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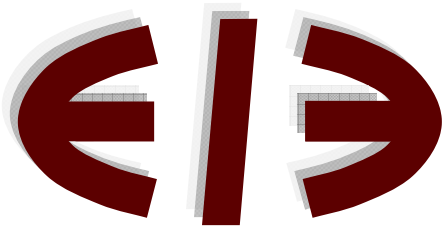

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R&D Strategy of Small and Medium Enterprises in India

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Abstract: The liberalization of economic policies in the last two decades and intensifying market competition tend to be a cause of policy concern for the survival of SMEs in emerging economies like India. These SMEs account for the largest chunk of industrial units and employment in the national economy. Yet, most of them are competing with deeply inadequate resources, especially by means of weak technological capabilities. The present study has provided not only preliminary estimates on SME R&D investments in Indian manufacturing and their broad trends and patterns, but also contributed to the understanding of factors driving the SME in-house R&D activities. It shows that Indian SMEs continue to be vulnerable among all firms as they have the lowest incidence of doing in-house R&D and their R&D intensities have fallen in the last decade. Based on the results from three-step Censored Quantile Regression, this study has suggested a set of useful policy implications for enhancing SME R&D.

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

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1. Introduction

In the present era of globalizing national markets, the role of technological capabilities has become critical for firms' survival and growth. National firms are now operating in a vastly intensified competitive environment due to removal of import and FDI protection measures and the radical shift in the intellectual property right (IPR) regime from process to product patent scheme. This increased market competition makes it more difficult for firms to survive without improving their intensities of investment in research and development activities. While the large firms are well positioned to face these globalizing competitive challenges given their better strategic asset bundle and resources, small and medium enterprises (SMEs) are expected to be at greater risks (Etemad, 2004; Pradhan and Sahu, 2008).

SMEs in emerging economies like India are doubly negatively affected: because they are prohibited from using their favourite strategy of reverse engineering under the new technology policy regime, and are also denied any refuge in policy protection as the current openness policies have reduced or removed the special treatments to SMEs in industrial policies like exemption from price controls, product reservation, preference in government procurement, etc. The promotion of R&D among SMEs is therefore critical as these firms possess limited financial and intangible resources unlike their large counterparts. Rapidly changing consumer preferences, shorter product life cycle and growing quality consciousness clearly call for SMEs to upgrade their technological assets.

In the above backdrop, this study focuses on the in-house R&D activities of Indian manufacturing SMEs during the period 1991−2008. As the SME R&D behaviour continues to be an under-researched area in India and there is hardly any systematic analysis of the R&D determining factors among SMEs, the present study shall be useful to the existing R&D literature on Indian firms. The existing firm-level studies on industrial R&D in India have rarely differentiated between large firms and SMEs because the latter group did negligible R&D in the past and also due to the unavailability of required data and lack of definitional clarity on medium firms. 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 among Indian manufacturing SMEs.

