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Abstract: This study makes an early attempt to estimate the magnitude and intensity of manufacturing firms' R&D by Indian states during the period 1991–2008 and analyses the role of regional factors on firm-level R&D activities. As there is little research on state-wise R&D performance of firms in India, this study serves an important contribution to the academic and policy realm. It has brought out the fact the total manufacturing R&D investment in India is unevenly distributed regionally with a few states accounting for disproportionate share of it. Regional heterogeneity or inter-state disparities in R&D has increased between the 1990s and the first decade of the twenty-first century. In view of this persistent regional heterogeneity in R&D, the study has developed and estimated an empirical model for a sample of 4545 Indian manufacturing firms with R&D facilities located in single state and that explicitly includes regional factors as probable factors affecting R&D. The three-step Censored Quantitle Regression results confirm that regional factors play an important role in shaping the R&D intensity of the sample of firms. This led us to some useful policy suggestions for regional governments to promote local firms' R&D activities.

Keywords: Regional heterogeneity, R&D, manufacturing firms, Indian states, censored quantitle regression.

1. Introduction

Given the criticality of technological factors in determining growth, productivity, and competitiveness of nations, industries and firms, recent decades have seen a surge of academic explorations and policy focus on the issue of firms' R&D behaviour. Especially for late comers emerging markets like India, China, Brazil, etc., the relatively low participation and intensity of their firms in R&D has been the key challenge for policy makers to catch up with the developed economies. The ratio of R&D investments as a share of gross domestic product of these emerging countries, not withstanding its doubling for China while stagnating for India between 1999 and 2007 (Gilman, 2010), is still low when compared to the ratios for European countries and the U.S.

Although the existing R&D literature on emerging economies has contributed to the enhance understanding of factors influencing firms technological activities for policy purposes, there is distinctly inadequate attention devoted to the role of regional forces. Geographically vast emerging economies like India or China are characterized by enormous inter-regional differences in levels of economic development, per capita income, physical and socio-economic infrastructure, etc., and this regional heterogeneity can significantly affect firms' R&D performance. Therefore, there is a need to analyze the regional patterns of firms R&D investment in a given country and examine the factors that contribute to variations in such investment across regions.

In this context, the present study examines the R&D performance of manufacturing firms across Indian states and analyzes the factors that can explain inter-state differences in firms' R&D behaviour. It departs from existing literature on the issue by developing an expanded empirical framework that includes not just firm- and sector-specific factors mostly focused by previous studies but also a set of region-specific indicators.

2. State-wise patterns of R&D investments

In India, regional disparities in growth, productivity and industrial location have received a lot of academic and policy attention over time. However, explaining regional differences in industrial R&D, which is a crucial determinant of productivity, has been provided inadequate attention. Apart from the unavailability of required data, this poor attention to regional R&D appears to be a result of the domination of the neoclassical framework for analyzing regional economic growth. In the neoclassical model, knowledge gets diffused effortlessly to wither any technology gaps between geographical locations (Caniëls, 1996). However, contrary to this view, innovation and diffusion is specific to different location and there is continuing concentration of R&D across countries and regions within a given country.

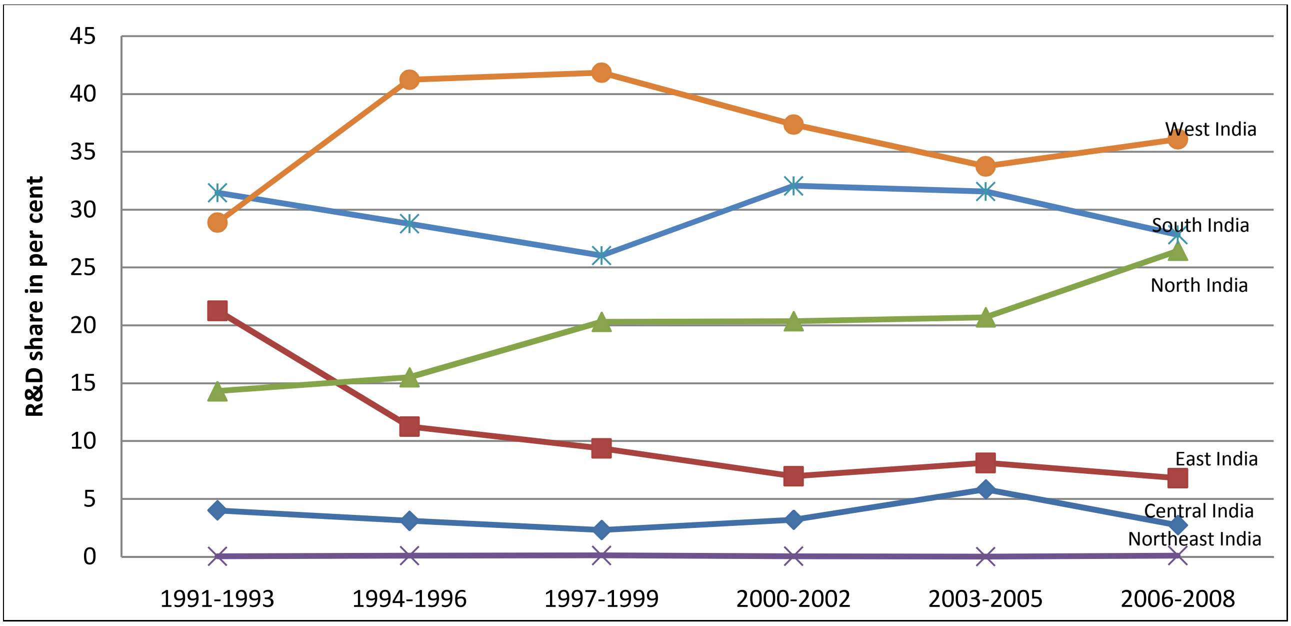
As there is no estimates exist on state-wise manufacturing R&D in India, testing the significance of regional heterogeneity in Indian firms' innovation is obviously constraint by the data unavailability. For this reason, the present study draws upon a unique locational dataset comprising a total of 8486 Indian manufacturing firms unbalancedly distributed over 1991–2008 to present here a preliminary set of estimates on state-wise manufacturing R&D investments. This dataset, which has been prepared for an ongoing research study entitled *Exploring Regional Patterns of Internationalization of Indian Firms: Learnings for Policy* supported by the Indian Council of Social Science Research (ICSSR), India, provides firms' plant location data as well as their R&D unit location data compiled from the *Directory of Recognised In-House R&D Units* released by the Department of Scientific & Industrial Research under the Ministry of Science and Technology, Government of India (please see the data appendix for more detail).

The regional trend and distribution of Indian manufacturing R&D, as summarized in Table-1 and Figure-1, verify a persistent heterogeneity in R&D investments among regions in India. It is found that the West India accounted for the largest share of national manufacturing R&D investment in 1991─99 (40 per cent), followed by South India with 27.6 per cent and North India with 18 per cent. Together these three regions claimed about 86 per cent of the total R&D while the remaining 14 per cent is shared by Central India, East India, and Northeast India. The share of these top three regions further went up to 89 per cent in 2000─08. As depicted in the Figure-1, the R&D shares of North India and West India are up 85 per cent and 25 per cent respectively between 1991─93 and 2006─08 while that of East India and Central India deteriorated significantly.

At individual state level, just about top five Indian states (Maharashtra, Tamil Nadu, Gujarat, Jharkhand, and Karnataka) accounted for more than 67 per cent of manufacturing R&D over 1991─99. The share of top five states (Maharashtra, Andhra Pradesh, Tamil Nadu, Haryana, and Gujarat) continued over 63 per cent share during 2000─08. The combined share of bottom 10 states remained low varying between two and three per cent in these sub-periods. This would imply that relatively a smaller set of Indian states comprise disproportionately larger share of total manufacturing R&D investments in the country.

The persistent unevenness in the regional distribution of R&D is also evident across different industry groups based on technological classification. The share of top five states in the R&D investments by high-technology industries is about 70 per cent in the 1990s and 66 per cent in the 2000s; the same ratio for medium-technology industries is 84 per cent in 1991─99 and 73 per cent in 2000─08 and for low-technology manufacturing industries it has increased from 58 per cent to 81 per cent.

Figure-1 Regional distribution of manufacturing R&D, 1991—1993 to 2006—2008



Source: SPIESR-GIDR locational dataset of Prowess manufacturing firms (2010)

The regional disparity in industrial R&D among Indian states is also mirrored in the inter-state distribution of the proportion and intensity of firms undertaking R&D activities. In terms of the proportion of firms doing R&D out of the total number of firms, most Indian states have shown modest probability of firms' doing R&D. So far, however, this ratio varies considerably across Indian states with a range of 4 per cent to 27 per cent in the 1990s and 5 per cent to 31 per cent in the 2000s (Table-2). The inter-state variability is far greater for the sub-sample of firms from the high-technology industries with a wider range of 2 per cent to 68 per cent in the 1990s (2 per cent to 50 per cent in the 2000s). There were just 9 Indian states and union territories during the period 1991—99 (out of total of 25 Indian sub-national entities) that possessed higher proportion of firms incurring R&D than the national average (8 in 2000—08).

In case of R&D intensity too regional disparity emerged as a distinctive feature of manufacturing firms' R&D in India. The magnitude of intensity of firms' R&D is observed to be quite small for the full sample at 0.25 per cent in 1991—99 but it increased to 0.4 per cent in 2000—08 (Tabke-2). However, this ratio differs significantly among Indian states. For individual states, the ratio of R&D expenses to sales ranged between 0 per cent and 1 per cent in the study sub-periods. The number of the bottom states that had R&D intensities below 0.1 per cent is eight in 1991—99 and six in 2000—08.

Table-1 Manufacturing R&D investments of Indian states, 1991─1999 & 2000─2008

Region/state	Manufacturing R&D expenses ($ millions)							
	1991─1999				2000─2008			
	Total	High-tech.	Medium-tech.	Low-tech.	Total	High-tech.	Medium-tech.	Low-tech.
Central India	**73.4 (2.8)**	**58.1 (2.9)**	**12.2 (2.4)**	**3.2 (2.3)**	**375.4 (3.6)**	**272.6 (3.2)**	**98.2 (8.1)**	**4.7 (0.9)**
Chhattisgarh	2.0 (0.1)	0.0 (0.0)	2.0 (0.4)	0.0 (0.0)	3.7 (0.0)	0.0 (0.0)	3.6 (0.3)	0.1 (0.0)
Madhya Pradesh	71.4 (2.7)	58.1 (2.9)	10.2 (2.0)	3.1 (2.2)	371.7 (3.6)	272.5 (3.2)	94.6 (7.8)	4.6 (0.9)
East India	**302.9 (11.5)**	**137.1 (6.9)**	**156.9 (30.6)**	**9.0 (6.4)**	**739.9 (7.2)**	**492.3 (5.7)**	**236.1 (19.4)**	**11.5 (2.2)**
Bihar	1.0 (0.0)	0.1 (0.0)	0.3 (0.1)	0.6 (0.5)	1.7 (0.0)	0.0 (0.0)	0.1 (0.0)	1.6 (0.3)
Jharkhand	227.4 (8.6)	85.6 (4.3)	141.3 (27.6)	0.5 (0.4)	514.6 (5.0)	335.6 (3.9)	178.5 (14.7)	0.6 (0.1)
Orissa	6.3 (0.2)	0.0 (0.0)	6.2 (1.2)	0.1 (0.0)	148.2 (1.4)	92.9 (1.1)	54.7 (4.5)	0.6 (0.1)
West Bengal	68.2 (2.6)	51.4 (2.6)	9.1 (1.8)	7.8 (5.6)	75.3 (0.7)	63.8 (0.7)	2.8 (0.2)	8.7 (1.7)
North India	**472.3 (18.0)**	**357.5 (18.1)**	**89.4 (17.4)**	**25.4 (18.2)**	**2477.3 (24.0)**	**1994.8 (23.3)**	**259.5 (21.4)**	**223.0 (42.8)**
Delhi	17.3 (0.7)	17.2 (0.9)	0.0 (0.0)	0.1 (0.1)	113.6 (1.1)	112.9 (1.3)	0.0 (0.0)	0.7 (0.1)
Haryana	200.0 (7.6)	112.6 (5.7)	79.9 (15.6)	7.5 (5.4)	986.0 (9.6)	794.5 (9.3)	175.1 (14.4)	16.4 (3.1)
Himachal Pradesh	32.4 (1.2)	30.9 (1.6)	0.4 (0.1)	1.1 (0.8)	104.1 (1.0)	98.7 (1.2)	2.0 (0.2)	3.4 (0.6)
Jammu & Kashmir	0.7 (0.0)	0.7 (0.0)	0.0 (0.0)	0.0 (0.0)	1.1 (0.0)	0.8 (0.0)	0.4 (0.0)	0.0 (0.0)
Punjab	71.2 (2.7)	61.0 (3.1)	1.3 (0.3)	8.9 (6.4)	269.1 (2.6)	246.4 (2.9)	1.4 (0.1)	21.3 (4.1)
Uttar Pradesh	97.6 (3.7)	82.2 (4.2)	7.6 (1.5)	7.8 (5.6)	823.7 (8.0)	609.3 (7.1)	34.5 (2.8)	179.8 (34.5)
Uttarakhand	52.7 (2.0)	52.6 (2.7)	0.1 (0.0)	0.0 (0.0)	179.6 (1.7)	132.2 (1.5)	46.0 (3.8)	1.4 (0.3)
Northeast India	**2.6 (0.1)**	**0.1 (0.0)**	**0.0 (0.0)**	**2.5 (1.8)**	**8.0 (0.1)**	**0.0 (0.0)**	**4.3 (0.4)**	**3.6 (0.7)**
Assam	2.6 (0.1)	0.1 (0.0)	0.0 (0.0)	2.5 (1.8)	7.8 (0.1)	0.0 (0.0)	4.2 (0.3)	3.5 (0.7)
South India	**727.3 (27.6)**	**554.2 (28.0)**	**119.1 (23.2)**	**54.0 (38.6)**	**3036.0 (29.4)**	**2705.4 (31.6)**	**147.4 (12.1)**	**183.2 (35.2)**
Andhra Pradesh	151.1 (5.7)	119.2 (6.0)	15.9 (3.1)	16.1 (11.5)	1072.0 (10.4)	969.4 (11.3)	31.2 (2.6)	71.4 (13.7)

