)

B. R&D Intensity (%)

Period	Domestic private		Foreign-owned	Public sector	Total
	Standalone	Group Affiliated			
Small Firms					
1991−94	0.049	0.087	0.183	0.009	0.075
1995−99	0.076	0.204	0.158	0.009	0.135
2000−04	0.077	0.149	0.111	0.000	0.098
2005−08	0.065	0.133	0.284	0.000	0.088
All years	0.070	0.155	0.176	0.005	0.102
Medium Firms					
1991−94	0.046	0.092	0.101	0.114	0.074
1995−99	0.106	0.202	0.481	0.316	0.168
2000−04	0.062	0.240	0.285	0.193	0.116
2005−08	0.067	0.378	0.398	0.251	0.133
All years	0.071	0.244	0.321	0.226	0.130

Note: Classification of these four groups of SMEs is as per the Prowess information; Firms for whom exact ownership group is not available were excluded; While calculating R&D intensity both R&D incurring and not incurring firms are included; Figures in parenthesis are percentage shares to the total.

Source: Same as Table-1.

2.3. Industry Trends of SME R&D

The R&D investment by Indian SMEs is observed to be sectorally concentrated. The top four industries, namely chemicals & chemical products, electrical & optical equipment, drugs & pharmaceuticals and machinery & equipment account for as much as 80 per cent of the total SME R&D in 1990s, which went up further to 88 per cent in 2000s (Table-3). These industries remain the top R&D contributing sectors for all the sub-periods across small firms and medium firms. This sectoral concentration is not just unique to Indian SMEs but a global phenomenon observable for many OECD countries (National Science Foundation, 2008). Partly this concentration merely reflects technological character of different sectors and the more technology-intensive a sector is the more is its R&D share. However, the low R&D share of transport equipment does raise concerns as India is presumed to have been successful in creating competitive advantage in this sector.

To a greater extent higher SME R&D intensities are confined to technology intensive sectors. In 2000−08, the highest R&D intensive SMEs came from chemicals with 0.34 per cent of R&D intensity, followed by pharmaceuticals (0.28 per cent), electrical & optical equipment (0.27 per cent), machinery & equipment (0.2 per cent), coke & petroleum products (0.16 per cent) and transport equipment (0.1 per cent). This pattern of inter-industry distribution of Indian SME R&D is quite similar to global distribution of R&D across manufacturing sector (Figure-2). There is, however, concerns over marginal proportion of sales that Indian SMEs from these knowledge-based sectors are spending in comparison to their global competitors from developed countries. During 1995−2002, the R&D intensity of Indian SMEs in chemicals, pharmaceuticals, machinery, electrical equipment, transport equipment and petroleum products respectively found to be 20-, 28-, 24-, 27-, 18-, and 19-times lower than those of firms from G7 countries.

In addition to possessing a very low scale of R&D across strategic sectors, Indian SMEs' R&D intensity further dwindled between 1990s and 2000s: the most significantly in transport equipment (-50 per cent), followed by pharmaceuticals (-31 per cent), machinery & equipment (-12 per cent) and relatively less in electrical & optical equipment (-2 per cent). Decline in R&D intensity between these two periods is also reported by SMEs from basic metal, food, paper, non-metallic mineral products, miscellaneous and diversified manufacturing activities. In spite of Indian SMEs from so many industries have reduced their R&D investment as a proportion of sales, it is interesting to note that Indian SMEs from chemicals and coke & petroleum products have significantly improved their R&D intensity in 2000s.

Table-3 R&D Intensity of Indian Manufacturing SMEs by Sectors, 1991−2008

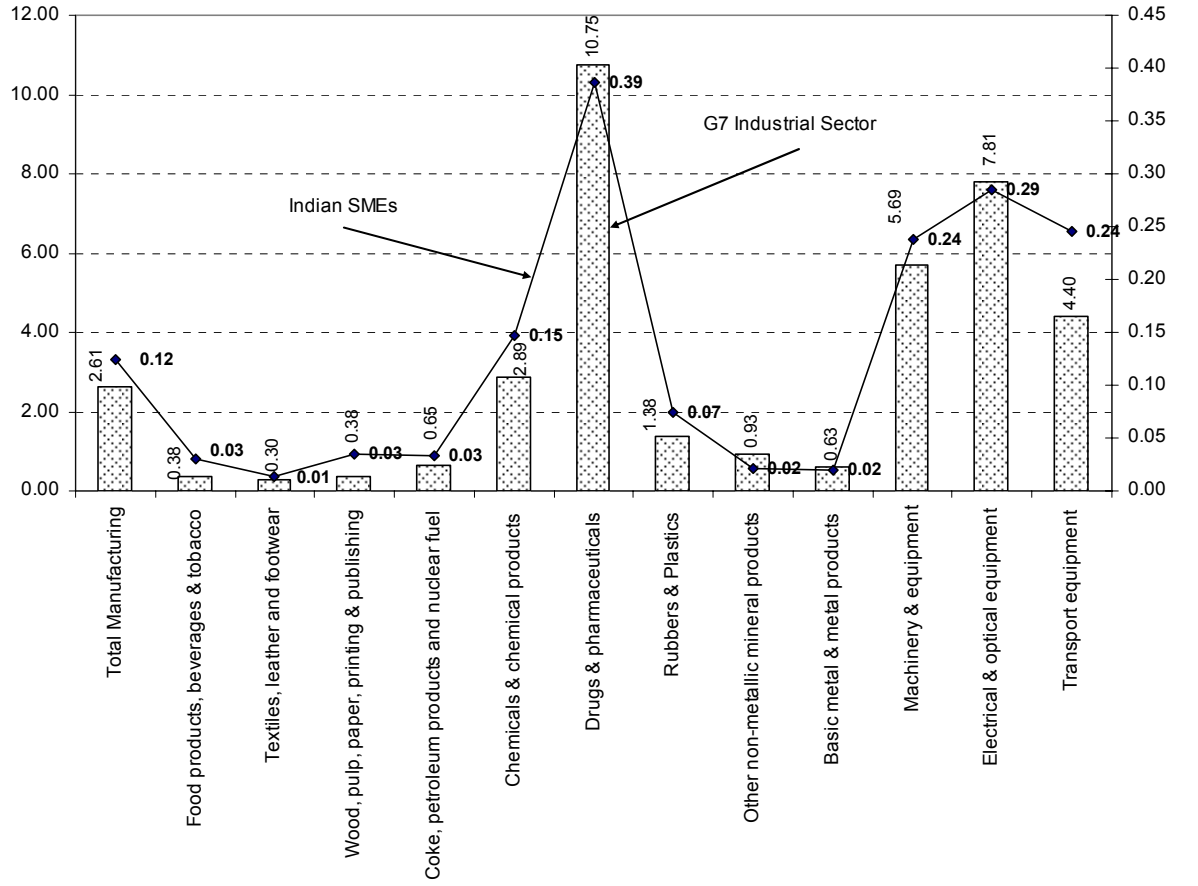
(Percent)