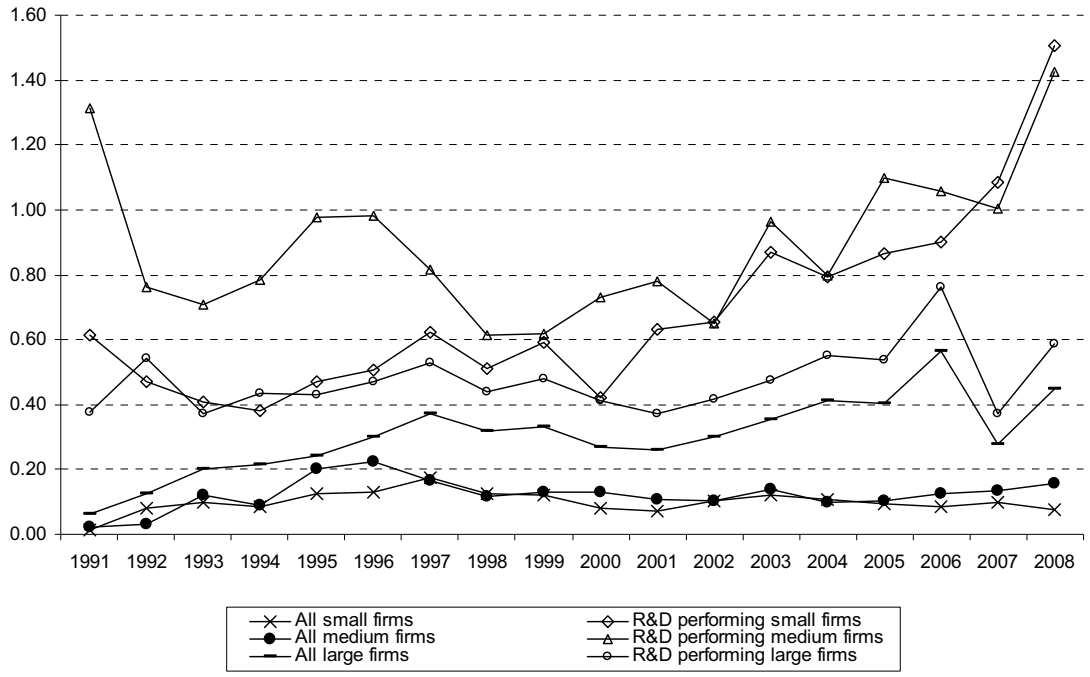
2. SME R&D Trends in Indian Manufacturing

For estimating the size and patterns of SME R&D, the present study draws upon the recently updated firm-level Prowess database of the Centre for Monitoring Indian Economy (2009) and could identify a set of 5237 Indian manufacturing SMEs in the total sample of over 9200 manufacturing firms. The SME classification used in this study is according to investment ceilings specified by the Micro, Small and Medium Enterprise Development Act, 2006 and is based on available firm-specific latest year data on cumulative investment in plant and machinery.

The estimated size and trends of R&D investments by Indian firms across sizes have been presented in Figure-1 and Table-1. It is apparent that Indian manufacturing firms are generally characterized by a 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 a year during 1991−2008. This share slides to 16 per cent and 8.5 per cent for medium firms and small firms respectively. The study 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.

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

(Percent)



Source: Same as Table-1.

As a large proportion of small firms are not doing R&D, the group of small firms exhibit abysmally low level of R&D intensity among all the three size categories of firms. Their R&D intensity is just 0.1 per cent during the study period. Between 1991−99 and 2000−08, small firms' average R&D intensity experienced a 21 per cent fall from 0.12 per cent to 0.09 per cent. The elasticity of R&D expenses to total sales of these small firms, which was 2.53 in 1990s, also fell to 0.94 in 2000s. This falling R&D elasticity and intensity of small firms is a clear concern for policy makers interested in strengthening the capacities of small firms to meet the globalization process.

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.

The group of medium firms, albeit better than small firms in incidence and intensity of undertaking in-house R&D, is also found to have unimpressive performance in the study period. The annual R&D intensity of medium firms fluctuated below 0.2 per cent mark in the overall period with a declining trend in the sub-period 1996–2004 (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, it is the group of large firms that is found to be driving the recent growth of manufacturing R&D in India. Large firms have been pushing up their R&D intensity for the most part of the study period (Figure-1). Their R&D intensity appreciated by a whopping 39 per cent from 0.27 per cent in 1990s to 0.38 per cent in 2000s. Large firms' R&D intensity not only exceeded that of SMEs throughout but the gap has only increased over time.

The evidence presented here, therefore, points to a marked slowdown in the R&D activities of Indian SMEs during the first decade of the twenty-first century. While large firms continue to expand their intensity of R&D activities, SMEs have constricted the same. This shows how Indian manufacturing SMEs are not able to sustain their R&D activities recently 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 may threaten their survivability in the long run.