Karnataka	219.3 (8.3)	196.9 (10.0)	8.2 (1.6)	14.2 (10.1)	855.6 (8.3)	764.9 (8.9)	22.6 (1.9)	68.1 (13.1)
Kerala	28.5 (1.1)	13.2 (0.7)	6.5 (1.3)	8.8 (6.3)	50.2 (0.5)	27.8 (0.3)	12.5 (1.0)	9.9 (1.9)
Pondicherry	11.6 (0.4)	11.3 (0.6)	0.3 (0.1)	0.0 (0.0)	18.9 (0.2)	18.4 (0.2)	0.4 (0.0)	0.1 (0.0)
Tamil Nadu	316.8 (12.0)	213.7 (10.8)	88.2 (17.2)	14.9 (10.7)	1039.3 (10.1)	924.9 (10.8)	80.6 (6.6)	33.7 (6.5)
West India	**1052.5** **(40.0)**	**871.7** **(44.1)**	**134.9** **(26.3)**	**45.9** **(32.8)**	**3673.7** **(35.6)**	**3109.8** **(36.3)**	**469.3** **(38.6)**	**94.5** **(18.2)**
Dadra & Nagar Haveli	13.6 (0.5)	11.9 (0.6)	1.6 (0.3)	0.1 (0.0)	93.5 (0.9)	89.4 (1.0)	4.0 (0.3)	0.1 (0.0)
Daman & Diu	0.5 (0.0)	0.5 (0.0)	0.0 (0.0)	0.0 (0.0)	11.5 (0.1)	11.2 (0.1)	0.2 (0.0)	0.1 (0.0)
Goa	2.6 (0.1)	2.4 (0.1)	0.2 (0.0)	0.0 (0.0)	78.3 (0.8)	75.9 (0.9)	1.0 (0.1)	1.3 (0.3)
Gujarat	237.0 (9.0)	185.9 (9.4)	41.8 (8.2)	9.4 (6.7)	901.9 (8.7)	685.1 (8.0)	204.5 (16.8)	12.3 (2.4)
Maharashtra	767.8 (29.2)	661.1 (33.4)	81.5 (15.9)	25.2 (18.0)	2511.8 (24.4)	2203.5 (25.7)	237.5 (19.6)	70.7 (13.6)
Rajasthan	31.0 (1.2)	9.9 (0.5)	9.9 (1.9)	11.2 (8.0)	76.7 (0.7)	44.7 (0.5)	22.1 (1.8)	9.9 (1.9)
Grand Total	**2631.0** **(100)**	**1978.6** **(100)**	**512.6** **(100)**	**139.9** **(100)**	**10310.2** **(100)**	**8574.8** **(100)**	**1214.8** **(100)**	**520.6** **(100)**

Note: Percentage share in parentheses; High-tech includes chemicals, pharmaceuticals, electrical & optical equipment, machinery & equipment and transport equipment; Medium-tech comprises basic metal, coke & petroleum products, rubbers & plastics and other non-metallic mineral products; Low-tech covers manufacturing activities related to food products including beverages & tobacco, leather, textiles, publishing & printing, pulp & paper and other manufacturing including diversified.

Source: Same as Figure-1.

Table-2 State-wise proportion of R&D doing firms and R&D intensity, 1991–1999 & 2000–2008

Region/state	Average annual proportion of R&D doing firms to all firms (%)								R&D intensity (%)							
	1991–1999				2000–2008				1991–1999				2000–2008			
	Total	High-tech.	Medium-tech.	Low-tech.	Total	High-tech.	Medium-tech.	Low-tech.	Total	High-tech.	Medium-tech.	Low-tech.	Total	High-tech.	Medium-tech.	Low-tech.
Central India	**11.6**	**17.8**	**9.9**	**6.8**	**14.9**	**20.0**	**14.9**	**9.4**	**0.13**	**0.35**	**0.05**	**0.03**	**0.37**	**0.99**	**0.18**	**0.02**
Chhattisgarh	7.8	14.8	8.3	4.0	12.2	20.4	12.9	7.8	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01
Madhya Pradesh	12.3	18.0	10.8	7.2	15.6	20.1	16.2	9.6	0.19	0.36	0.10	0.03	0.55	1.00	0.44	0.02
East India	**16.7**	**24.4**	**15.5**	**10.9**	**15.1**	**27.1**	**12.4**	**9.4**	**0.21**	**0.52**	**0.17**	**0.04**	**0.24**	**0.93**	**0.11**	**0.03**
Bihar	18.6	18.1	13.6	21.7	15.5	1.6	13.0	20.3	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.02
Jharkhand	21.4	19.0	24.0	20.7	16.6	19.5	13.3	22.6	0.90	1.40	0.75	0.22	1.09	2.22	0.57	0.09
Orissa	9.3	2.3	14.6	5.0	12.8	14.5	15.8	7.6	0.03	0.00	0.04	0.00	0.32	1.32	0.16	0.01
West Bengal	17.7	28.7	13.7	10.3	15.3	31.9	10.6	8.1	0.10	0.34	0.02	0.04	0.05	0.21	0.00	0.03
North India	**16.0**	**19.6**	**13.9**	**12.3**	**20.9**	**26.8**	**16.7**	**15.5**	**0.23**	**0.36**	**0.13**	**0.06**	**0.49**	**0.84**	**0.15**	**0.24**
Delhi	12.7	19.0	28.6	0.9	9.9	20.2	0.0	3.4	0.99	3.05	0.07	0.01	0.64	1.84	0.00	0.01
Haryana	17.4	20.8	18.7	11.3	25.4	34.6	17.8	15.5	0.32	0.37	0.31	0.13	0.62	1.08	0.24	0.12
Himachal Pradesh	14.8	16.6	8.2	17.2	20.4	20.6	12.1	26.0	0.28	0.42	0.02	0.06	0.32	0.42	0.05	0.07
Jammu & Kashmir	13.3	13.5	23.1	0.0	11.5	10.3	30.6	0.0	0.03	0.03	0.01	0.00	0.01	0.01	0.05	0.00
Punjab	18.9	22.8	8.7	19.5	23.6	29.7	16.9	21.6	0.22	0.44	0.02	0.08	0.43	1.11	0.01	0.12
Uttar Pradesh	15.7	20.1	13.9	11.7	22.2	28.2	21.0	16.8	0.12	0.24	0.03	0.04	0.45	0.82	0.05	0.49
Uttarakhand	11.8	17.0	9.9	0.5	13.6	20.2	3.3	3.1	0.30	0.45	0.01	0.00	0.42	0.43	1.41	0.02
Northeast India	**12.8**	**13.0**	**1.0**	**15.1**	**18.5**	**11.3**	**16.2**	**19.8**	**0.01**	**0.02**	**0.00**	**0.06**	**0.01**	**0.00**	**0.01**	**0.07**
Assam	13.2	13.0	1.1	15.6	17.9	11.5	15.5	18.9	0.01	0.02	0.00	0.06	0.01	0.00	0.01	0.07
South India	**16.8**	**26.1**	**12.4**	**8.8**	**22.7**	**34.6**	**18.0**	**12.4**	**0.29**	**0.61**	**0.12**	**0.09**	**0.49**	**1.48**	**0.05**	**0.16**
Andhra Pradesh	13.9	21.3	9.5	8.8	21.1	30.8	15.3	12.3	0.21	0.59	0.04	0.10	0.60	2.25	0.03	0.24
Karnataka	20.3	28.1	14.5	13.6	28.9	38.6	21.7	21.3	0.47	0.86	0.06	0.14	0.65	1.82	0.04	0.21
Kerala	11.8	21.5	11.3	5.6	14.8	30.0	9.1	9.4	0.07	0.18	0.02	0.16	0.05	0.36	0.02	0.11
Pondicherry	27.3	68.0	26.0	4.2	23.2	49.8	20.4	1.0	0.93	2.00	0.13	0.00	1.02	2.55	0.06	0.02
Tamil Nadu	17.3	27.6	13.7	7.2	22.4	35.5	21.4	9.4	0.35	0.52	0.38	0.06	0.50	1.04	0.11	0.08

West India	**16.1**	**21.8**	**12.5**	**9.3**	**20.4**	**28.9**	**15.0**	**11.7**	**0.28**	**0.52**	**0.10**	**0.07**	**0.38**	**0.98**	**0.09**	**0.07**
Dadra & Nagar Haveli	6.3	4.5	12.2	2.3	8.4	7.5	12.4	4.5	0.14	0.33	0.06	0.00	0.33	0.84	0.04	0.00
Daman & Diu	3.9	6.7	0.0	2.9	5.0	7.4	0.5	5.7	0.02	0.03	0.00	0.00	0.11	0.14	0.01	0.01
Goa	14.2	27.1	3.1	0.0	31.6	41.6	22.4	17.1	0.05	0.07	0.02	0.00	0.83	1.15	0.06	0.13
Gujarat	12.7	17.4	6.2	9.1	17.1	24.3	9.6	10.4	0.21	0.37	0.10	0.05	0.26	0.72	0.10	0.03
Maharashtra	20.7	28.6	17.4	9.5	25.5	36.8	19.4	12.7	0.35	0.67	0.10	0.07	0.48	1.22	0.09	0.10
Rajasthan	13.7	13.9	12.6	14.6	16.5	18.5	17.0	14.2	0.11	0.10	0.12	0.13	0.14	0.26	0.11	0.06
Grand Total	**16.1**	**22.4**	**12.7**	**9.9**	**20.4**	**29.4**	**15.7**	**12.6**	**0.25**	**0.49**	**0.11**	**0.07**	**0.40**	**1.05**	**0.09**	**0.13**

Note: High-tech includes chemicals, pharmaceuticals, electrical & optical equipment, machinery & equipment and transport equipment; Medium-tech comprises basic metal, coke & petroleum products, rubbers & plastics and other non-metallic mineral products; Low-tech covers manufacturing activities related to food products including beverages & tobacco, leather, textiles, publishing & printing, pulp & paper and other manufacturing including diversified.