Industry	Small Firms			Medium Firms			Total SMEs		
	1991−99	2000−08	Growth	1991−99	2000−08	Growth	1991−99	2000−08	Growth
Basic metal & metal products	0.03 (3.62)	0.00 (0.56)	-85.4	0.06 (5.63)	0.01 (1.26)	-78.4	0.04 (4.40)	0.01 (0.89)	-80.3
Chemicals & chemical products	0.12 (18.07)	0.24 (27.17)	104.7	0.09 (7.79)	0.49 (33.16)	430.8	0.11 (14.05)	0.33 (30.03)	196.9
Coke & petroleum products	0.10 (0.65)	0.23 (3.73)	138.7	0.06 (0.26)	0.01 (0.08)	-84.3	0.09 (0.49)	0.16 (1.98)	88.3
Diversified	0.09 (2.34)	0.03 (0.25)	-64.6	0.00 (0.00)	0.00 (0.00)		0.08 (1.42)	0.03 (0.13)	-58.4
Drugs & pharmaceuticals	0.30 (24.58)	0.23 (26.31)	-25.4	0.66 (29.93)	0.47 (14.98)	-29.1	0.40 (26.67)	0.28 (20.90)	-30.8
Electrical & optical equipment	0.25 (18.39)	0.27 (28.99)	8.1	0.29 (29.73)	0.26 (21.10)	-12.2	0.27 (22.82)	0.27 (25.23)	-1.9
Food products, beverages & tobacco	0.05 (5.85)	0.01 (1.27)	-86.9	0.02 (2.07)	0.01 (1.13)	-59.2	0.04 (4.37)	0.01 (1.21)	-81.6
Leather & leather products	0.00 (0.05)	0.01 (0.18)	266.2	0.03 (0.21)	0.02 (0.21)	-28.3	0.01 (0.11)	0.01 (0.19)	65.4
Machinery & equipment	0.20 (16.64)	0.06 (3.97)	-68.3	0.27 (17.06)	0.35 (20.52)	29.1	0.22 (16.80)	0.20 (11.88)	-12.5
Other manufacturing	0.03 (0.83)	0.01 (0.95)	-83.1	0.00 (0.01)	0.00 (0.00)	-100.0	0.02 (0.51)	0.00 (0.50)	-87.6
Other non-metallic mineral products	0.02 (0.25)	0.00 (0.00)	-100.0	0.01 (0.53)	0.03 (0.27)	139.7	0.02 (0.36)	0.01 (0.13)	-13.0
Publishing & printing	0.00 (0.00)	0.01 (0.05)		0.00 (0.00)	0.00 (0.00)		0.00 (0.00)	0.00 (0.03)	
Pulp & paper products	0.06 (0.74)	0.13 (1.12)	132.3	0.11 (1.10)	0.00 (0.03)	-98.1	0.07 (0.88)	0.06 (0.60)	-20.9
Rubbers & Plastics	0.05 (1.11)	0.03 (0.71)	-36.8	0.06 (1.86)	0.09 (2.84)	49.4	0.05 (1.40)	0.06 (1.73)	18.2
Textiles & textile products	0.00 (0.26)	0.01 (0.93)	298.3	0.03 (1.72)	0.06 (2.89)	140.0	0.01 (0.83)	0.03 (1.87)	180.7
Transport equipment	0.31 (6.63)	0.21 (3.72)	-33.0	0.09 (2.10)	0.05 (1.53)	-46.0	0.22 (4.86)	0.11 (2.67)	-49.9
Wood & wood products	0.01 (0.01)	0.04 (0.08)	195.6	0.00 (0.00)	0.00 (0.00)		0.00 (0.01)	0.02 (0.05)	669.5
Total	0.12 (100)	0.09 (100)	-20.7	0.14 (100)	0.13 (100)	-9.8	0.12 (100)	0.11 (100)	-15.1

Note: Figures in parenthesis are percentage shares to the total R&D expenses.

Source: Same as Table-1.

Figure-2 Indian SME R&D Intensity in Global Context, 1995–2002
(Percent)



Note: G7 include Canada, France, Germany, Italy, Japan, United Kingdom, and United States; G7 R&D intensity is defined using valued of production whereas Indian SME R&D is calculated using sales.

Source: Based on STAN Indicators Database ed.2005, OECD and Prowess database (2009), CMIE.

2.4 Top 15 R&D-intensive Indian SMEs

Table-4 provides the list of leading R&D doing SMEs in Indian manufacturing sector and some basic information about them. To determine this list we concentrated on the recent sub-period 2000–2008 and those firms that have at least seven years of existence in the dataset during this sub-period and have done minimum of four years of R&D. For the purpose of ranking, we constructed an R&D performance index of Indian SMEs that captures regularity and intensity of R&D activities undertaken by a firm over this sub-period. It is a simple average of normalized values of two variables, R&D intensity and the proportion of years a firm reported R&D out of total number of years of its data. The second variable is a broad indicator of firms' regular participation in in-house R&D activities and the first variable measure the breadth of such activities undertaken. These two variables are standardized by dividing them with their respective mean.

Virtually all the major R&D intensive SMEs in the Indian manufacturing are observed to be from high technology-based industries. The pharmaceutical sector dominated the list with a total of 6 SMEs that accounted for 40 per cent of the total 15 largest R&D intensive Indian SMEs. Electrical & optical equipment accounted for another 33 per cent (5 SMEs), followed by chemicals & chemical products (2 SMEs) and machinery & equipment (2 SMEs) 13 per cent each. Small manufacturing firms with 8 entries head the list of largest R&D intensive SMEs outperforming their medium counterparts with remaining 7 entries.

It is also clear that a number of relatively younger SMEs established since 1985 figured in the list while older SMEs remained among the top R&D doing firms. By incorporation year, 8 SMEs originated in pre-1985 period (53 per cent) and another 7 SMEs (47 per cent) came from post-1984 period. The list represented 10 private Indian owned SMEs (67 per cent), 3 private Indian group affiliated SMEs (20 per cent) and 2 foreign-owned SMEs (13 per cent). Therefore, the list of top R&D intensive SMEs is overwhelmed by domestic owned individual firms not affiliated to either large Indian business groups or foreign firms.

The average R&D intensity of these leading SMEs over 2000–2008 is higher than 1 per cent level: there are just three SMEs having R&D intensity of less than 2 per cent, another six SMEs had above 2-3 per cent and remaining five had R&D intensity higher than 3 per cent. Out of the total available years of their data, eight SMEs have done R&D throughout and another four SMEs reported R&D for majority of the years (above 78 per cent of their available years). For their latest year of available data, barring Aishwarya Telecom, all these SMEs have shown significant level of R&D intensities.

Table-4 List of Top 15 R&D doing SMEs in Indian Manufacturing, 2000–2008

(Percent)

Company	Year of incorporation	Economic activity	Ownership group	R&D Performance Score	No. of Years reporting R&D	Period R&D Intensity (%)	R&D Intensity (%) for 2008	SME Type
Avantel Softech Ltd.	1990	Communication & broadcasting equipment	Private (Indian)	4.446	7	6.387	6.350	Small
Atotech India Ltd.	1996	Chemicals	Private (Foreign)	4.345	8	6.090	6.670	Small
Kavveri Telecom Products Ltd.	1996	Broadcasting equipment	Private (Indian)	4.179	8	5.818	5.089	Medium
D I L Ltd.	1951	Drug formulations	Private (Indian)	3.339	5	4.903	12.808*	Small
High Energy Batteries (India) Ltd.	1961	Storage batteries	Seshasayee Group	2.716	8	3.529	3.803	Medium
Aishwarya Telecom Ltd.	1995	Communication equipment, nec	Private (Indian)	2.334	7	2.784	0.521	Small
Haryana Leather Chemicals Ltd.	1985	Leather auxilliaries	Private (Indian)	2.196	9	2.558	1.507	Medium
Brabourne Enterprises Ltd.	1967	Drug formulations	RPG Enterprises Group	2.042	7	2.305	3.240	Small
Frick India Ltd.	1962	Commercial refrigerators	Private (Foreign)	1.972	9	2.190	4.780	Medium
Mro-Tek Ltd.	1984	Communication & broadcasting equipment	Private (Indian)	1.920	7	2.338	3.814	Small
Shree Dhootapapeshwar Ltd.	1948	Ayurvedic & unani medicaments	Shree Dhootapapeshwar Group	1.852	7	1.992	1.527**	Small
Revathi Equipment Ltd.	1977	Drilling machines	Private (Indian)	1.825	9	1.948	1.396	Medium
A B L Biotechnologies Ltd.	1992	Drugs & pharmaceuticals	Private (Indian)	1.794	6	2.249	3.014	Small
N G L Fine-Chem Ltd.	1981	Pharmaceutical products, nec	Private (Indian)	1.656	6	2.021	2.375	Medium
Bal Pharma Ltd.	1987	Drug formulations	Private (Indian)	1.470	8	1.482	1.162	Medium

Note: * and ** respectively denote R&D intensity is for 2005 and 2006.
Source: Same as Table-1.