When the study analyzed the sub-samples of R&D doing firms across different firm sizes, a different pattern of manufacturing R&D performance has been observed. This has been done because the proportion of R&D doing firms vary greatly over firm sizes and it is useful to concentrate on the sub-samples of R&D doing SMEs and R&D doing large firms. In this sub-sample analysis, SMEs are found to do well than their large counterparts—SMEs' R&D intensities are consistently higher than that of large firms, except for two years in the case of small firms. In fact, the set of R&D doing SMEs have generally increased their R&D intensities in the last decade to reach 1.5 per cent in 2008, nearly twice that of R&D doing large firms (Figure-1, Table-1). Since the 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 doing R&D. Therefore, unlike the negative trends of SME R&D that one observed based on the overall sample (that includes both R&D-doing SMEs and R&D not doing SMEs), the R&D doing sub-sample analysis provides an optimistic picture altogether.

These sub-sample 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:

(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 if one moves from large firms to medium firms and then to small firms.

(iii) The sub-set of R&D doing SMEs is way ahead in R&D intensity than the sub-sample of R&D doing large firms. Therefore, the 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 the 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 improving their in-house R&D activities.

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

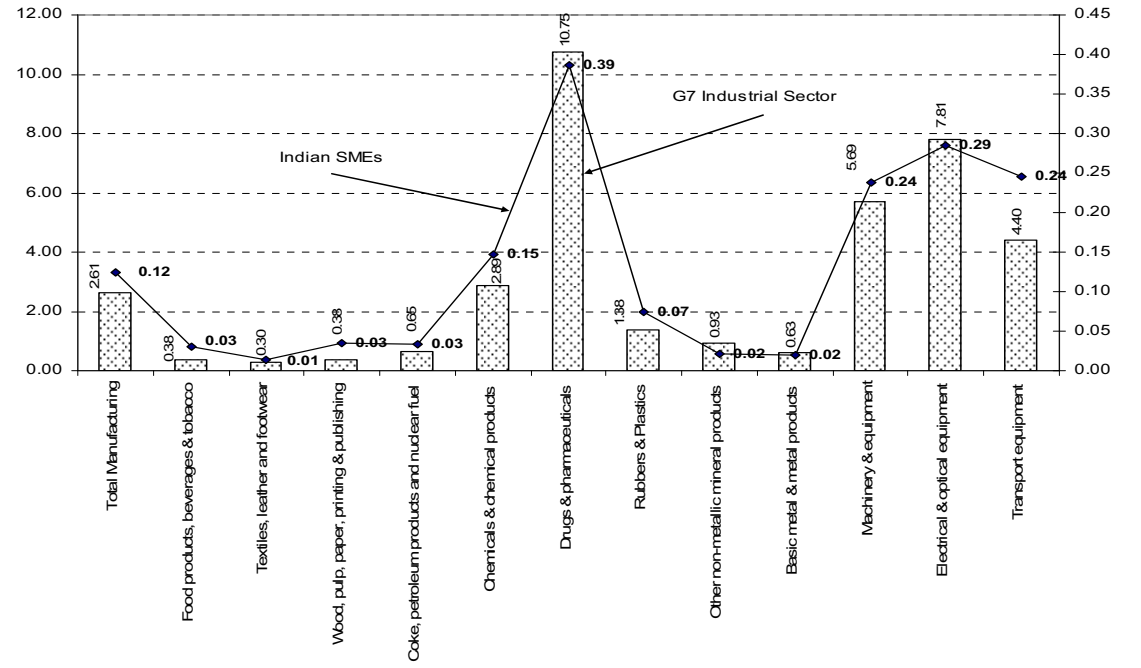
2.3. Industry Trends in SME R&D

Another visible feature of the SME R&D in India is its sectoral concentration. 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. 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 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 concern as India is presumed to have been successful in creating some competitive advantage in this sector.