Source: Same as Figure-1.

As these statistics indicate, there is a continuing inter-state difference in the observed probability and intensity of R&D among local firms. What causes firms' R&D behaviour to vary across sub-national geographies, therefore, is a crucial issue for both regional development and long term competitiveness of national advantages. In the context of industrial R&D in India, it is important to pay special focus on regional factors that enable a selected group of states to do disproportionate R&D performance than others. This could constitute an important policy lessons for states lagging behind in R&D activities.

In what follows, the study briefly reviews the theories of innovation and develops an extended framework of firms' R&D in a regional setting for analyzing inter-state heterogeneity in industrial R&D in India.

3. Theories of Innovation and Determinants of Firms' R&D Behaviour

The recent literature on industry, trade and foreign investment has pointed out a persistent productivity differences among firms within a given industry (Wagner, 2007). This intra-industry firm heterogeneity has been duly incorporated into theories explaining firms' choice of exporting and foreign production (Melitz, 2003; Helpman et al., 2004). As R&D is a crucial determinant of firms' productivity (Griliches, 1998), much of this heterogeneity is likely to be resulting from inter-firm differences in the probability and intensity of doing R&D investments. The theories of innovation can help us in understanding factors that causes asymmetric R&D behaviours among firms. In what follows, we explore the theoretical and empirical literature to identify potential factors affecting firms' R&D behaviour.

3.1. Market structure and firm size

Schumpeter (1934) asserted that innovation is the key driver of economic development. The discontinuous manifestation of 'new combinations' in the Schumpeterian theory of innovation ensures that capitalistic economies shift from a routine economic growth bounded by continuous adaptation around small external changes to the path of dynamic economic development (Hagedoorn, 1996). These new combinations reflected in new product, new process, new market, new source of raw materials and new organisation greatly facilitate the process of development by radicalizing and endogenizing the economic structure. Schumpeter (1942) later saw imperfectly competitive markets as a necessary condition for technological progress. As such, large firms in concentrated markets are seen as agents of technical change.

Following the Schumpeterian paradigm, market concentration and firm size are invariably included as two important determinants of R&D activities (Siddharthan, 2009). Relatively concentrated industries are hypothesized to encourage firms' R&D activities as they offer greater appropriation of returns from R&D and higher price-cost margins than more competitive industries. However, if the current monopoly profit is very large and there are strong barriers to potential entry, monopoly power may turn out to be a threat for innovation. In Fishman and Rob's (1999) theoretical model, large sized firms are expected to invest more in R&D than smaller ones because the effect of cost reduction (implemented through R&D) applies to a larger customer base and so is more profitable for them. Moreover, large size represents large resource base and higher risk taking capabilities conducive for greater firm-level innovative activity. Empirical findings on the role of market concentration and firm size in R&D activity, however, are found to be mixed (Cohen, 1995; Subodh, 2002). Nonetheless, empirical studies related to Indian firms in the last decade (i.e. 2000–2008) predominantly suggestive of a positive relationship between firm size and R&D, at least for a specific range of sales when non-linearity was detected (Pradhan, 2002, 2010; Kumar and Aggarwal, 2005; Kathuria, 2008; Narayanan and Bhat, 2009; Ghosh, 2009; Narayanan and Thomas, 2010). With regard to the role of industry concentration, Pradhan (2010) reported a positive impact on firms' R&D while Kathuria (2008) obtained a negative effect for relatively a small sample.

3.2. Sectoral technological opportunities

In addition to market structure and firm size, sectoral technological characteristics are theorized to have independent influence on firm-level R&D efforts. A section of the evolutionary theory (Malerba and Orsenigo, 1995, 1996; Breschi et. al., 2000; Malerba, 2002, 2005) tends to relate firm-level innovative activities to sector-specific technological environment defined by specific configuration of the extent of technological opportunities, appropriability, cumulativeness of technical competencies and nature of the knowledge base. Industries most often substantially vary in terms of these features of technological regime, which can be an important source of inter-firm differences in R&D activities across sectors. Pavitt's (1984) seminal sectoral taxonomy on innovation has already emphasized about the existence of differences in the sources of innovation across sectors. Therefore, differences in technological opportunities and appropriability conditions across industries are important determinants of firms' technological strategies.

3.3. Business group affiliation

In a given industry firms differ from each other not only in terms of size but also by a host of other firm-specific characteristics crucial in affecting firm-level R&D investments. In the recent literature firms' affiliation to domestic business group has been advanced as an important R&D determinant, especially for firms from emerging market economies. Business groups are argued to have emerged to internalize market failures and asymmetric access to information that are rampant in emerging economies (Guillén, 2000; Khanna & Palepu, 2000). In the absence of facilitating institutions, information and infrastructure, standalone or non-group firms faces greater risks and uncertainty in doing R&D while the group ties tend to help the affiliate firms to reduce transaction cost by sharing of information, inputs, skills, infrastructure, technologies, etc. for mutual advantages (Chang and Hong 2000; Chang *et al.*, 2006). Mahmood and Mitchell (2004) went further to hypothesized that business groups facilitates innovation of affiliated firms by providing requisite institutional infrastructure but negatively affect R&D of non-group firms. Business groups unlike standalone firms have preferential access to resources needed for creating innovation infrastructure and with greater interrelationships among diversified areas may foreclose markets to the latter. For a sample of South Korean and Taiwanese firms, Chang et. al. (2006) observed that the superior innovativeness of business groups over independent firms was limited to just South Korea in the early 1990s period, but not for Taiwan. Belenzon and Berkovitz (2010) for a set of European firms reported group firms to be more innovative than independent firms, especially in industries that rely more on external funding. Pradhan (2010) for a sample of Indian manufacturing firms with separate estimations for large firms and small and medium firms confirmed that group affiliation tends to promote firms' R&D intensity.

3.4. MNE affiliation

Foreign ownership is another potential factor important for firms' R&D activities in the host developing countries. Multinational enterprises (MNEs) possess a set of competitive advantages emanating from technologies, skills, brands, etc., which they exploit by undertaking direct production in host countries (Hymer, 1960). This implies transfer of tangible and intangible resources from foreign parents to their subsidiaries in the host countries. As foreign-owned subsidiaries mostly draw upon the knowledge base of parent companies, they have limited incentive and scope for undertaking local R&D except for adaptation and minor modifications required by local demand and factor conditions. The earlier literature in the 1960s–1980s largely assigned a minor role for foreign affiliates in host country R&D activities (Lall, 1995; Rasiah, 2007). However, the last decade has seen rapid internationalization of R&D activities of MNEs that are increasingly relocating critical R&D offshore to emerging economies (UNCTAD, 2005; De Beule, 2010). As MNEs are looking for new locations with low cost skilled manpower and high innovation potential, their foreign affiliates are increasingly entrusted with important innovative activities. In this context, R&D activities of foreign affiliates assumed significant role in host developing countries. Though the earlier studies on India related to the 1980s–1990s largely reported a lower R&D intensity of foreign owned firms than that of domestic firms (Pradhan, 2002; Kathuria, 2008), the most recent study covering the longer period during 1991-2008 and relatively a large sample with superior econometric tools like the three-step Censored Quantile Regression has found the reverse (Pradhan, 2010). This would indicate that the role of foreign ownership in R&D of Indian firms has got transformed from a negative effect in the past into a positive one in the recent period.

3.5. Technology imports

As the acquisition of new technologies by firms can also be from purchases from external sources, the literature has seen a continuing debate on how in-house R&D and external technology acquisitions are related (Siddharthan, 2000). Two important but conflicting propositions have been advanced on this issue. Perhaps, the earliest one is the portrayal of a complementary relationship between firms' imports of foreign technologies and in-house R&D. Traditionally, imports of technologies in embodied and disembodied forms are known to be an important source of technological capability building in developing countries, which are assumed to be mostly technology-followers in the economic theory (Vernon, 1966; Forbes and Wield, 2000; Lin, 2010). However, efficient absorption of imported foreign technologies is likely to motivate the importing firms to undertake in-house R&D for local adaptations leading to a complementary outcome. The past literature on technology developments in developing countries during the 1970s to the 1980s have strongly supported the view that local R&D in these countries were more of adaptive innovation associated with imports of foreign technologies (Nelson, 1987; Teitel, 1987; Bell and Pavitt, 1995). However, the other view tends to present a substituting connection between external technologies and in-house R&D. As argued in the strategic management theory (Prahalad and Hamel, 1990; Porter, 1996), a firm can't sustain its core competencies by relying on mere outsourcing of R&D function to a third party or on purchase of foreign technologies, without investing in continuous up-gradation and renewal of critical technologies in-house. In a liberalized policy regime, when all firms have easy access to external technologies through imports, it is only the sub-set of those firms that can creatively modify the imported technologies (implying in-house R&D) will do better in the market place (Siddharthan, 2000). In a similar vein, Tsai and Wang (2008) based on a sample of 341 Taiwanese electronics-manufacturing firms over the period from 1998 to 2002 have found that firm performance is not significantly affected by external technology acquisition per se but the positive impact of external technology on firm performance increases with the level of their internal R&D efforts. This brief review implies that firms are likely to have an integrative technological strategy where in-house R&D and investments in external sources of technologies tend to complement each other (Lall, 1983; Katrak, 1985; Siddharthan, 1988; Pradhan, 2002).

3.6. Export-orientation

The role of firms' participation international markets, represented by the degree of export orientation, in their R&D process has increasingly received theoretical and empirical focus during the last couple of decades. According to Hughes (1986) exporting encourages R&D investments because R&D fetches greater return in export markets characterize by differential consumer preferences and higher levels of product differentiation and competition than the domestic market. As global markets are intensely competitive in terms of product quality, differentiation, productivity, manufacturing practices and after-sales services than domestic markets, exporting is likely to help firms become more innovative (Braga and Wilmore, 1991; Siddharthan and Agarwal, 1992; Rasiah, 2007, Pradhan and Singh, 2009). Firms serving both domestic and export market possess the advantage of a larger market to do R&D and greater incentive to absorb knowledge spillovers from exports than a local market-oriented firms. A number of recent studies (e.g. Salomon and Shaver, 2005; Liu and Buck, 2007; Ramstetter and Yang, 2009; Damijan et. al. 2010; Pradhan, 2010) have provided evidence that exporting plays a positive role in firms innovative activities.

3.7. Firm age

There is also a theoretical and empirical view that the age of the firm may possesses important implication for their R&D activities. In their learning model of industrial and firm dynamics, Ericson and Pakes (1995) proposed that firms evolve through an active and dynamic collection of learning and prediction about the optimum level of operation over their life cycle. In the case of Jovanovic (1982) firms' learning take place in passive manner. As per these learning models, incumbent older firms are likely to have greater stock of accumulated learning and information over the past than the new entrants (i.e. young firms) into the industry. Since new firms enter being uncertain about the optimal level of their cost and profit, one may expect them to be hesitant in doing risky R&D strategy in their initial years of the life cycle than their older counterparts. This may implies a positive feedback from firm age to its R&D propensity.

3.8. Profitability

The role of internal finance in firms' R&D efforts has been widely explored in the innovation literature (Hall, 2002). Hall and Lerner (2010) argued that the sources of external finance like new debt and equity for undertaking R&D investments is much more expensive than internal finance (i.e., retained earnings) due to the existence of asymmetric information, principal-agent conflict, and tax considerations. This implies that internal cash flow as reflected by profitability can have a bearing firms' R&D decision. According to Pradhan and Singh (2009) higher profit margins increase the size of internally generated resources potentially available to a firm for supporting a sustained in-house R&D programme. In emerging economies where market imperfections are widespread and firms' face extreme difficulty in accessing finance from institutional credit and capital markets, firms R&D decision can be predicted to be more sensitive to the level of internal resources represented by profit margins (Himmelberg and Petersen, 1994; Pradhan, 2002, 2010; Kumar and Aggarwal, 2005).