3. Determinants of SME R&D: Empirical Framework and Analysis

In the light of the continuance of majority of Indian SMEs not doing R&D, it is important to analyze factors that motivate a SME to embark on in-house research activities. The extant literature on R&D behaviour of Indian firms is mostly based on large firm analysis and its results should be reexamined from the experiences of SMEs given their known distinctive nature firm-specific characteristics. SMEs reflects greater flexibility, more focus on local market, mostly supported by local social networks like family and friends, constrained resources and higher incidence of sickness and economic failures. These features of Indian SMEs have been widely documented by different All India Census on Small Scale Sector conducted by the Office of the Development Commissioner, Small Scale Industries (DCSSI) under the Ministry of Small Scale Industries.

3.1. Conceptual Framework and Hypotheses

The R&D behaviour of a SME, similar to that of a large firm, can be conceptualized into its decision on whether it will undertake R&D activity or not, and, if yes, how much resource it will devote for this purpose. As R&D is costly and risky strategy, this is a challenging decision for small firms given their limited financial resources and skills. However, the fact remain that there exists a sub-group of SMEs, however small their proportion may be, that are consistently been taking R&D decision. Therefore, there is a pronounced need for identifying factors motivating these SMEs to undertake R&D.

In this study we propose a simple conceptual framework that embodies a multilevel approach to the R&D behaviour of Indian SMEs. It consists of three sets of possible factors that are usually theorized to motivate a firm to do R&D in the empirical literature (Figure-3). The first set of factors consists of a number of firm-specific forces that can have an impact on firm R&D decision. Since R&D is firm's internal decision, firm's own characteristics like firm size, firm age, external technology purchase, export orientation, raw material imports, foreign ownership, business group affiliation and profitability might influence the decision making. The second set of factors includes a number of industry-specific variables and third set consists of a number of explanatory variables representing the policy environment.

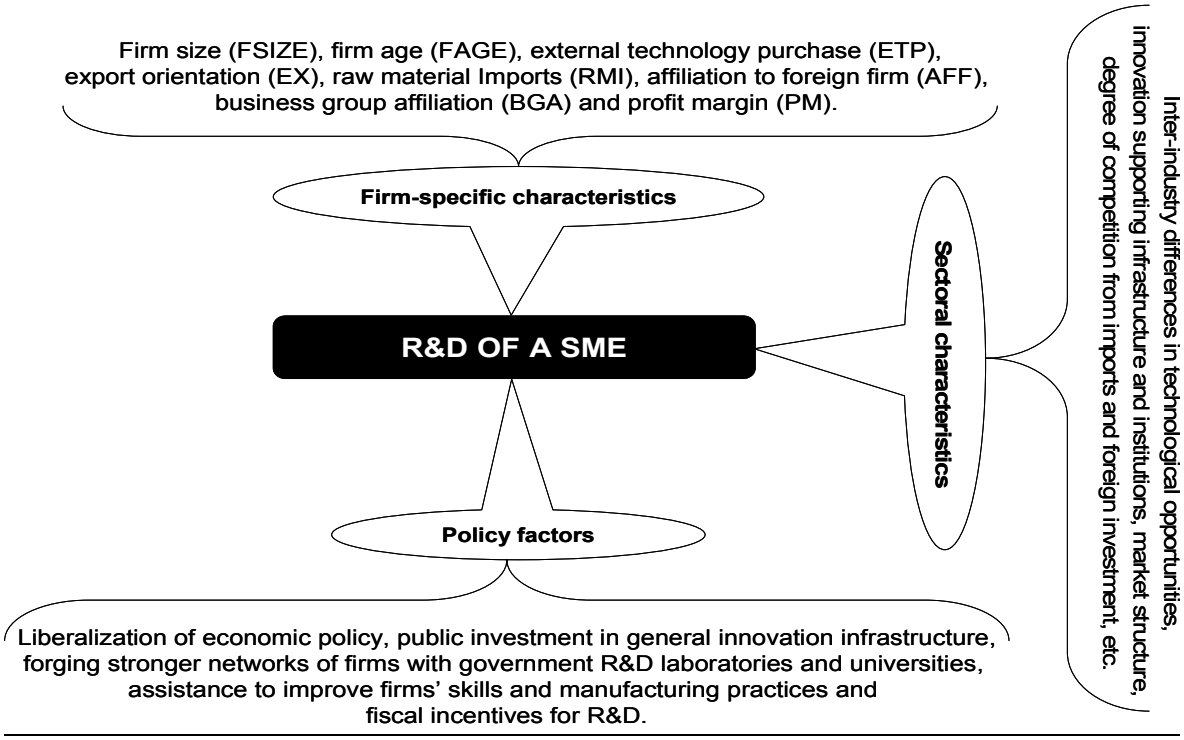
3.1.1. Firm-specific Factors

With regard to the firm size (*FSIZE*), previous empirical studies have found a decisive role for it in firms' R&D performance. Following the Schumpeterian assertion that large-scale enterprises are the key to innovation driven capitalist development, firm size is postulated to have independent advantages in conducting R&D. In addition to larger resource base and greater risk taking capabilities, larger the firm generally implies the higher incentive to do R&D because the effect of cost reduction (effected via R&D) applies to a larger output and so is more profitable for them (Cohen and Klepper, 1996; Fishman and Rob, 1999). However, a number of empirical studies in India as reviewed by Kathuria (2008) and elsewhere as reviewed by Cohen and Klepper (1996) suggested that the influence of firm size on R&D performance is subject to a critical level of firm size. Is the existing finding on the impact of firm size applicable to the sample of small and medium firms? Even within a

population of SMEs defined by policy specified critical limits in plant and machinery investments; there exists considerable disparities in firm size. As long as there are heterogeneity in sizes among SMEs, firm size could still be a relevant explanatory factor in SME R&D. In this study, we expected a positive impact of *FSIZE* on Indian SMEs' R&D performance. A quadratic term of *FSIZE* has also been included to check for possible non-linear relationship between firm size and R&D intensity.

The firm age (*FAGE*) can be viewed as a dynamic collection of learning and information resources of the firm as it evolve over its life cycle. Older and established SMEs, unlike newly started SMEs, are likely to have long accumulation of learning and experience in organizing production and dealing with buyers and inputs suppliers. As the results of R&D require a longer term of regular investment, older SMEs with their past learning from business and production are likely to have some advantages in incurring in-house R&D.

Figure-3 A Conceptual Model on R&D Bahaviour of SMEs



The in-house R&D performance of Indian SMEs can also be dependent on the degree of their external technology purchases (*ETP*). Given their limited in-house R&D capabilities, Indian manufacturing firms have historically been buying external technical know-how through technological licenses and joint venture agreements. In fact the importance of external technology purchase has gone up significantly in the liberalized phase of Indian economy (Pradhan and Puttaswamaiah, 2008). The technology payments made abroad for licenses, patents, know-how and technical assistance as a ratio of sales over 1991–2001 has consistently been higher than in-house R&D as a ratio of sales for Indian manufacturing,

except for two years. As the purchase of external technologies is an alternative way of strengthening firms' competitive capabilities, it can discourage in-house R&D of purchasing firms. However, prior studies on Indian firms overwhelmingly uphold a positive relationship between in-house R&D and external technology purchase (e.g. Lall, 1983; Katrak, 1985; Siddharthan, 1988; Deolalikar and Evenson, 1989; Pradhan, 2002). It has been suggested that Indian firms have undertaken more in-house R&D to effectively absorb, adapt and improved the purchased external technologies. Given the intense nature of competition and shorter product cycle, purchase of external technologies alone will not guarantee the long run survival without complementing them with in-house R&D to generate unique firm-specific competitive advantages. Therefore, the decision of making technologies (i.e. in-house R&D) and buying technologies (i.e. purchase of external technologies) are expected to go together for Indian SME firms if they adopt a complementary strategy of 'make' and 'buy'. *ETP1* (expenses for technology payment as a per cent of sales) and *ETP2* (investment in foreign capital goods as a per cent of sales) are hence postulated to have positive impacts on in-house R&D of Indian SMEs.