The higher SME R&D intensities in the Indian manufacturing sector are more confined to technology intensive industries. In 2000−08, the highest R&D intensive SMEs came from chemicals with 0.34 per cent, 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 pattern of R&D intensity across manufacturing activities (Figure-2). There is, however, concern 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 (Figure-2).

It is also a matter of concern that Indian SMEs' R&D intensity has further dwindled between 1990s and 2000s across strategic sectors: 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). This declining trend in R&D intensity between these two periods can also be seen for SMEs in basic metal, food, paper, non-metallic mineral products, miscellaneous and diversified manufacturing activities.

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 the production value whereas Indian SME R&D is calculated using sales.

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

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

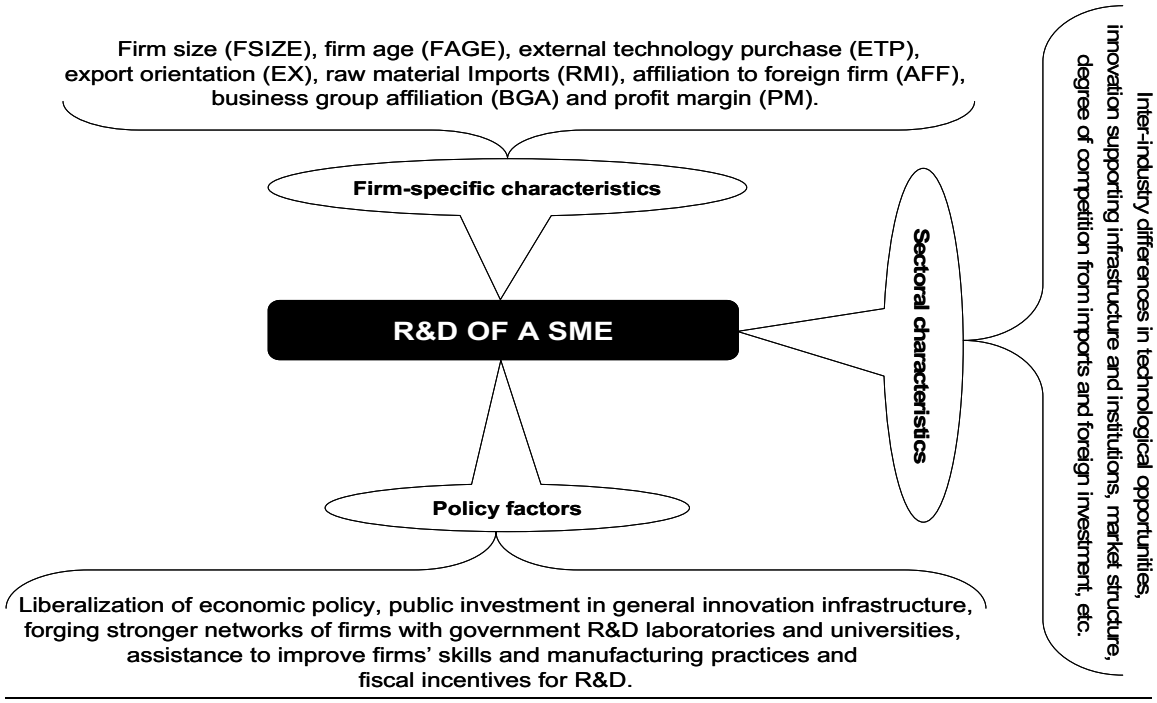
In the light of the continuance of majority of Indian SMEs not doing R&D, it is important to analyze factors that motivate a SME to embark on in-house research activities. The extant literature on R&D behaviour of Indian firms is mostly based on large firm analysis and its results should be reexamined from the experiences of SMEs given their known distinctive nature firm-specific characteristics. SMEs reflect greater flexibility, more focus on local market, mostly supported by local social networks like family and friends, resource constraint and higher incidence of sickness and economic failures.

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 as presented in Figure-3 and 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. These sets of factors are discussed below.