3.9. Foreign competition

The idea that changes in the intensity of foreign competition may influence firms' technical efficiency is one of the key predictions provided by the 'new' trade theory (Tybout, 2003). Empirical evidence on import liberalization (reduction in tariffs and removal of non-tariff barriers) as reviewed by Tybout (2003) strongly suggests that it causes increased competitive pressures and supplies more product varieties to the domestic market, which in turn leads to a process of selection where only productive firms survive with greater resources and aggregate productivity increases. In this process of adjustment surviving firms are expected to increase their R&D investments to reduce costs and improve product quality to defend or expand their market share. Impullitti and Licandro (2010) have provided a robust and dynamic industry model with firm heterogeneity where trade liberalization or import competition tend to reduce mark-ups/price-cost margins and force less productive firms out of the domestic market while redistribute resources in favour of more productive firms and increases their incentives to innovate. This pro-innovation effect of import competition can be expected to be similar when foreign competition results from the entry of new foreign firms into the industry. In addition to competitive effect, foreign investments may stimulates local innovations by creating forward and backward linkages, demonstrating new technologies and management practices, and generating knowledge spillovers as extensively emphasized in the literature (UNCTAD, 1999, 2001). As the assessment of the role of foreign competition in firms' R&D involves a relevant market with a product, the import and FDI competition are essentially measured at the sectoral level. Therefore, industries facing greater magnitude of external competition through cheap imports and increasing inward FDI flows are expected to show different R&D intensities of their firms than industries that are relatively less exposed to these global competitive pressures.

3.10. Fiscal incentives

In the literature of sectoral innovation system, institutions comprising rules and regulations significantly affect learning and innovation processes of firms and their interactions with each other and non-firm agents like universities, R&D institutions, government departments and agencies, industry associations and trade-unions (Malerba, 2002). In addition to sector-specific industrial policies and regime for patent protection, governments have adopted various fiscal policies like research grants, tax allowances and subsidies to boost firms R&D investments. These fiscal incentives are required as market forces alone are not sufficient to stimulate private R&D investments (OECD, 2003). However, the extensive studies on this issue have thrown up very mixed findings on role of public R&D subsidies (David et. al., 2000).

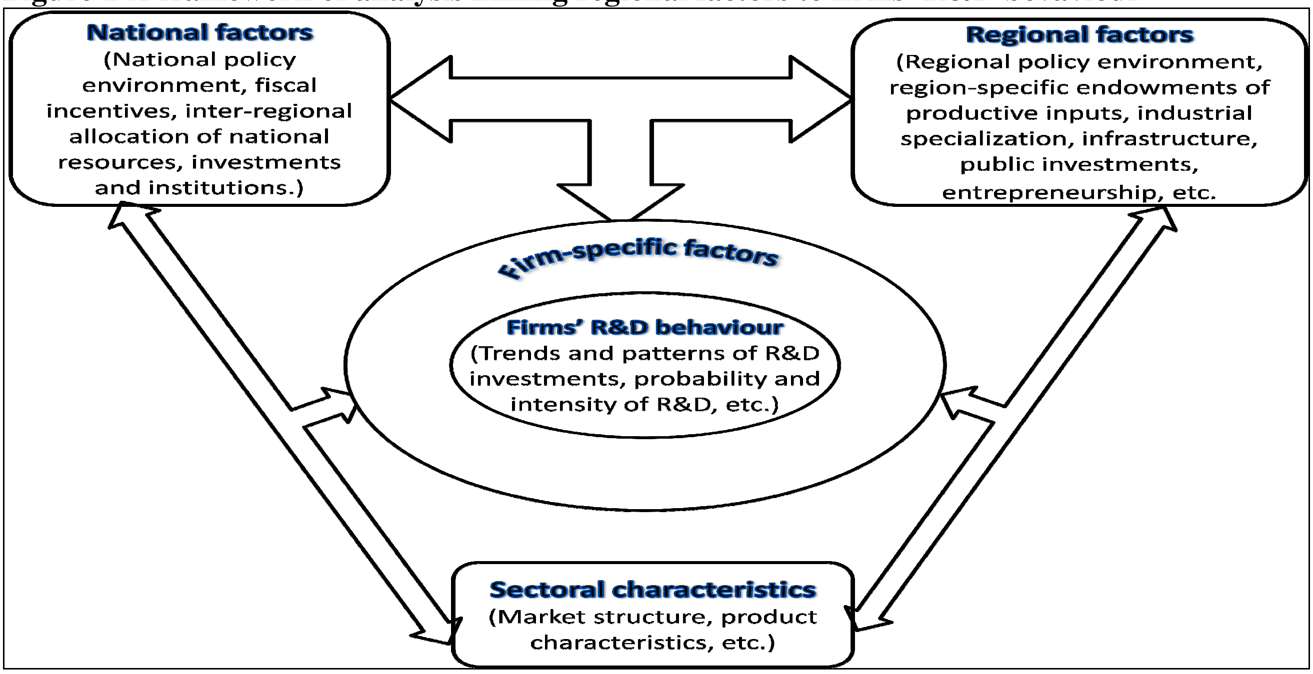
4. A framework for firms' R&D with regional heterogeneity

Traditionally firm-specific factors, sectoral dynamics and fiscal incentives have been seen as the main determinants of firms R&D performance as reviewed in the foregoing section. However, R&D investments of firms involve a dimension of space as well. Regional/local environment where a firm is located may have a decisive influence on its R&D behaviour. As emerging economies are characterized by wide spread regional heterogeneity in terms of levels of development, socio-economic infrastructure, labour markets, etc., a comprehensive theory of innovation needs to also include regional factors into the analysis of inter-firm variations in R&D activities. In the following discussion, we have proposed an alternative framework for the analysis of R&D that emphasizes the role of regional factors.

As set out in Figure-2 the performance of firms' R&D is argued to be dependent on, among other factors, local policy environment and institutions of different regions within a country. According to Porter (1998) competitive advantage resides in the locations in which firms are embedded. Regions are likely to differ greatly with regard to Porter's Diamond of competitive advantages comprising factor conditions, demand characteristics, presence of related and supporting industries, and competitive strategy, structure and rivalry of the firms. As the recent theoretical developments treat innovation as localized and a locally embedded process (Storper, 1997; Kirat and Lung, 1999; Doloreux and Parto, 2004; Asheim and Gertler, 2005), spatial differences in the diamond conditions may explain why firms from certain regions are more dynamic and innovative than those from other regions. Porter et. al. (2001) while analyzing five different regions (Atlanta, Pittsburgh, the Research Triangle, San Diego and Wichita) within the U.S. also found that these regions differ deeply in terms of economic performance and innovation output; and successful regions are those that able to create specialized local economies to offer comparative advantages to local companies and that differ from other regions. Kroll and Zenker (2009) in their regional analysis of European R&D observed that a limited number of leading regions accounted for major share of R&D investment indicating continuing regional heterogeneity in the European Research System.

In the analysis of regional economic resilience (Hill et. al., 2008; Pendall et al., 2010; Simmie and Martin, 2010), a region is visualized as resilient if its economy is able to avoid becoming locked into a low-level equilibrium (i.e. inefficient equilibria) and is also capable to avoid being thrown out of its previous efficient equilibrium state by an exogenous shock. If these conditions are not met, a region is termed as non-resilient. This suggests that regions have asymmetric abilities to reach an efficient growth path and to recover successfully from shocks when they were thrown off from their growth paths. This regional capability of resilience can be crucially linked to regions' exiting knowledge base and evolving innovative capacity defined by interactions between firms, universities, R&D institutions, training centres, etc., base locally there. A region can bounce back after a negative external shock because its firms possess frontier technologies or quick to innovate new products, processes and organizational management that help it to improve and reshape its competitive profile.

Figure-2 A framework of analysis linking regional factors to firms' R&D bevaviour



Source: Own construction.

Cross-country literature exploring determinants of national technological activities (Furman, 2002; Falk, 2006; Mathieu and van Pottelsberghe de la Potterie, 2008) and those analyzing location of R&D activities by MNEs (Cantwell and Piscitello, 2002, 2005; Liu and Chen, 2003; Mariani, 2002; Shimizutani and Todo, 2008) have indicated a range of locational factors that may be relevant even for R&D bavaiour of firms at the regional level. Taking cue from this empirical literature, following regional factors are considered potentially important for the inter-firm variation in R&D efforts.

4.1. Market-related factors

Regions vary in the size, growth and the nature of local demand. Inter-regional differences in these demand related factors can be relevant for firms R&D performance. The new economic geography theories predict manufacturing firms to locate in regions with larger demand, which allows them to minimize transport costs and realize scale economies (Krugman, 1991; Amiti, 1998). In the sense of the theoretical model of Desmet and Parente (2010), regions with larger local markets represent larger customer base with a preference for larger variety of goods. This increases price elasticity of demand as larger regional market size implies greater substitution between varieties and also lowers mark-ups forcing local firms to become larger to break even. This process facilitates innovation as local firms can amortize R&D costs over more goods. Therefore, firms R&D can be seen as an increasing function of the size of regional markets. Allred and Steensma (2005) confirmed that the firms operating in large economies undertake more R&D and argued that large size of economies reflect both the resources to pursue successful innovation strategies and market pressures from customers to do so. Braconier (2000) for a group of OECD-countries obtained a very high elasticity of per capita R&D expenditures with respect to domestic per capita income and has provided evidence that higher per capita incomes lead to more R&D per capita. Birdsall and Rhee (1993) for a sample of developing countries reported the initial level of per capita GDP to be a major factor in explaining inter-country differentials in national R&D intensity (i.e. R&D expenditures as a per cent of GDP). In addition to its size, the growth of regional market can also contribute to R&D activities of local firms because growth creates both opportunities and need for innovation.

4.2. Input-related factors

Regional divergences in the availability of productive resources are a crucial factor for the distribution of economic activities over space. Similarly, firms' ability to innovate is likely to be geographically concentrated given the spatial differences in availability of specialized resources and knowledge inputs (Feldman, 1993). As R&D is human capital intensive activity (Zeng, 1997), regions with greater availability of skilled and experienced workers likely to have local firms with higher R&D activities than regions poor in endowment of skilled manpower. Following the endogenous growth model of Redding's (1996), one may presume that firms' profit seeking R&D is closely related to their host region's base in education and training. Regions with deficiencies in education and training are also those that offer little incentive to local firms to undertake R&D. A number of empirical studies tend to suggest a positive effect of availability of skilled labour force on technological activities proxied by R&D or patent (Bania et al., 1992; Birdsall and Rhee, 1993; ÓhUallacháin and Leslie, 2007; Usai, 2008; Gumbau-Albert and Maudos, 2009).

The importance of science and technology (S&T) institutions like universities, training institutes and public R&D laboratories for firms' innovation activities has grown rapidly in the present time (Cohen, et al., 2002; Gunasekara, 2006; Hughes, 2006; Kazakova and Atoyan, 2006; Rasiah and Chandran, 2009). Universities, in addition to supply highly qualified human resources, have assumed important knowledge generating role by supporting academic research and knowledge sharing through organizing meetings, conferences, workshops, and publication. Increasingly these knowledge institutions are partnering industry for innovation by conducting special programme on entrepreneurship and knowledge management, industry funded research programme, joint R&D programme, sharing of facilities, etc. In the literature of innovation system, innovation occurs in an interactive learning process among firms and their interaction with knowledge-based institutions including universities and technological institutes (Lundvall, 2007). It is a known fact that these institutional factors operate at different spatial scales (Cooke et al., 1998) and regions vary greatly in possessing these knowledge institutions and degree of local firms' interactive involvement with these institutions. As universities and other S&T institutions are specific to individual locations, regions hosting greater number of such institutes are likely to offer their firms more dynamic institutional environment for innovation than regions not possessing them. Caniëls (1996), for a sample of European regions, has found that geographic proximity to higher education is an important determinant of regional innovativeness.

Several studies have confirmed a critical role of infrastructure (telecommunication, transport, and energy) in the regional-disparities of economic growth (Sahoo and Saxena, 1999; Demurger, 2001; Del Bo et al., 2010; De and Ghosh, 2005). Regions suffering from inadequate supply of this general-purpose input, for instance power shortage, are likely to have strong diamond disadvantage in Porter's terminology (Porter, 2000). Smith (1997) argued that the provision of infrastructure has a direct impact on economic performance and technological choice. Transport and telecommunication infrastructures that respectively affect transport costs and provide significant network externalities play a critical role in innovation system.