The market focus of a SME is also likely to influence its R&D decision. A SME that is serving a global market faces a different set of market competition than another SME that concentrates on local or national market. Global markets are more demanding in terms of product quality, differentiation, productivity, manufacturing practices and after-sales services than local markets. Therefore, exporting SMEs are forced to undertake considerable R&D effort to improve their competitiveness and to meet heightened competition. Their R&D investments are also necessitate for absorbing knowledge spillovers from export activities regarding evolving technological and market conditions overseas (Aw, Roberts and Winston, 2005). Moreover, exporting SMEs have the advantage of a larger market to do R&D activities than a local market-oriented SME. Braga and Wilmore (1991) for Brazil, Siddharthan and Agarwal (1992) for India and Rasiah (2007) for a sample of auto parts firms from a number of East Asian and South-East Asian countries have indicated the possibility of favourable impact of exports on firms' R&D behaviour. The variable export intensity (*EX*) hence is hypothesized to have a positive correlation with R&D activities of Indian SMEs.

Some studies have acknowledged the role of imports of intermediate inputs as another channel of knowledge-spillovers for importing firms. The learning, variety and quality effects of cheap imported inputs have been significant for firms' productivity growth (Halpern et. al., 2005; Amit and Konings, 2007) and such effects can serve to positively influence R&D behaviour of Indian SMEs. Firms that source their entire raw material requirements locally are sure to miss the spillovers of information and knowledge that imported raw materials brings with them. Thus, the study expects a positive impact of raw materials imports (*RMI*) on firms' R&D activities.

The SME affiliation to large Indian business groups could be another conducive factor for R&D performance of Indian SMEs. The affiliated SMEs are likely to do more R&D by capitalizing on pool resources of the group and intra-group sharing of information and technologies over related sectors of production. These affiliated SMEs easily overcome financial and skill shortages that characterizes small firms in undertaking R&D. Mahmood and Mitchell (2004) argued that business groups while promotes R&D of affiliated firms in

emerging economies but also creates entry barriers for non-group firms in conducting R&D. Groups not only have preferential access to resources needed for creating innovation infrastructure than most independent firms but also can foreclose markets to the latter given greater interrelationships among diversified groups. In view of this, we expect that business group affiliation (*BGA*) shall come out with a positive impact on SME R&D behaviour.

The participation of foreign investors in SMEs signifies the benefits of a larger and deeper endowment of technological advantages. The targeted SME receiving FDI now have access to the knowledge base of the foreign parent. This may lessen its true need of incurring in-house R&D except small modifications in production technologies and equipments related to the technology transfer from parent to the concerned SME. However, foreign parents are increasingly relocating critical R&D off-shore to emerging economies in recent years (UNCTAD, 2005) and it is to be seen if foreign affiliated Indian SMEs are some beneficiary of this new developments. The impact of affiliation to foreign firms (*AFF*) can, therefore, have mixed impact on the SMEs' R&D activities with an ambiguous overall impact.

As the shortage of funds has been found to be the most crucial factor, inter alia, for non-adoption of improved technology by small entrepreneurs in India (Sahu, 2008), the profits earned by Indian SMEs can be argued to be an important source of funds to support their R&D investments. In spite of the existence of favourable legal provision, Indian SMEs are known to have extreme difficulty in accessing resources from formal credit markets (Morris *et al*., 2001) and other institutions like capital markets. In this context, it is believed that internally generated finance as reflected in profit margins (*PM*) of SMEs can play a crucial role in their R&D activities. Himmelberg and Petersen (1994) for a sample of small U.S. firms in high-tech industries, Pradhan (2002) for a sample of Indian pharmaceutical firms and Kumar and Aggarwal (2005) for a sample of Indian manufacturing firms have reported profitability as an important determining factor for firms' R&D investment.

3.1.2. Sectoral Characteristics

The inter-SME variation in R&D intensity may also depends on which sectors do they come from. Productive sectors are known to differ according to their innovative opportunities or intensities (e.g. see Pavitt, 1984) and SMEs coming from technology-intensive sectors are likely to reflect higher R&D performance than those from low-technology based industries. There are also sectoral differences in terms of market structure, degree of competition from imports and entry of foreign firms. In Schumpeterian perspective of capitalist development, it is not just the large size of firms but the operation of large firms in imperfectly competitive markets is conducive for technical progress. More concentrated industries offer greater appropriation of returns from R&D and higher price-cost margins than relatively competitive industries. Therefore, SMEs operating in a more concentrated market possess higher incentive to engage in R&D than those from a competitive market. However, this stimulating effect will be smaller if the current monopoly profit is very large and there are little competitive forces via potential entry. Other things being constant, industries facing greater magnitude of external competition through cheap imports and increasing inward FDI flows can show different R&D intensities of their firms than industries relatively less exposed to global competitive pressures. On the one hand growing external competition may discourage

R&D by lowering anticipated market power of SMEs and on the other hand it may invite reactive R&D by SMEs to protect their market share. Given that the degree of industrial concentration and external competition involves both positive and negative impacts on R&D by small firms, the exact nature of their net impacts can only be examined empirically. In this study, industry level R&D intensity (IRD) and Herfindahl index (HI) have been used to measure industry level technological opportunities and industrial concentration respectively. The share of foreign owned enterprises in industry domestic sales is employed to measure the degree of competition from foreign investment (CFI). The ratio of imports to domestic demand at industry level is employed to account for the intensity of import competition (IMP).

3.1.3. Policy Factors

The R&D behaviour of Indian SMEs can be argued to be influenced by different components of public policy. The liberalization of macro economic policies towards imports and foreign suppliers can alter market competition at sectoral level and thus can impact SME R&D as discussed previously. In addition to the general science and technology policy of the government and individual policies of different government departments related to key sectors (e.g. like chemicals and pharmaceuticals, telecommunication, information technologies etc., and SME sector), the provision of different fiscal benefits for R&D activities can play a crucial role. In India SMEs have been provided with different government supported schemes like SIDBI's Technology Development and Modernization Fund (provides low cost finance for the purchase of capital equipment, technical know-how, upgradation of process technology and products, improvement in packaging and acquisition of quality certification), ISO-9000 Reimbursement Scheme and Credit Linked Capital Subsidy Scheme for Technology Upgradation[2] (Pradhan and Sahu, 2008). In addition to above measures, government has been providing direct incentives for increasing in-house R&D activities of a firm irrespective of size. Any industrial unit receiving recognition from the Department of Scientific & Industrial Research (DSIR) for its in-house R&D centre is provided tax deduction equal to the revenue and capital expenditure spent on R&D and recently the allowed deduction has been increased to 150 per cent of the research expenses. Given the multifaceted aspect of public policy related to innovation, it is difficult to measure all the aspect. In this study, we have only focus on the direct fiscal incentive aspect of the policy. The study has used residual fiscal benefits[3] claimed by an SME as a per cent of its sales (FSB) as a measure of government incentives for R&D.

[2] The Credit Linked Capital Subsidy Scheme for Technology Upgradation was launched in October, 2000, modified in 2005 and ended on 31st March, 2007. This scheme had provided for 15 per cent capital subsidy on institutional loan (not exceeding Rs. 1 crore) taken by small units modernizing their production equipment and techniques.

[3] Net fiscal benefits = (total fiscal benefits–benefits for exports–contribution from oil pool account–sales tax benefits).