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



3.1.1. Firm-specific Factors

Previous empirical studies have found a decisive role of firm size (*FSIZE*) in the enterprise level R&D performance. In addition to larger resource base and greater risk taking capabilities, larger the firm generally implies the higher incentive to do R&D as the effect of cost reduction (effected via R&D) applies to a larger output and hence, more profitability (Cohen and Klepper, 1996; Fishman and Rob, 1999). When SMEs are a heterogeneous group, one can still expect 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 that may exist between firm size and R&D intensity as indicated by a number of previous studies (Kathuria, 2008; Cohen and Klepper, 1996).

SME R&D decision could be affected by other firm-specific factors like the age of the firm (*FAGE*), external technology purchases (*ETP*), export orientation (*EX*), raw material imports (*RMI*), domestic business group affiliation (*BGA*), foreign firm affiliation (*AFF*) and profit margins (*PM*). *FAGE* can be viewed as a dynamic collection of learning and information resources of the firm as it evolves over its life cycle. 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 than newly started SMEs.

As firms may simultaneously use in-house R&D and purchase of external R&D results to upgrade their overall technological competencies, SME R&D can be hypothesized to be positively related to the degree of *ETP*. Indian firms have historically been buying external technical know-how through technological licenses and joint venture agreements (Pradhan and Puttaswamaiah, 2008) and are undertaking more in-house R&D to effectively absorb, adapt and improved the purchased external technologies. Given this complementarity between these two modes of technology improvements (e.g. Lall, 1983; Katrak, 1985; Siddharthan, 1988; Pradhan, 2002), *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 postulated to have positive impacts on SME in-house R&D activities.

EX is likely to possess a favourable influence on firms' R&D decision (Braga and Wilmore, 1991; Siddharthan and Agarwal, 1992; Rasiah, 2007) as global markets are more demanding in terms of product quality, differentiation, productivity, manufacturing practices and after-sales services than local markets. Moreover, exporting SMEs have the advantage of a larger market to do R&D and greater incentive to absorb knowledge spillovers from exports than a local market-oriented SME. *RMI* is known to have learning, variety and quality effects on importing firms' productivity growth (Halpern et. al., 2005; Amit and Konings, 2007) and these effects could have positive influence on SME R&D as well.

BGA reflects affiliated SMEs' access to the pool resources of the business group and scope to capitalize on intra-group sharing of information and technologies over related sectors of production. These group linked SMEs can overcome financial and skill shortages that characterizes small firms in undertaking R&D. Mahmood and Mitchell (2004) argued that business groups promote R&D of affiliated firms in emerging economies but are creators of 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. *AFF* can provide FDI receiving SMEs access to a larger and deeper endowment of technological advantages of the foreign parent firms. This may lessen their true need of incurring in-house R&D except small modifications related to the technology transfer from parent to the concerned SME. However, foreign parents are increasingly relocating critical R&D offshore 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. Therefore, the overall role of *AFF* in SMEs' R&D activities is postulated to be ambiguous in nature.

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), *PM* can play a crucial role in SME R&D. 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. Therefore, internally generated finance as reflected in *PM* could be an important R&D determinant (Himmelberg and Petersen, 1994; Pradhan, 2002; Kumar and Aggarwal, 2005).

3.1.2. Sectoral Characteristics

SME R&D intensities may also depend on which sectors do they come from. Productive sectors are known to differ in 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. Relatively concentrated industries are likely to be hosts to R&D intensive SMEs as they offer greater appropriation of returns from R&D and higher price-cost margins than more competitive industries. However, this stimulating effect will be smaller if the current monopoly profit is very large and there are little competitive forces via potential entry. Ceteris paribus, 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 that are relatively less exposed to these global competitive pressures. Growing external competition may discourage R&D by lowering anticipated market power of SMEs as well as it may invite reactive R&D by SMEs to protect their market share. As 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 ascertained empirically. In this study, industry level R&D intensity (IRD) and Herfindahl index (HI) are employed 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 used as a proxy 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 macroeconomic policies towards imports and foreign investments can alter market competition at sectoral level and, thus, can impact SME R&D as argued 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. 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[1] claimed by an SME as a per cent of its sales (FSB) as a measure of government incentives for R&D.