4.3. Other region-specific factors

The degree to which location matters to innovation is also argued to be dependent upon the type and composition of activity within a location (Feldman, 1999). Regions have dissimilar sectoral specialization that may affect firms' technological efforts. Regions dominated by firms operating in technology-intensive products/activities are likely to show greater R&D performance than regions relatively specializing more in low technology activities. This is because technology-intensive products offer greater technological opportunities, externalities and possess higher income elasticity of demand.

Another regional factor that could influence firms' R&D is the regional distribution of foreign firms. Regions receiving greater proportion foreign investments within a given host country are likely to face more competitive pressures that may affect the local R&D intensity. Local firms operating in a region may find it technologically beneficial from the presence of large number of foreign firms as FDI is known to generate knowledge-spillovers. Cheung and Lin (2004) for a sample of 30 Chinese provinces and administrative cities found that there exist positive spillover effects of FDI on the number of domestic patent applications by regions.

Empirical specification

The above discussions indicate that firms R&D may potentially be explained as a function of different factors related to firm, sector, policy and region. This relationship can be summarized as follows:

$$RDIN_{it} = \beta_0 + \beta_1 AGE_{it} + \beta_2 SIZE_{it} + \beta_3 SIZE^2_{it} + \beta_4 ETP1_{it} + \beta_5 ETP2_{it} + \beta_6 FEX_{it} + \beta_7 PM_{it} + \beta_8 AFF_i$$
$$+ \beta_9 BGA_i + \beta_{10} HI_{jt} + \beta_{11} RDS_{jt} + \beta_{12} FIS_{jt} + \beta_{13} IMS_{jt} + \beta_{14} FSB_{it} + \beta_{15} SDP_{kt} + \beta_{16} SDPG_{kt}$$
$$+ \beta_{17} PSDP_{kt} + \beta_{18} SERL_{kt} + \beta_{19} SINS_{kt} + \beta_{20} STI_{kt} + \beta_{21} SPL_{kt} + \beta_{22} SFF_{kt} + \varepsilon_{it} \quad \ldots\ldots\ldots\ldots(A)$$

Where explanatory variables are as measured in Table-3 and ε_{it} is the random error term.

5. Data Sources, Estimations and Inferences

The estimation of the empirical Model A obviously requires a multi-dimensional dataset related to firms, sectors, policy and states, which are not readily available in a single source. The present study, therefore, relies on a wide number of sources of information for compiling a suitable dataset for the empirical analysis. It draws upon a unique locational dataset of Indian manufacturing firms built for an ICSSR research project (see Appendix for a note on this dataset and Table-A1 presenting the number of sample manufacturing firms by Indian states for the selected states). The annual data on all the firm-specific and policy variables during the period 1995─2008 were collected from this database. Sector-specific variables such as industry level R&D intensity, Herfindahl index and foreign firms' share in domestic sales for this study period are also computed from the same database. The estimation of other sectoral indicator, namely import competition is based on industry level production data from various reports of the *Annual Survey of Industries* (ASI) brought out by the Central Statistical Organization (CSO) under the Ministry of Statistics and Programme Implementation, Government of India and trade data (i.e. exports and imports) from the OECD bilateral trade dataset.

The region-specific annual data related to real SDP, growth of real SDP, and real per capita SDP were obtained from various CSO statements on state domestic products[1]. The annual data on state level higher education enrolments and institutions were collected from various issues of the *Selected Educational Statistics* published by the Department of Higher Education under the Ministry of Human Resource Development, Government of India and various annual reports of the Ministry of Human Resource Development, Government of India. The state level teledensity data comes from the *Compendium of Selected Indicators of Indian Economy* (Volume I) of the CSO (2009). The yearly data on *SPL* and *SFF* were calculated based on the locational dataset indicated above.

[1] These statements are available at: http://www.mospi.gov.in/mospi_nad_main.htm .

Table-3 Description and Measurement of Variables

Variables	Symbols	Measurements
Dependent Variable		
R&D Intensity	$RDIN_{it}$	R&D expenditure as a per cent of total sales of *i*th firm in *t*th year.
Independent variables		
Firm-specific variables		
Firm Age	AGE_{it}	Natural log of the age of *i*th firm in number of years from the year of its incorporation.
Firm Size	$SIZE_{it}$	Natural log of total sales (Rs. Million) of *i*th firm in *t*th year.
Firm Size Squared	$SIZE^2_{it}$	Squared of the natural log of total sales (Rs. Million) of *i*th firm in *t*th year.
External Technology Purchase	$ETP1_{it}$	Expenses in royalties, technical and other professional fees paid abroad by *i*th firm as a per cent of sales in the year t.
	$ETP2_{it}$	Expenses on imports of capital goods and equipment by *i*th firm as a per cent of sales in *t*th year.
Export Intensity	FEX_{it}	Goods and services exports of *i*th firm as a per cent of sales in the year t.
Affiliation to Foreign Firm	AFF_{i}	Assume 1 if *i*th firm has affiliation to a foreign firm, 0 otherwise.
Business Group Affiliation	BGA_{i}	Assume 1 if *i*th firm has affiliation to a domestic business group, 0 otherwise.
Profit Margin	PM_{it}	Profit before tax of *i*th firm as a per cent of sales in the year t.
Industry-specific variables		
Sectoral R&D intensity	RDS_{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	FIS_{jt}	Foreign firms' share in domestic sales of *j*th industry in *t*th year.
Import competition	IMS_{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 (net of benefits related to exports and oil pool) received by *i*th firm as a per cent of sales in the year t.
Region-specific variables		
Demand-related factors		
State domestic product (net)	SDP_{kt}	Natural log of SDP (constant 1999–00 Indian Rs.) of *k*th Indian state in year t.
Growth of SDP	$SDPG_{kt}$	Annual percentage change in SDP (constant 1999–00 Indian Rs.) of *k*th Indian state in year t.
Per capita SDP	$PSDP_{kt}$	Natural log of per capita SDP (constant 1999–00 Indian Rs.) of *k*th Indian state in year t.
Input-related factors		
State higher education enrolments	$SERL_{kt}$	Higher education enrolments (1000) per firm in *k*th Indian state for *t*th year.
State institutions	$SINS_{kt}$	Higher education institutions (excluding colleges for general education) per firm in *k*th Indian state for *t*th year.

State telecom infrastructure	STI_{kt}	Telephones per 100 population in *k*th Indian state for *t*th year.
Other regional factors		
State industrial specialization	SPL_{kt}	Percentage share of high technology sectors in total manufacturing production (proxied by sales) of *k*th Indian state in year t.
State presence of foreign firms	SFF	Percentage share of foreign firms in total number of firms located in *k*th Indian state in year t.

Note: High technology sectors include chemicals, pharmaceuticals, electrical & optical equipment, machinery & equipment and transport equipment; Higher education comprises universities, deemed universities, institutions of national importance, research institutes, colleges for professional education (e.g. engineering, technology, architectural and medical colleges) and colleges for general education.

5.1. Method of Estimation

The empirical estimation of the Model A is characterized by two issues, namely the censoring nature of the dependent variable and the possibility of a number of independent variables being not strictly exogenous. In the face of the censoring character of the R&D intensity, this study departing from the existing literature has adopted the three-step censored quantile regression (CQR) as the preferred method of analysis. The previous studies have mostly used the maximum likelihood Tobit estimation (Tobin, 1958) for analysing R&D intensity of Indian firms. The use of the traditional Tobit method for analyzing determining factors of R&D intensity is questionable because the firm-level Indian manufacturing sample tends to suffer from extreme censoring (more than 70 per cent of observations possess zero values) and non-normal and heteroscedastic errors (Pradhan, 2010). As compared to Tobit, Powell's (1986) censored quantile regression is more robust and provides consistent estimates when there is heteroscedastic, non-normal and asymmetric errors (Powell, 1986; Chay and Powell 2001; Wilhelm, 2008).

Chernozhukov and Hong (2002) have suggested a three-step algorithm to the CQR to deal with samples with heavy censoring and high dimensionality. In the first step, a logit probability model for the full sample is estimated to arrive at an appropriate sub-sample where the quantile line resides 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 at 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 one of the important problems of our sample is heavy censoring where the 75th percentile value of the distribution of R&D intensity is zero, the three-step CQR as enumerated above comes closest to be a useful quantitative tool. It is apparent that the ability of this method to deliver more precise estimates is also dependent upon the choice of quantile that depart from the censoring point upward. In view of the higher censoring level in our dataset, the distribution of the R&D intensity has been centered at 95 per cent quantile in the three-step CQR estimation.

The other methodological issue acknowledged by this study is the inherent endogeneity bias arising from independent variables that are not strictly exogenous. This is especially obvious in the case of firm-level explanatory variables. The empirical research, for instance, presents R&D to be an important determinant of firms' export performance (e.g. Pradhan, 2008) indicating existence of bi-way feedbacks between them. Similarly, R&D intensity may have a favourable influence on other firm-specific factors like firm survival (age), size, profit and purchase of foreign technologies. In view of the possible reverse feedbacks from these explanatory variables to the dependent variable, the study has introduced all the firm-specific variables, except *AFF* and *BGA* dummies, in one year lagged form to minimize the simultaneity bias.

In a multidimensional empirical setting covering 22 explanatory variables, multicollinearity is expected to be a potential sample problem. An examination of this aspect for the final estimable sample obtained in the second step of the Chernozhukov and Hong's CQR algorithm throws up high correlation between *SIZE* and $SIZE^2$, *PSDP* and *STI*, and *SERL* and *SINS*. This is true for full sample of all firms and subsamples of firms by high-technology, medium-technology and low-technology activities. As a way to minimize the negative effect of such correlations, *STI* and *SERL* are respectively regressed on *PSDP* and *SINS* and are substituted by respective regression residuals. In place of *SIZE* (and $SIZE^2$) its group mean centered series has been used.

5.2. Econometric Results and Interpretation

The model A has been estimated for the full sample of manufacturing firms having single-state based R&D facilities as well as their three sub-samples based on technology intensity, namely high-, medium- and low-technology industries during the period 1995–2008. The idea here is to see how the importance of different non-region and region-specific factors in explaining firm's R&D differs over technology intensity of manufacturing activities. Table-4 summarizes the results obtained for the total manufacturing firms and their technology sub-samples. The reported F statistic gives the overall significance of the fitted model and it can be seen that all the estimated models are statistically highly significant.

As the focus of this study is on regional heterogeneity in industrial R&D, discussion on the results on region-specific factors preceded that describing the effects of non-regional determinants.

5.2.1. Regional factors and R&D

Among the regional factors, the role of market-related variables in explaining firms' R&D behaviour is found to be mixed. On the contrary to our expectations, *SDP* and *PSDP* are not significant at the full sample and majority of the subsample estimations. However, a significantly negative role of *SDP* and *PSDP* can be seen for the high-technology and low-technology subsamples respectively. *SDPG* has an insignificant coefficient throughout. This may suggests that differences in regional market size, growth and income conditions play a minor role in differentiating firms' R&D performance across Indian states. It appears that Indian manufacturing firms coming from states with relatively smaller size of regional market and income possess similar or even better R&D activities than those coming from other regions. This result is remarkable in the sense that it highlights the fact that small size of regional market and income may not constraint smaller Indian states to push their firms for higher R&D performance if suitable policy and infrastructural support system exist at the regional level.