Taking into account all the three sets of explanatory variables as discussed above, the empirical framework adopted in the present study has the following form:

$$RDINT_{it} = \beta_0 + \beta_1 FAGE_{it} + \beta_2 FSIZE_{it} + \beta_3 FSIZE^2{}_{it} + \beta_4 ETP1_{it} + \beta_5 ETP2_{it} + \beta_6 EX_{it} + \beta_7 RMI_{it} + \beta_8 AFF_i + \beta_9 BGA_i + \beta_{10} PM_{it} + \beta_{11} IRD_{jt} + \beta_{12} HI_{jt} + \beta_{13} CFI_{jt} + \beta_{14} IMP_{jt} + \beta_{15} FSB_{it} + \varepsilon_{it} \quad ...(A)$$

Where explanatory variables are as measured in Table-5 and ε_{it} is the random error term.

Table-5 Description and Measurement of Variables

Variables	Symbols	Measurements
Dependent Variable		
R&D Intensity	$RDINT_{it}$	R&D expenditure as a per cent of total sales of *i*th SME in *t*th year.
Independent variables		
Firm-specific variables		
Firm Age	$FAGE_{it}$	The age of *i*th SME in number of years from the year of its incorporation.
Firm Size	$FSIZE_{it}$	Total sales (Rs. Million) of *i*th SME in *t*th year.
External Technology Purchase	$ETP1_{it}$	Expenses in royalties, technical and other professional fees by *i*th SME as a per cent of sales in the year t.
	$ETP2_{it}$	Expenses on imports of capital goods and equipment by *i*th SME as a per cent of sales in *t*th year.
Export Intensity	EX_{it}	Goods and services exports of *i*th SME as a per cent of sales in the year t.
Raw Material Imports	RMI_{it}	Imports of raw materials by *i*th SME as a per cent of sales in *t*th year.
Affiliation to Foreign Firm	AFF_i	Assume 1 if *i*th SME has affiliation to a foreign firm, 0 otherwise.
Business Group Affiliation	BGA_i	Assume 1 if *i*th SME has affiliation to a domestic business group, 0 otherwise.
Profit Margin	PM_{it}	Profit before tax of *i*th SME as a per cent of sales in the year t.
Industry-specific variables		
Sectoral R&D Intensity	IRD_{jt}	R&D expenses of *j*th industry as a per cent of industry sales in *t*th year.
Sectoral Concentration	HI_{jt}	Herfindahl Index of *j*th industry in *t*th year based on domestic sales.
Competition from Foreign Investment	CFI_{jt}	Foreign firms' share in domestic sales of *j*th industry in *t*th year.
Import competition	IMP_{jt}	Imports as a per cent of domestic demand (= production + imports - exports) of *j*th industry product in *t*th year.
Policy variable		
Fiscal benefits	FSB_{it}	Residual fiscal benefits received of ith SME as a per cent of sales in the year t.

3.2. Data Source, Estimation Method and Results

For the empirical analysis of the Model A, this study compiled required data from a number of published and unpublished sources of information. The Prowess database of the Centre for Monitoring Indian Economy (2009) has been the primary source for all firm-specific and policy variables. The measurement of independent variable (*FSB*) R&D allowance is defined to be residual fiscal benefits (net of fiscal benefits related to exports, oil pool and sales tax) is beset with a number of significant limitations though. In the prowess database different components of total fiscal benefits are not available for majority of SMEs and also the reported break-ups may not be reliable for small firms. In this context finding on this explanatory variable should be interpreted cautiously. Sectoral R&D intensity, Herfindahl index and foreign firms' share in domestic sales are also computed from the same database. The estimation of import competition at ISIC Rev.3 industry groups, however, took us to the OECD bilateral trade database and various reports of the Annual Survey of Industries (ASI), Central Statistical Organization, India[4]. Industry-wise trade (i.e. exports and imports) and production data related to India were respectively drawn from the OECD dataset and ASI.

The estimation of Model A is characterized by the fact that many independent variables are not strictly exogenous and possess feedbacks to the dependent variable. This violates an important classical assumption of zero correlation between the concerned independent variable and the error term. For instance, R&D is known to be an important determinant of firms' export performance. R&D intensity may also be factor to increase firm survival (age), size, profit and purchase of foreign technologies. The size of R&D related tax exemption received by an SME is clearly dependent upon the actual amount it has spent on doing research activities. In view of this, all the firm-specific and policy related explanatory variables, except ownership dummies, are introduced in one year lagged form to avoid the simultaneity bias.

Keeping in mind the censoring nature of the dependent variable in Model A, the present study consider two methods of estimation namely, Tobin's maximum likelihood (ML) estimation and Powell's (1986) censored quantile regression (CQR). While the former is a parametric estimation, later is a semi-parametric approach. The Tobit ML estimation shall provide consistent coefficient estimates when errors satisfy the assumptions of normality and homoscedasticity (Tobin, 1958). However, Skeels and Vella's conditional moment test conducted after Tobit estimation for both SMEs and large firms show that errors in the estimated models are not normally distributed[5]. In view of these problematic errors, Tobit estimation shall results in inconsistent coefficient estimates. Powell's CQR estimator, however, provides consistent estimates when there is heteroscedastic, non-normal and asymmetric errors[6] (Powell, 1986; Chay and Powell 2001; Wilhelm, 2008). Given its

[4] I thank Agnes Cimper (OECD Directorate for Science, Technology and Industry, Economic Analysis and Statistics Division) for kindly sharing the BTD data on India.

[5] This test implement Drukker (2002) suggested parametric bootstrap approach to Skeels and Vella's conditional moment test. Estimated conditional moments for SMEs and large firms are 394.17 (Prob>chi2= 0.00000) and 2119.9 (Prob>chi2= 0.00000) respectively. Therefore, the null hypothesis of normal errors in Tobit estimation is not accepted in our case.

[6] Symmetrically censored least square (SCLS) is another alternative to Tobit but Monte Carlo experiments do not support its use when there is heteroskedasticity or non-normality (Wilhelm, 2008).

robustness to these problematic errors the present study has finally adopted CQR as the preferred method of estimation. When the CQR is estimated setting θ conditional quantile of the dependent variable as 0.5 and assuming that the errors have a zero median, it represent a special class of estimator known as the censored least absolute deviation (CLAD) provided by Powell (1984).

Given that the dependent variable in our sample is extremely censored, the choice of quantile used in the CQR estimation is important for obtaining informative estimates for the empirical model. As shown in Table-1 earlier, less than 10 per cent of SMEs undertake R&D annually and just around 30 per cent of large firms are R&D-incurring. In such scenario, choosing a lower quantile like median as done in the CLAD shall leads to imprecise estimates and convergence problem. Given the higher censoring levels in our dataset, the distribution of the R&D intensity for SMEs and large firms in the CQR has been respectively centered at 95 per cent quantile and 75 per cent quantile.

The estimation of CQR in this study follows the three-step algorithm suggested by Chernozhukov and Hong (2002) for samples with heavy censoring and high dimensionality. In the first step, a logit probability model for the full sample is estimated to choose an appropriate sub-sample where the quantile line stays above the censoring point. After estimating the model of probability, $p_i = p(\dot{X}_i^{'}\beta) + \varepsilon_i$ (where p_i is an indicator of not censoring and $\dot{X}_i^{'}$ is a suitable transformation of x_i), a subset of observations $S_0(c) = p(\dot{X}_i^{'}\hat{\beta}) > 1-\theta+c$ were selected. The trimming constant c lies strictly between 0 and θ (the chosen conditional quantile level in which one want to estimate the model). As suggested by Chernozhukov and Hong (2002) c is choosen such that $\#S_0(c)/\#S_0(0)=0.9$. In the second step, an ordinary quantile regression is estimated for the sub-sample S_0 and an initial estimator $\hat{\beta}_\theta^0$ is obtained. This initial estimator is consistent but inefficient. Based on this estimator the final sub-sample $S_f(k) = p(\dot{X}_i^{'}\hat{\beta}_\theta^0) > 0+k$ is selected, where k is another trimming constant similar to c in step 2. Following the existing practice (Gustavsen, Jolliffe and Rickertsen, 2008; Schmillen and Möller, 2009), we have set k=0 and to arrive at a good and robust sample size it is required that $\#S_f/\#S_0>0.66$ and $\#\{S_0 \subset S_f\}/\#S_f < 0.1$. In the third step quantile regression with bootstrap standard errors with 1000 replications is fitted for S_f.