In view of the above discussion, 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-2 and ε_{it} is the random error term.

Table-2 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.

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

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. Estimation and Results

3.2.1. Data sources

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[2]. Industry-wise trade (i.e. exports and imports) and production data related to India were respectively drawn from the OECD dataset and ASI.

3.2.2. Methods of estimation

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.

Given the censoring nature of the dependent variable in Model A, the present study has considered two methods of estimation namely, Tobin's (1958) maximum likelihood Tobit estimation and Powell's (1986) censored quantile regression (CQR). Between these two methods, Powell's CQR estimator is more robust and provides consistent estimates when there is heteroscedastic, non-normal and asymmetric errors (Powell, 1986; Chay and Powell 2001; Wilhelm, 2008). The consistency of Tobit results is susceptible to any of these problematic errors. The Skeels and Vella's conditional moment test conducted on our sample

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

indicates that errors in the estimated models are not normally distributed and Tobit coefficient estimates are inconsistent for our samples[3]. Therefore, inferences drawn from the CQR results are more reliable than those from Tobit results in this study.

The test for collinearity among explanatory variables as presented in Table-3 indicates moderate values of variance inflation factor (VIF) for both SMEs and large firm samples. In only the case of firm size and its squared term, the VIF value is slightly larger but less than the thumb value of 5. This moderate collinearity among explanatory variables in our sample is not serious for the estimated standard errors of the coefficients.

The three-step CQR

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 probability model, $p_i = p(\dot{X}_i^{'}\beta) + \varepsilon_i$ (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 $\#\{S_0 \not\subset S_f\}/\#S_f < 0.1$. In the third step quantile regression with bootstrap standard errors based on 1000 replications is fitted for S_f.

As 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 a scenario, choosing a lower quantile like median 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.

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

[3] 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.

to model firms' R&D behaviour, often ignoring the small proportion of R&D doing firms in their sample.

3.2.3. Findings

Table-3 summarizes the results obtained from the applications of the three-step CQR and Tobit estimations for SMEs and large firms[4]. It can be seen that the F and Chi-square values testing the overall significance of estimated CQR and Tobit equations respectively, and both for SMEs and large firms, are statistically different from zero. This suggests fitted models are explaining meaningfully the variations in the R&D behavior of Indian manufacturing firms. As noted earlier, our interpretation on the performance of individual variables is based on the CQR results overriding those from the Tobit estimation. It may be pointed out here that inferences from Tobit are similar to those from CQR in majority cases, but often with relatively lower level of significance (e.g. *EX, RMI* and *PSB* for SMEs and *PM* for large firms). In some cases, Tobit led to opposite conclusion as compared to CQR, for instance, on the role of PM and HI for SMEs and $FSIZE^2$ and FSB for large firms.

Empirical findings on individual factors suggest that SMEs with certain characteristics possess incentives and abilities far superior to those possessed by other SMEs for conducting in-house R&D activities. The positive and significant coefficients of *FAGE* corroborate that longer surviving firms that tend to possess higher stock of accumulated learning and experience are favourably placed in undertaking R&D activities. This result is true for both SMEs and large firms in Indian manufacturing sector and across methods of estimations.

FSIZE and $FSIZE^2$ respectively with significantly positive and negative coefficients would suggest that Indian firms possessing large sizes may enjoy higher R&D scale but this positive effect is only up to a critical level of size. This non-linear relationship between R&D and firm size in Indian manufacturing has also been reported by a number of earlier studies based on samples of large firms (e.g. Pradhan, 2002; Narayanan and Thomas, 2010) and the present finding indicate that the same relationship holds for the SMEs as well. As the majority of SMEs fall far behind the critical limit, increase in size can translate into significant growth of SME R&D in India.