Table-4 Three-step CQR Analysis of Firms' R&D Determinants in Indian Manufacturing Sector

Dependent Variable: R&D Intensity

Independent variables	Coefficients (Absolute bootstrap t-statistic)			
	Full sample	High-tech subsample	Medium-tech subsample	Low-tech subsample
AGE_{it-1}	0.110190*** (9.62)	0.126741** (2.13)	0.225909*** (8.55)	0.066059*** (6.78)
$SIZE_{it-1}$	0.103418*** (9.79)	0.172296*** (5.03)	0.029764 (1.47)	0.042711*** (3.62)
$SIZE^2_{it-1}$	-0.016459*** (8.78)	-0.018435 (1.22)	-0.009607** (2.19)	-0.020172*** (4.09)
$ETP1_{it-1}$	-0.001661 (0.05)	0.061776 (0.67)	0.137051* (1.68)	0.197738 (1.28)
$ETP2_{it-1}$	0.000180 (0.02)	0.074822*** (2.65)	0.017714 (1.12)	0.000138 (0.03)
FEX_{it-1}	0.002441*** (3.24)	0.014282*** (3.53)	0.006666*** (2.90)	-0.000678*** (2.63)
PM_{it-1}	-0.001132*** (3.40)	-0.002965*** (4.72)	0.000516 (1.45)	-0.000136 (0.48)
AFF_i	0.387970*** (5.45)	0.201773* (1.69)	0.262834** (2.51)	0.437972** (2.28)
BGA_i	0.296891*** (9.95)	0.497024*** (5.85)	0.160655*** (3.73)	0.174243*** (5.89)
HI_{jt}	-0.561191*** (4.33)	-11.235850*** (4.17)	0.054085 (0.09)	0.143996 (1.01)
RDS_{jt}	1.877414*** (15.92)	1.581299*** (11.29)	0.299703 (1.28)	-0.001508 (0.02)
FIS_{jt}	0.004521*** (4.80)	-0.001874 (0.24)	-0.000772 (0.16)	-0.005236*** (4.97)
IMS_{jt}	0.003602*** (3.69)	-0.005827** (1.98)	-0.004699* (1.76)	-0.000706 (0.82)
FSB_{it}	-0.008659*** (3.56)	-0.027157*** (6.86)	-0.004138 (0.27)	-0.002316 (0.83)
SDP_{kt}	-0.037552 (1.60)	-0.185994** (2.07)	0.006729 (0.19)	-0.012886 (1.04)
$SDPG_{kt}$	0.002543 (1.56)	0.007895 (1.06)	-0.003391 (1.60)	-0.000967 (0.58)
$PSDP_{kt}$	0.056588 (1.34)	0.041014 (0.25)	0.120420 (1.61)	-0.100442*** (3.03)
$SERL_{kt}$	0.001655 (0.21)	-0.003333 (0.05)	0.017013* (1.90)	0.000369 (0.23)
$SINS_{kt}$	0.021409*** (3.13)	0.256085*** (4.13)	0.013069 (1.20)	0.023825*** (3.62)
STI_{kt}	-0.002752 (1.18)	0.002166 (0.41)	-0.010932*** (4.16)	0.012104** (2.02)
SPL_{kt}	0.005805*** (6.45)	0.009100* (1.79)	0.002904** (2.06)	0.003255*** (4.84)
SFF_{kt}	0.012983*** (4.28)	0.042291** (2.33)	-0.003963 (0.80)	0.006131** (1.96)
Constant	-0.847792*** (2.96)	1.152311 (0.81)	-1.716665*** (3.52)	0.997428*** (3.36)
F-value!	118.48	34.87	14.23	18.45
Prob > F	0.0000	0.0000	0.0000	0.0000
Observations	28813	14110	5519	7250
No. of R&D-firms@	1367	900	222	228
No. of total firms@	4545	2096	873	1249
Proportion of R&D firms@	30.1	42.9	25.4	18.3

Note: Absolute value of bootstrap t-statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%; !-test values are obtained from the independent tests conducted to check if the coefficient of all explanatory variables are simultaneously zero using the testparm command in the STATA; @- Number of firms from the final sample obtained in the second step of the Chernozhukov and Hong's CQR algorithm as described in the text.

The role of the availability of human capital indicated by *SERL* on R&D efforts of Indian manufacturing firms is found to be weak. It comes up with a positive sign that failed to achieve any acceptable level of statistical significance in the full sample of manufacturing firms. It has an insignificant coefficient in the case of high- and low-technology subsamples and a positive effect moderately significant for the medium-technology subsample. Therefore, firms locating their R&D units in states with relatively larger enrolment in higher education are not likely to have R&D intensities significantly different from those of firms doing R&D in other states. This feature characterizes the full sample as well as subsamples of high- and low-technology industries. Apparently, greater degree of spatial mobility among highly skilled R&D professionals in India appear to be obviating the manpower constraints placed on the technological activities of firms located in Indian states with poor endowments of human capital.

The presence of science and technology institutions including universities, Indian Institute of Technologies (IITs), research institutions, etc., represented by *SINS* turns out with a consistently positive effect on firms R&D across all the estimations and is statistically significant for the full sample and subsamples of high- and low-technology firms. This suggests that state with plenty of S&T institutions led to greater R&D performance of local firms. Local companies appear to be benefitting technologically from the existence of academic and technology institutions though formal/informal interaction, collaborations and networking with them. It is important to note that the positive role of S&T institutions is not limited to high-technology firms only but even low-technology firms have leveraged them for better R&D performance.

There are mixed findings on the role of *STI*, the telecommunication infrastructure, in firms' R&D activities. It is observed to have a non significant role in the case of full sample and subsample of high-technology industries. However, it has a negative effect in the case of medium-technology subsample and a positive effect for low-technology firms and both effects are significantly different from zero. It would appear that the higher levels of local telecommunication infrastructure do not seem to be helping firms to have greater intensity of R&D in medium-technology industries while it is an important factor for superior R&D performance of low-technology firms in the host states. Thus, *STI* does not work in the similar fashion for different categories of firms over technological classification.

Among all the state-level indicators, the industrial specializations of Indian states around relatively technology-intensive manufacturing activities, *SPL*, has a predicted positive and significant effect throughout. This would indicate the expectation that states with greater degree of *SPL* also host more R&D-intensive firms than other states. Interestingly, the favourable role of the specialization factor is not limited to high-technology subsample and covers other two categories of subsamples as well. One may tends to view the favourable role of the specialization on R&D of low-technology firms as an indication of some sort of knowledge spillovers from the domination of high-technology firms in industrial activities of the state. Regions those are successful in diversifying their industrialization profile more towards relatively technology-intensive industries have a clear advantage in pushing even their low-technology firms to a higher R&D frontier.

SFF capturing the effect of the presence of foreign companies on local firms' R&D is found to exert a significant and positive influence in the full sample and subsamples of high-and low-technology categories of firms. This would suggest that states hosting greater number of foreign firms are likely to enjoy significant competitive pressures and knowledge-spillovers from FDI to succeed in pushing up R&D activities of their local firms. The positive effect of the location of FDI is likely to be more significant for local firms in the high- and low-technology manufacturing activities.

5.2.2. Firm characteristics and R&D

Among the firm-specific variables, *AGE* enjoys a positive and significant effect across estimations. This would corroborate the hypothesis that R&D performance is greater for older and established firms than younger ones. This finding is consistent with the prediction from the learning models where older and surviving firms are likely to accumulate greater stock of learning and experience that may translate into their more R&D activities.

As hypothesized, firm size has emerged as an important determinant of inter-firm differences in R&D intensity for the full sample. *SIZE* and $SIZE^2$ both possessed significantly positive and negative effect respectively. This verifies that R&D intensity is non-linearly related to the firm size resembling an inverted U-shaped curve. Obviously the R&D intensity of sample firms is positively associated with increases in firm size up to a threshold, after that it decreases. While explaining the subsample R&D intensities, the non-linear effect of firm size is valid only for low-technology subsample. While the firm size failed to achieve significance level for medium-technology subsample, it is positively significant for the subsample of high-technology firms. Apparently, firm size is linearly and positively related to R&D by high-technology firms while it plays a minor role in the R&D behaviour of medium-technology firms.

ETP1 and *ETP2*, representing external technology purchases are found to have limited role in the R&D intensity of Indian manufacturing firms. They are found to have non-significant coefficients across estimations barring one subsample each. *ETP1* achieved significance with a positive sign only for the subsample of medium-technology industries while *ETP2* comes up with a positive and significant coefficient just for subsample of high-technology industries. The purchase of disembodied foreign technologies, hence, doesn't appear to be either substituting in-house R&D of Indian firms or complementing the same at the overall manufacturing level. However, it has a complementary role for a subset of Indian firms belongs to medium-technology industries. The imports of foreign capital goods seem to favourably affect the R&D intensity of the subsample of high-technology firms with no significant influence on other subsets of firms.

FEX has a positive and significant effect on firms' R&D in the full sample and subsamples of high- and medium-technology firms. Therefore, greater participation in international markets provide incentives and learning for firms to undertake more R&D activities generally and in the case high-and medium-technology products specifically. Exporting, however, do not appear to have succeeded in encouraging firms to do more R&D in low-technology based products.

PM has not performed as per our prediction. It has a negative sign normally and turns significant in the case of full sample and high-technology subsample. Apparently, profitability has failed in prompting Indian firms to do more R&D. This can happen if Indian firms generally view R&D as a strategy of long-term growth and viability and their R&D expenditures stand independent of the fluctuations in their short-term profitability. However, the strongly negative sign of profit margin in the case of Indian high-technology manufacturing firms suggest that decreases in profitability may encourage these firms' to increase their R&D intensity. This behaviour of Indian high-technology firms is quite similar to the behaviour of Japanese enterprises. As observed by Hundley et. al. (1996) Japanese firms were found to be stepping up their R&D when faced with short-term profitability declines indicating long-term enterprise commitment of various stakeholders in Japanese companies. It is an interesting research issue if the Japanese experience is true for Indian high-technology firms and warrant further research.

AFF, the dummy variable for foreign-owned firms, has the predicted positive sign across estimations and is statistically different from zero. It would appear that firms with foreign ownership have distinctly higher R&D intensity than purely domestic-owned firms, holding other factors being constant. This result stand in contrast to the findings from earlier studies that reported non-significant or negative coefficient for the ownership dummy in their estimated R&D equation (e.g. Pradhan, 2002; Kumar and Aggarwal, 2005). From this, one may conclude that the role of foreign ownership in the Indian manufacturing sector has evolved from an earlier phase of marginal R&D contributor to be a significant driver of R&D activities in the recent period. This is clearly a result of global MNEs delegating higher-order R&D activities to their Indian affiliates in addition to their traditional function of adaptive R&D (Reddy, 1997).

The importance of business group affiliation, *BGA*, in the R&D performance of Indian enterprises has been strongly indicated by this empirical analysis. *BGA* has a robust positive sign throughout and is statistically significant. It tends to support the contention that firms affiliated to domestic business groups have higher R&D depth because of access to group resources, networks, and information and complementarities with the other group affiliates. Group affiliation is, thus, emerged as a major element of competitive positioning and sustainable R&D strategy of Indian manufacturing firms.

5.2.3. Sectoral factors and R&D

The coefficient of *HI* in the full sample as well as the subsample of high-technology firms is found to have a negative sign with a higher level of significance. These results vindicate a negative relationship between the market concentration and R&D performance of Indian firms. That is, Indian firms from relatively less concentrated industries are likely to have more R&D performance than those operating in concentrated industries. A number of earlier studies have also verified the proposition that the degree of competitive rivalry and R&D are positively connected (e.g. Geroski, 1990; Raider, 1998). Moreover, our results suggest that this relationship is not verified in the case of subsamples of medium- and low-technology industries.

As postulated *RDS*, representing the sectoral technological opportunities, turns out with a positive and significant coefficient for the full sample and subsample of high-technology firms. This supports the prediction that industries with greater technological opportunities are likely to have higher R&D performing firms than industries characterized by limited technological prospects. Since the medium- and low-technology industries tend to embody the latter characteristics, not so significant effects of *RDS* for their firms is consistent with the overall hypothesis of inter-sectoral differences in technological opportunities.

At the full sample level, the two variables capturing external competition, namely *FIS* and *IMS* both possessed positive and significant influences on firms' R&D activities. This would imply that product market competition from foreign firms and imports are likely to increase R&D of domestic firms as a market defensive strategy. However, the effects of both variables turn negative at the subsample estimations. *FIS* possesses strongly negative sign for the low-technology subsample while *IMS* has significantly negative effect for both the subsamples of high- and medium-technology industries. Therefore, the impacts of external competition is while detectable at the overall sample level to be favourable, their role is either not so definite or negative at the disaggregated level of analysis.