This adoption of three step CQR by the present study is useful to the literature on R&D by Indian firms as the existing studies have overwhelmingly used the traditional Tobit approach to model firms' R&D behaviour, often ignoring the small proportion of R&D doing firms in their sample. Table-6 summarizes the results obtained from the applications of the three step CQR estimations for SMEs and large firms[7]. It can be seen that the F values testing the overall significance of estimated CQR equations for SMEs and large firms are statistically different from zero. This suggests fitted CQRs are explaining meaningfully the variations in the R&D behavior of Indian firms. The performance of different explanatory variables is discussed below.

[7] Dr. Geir W. Gustavsen and Prof. Kyrre Rickertsen kindly provided the STATA do file for the estimation of the three steps CQR for this paper. All the estimations in this paper are based on the statistical package, namely STATA (version 10).

Table-6 Three Step CQR Estimation of R&D Intensity (%) of SMEs and Large Firms in Indian Manufacturing

Dependent Variable: R&D Intensity

Independent variables	Coefficients (Absolute bootstrap t-statistic)	
	SMEs	Large Firms
$FAGE_{it-1}$	0.0019448***	0.0030353***
	(9.40)	(27.82)
$FSIZE_{it-1}$	0.0004425***	0.0000027***
	(9.64)	(3.24)
$FSIZE^2_{it-1}$	-1.05e-07***	-1.89e-12**
	(7.40)	(2.21)
$ETP1_{it-1}$	0.0002669	0.0006114
	(0.03)	(0.41)
$ETP2_{it-1}$	-0.0004799	-0.0000063
	(0.31)	(0.08)
EX_{it-1}	0.0042525***	0.0019703***
	(10.85)	(23.76)
RMI_{it-1}	0.0189248***	-0.0001074
	(9.19)	(0.97)
PM_{it-1}	0.0001815***	0.0001848***
	(11.24)	(3.71)
AFF_i	0.3453753**	0.1795872***
	(2.03)	(16.66)
BGA_i	0.4638443***	0.1136036***
	(11.52)	(26.30)
HI_{jt}	0.0000062	0.0000155***
	(0.88)	(3.79)
CFI_{jt}	0.0124561***	0.0016866***
	(12.17)	(10.40)
IRD_{jt}	0.3612285***	0.6437174***
	(7.83)	(20.37)
IMP_{jt}	0.0130518***	0.0007993***
	(11.53)	(5.16)
FSB_{it-1}	-0.0237511***	-0.0028933***
	(12.23)	(7.22)
Constant	-0.5392959***	-0.2628717***
	(13.09)	(30.42)
F-value!	38.15	168.44
Prob > F	0.0000	0.0000
Pseudo R2	0.0772	0.0850
Observations	16724	25189

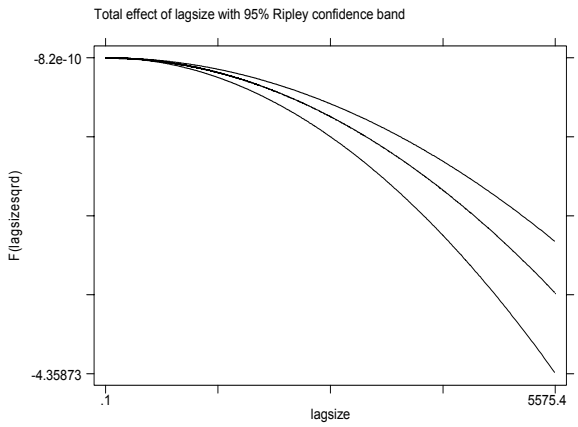
Note: Absolute value of bootstrap t-statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%; F-values are obtained from independent tests conducted to check if the coefficient of all explanatory variables are simultaneously zero using the testparm command in the STATA.

Firm-specific factors

FAGE as per the prediction is observed to have a positive and significant role in influencing the R&D activities of both SMEs and large firms in Indian manufacturing sector. This corroborate that longer surviving firms that tends to possess greater accumulation of learning and experience are favourably placed in undertaking R&D activities. *FSIZE* and its quadratic terms respectively have positive and negative coefficients and are statistically significant for Indian SMEs as well as large firms. From this it appears that R&D of Indian firms are likely to goes up with increasing firm size but once a critical level in size is crossed the effect turn negative. This non-linear relationship between R&D and firm size in Indian manufacturing has also been observed in some of earlier studies for samples of large firms (e.g. Kumar and Saqib, 1996; Pradhan, 2002; Narayanan and Thomas, 2010) and the finding from this study indicate that the same relationship holds for SMEs as well. However, the critical size at which the total effect of firm size turn zero for SMEs comes relatively faster given their size distribution than for large firms (Figure-4).

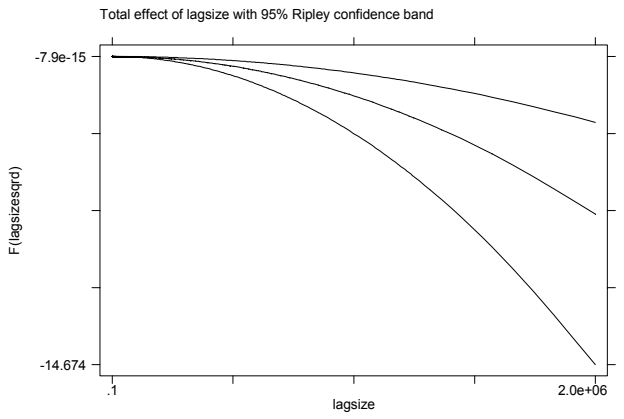
Figure-4 Estimated Relationship Between Firm Size and R&D

A: For SMEs



Note: Total effect of firm size for SMEs has the maximum when their sales reach the threshold of Rs. 2117 million; 3rd quartile sales of these firms is estimated to be just Rs. 209 million.

B: Large Firms



Note: Total effect of firm size for large firms has maximum when their sales reach the threshold of Rs. 704762 million; 3rd quartile sales of these firms is found to be just Rs. 1614 million.

ETP1 and *ETP2* both representing disembodied and embodied technology purchases turn out with positive and negative signs respectively but none is statistically significant. This implies that R&D of Indian SMEs as well as large firms is neither complemented by external technology purchase nor substituted by it. This is contrary to the earlier findings that found a positive relationship between the two (Lall, 1983; Katrak, 1985, Siddharthan, 1988; Deolalikar and Evenson, 1989; Basant, 1997). This past literature generally argued that Indian R&D was basically adaptive in nature and hence imports of foreign technology required further R&D on the part of importing Indian firms to absorb, adapt and assimilate the imported knowledge to local conditions. The present study, which is based on a longer and recent period, found that external technology purchase is no longer significant for Indian

firms' R&D. This may imply that the nature of R&D by Indian SMEs and large firms has improved significantly from their earlier stage of adaptive innovation based on imported foreign technologies.

The export intensity variable *EX* has the expected positive and significant coefficients throughout. Thus, the participation in global markets appear to be a propelling factor for enhancing R&D activities of both SMEs and large firms. The competitive pressure and the scope of learning increases considerably as firms go beyond domestic markets, which in turn encourage their in-house R&D investments. The imported raw material *RMI* has a positive and significant effect on R&D of SMEs but is insignificant with a negative sign for large firms. SMEs, therefore, learns considerably from purchase of raw materials from technologically advance overseas inputs suppliers and are encouraged to increase their R&D intensity. Imported inputs do not appear to be such an important factor for R&D activities of large firms.