As expected, *EX* comes up with positive and significant coefficients throughout. Thus, the participation in global markets appears 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 positive and significant effect of *RMI* for SME R&D and its insignificant coefficients for large firms would implies that Indian SMEs learns immensely from purchase of raw materials from technologically advance overseas inputs suppliers and are encouraged to increase their R&D intensity. However, imported inputs do not appear to be such an important factor for R&D activities of large firms.

[4] 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-3 Three-step CQR and Tobit Estimation of R&D Intensity (%) of SMEs and Large Firms in Indian Manufacturing

Dependent Variable: R&D Intensity

Independent variables	Coefficients (Absolute bootstrap t-/Z-statistic)				Variance Inflation Factor	
	SMEs		Large Firms		SMEs	Large Firms
	CQR	Tobit	CQR	Tobit		
$FAGE_{it-1}$	0.00195*** (9.40)	0.01654*** (4.83)	0.00304*** (27.82)	0.10341*** (3.86)	1.05	1.05
$FSIZE_{it-1}$	0.00044*** (9.64)	0.00436*** (6.38)	2.7e-06*** (3.24)	0.00005*** (2.94)	3.02	4.46
$FSIZE^2_{it-1}$	-1.1e-07*** (7.40)	-8.3e-07*** (5.28)	-1.9e-12** (2.21)	-2.6e-11 (1.61)	2.97	4.26
$ETP1_{it-1}$	0.00027 (0.03)	-0.00345 (0.19)	0.00061 (0.41)	0.00540 (0.21)	1.01	1.08
$ETP2_{it-1}$	-0.00048 (0.31)	-0.00288 (0.69)	-0.00001 (0.08)	-0.00074 (0.08)	1.02	1.16
EX_{it-1}	0.00425*** (10.85)	0.01040** (2.27)	0.00197*** (23.76)	0.04272*** (2.84)	1.07	1.08
RMI_{it-1}	0.01893*** (9.19)	0.01246* (1.77)	-0.00011 (0.97)	0.00963 (1.46)	1.08	1.19
PM_{it-1}	0.00018*** (11.24)	0.00023 (0.88)	0.00019*** (3.71)	0.00243** (2.50)	1.0	1.0
AFF_i	0.34538** (2.03)	2.04197*** (5.21)	0.17959*** (16.66)	5.80224*** (4.10)	1.03	1.12
BGA_i	0.46384*** (11.52)	2.24703*** (5.59)	0.11360*** (26.30)	4.44139*** (4.22)	1.05	1.12
HI_{jt}	0.00001 (0.88)	0.00080*** (2.96)	0.00002*** (3.79)	0.00144*** (2.97)	1.13	1.15
CFI_{jt}	0.01246*** (12.17)	0.11502*** (5.84)	0.00169*** (10.40)	0.18117*** (3.69)	1.23	1.18
IRD_{jt}	0.36123*** (7.83)	0.90727*** (6.20)	0.64372*** (20.37)	2.92322*** (5.09)	1.09	1.11
IMP_{jt}	0.01305*** (11.53)	0.04348*** (5.68)	0.00079*** (5.16)	0.05041*** (3.73)	1.06	1.03
FSB_{it-1}	-0.02375*** (12.23)	-0.21710* (1.75)	-0.00289*** (7.22)	-0.03597 (1.40)	1.01	1.01
Constant	-0.53930*** (13.09)	-13.85931*** (6.42)	-0.26287*** (30.42)	-23.08314*** (3.91)		
F-value	38.15!		168.44!			
Prob > F	0.0000		0.0000			
Wald chi2 value		51.66		42.50!		
Prob > chi2		0.0000		0.0001		
Pseudo R2	0.0772	0.0676	0.0850	0.0276		
Observations	16724	23296	25189	35180		

Note: Absolute value of bootstrap t- and z-statistics in parentheses for CQR and Tobit results respectively; * significant at 10%; ** significant at 5%; *** significant at 1%; !-test 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.