5.2.4. Fiscal incentives and R&D

The sole policy variable, *FSB*, included in the study has a negative effect on firms' R&D throughout and reaches statistical significance in the full sample and subsample of high-technology firms. Therefore, Indian firms receiving fiscal incentives seem to have a significantly lower depth of R&D. As argued by Pradhan (2010), this negative effect could be a result of idiosyncratic policy regime in India where R&D tax allowance is restricted to a rather small set of firms receiving recognition from the DSIR (Department of Scientific & Industrial Research). Limited awareness about the DSIR recognition or as it involves fixed cost of documentation and inspection with validity for a very short period, a large number of R&D performing Indian firms may not be availing this recognition and, hence, fail to avail the possible tax exemption for R&D. It could be possible that non-DSIR recognized firms that do not receive R&D tax allowance have expanded their R&D at a faster space during the study period while DSIR recognized units receiving fiscal allowance have lagged behind in expanding their R&D. However, this issue merit more investigation to arrive at some definitive conclusion on the effectiveness of tax instrument on R&D in India.

6. Concluding remarks

This study has made a preliminary contribution to the understanding of Indian firms' R&D behaviour from a multidimensional setting incorporating regional heterogeneity hitherto ignored in the literature. Based on a unique locational database of Indian manufacturing firms from the Prowess, it has made an early attempt to estimate the state-wise R&D investments in the manufacturing sector and explored if regional heterogeneity play any role in firms' R&D behaviour.

The estimated Indian manufacturing R&D shows that it takes place disproportionately across the space and a predominant share of it comes from a few Indian states. In the case of high-technology industries, state-wise distribution of R&D is even more uneven. Importantly, the regional concentration of manufacturing R&D in India has increased over time. These results emphasized the importance of regional heterogeneity in the analysis of R&D in India. Firms from a few Indian states do considerably higher amount of R&D than those from the remaining majority of Indian states. This observation is evident also from the analysis of inter-state variations in the proportion of firms doing R&D and R&D intensity.

As the bulk of Indian manufacturing R&D is conducted in a few states, the study went further and analyzed the determinants of inter-firm R&D intensity based on an empirical framework that explicitly introduced regional characteristics as potential determining factors. The model was estimated by the three-step CQR method which is more appropriate and robust to the extremely censored R&D distribution of Indian firms than the traditionally employed Tobit estimation.

Even after controlling for firm-, sector- and policy-specific variables, regional factors are found to exert strongly distinctive effects on the R&D performance of Indian manufacturing firms. This highlights the role of regional heterogeneity in shaping the state-wise R&D patterns during the study period.

Regional factors

The empirical results reveal that regional market characteristics play a minor role in influencing firms' R&D intensity across Indian states. In general, manufacturing firms located in states with relatively larger market or higher per capita incomes are more likely to reflect R&D depth similar to those shown by firms from other states. The growth of regional market also makes little difference to the pattern of inter-firm R&D performance. This limited role of regional market may be seen as a result of Indian federal setup where firms from smaller states enjoy easier accessibility to the local markets in larger states. Therefore, firms locating in smaller states may not necessarily suffer any special disadvantage in doing more R&D when they have easier access to the national market.

The findings on higher education enrolments highlight another interesting Indian experience that the limited availability of skilled human resources does not prevent the firms from the concerned Indian states to do better R&D performance. In a federal setup where there is no legal restriction on movement of people across states, the greater mobility of highly skilled professional and R&D manpower may allow firms based in states with poor human resources to accomplish superior R&D. However, the local abundance of S&T institutions is a critical factor for Indian states to be able to promote local firms' R&D. In other words, states providing greater spatial access to S&T institutions are likely to possess R&D-intensive firms than other states lacking such institutions. This provides strong rationale for states aspiring to promote R&D to expand their base in academic and research institutions and to ensure that these are evenly distributed within their geography.

The state-level telecommunication infrastructure is found to be not so significant factor to distinguish inter-firm R&D variations across Indian states for the full sample. As the teledensity has gone up significantly across Indian states in the last two decades with rapid catch-up by lagging states, its role is probably not so important for distinguishing Indian firms R&D patterns between states. However, it favour R&D in low-technology subsample while negatively influence the same in medium-technology subsample. This seems to suggest that level of telecommunication infrastructure is non-linearly linked R&D over technological classification of firms.

Another important state-specific factor that crucially affects firms' R&D is the nature of industrial specialization adopted by the state. A state that has promoted dominantly high-technology industries within the manufacturing sector is likely to show greater R&D intensities among its firms than another state specializing in low-technology manufacturing activities. Therefore, Indian states adopting strategic industrial policies to promote knowledge-based manufacturing tend to supersede other states in industrial R&D. States focusing more on low-technology sectors not only possess lower R&D in the total manufacturing sector but also in their specialized area (i.e. low-technology industries). Whereas the knowledge-spillovers ensure that the states inheriting a manufacturing base dominated by high-technology production enjoy higher R&D even in the low-technology industries.

The analysis has also found that the presence of foreign firms in the state plays an important role in facilitating R&D activities of local firms. Indian states that are successful in hosting greater number of foreign firms are also observed to have significantly higher R&D activities of local firms than states relatively unsuccessful in attracting FDI. Apparently, this result adds to the existing literature that the spatial proximity to foreign firms can have independently positive effect on local firms' R&D, even when one control for the influence of FDI at the firm (i.e. *AFF*) and sectoral level (i.e. *FIS*).

Non-regional determinants

The firm age, size (up to the critical level), degree of export-orientation, foreign ownership, and affiliation to domestic business groups appear to have played significantly favourable role in firm-level R&D activities. Hence, firms which are relatively younger, smaller, primarily domestic market player, lacking equity participation of foreign shareholders and standalone (non-group) entities have their weakness in achieving higher R&D performance. Local/state governments, therefore, for improving their industrial R&D can adopt policies or create infrastructure that facilitate local firms increasing participation in international markets and promote industrial clustering of firms to minimize the constraint of their small size.

The analysis also brings out that firm's R&D is positively dependent upon sectoral level degree of competitive rivalry, technological opportunities and competitive pressures from imports and foreign firms. However, the policy variable, fiscal incentives, appear to have a discouraging role in firms' R&D intensity.

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Appendix

The dataset: The SPIESR-GIDR locational dataset of Indian manufacturing firms has been compiled for the ongoing ICSSR sponsored research project entitled *Exploring Regional Patterns of Internationalization of Indian Firms: Learnings for Policy*, which is being jointly directed by Jaya Prakash Pradhan and Keshab Das. This dataset is a unique database that classifies a total of 8486 Indian manufacturing firms obtained from the Prowess database of the Centre for Monitoring Indian Economy (2009) into different Indian states and union territories based on their plant location, product profile (producer of single or multi-products), and size of production (capacity/actual). As the location information obtained from the Prowess is not comprehensive and there is no information available related to plant location for 1000 odd companies, these data gaps have been filled with information collected through intensive internet searches of company websites, annual reports, consultancy reports, etc.

Taking recourse to the most recent location information on number of plants, size of production and number of states where plants exist, manufacturing firms have been broadly divided into what are termed as i. 'single-state based firms' and ii. 'multi-state based firms'. The former comprises of 7357 firms and accounts for about 87 per cent of the total number of firms which have all of their production units located in a single state/union territory (UT). The latter includes a total of 1129 firms those have plants located in more than one state/UT. Nearly 25 per cent of these multi-state based firms are producers of single products and have given information on their plant sizes, based on which sales/exports of these firms are divided into different states where their plants are located. The state-wise breakups of a firm's total sales/exports are based on the application of states' share in the aggregate production capacity of the firm. For the remaining single product multi-state based firms for which plant size data is insufficient and those firms that are producing multiple products (where plants sizes are in different units of measurements or not available), the study has assumed uniform economic size of plants for a firm to derive the state-wise production shares for fragmenting its total sales/exports across host states.

While the use of production share to derive state-wise sales/exports of a firm is a practical approach, the same may not be so for estimating state-wise R&D. This is because the location of R&D units by a firm may differ from the location of its production units. There is no reason to expect that a single-state based firm may not possess R&D units beyond its host state (i.e. state where its plant is located). Similarly, a multi-state based firm may have or may not have not have R&D units in each of the state where its plant is located.

In view of such possibility, the study draws upon the locational information on a total of 752 manufacturing firms' R&D units compiled from the *Directory of Recognised In-House R&D Units* (2003, 2005, 2006, 2007, 2008) released by the Department of Scientific & Industrial Research under the Ministry of Science and Technology, Government of India. Of the total, 646 firms (nearly 86 per cent) had R&D units located in single state. After merging the locational information on R&D units of 752 firms with their plant information database prepared earlier, we found that nearly 94 per cent of single-state based firms and about 75 per cent of multi-state based firms in the DSIR sample had their R&D units located in single state. Assuming that firms distribute their R&D investment equally across different R&D units, we obtained state-wise share to divide a firm's R&D. For firms not having coverage in the DSIR dataset, we have used the production share with its known limitation. However, given the predominance of single-state based firms in the sample, the magnitude of the bias may not be very serious. As this is the preliminary exercise to derive state-wise industrial sales/exports/R&D for an important phase of the evolution of globalized India, results obtained should be taken as useful starting estimates on these state-level variables.

Table-A1 State-wise number of sample manufacturing firms

State/UT	Total number of firms					Number of R&D doing firms				
	1991	1995	2000	2005	2008	1991	1995	2000	2005	2008
Chhattisgarh	26	42	44	50	45		4	3	8	4
Madhya Pradesh	122	230	214	215	152	4	30	29	30	25
Bihar	25	30	33	38	25	3	5	4	5	3
Jharkhand	31	46	51	53	44	4	11	12	6	10
Orissa	47	71	72	86	68	1	6	7	11	9
West Bengal	191	264	349	383	271	4	51	61	47	50
Delhi	4	22	69	109	53		2	5	11	5
Haryana	138	246	296	306	254	5	47	60	78	80
Himachal Pradesh	53	107	116	125	118	3	22	20	30	23
Jammu & Kashmir	15	22	23	31	27		4	3	3	3
Punjab	92	148	163	180	138	4	35	37	36	37
Uttar Pradesh	203	357	374	375	276	7	62	75	81	71
Uttarakhand	50	78	91	105	97	2	13	14	13	18
Assam	39	57	75	93	53		7	10	16	11
Andhra Pradesh	196	387	432	418	327	4	60	72	85	83
Karnataka	197	308	330	351	272	8	71	83	96	92
Kerala	79	122	134	169	105	3	14	23	18	20
Pondicherry	10	24	22	27	15	1	9	6	5	5
Tamil Nadu	381	595	670	691	494	7	121	142	149	128
Dadra & Nagar Haveli	50	125	134	130	105		10	13	12	6
Daman & Diu	18	51	64	74	62		2	3	3	4
Goa	19	28	33	27	23		6	6	8	12
Gujarat	342	700	713	658	562	7	103	108	107	119
Maharashtra	556	1003	1160	1186	854	23	230	256	296	253
Rajasthan	107	205	212	241	178	4	32	30	42	32

Source: SPIESR-GIDR locational dataset of Prowess Manufacturing firms (2010).