The profit margin *PM* comes up with a predicted positive coefficient that is statistically different from zero for SMEs and large firms. Thus, the Indian companies appear to have largely relied on surpluses of resources internally generated in the production process to adopt a deeper R&D strategy. The other two firm-specific variables, *AFF* and *BGA* also turn out with a significantly positive effect on the extent of R&D intensity of both SMEs and large firms. This would corroborates the expectation that the equity participation of foreign investors and large domestic business houses in Indian SMEs creates fovourable conditions for improving SME R&D activities. Small firms seem to have been benefitting from the strength of foreign investing firms in terms of resources and technological assistance to build their base of R&D activities. Affiliation to domestic business groups for similar reasons also favors greater R&D intensity of SMEs. These two factors similarly encourage a greater R&D focus among large firms.

Sectoral factors

The Herfindahl index *HI* included to control sectoral differences in market concentration comes up with a hypothesized positive effect in estimations while explaining R&D intensity of SMEs and large firms but the effect is statistically different from zero only in the case of large firms. It would appear that R&D behaviour of Indian large firms is more sensitive to the differential market structure across sectors but not so for SMEs. Large firms possessing major market shares are more affected by increase in market concentration and are forced to undertake more R&D as a defensive strategy. The R&D of SMEs with moderate market shares appear to be insignificantly affected by sectoral concentration.

The coefficients of *CFI* and *IMP* respectively measuring competition from foreign firms and cheap imports have turn up with significantly positive signs for both SMEs and large firms. Hence, the increasing competitive pressures from expansion of imports and foreign firms involved greater R&D by domestic firms irrespective of firm sizes to preserve their competitiveness in the domestic market. *IRD* is also consistently significant across estimations with a positive sign. This confirms that inter-sectoral differences in technological opportunities are a crucial determinant of firms R&D behaviour. SMEs and large firms are

likely to have greater R&D intensity in technology-intensive sectors than in low technology sectors.

Policy factor

FSB, capturing the fiscal allowance for in-house-R&D efforts of firms comes up with a significantly negative effect on R&D activities of SMEs and large firms. This implies that Indian firms receiving residual tax allowance (i.e. the deduction equal to or greater than the actual amount of R&D expenses undertaken from the taxable income[8]) in the last year are likely to invest less on R&D in the current year. One can suspect that this negative relationship may partly be a result of the measurement error of the variable as mentioned earlier rather then genuine impact of R&D tax rebate. Also it could have resulted from the fact that non-DSIR recognized firms that do not receive R&D tax allowance have expanded their R&D while DSIR recognized units that are receiving such fiscal allowance not be expanding their R&D in the following year after claiming the tax allowance. Since DSIR recognition for a year or so comes with a fixed cost of documentation and inspection, Indian firms appear to be making a large size of R&D investment in the year that they are getting the recognition and not in the subsequent years. As the fiscal benefits for R&D has been estimated through a residual approach in this paper and also based on imprecise data available in the dataset, the obtained result should be interpreted with caution and it will be misleading to draw any conclusion on the effectiveness of tax instrument on R&D.

4. Concluding Remarks

Technology has come to be a critical strategy for national firms' growth and survival in the last two decades of liberalization process. The period since early 1990s is a crucial phase of competitive restructuring in the Indian domestic market place with large scale entry and expansion of foreign firms, inflow of cheap imports and emergence of product patent regime. These changes in policy framework throw critical challenges to domestic SMEs to upgrade their technological and skill capability urgently. R&D being the main driver of enhancing competitiveness, an analysis of R&D investment patterns and trends by SMEs—the largest categories of firms in Indian industries with substantial employment share—is of a critical public policy issue.

This study, using firm-level data for a sample of manufacturing firms, has analyzed R&D activities by firm sizes and examined the role of different firm-specific, sectoral and policy variables that impacts SME R&D behaviours. In general, SME R&D in Indian manufacturing is found to be characterized by a number of interesting features. First, SMEs possesses a very low incidence of doing R&D and spend a small proportion of their sales in such activities. It is also observed that the magnitude of R&D intensity of SMEs has gone down in 2000s as compared to 1990s. This is in contrast to a rising R&D investment trend from large firms in these years. The low and declining SME R&D intensity seems to suggest that small firms are falling behind in upgradation of technological capabilities than their large counterparts that

[8] Tax deductions for Indian firms from various sectors have been variously increased overtime from 100 per cent to 125 per cent in 1990s and to further 150 per cent in late 2000s (up to March 31, 2012).

are consistently pushing up their R&D investments. Second, the subgroup of R&D-doing SMEs, however, is found to be ahead of the subsample of R&D-incurring large firms in terms of R&D intensity. Third, SME R&D in Indian manufacturing is increasingly getting concentrated among a small group of R&D-doing SMEs in the recent period. Fourth, domestic business group affiliated SMEs have emerged as the major source of SME R&D followed by standalone SMEs. However, SMEs with foreign investment tends to have the highest R&D intensity followed by domestic business group affiliated SMEs. Finally, SME R&D investment is sectorally concentrated with just four industries accounting for as high as 80 per cent of total SME R&D.

The discouraging R&D performance of SMEs in the last two decade underscore an uneven technological development that is taking place across firm size within Indian manufacturing sector. While large firms are increasing their R&D involement over years, SMEs remain the most vulnerable section of enterprise with least probability of incurring R&D and a minor R&D intensity. Apparently this calls for identification of factors that promote or inhibit SMEs' R&D investment and promulgation of suitable policy interventions to increase R&D intensiveness of these SMEs on a sustain basis.

The empirical findings on the quantitative analysis of firms' R&D behaviour significantly contribute to the understanding of different factors influencing SME R&D in Indian manufacturing. These results confirmed that SME R&D is a positive outcome of firm-specific factors like age, size, exports, imported raw materials, profit margins and affiliations to domestic business groups and foreign firms. This suggests that policies encouraging SMEs participation in international markets for both exports and imports of raw materials may increase SME R&D. A more active policy to promote investment from domestic business groups and foreign firms into the SME sector may also help small firms to increase their R&D performance. The Small and Medium Enterprises Development (MSMED) Act, 2006 that has removed the 24 per cent ceiling for ownership of SME units by large domestic firms and foreign investors is a welcome step[9]. Increasing involvements of foreign firms and domestic business groups in SME sector is likely to offers significant advantages to SMEs in pushing up their R&D. Since large proportion of SMEs significantly falls short of the critical firm size where the total effect of size turn negative, there appear to be size constraint on achieving full R&D potential of Indian SMEs. In this case, promotion of industrial cluster among SMEs can be useful to minimize the limitation of their small size on R&D. As the internal finance generated by profitability of SMEs tends to be moderate given their reliance on low cost competition, the provision of cheap finance appears to be another policy option for expanding SME R&D. In such a context, facilitating SMEs access to capital markets and venture capital funding could act as a catalyst for SME R&D.

The analysis also points to the positive role played by growing competitive pressures from foreign firms and imports at sectoral level in spurring the SME R&D. Industry-specific policies can be consider to further open up industrial sectors that are relatively less open to the dynamics of international competitive pressure presently. Inter-industry differences in technological opportunities are other important determinant of SME R&D behaviour. The

[9] Presently, this 24 per cent ownership ceiling is limited to units manufacturing 24 items reserved for the SMEs sector.

fiscal benefits appear to have a negative impact on SME R&D but we suspect that this result could be an outcome of measurement problem. This study has made an exploratory analysis of SME R&D and drawn some tentative conclusions subject to the limitations of available data. These preliminary findings on SME R&D behaviour should be reconfirm by further quantitative studies on the issue.

Reference

Alagh, Y.K. (1998)' 'Technological Change in Indian Industry', *Economic and Political Weekly*, 33 (4), pp. 181−184.