In the CQR estimation *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 significantly relied on surpluses of resources internally generated in the production process to adopt a deeper R&D strategy. *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 corroborate the perception that the equity participation of foreign investors and 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.

ETP1 and *ETP2* representing disembodied and embodied technology purchases turn out with positive and negative signs respectively in the CQR method 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 (e.g. Lall, 1983; Katrak, 1985, Siddharthan, 1988; 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.

From the CQR estimation *HI* reflecting sectoral differences in market concentration comes up with a hypothesized positive effect while explaining R&D intensity of SMEs and large firms but the effect is significant only for 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 main benefactors as market concentration increases the return to their R&D investments. The R&D of SMEs with moderate market shares appear to be insignificantly affected by sectoral concentration.

CFI and *IMP* respectively measuring competition from foreign firms and cheap imports have turn up with significantly positive coefficients for both SMEs and large firms. It would suggest that increasing competitive pressures from growing imports and expansion of foreign firms are likely to invite greater R&D by domestic firms to defend their domestic market share. *IRD* is 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.

FSB, capturing the fiscal allowance for R&D 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[5]) 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 are not 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.

Overall, it is the higher levels of factors like age (*FAGE*), size (*FSIZE*), export intensity (*EX*), imported inputs (RMI), affiliation to domestic business groups, participation of foreign promoters, and profit margins (PM) that enable Indian SMEs to achieve greater intensity of R&D performance.

4. Concluding remarks

SMEs in emerging markets like India are now operating in an increasingly open economy. While the national market became intensely competitive in the recent past due to new entry and cheap imports, SMEs have to survive with a dwindling policy support and to compete under a stronger IPR regime. Without improving their technological capability, it would be an uphill task for Indian SMEs to continue their past market success. There is, therefore, an urgent case for understanding trends and patterns of SME R&D in India.

Estimates on R&D investments of Indian manufacturing firm by sizes presented in this study indicate that SMEs possess a very low incidence of doing R&D and spend a small proportion of their sales in such activities compared to large firms. SMEs' R&D intensity is found to have markedly declined in the last decade as compared to the 1990s. In contrast, R&D intensity of large firms has increased substantially between these periods. It perhaps indicates that small firms are falling behind in upgradation of technological capabilities than their large counterparts. Moreover, there is evidence on SME R&D getting concentrated to a small group of R&D-doing SMEs in the recent years. It is also clear that R&D investments by SMEs come largely from a few industries.

Thus, in general, it may be infer that there is an uneven trend in the recent technological activities of different firms in the Indian manufacturing sector. The large firms are more aggressive in their R&D investment while SMEs operate with least R&D probability and intensity. This is an important indication that SMEs remain the most vulnerable section of Indian manufacturing enterprises.

[5] 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).

It is evident from the quantitative analysis that SME R&D decision depends on a number of firm- and sector-specific factors. SMEs' preference for R&D is found to generally increase as they grow up in their age, expand their size of operation, get engaged in exports and imports of raw materials, receive strategic investments from domestic business groups and foreign firms, and enjoy higher profitability. It is revealing and useful to note that policies targeting SMEs' participation in international markets for both exports and sourcing of raw materials could push SME R&D upward. Also, liberalizing/increasing the ceiling of equity participation from domestic business groups and foreign firms in the SME sector may add to the advantages of SMEs in R&D activities.

It may also be inferred from the empirical results that creating conditions for overcoming the limitation of small size is of vital importance for achieving full R&D potential of Indian SMEs. We suggest policies to promote industrial clustering of SMEs to minimize the constraint of their small size on R&D. As SMEs possess a moderate level of profitability due to their reliance on low cost competition, the provision of cheap finance appears to be another policy option for expanding SME R&D. One would expect, therefore, measures facilitating SMEs access to capital markets and venture capital funding to be associated with higher levels of SME R&D.

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