Table- A2 State level manufacturing R&D investments, US$ million, 1991–2008

Region/state	Manufacturing R&D ($ millions)																	
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Central India	4.03	4.20	5.13	6.86	8.93	11.47	13.05	10.89	8.86	11.40	14.01	20.31	22.41	110.20	31.52	42.06	50.14	73.37
Chhattisgarh			0.04	0.02	0.05	0.25	1.44	0.00	0.23	0.53	0.20	0.23	0.24	0.39	0.42	0.42	0.61	0.67
Madhya Pradesh	4.03	4.20	5.09	6.84	8.88	11.23	11.61	10.88	8.64	10.87	13.81	20.08	22.17	109.80	31.10	41.64	49.52	72.70
East India	24.20	22.45	24.16	19.61	36.05	43.26	49.96	46.96	36.24	34.69	34.61	30.39	87.60	56.78	84.22	97.74	151.76	162.13
Bihar	0.04	0.08	0.03	0.06	0.07	0.15	0.18	0.18	0.19	0.05	0.26	0.26	0.25	0.29	0.31	0.19	0.07	0.07
Jharkhand	22.72	19.24	15.93	13.11	26.69	31.82	38.13	33.38	26.37	26.10	23.86	21.97	29.79	37.71	66.08	74.87	121.42	112.83
Orissa	0.03	0.03	0.25	0.13	0.32	0.85	0.81	2.34	1.50	1.11	1.02	1.02	50.36	10.89	11.51	16.00	21.84	34.48
West Bengal	1.42	3.09	7.95	6.31	8.97	10.44	10.85	11.07	8.17	7.43	9.46	7.14	7.20	7.89	6.32	6.68	8.43	14.74
North India	6.25	16.13	25.29	35.83	42.82	57.70	77.45	89.75	121.10	106.36	89.55	95.52	137.03	191.34	254.86	779.00	318.45	505.15
Delhi		0.01	0.88	1.86	1.95	2.98	3.29	3.45	2.88	3.64	2.87	3.73	6.89	15.35	13.15	23.43	22.69	21.82
Haryana	1.38	6.83	11.12	15.44	16.85	21.85	34.40	32.77	59.33	56.21	47.59	42.88	47.41	60.80	99.21	421.47	98.21	112.27
Himachal Pradesh	0.32	0.25	1.19	2.36	3.73	5.37	5.43	4.83	8.98	4.91	4.75	6.54	8.77	11.87	11.95	16.82	15.91	22.59
Jammu & Kashmir			0.08	0.05	0.07	0.19	0.07	0.17	0.06	0.10	0.01	0.09	0.17	0.31	0.05	0.09	0.16	0.12
Punjab	0.37	2.30	3.59	5.55	7.94	13.26	12.98	14.98	10.24	8.66	8.50	12.18	16.23	22.60	37.20	50.13	55.75	57.89
Uttar Pradesh	0.14	2.41	4.04	4.64	5.97	7.97	12.58	26.78	33.09	25.54	17.86	22.09	49.31	69.13	80.56	252.00	102.80	204.41
Uttarakhand	3.97	4.27	4.34	5.89	6.30	6.02	8.67	6.73	6.50	7.30	7.98	8.00	8.25	11.28	12.75	15.06	22.93	86.04
Northeast India		0.01	0.13	0.07	0.09	0.67	0.55	0.44	0.63	0.33	0.19	0.22	0.19	0.16	0.27	0.80	1.07	4.74
Assam		0.01	0.13	0.07	0.09	0.67	0.55	0.44	0.63	0.31	0.18	0.21	0.18	0.16	0.24	0.73	1.06	4.70
South India	20.37	35.41	49.01	62.84	79.25	110.82	119.80	124.86	124.96	135.55	152.43	170.83	215.83	307.21	366.57	417.79	515.46	754.29
Andhra Pradesh	3.95	8.00	10.43	14.78	19.28	24.19	24.22	22.09	24.16	24.76	33.39	50.68	78.20	115.62	134.01	157.10	195.15	283.13
Karnataka	4.02	9.20	17.37	18.83	21.43	21.20	39.82	46.11	41.32	46.36	54.15	51.36	56.03	79.54	81.57	113.75	131.31	241.50
Kerala	1.08	0.22	2.42	1.88	3.10	4.38	3.95	8.35	3.09	16.18	4.79	9.23	4.05	5.72	2.86	1.35	1.51	4.49
Pondicherry	0.02	0.25	0.06	0.36	0.88	5.20	0.83	2.62	1.34	1.93	1.49	1.48	1.53	1.98	3.97	2.01	2.32	2.15
Tamil Nadu	11.31	17.75	18.73	26.99	34.55	55.85	50.97	45.64	55.03	46.31	58.60	58.08	76.02	104.35	144.15	143.58	185.17	223.01
West India	7.89	30.22	58.11	70.25	115.46	176.48	251.85	172.20	170.01	149.20	182.37	203.00	227.28	311.19	412.22	569.90	763.89	854.60
Dadra & Nagar Haveli		0.81	0.05	0.79	0.93	0.87	2.69	3.93	3.51	2.82	3.45	7.69	11.15	13.59	14.80	16.98	17.59	5.45
Daman & Diu		0.02			0.07	0.18	0.13	0.06	0.05	0.19	0.00	0.82	1.07	0.48	0.73	0.79	3.30	4.12
Goa		0.01	0.23	0.25	0.76	0.32	0.14	0.52	0.35	0.30	0.29	0.29	0.28	4.46	5.22	16.55	22.01	28.90

Gujarat	1.93	7.47	16.74	17.79	27.85	45.02	35.06	38.59	46.60	33.40	46.40	51.57	49.47	65.79	99.38	153.32	203.77	198.84
Maharashtra	5.74	21.50	39.67	48.04	80.60	123.16	208.08	125.93	115.05	108.44	126.83	139.33	159.33	220.16	285.22	372.18	502.17	598.11
Rajasthan	0.22	0.40	1.42	3.37	5.25	6.93	5.76	3.16	4.45	4.06	5.40	3.30	5.99	6.71	6.88	10.09	15.05	19.18
Grand Total	62.75	108.41	161.82	195.45	282.60	400.42	512.66	445.09	461.81	437.54	473.17	520.27	690.34	976.88	1149.66	1907.29	1800.77	2354.28

Note: R&D figures for Chandigarh, Arunachal Pradesh, Meghalaya, Nagaland, Tripura, and Andaman & Nicobar Islands are not provided here given that they have limited number of manufacturing firms (i.e. they do not have consistently at least five firms each year during the study period) in the sample but they were included at the respective regional aggregation and national total estimates.

Source: SPIESR-GIDR locational dataset of Prowess Manufacturing firms (2010).

Table- A2 State level manufacturing R&D intensity (%), 1991–2008

Region/state	**R&D as a per cent of sales**																	
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Central India	0.074	0.087	0.116	0.130	0.138	0.157	0.185	0.156	0.132	0.163	0.205	0.302	0.289	1.147	0.268	0.321	0.293	0.348
Chhattisgarh	0.000	0.000	0.003	0.001	0.002	0.012	0.075	0.000	0.013	0.028	0.011	0.013	0.011	0.013	0.011	0.010	0.010	0.008
Madhya Pradesh	0.119	0.132	0.171	0.192	0.200	0.216	0.226	0.216	0.174	0.213	0.279	0.409	0.401	1.649	0.401	0.476	0.460	0.564
East India	0.156	0.167	0.198	0.153	0.221	0.239	0.259	0.255	0.201	0.164	0.154	0.141	0.364	0.197	0.245	0.230	0.284	0.254
Bihar	0.001	0.004	0.002	0.003	0.003	0.005	0.005	0.005	0.005	0.001	0.005	0.005	0.005	0.005	0.005	0.002	0.001	0.001
Jharkhand	0.759	0.735	0.685	0.525	0.904	0.968	1.172	1.178	1.052	0.931	0.850	0.828	0.897	0.851	1.130	1.154	1.385	1.120
Orissa	0.001	0.001	0.012	0.006	0.012	0.029	0.030	0.084	0.062	0.042	0.038	0.042	1.550	0.257	0.198	0.241	0.256	0.340
West Bengal	0.018	0.049	0.135	0.100	0.114	0.117	0.112	0.118	0.086	0.066	0.080	0.061	0.058	0.056	0.040	0.032	0.033	0.048
North India	0.032	0.094	0.162	0.203	0.183	0.212	0.258	0.301	0.414	0.310	0.243	0.265	0.347	0.394	0.438	1.153	0.379	0.496
Delhi	0.000	0.014	1.054	1.313	1.717	1.029	1.643	1.017	0.683	0.595	0.413	0.468	0.643	0.706	0.526	0.821	0.947	0.480
Haryana	0.024	0.136	0.250	0.314	0.243	0.264	0.374	0.363	0.679	0.539	0.413	0.382	0.390	0.411	0.551	1.992	0.354	0.350
Himachal Pradesh	0.040	0.033	0.162	0.247	0.272	0.337	0.328	0.263	0.493	0.231	0.195	0.263	0.332	0.367	0.334	0.392	0.297	0.364
Jammu & Kashmir	0.000	0.000	0.037	0.021	0.026	0.059	0.015	0.042	0.013	0.020	0.002	0.014	0.027	0.040	0.006	0.009	0.013	0.008
Punjab	0.014	0.081	0.140	0.192	0.215	0.329	0.285	0.322	0.228	0.174	0.164	0.242	0.300	0.368	0.520	0.615	0.567	0.522
Uttar Pradesh	0.002	0.036	0.065	0.067	0.066	0.076	0.109	0.242	0.302	0.196	0.129	0.168	0.342	0.391	0.379	1.045	0.344	0.578
Uttarakhand	0.240	0.279	0.322	0.394	0.330	0.274	0.364	0.275	0.276	0.289	0.306	0.311	0.282	0.307	0.281	0.265	0.312	0.806
Northeast India	0.000	0.000	0.007	0.003	0.003	0.021	0.015	0.013	0.018	0.007	0.003	0.004	0.003	0.002	0.003	0.007	0.008	0.027

Assam	0.000	0.000	0.007	0.003	0.003	0.021	0.015	0.013	0.018	0.007	0.003	0.004	0.003	0.002	0.003	0.007	0.008	0.027
South India	0.082	0.163	0.237	0.269	0.277	0.343	0.369	0.364	0.360	0.332	0.344	0.406	0.448	0.530	0.509	0.498	0.483	0.620
Andhra Pradesh	0.061	0.136	0.176	0.212	0.228	0.258	0.276	0.220	0.228	0.206	0.242	0.388	0.533	0.694	0.678	0.680	0.656	0.795
Karnataka	0.083	0.235	0.466	0.440	0.413	0.378	0.665	0.721	0.624	0.647	0.806	0.723	0.680	0.684	0.515	0.583	0.525	0.802
Kerala	0.025	0.006	0.069	0.048	0.070	0.085	0.072	0.146	0.053	0.226	0.057	0.127	0.047	0.057	0.023	0.012	0.010	0.027
Pondicherry	0.022	0.307	0.071	0.332	0.546	2.024	0.436	1.832	0.913	1.238	0.850	0.789	0.676	0.807	2.058	1.008	1.087	0.834
Tamil Nadu	0.123	0.220	0.253	0.334	0.335	0.468	0.425	0.380	0.477	0.324	0.386	0.402	0.462	0.536	0.600	0.484	0.501	0.575
West India	0.022	0.097	0.201	0.211	0.267	0.361	0.507	0.324	0.330	0.249	0.255	0.315	0.309	0.349	0.384	0.447	0.468	0.394
Dadra & Nagar Haveli	0.000	0.154	0.010	0.100	0.081	0.065	0.191	0.254	0.219	0.162	0.178	0.412	0.567	0.565	0.489	0.439	0.337	0.088
Daman & Diu	0.000	0.019	0.000	0.000	0.024	0.054	0.031	0.015	0.012	0.033	0.001	0.125	0.160	0.050	0.067	0.052	0.159	0.151
Goa	0.000	0.003	0.063	0.055	0.132	0.050	0.019	0.072	0.049	0.034	0.043	0.039	0.033	0.502	0.532	1.375	1.492	1.688
Gujarat	0.018	0.082	0.196	0.173	0.211	0.306	0.228	0.234	0.295	0.178	0.173	0.231	0.200	0.220	0.265	0.332	0.350	0.253
Maharashtra	0.026	0.114	0.228	0.252	0.327	0.438	0.741	0.418	0.388	0.314	0.339	0.394	0.386	0.440	0.486	0.555	0.584	0.517
Rajasthan	0.010	0.019	0.071	0.134	0.156	0.182	0.155	0.082	0.133	0.114	0.141	0.095	0.146	0.137	0.118	0.135	0.146	0.158
Grand Total	0.060	0.120	0.193	0.207	0.234	0.292	0.360	0.305	0.321	0.261	0.252	0.295	0.347	0.405	0.393	0.552	0.411	0.434

Source & note: Same as Table-A2.