Amiti, M., and J. Konings (2007), 'Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia', *American Economic Review*, 97(5), pp. 1611–1638.

Aw, B.Y., M. J. Roberts and T. Winston (2005), 'The Complementary Role of Exports and R&D Investments as Sources of Productivity Growth', *NBER Working Paper*, No. 11774, National Bureau of Economic Research, Cambridge, MA 02138.

Bala Subrahmanya, M H (2006), 'Technological Innovations in Indian Small & Medium Enterprises (SMEs) Sector: Does Firm Size Matter?', *International Journal of Innovation and Learning*, 3 (5), pp 499−517.

Basant, R. (1997), 'Technology Strategies of Large Enterprises in Indian industry: Some Explorations', *World Development*, 25(10), pp. 1683−1700.

Bhattacharya, S., S.C. Sharma and K. Lal (2007), *Study of R&D and Innovation Activity of Firms in India*, A Report Prepared by the National Institute of Science, Technology and Development Studies (NISTADS) for the Department of Science and Technology, Government of India.

Chay, K. Y. and J. L. Powell (2001), 'Semiparametric Censored Regression Models', *Journal of Economic Perspectives*, 15 (4), pp. 29–42.

Chernozhukov, V. and H. Hong (2002), 'Three-Step Censored Quantile Regression and Extramarital Affairs', *Journal of American Statistical Association*, 97 (459), pp. 872–882.

Cohen, W.M. and S. Klepper (1996), 'A Reprise of Size and R&D', *The Economic Journal*, 106, pp. 925–951.

Deolalikar, A. B. and R. E. Evenson (1989), 'Technology Production and Technology Purchase in Indian Industry: An Econometric Analysis', *The Review of Economics and Statistics*, 71 (4), pp. 687–697.

Drukker, D. M. (2002), 'Bootstrapping a conditional moments test for normality after tobit estimation', *The Stata Journal*, 2(2), pp. 125–139.

Etemad, H. (2004), 'Internationalization of Small and Medium-sized Enterprises: A Grounded Theoretical Framework and an Overview', *Canadian Journal of Administrative Sciences*, 21(1), pp.1–21.

Fishman, A. and R. Rob (1999), 'The Size of Firms and R&D Investment', *International Economic Review*, 40(4), pp. 915–931.

Freeman, C. and L. Soete (1997), *The Economics of Industrial Innovation* (3rd Edition), Reprinted in 2004 by Routledge, London.

Gustavsen, G.W., D. Joliffe and K. Rickertsen (2008), 'Censored quantile regression and purchases of ice cream*', Food Economics*, 5*(3),* pp. 152–163.

Halpern, L., M. Koren and A. Szeidl (2005) 'Imported Inputs and Productivity', *CEPR Discussion Paper*, No. 5139.

Himmelberg, C. P. and B. C. Petersen (1994), 'R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries', *The Review of Economics and Statistics*, 76(1), pp. 38–51.

Kacker, S. (2005), 'Overcoming Barriers to Innovation for Indian SMEs', Paper presented at the INSME Annual Meeting on International Cooperation to Seize Innovation Opportunities for SMEs, Barcelona, Spain, 13−15 April.

Kathuria, V. (2008), 'The impact of FDI inflows on R&D investment by medium- and high-tech firms in India in the post-reform period', *Transnational Corporations*, 17(2), pp. 45–66.

Katrak, H. (1985), 'Imported Technology, Enterprise Size and R&D in a Newly Industrializing Country: The Indian Experience', *Oxford Bulletin of Economics and Statistics*, 47, pp. 213−230.

Kharbanda, V. P. (2001) 'Facilitating innovation in Indian small and medium enterprises– The role of clusters', *Current Science*, 80 (3), pp. 343−348.

Kumar, N. and A. Aggarwal (2005), 'Liberalization, outward orientation and in-house R&D activity of multinational and local firms: a quantitative exploration for Indian manufacturing', *Research Policy*, 34(4), pp. 441–460.

Kumar, N. and M. Saqib (1996), 'Firm Size, Opportunities for Adaptation, and In-house R&D Activity in Developing Countries: The Case of Indian Manufacturing', *Research Policy*, 25(5), pp. 712–722.

Lall, S. (1983), 'Determinants of R&D in an LDC: The Indian Engineering Industry', *Economic Letters*, 37 (3), pp.379−383.

Mahmood, I.P., and W. Mitchell (2004), 'Two Faces: Effects of Business Groups on Innovation in Emerging Economies', *Management Science*, 50 (10), pp. 1348–1365.

Morris, S., R. Basant, K. Das, K. Ramachandran and A. Koshy (2001), *The Growth and Transformation of Small Firms in India*, New Delhi: Oxford University Press.

Narayanan, K. and R. Thomas (2010), 'R&D and Internationalisation in the Pharmaceutical Sector in India', in Siddharthan, N.S. and K. Narayanan (eds.) *Indian and Chinese Enterprises: Global Trade, Technology and Investment Regimes*, Routledge, New Delhi, pp. 211–238.

National Science Foundation (2008) 'Science and Engineering Indicators 2008', Arlington, Virginia, USA.

Pavitt, K (1984), 'Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory', *Research Policy*, 13(6), pp. 343–373.

Powell, J.L. (1984), 'Least Absolute Deviations Estimation for the Censored Regression Model', *Journal of Econometrics*, 25, pp.303–325.

Powell, J.L. (1986), 'Censored Regression Quantiles', *Journal of Econometrics*, 32, pp. 143–155.

Pradhan, J. P. (2002), '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. and P. P. Sahu (2008) *Transnationalization of Indian Pharmaceutical SMEs*, Bookwell Publisher, New Delhi.

Pradhan, J.P. and S. Puttaswamaiah (2008) 'Trends and Patterns of Technology Acquisition in Indian Organized manufacturing: An Inter-Industry Exploration', *The Indian Journal of Economics*, LXXXIX(353), pp. 269–315.

Rasiah, R. (2007), 'Export Orientation and Technological Intensities in Auto Parts Firms in East and Southeast Asia: Does Ownership Matter?', *Asian Economic Papers*, 6(2), pp. 55–76.

Sahu, P. P., (2008), 'Technological Constraints of Small Scale Industries in India: Some Evidence from a Field Survey', in S. K. Bhaumik (ed.), *Reforms in Indian Agriculture for Employment Expansion and Poverty Reduction*, Sage Publications: New Delhi, pp. 498–516.

Schmillen, A. and J. Möller (2009), 'Determinants of Lifetime Unemployment - A Micro Data Analysis with Censored Quantile Regressions', *Working Papers*, No. 275, October 2009, Osteuropa-Institut Regensburg, University of Regensburg.

Siddharthan, N. S. (1988) 'In-house R&D, imported technology, and firm size: Lessons from Indian experience', *The Developing Economies*, XXVI-3, pp. 212−221.

Siddharthan, N. S., and R.N. Agarwal (1992), 'Determinants of R&D Decisions: A Cross-Section Study of Indian Private Corporate Firms', *Economic Innovation and New Technology*, 2(2), pp.103–110.

Siddharthan, N.S. (1992), 'Transaction costs, technology transfer, and in-house R&D', *Journal of Economic Behavior and Organization*, 18 (2), pp. 265−271.

Sikka, P. (1999), 'Technological innovations by SME's in India', *Technovation*, 19 (5), pp. 317−321.

Skeels, C. L. and F. Vella (1999), 'A Monte Carlo investigation of the sampling behavior of conditional moment tests in tobit and probit models', *Journal of Econometrics*, 92, pp. 275–294.

Tobin, J. (1958), 'Estimation of relationships for limited dependent variables', *Econometrica*, 26(1), pp. 24–36.

Wilhelm, M. O. (2008), 'Practical Considerations for Choosing Between Tobit and SCLS or CLAD Estimators for Censored Regression Models with an Application to Charitable Giving', *Oxford Bulletin of Economics and Statistics*, 70(4), pp. 559–582.