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Industrial Innovation System in India: Interlinkage between R&D And Production Structure

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Abstract

The present study attempts to examine the co evolution of industrial R&D structure and industrial production structure in India. This study covers the period 1981-2010 while classifying the industries into four industrial categories i.e. H-T, M-H-T, M-L-T and L-T. Trend growth rates and Karl Pearson's correlation coefficients are used to establish the relationship between structural change in industrial R&D and industrial output structure. The main findings highlight the structural transformation in industrial R&D is well evident with rising importance of H-T and M-H-T group of industries in R&D whereas M-L-T and L-T industrial R&D recorded declining trends.This study for the first time established empirical relationship between co evolution of structural change in industrial R&D and industrial output structure except M-L-T group of industries. An important policy implication that emerges for the sectoral innovation system is that developing countries like India should devote mote efforts to strength the innovation system while devoting higher proportion of resources for innovations.

Keywords: R&D expenditure, structural change, industrial structure, Co evolution, India.

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I. Introduction

Development is strongly associated with the transformation of structure of the economy. It entails not only the broad sectoral shifts among the three major sectors of the economy rather changes within industrial sector constitutes one of the most important traits of the modern economic growth. The descriptive account of structural change dates back to seminal work of Hoffman in terms of declining ratio between consumer and capital goods **(Hoffman 1958)**. Kuznets in his "stylized facts" also explains rising importance of producer goods in manufacturing whereas share of consumer goods fall **(Kuznets 1966)**. It is further validated by Chenery through empirical testing of patterns of industrial growth **(Chenery 1960)**.

The role of technical change along with associated institutional arrangements in modern economic growth accompanying structural transformation has been acknowledged by different structural economists from time to time in one form or another thus ranging from epochal innovations along with new social inventions and changes in preexisting organizational structure of the society, uneven technical advance and associated economies of scale and changes in factor proportions**(Kuznets 1966, Salter1960 and Chenery 1960)**.Technological progress which gives rise to new products, processes and new ways of using raw material acts as a major driver for changes in the industrial sector. Higher the rate of technological progress, faster will be the rate of structural change**(Kuznets 1966).**But Classical production function considered this technological progress to be exogenous **(Solow 1957)** and it is in late twentieth century that efforts are geared towards endogenise economic growth where R&D, human capital, education and skilled labour force play significant role in affecting long-term growth of nations **(Lucas 1988; Romer 1986)**.Although technological progress might be associated with many indicators i.e. R&D, scientific and technical manpower, patents, scientific and technical papers published. But due to limitations associated with many of these measures, it is R&D which is mainly considered to be representing technological progress. The role of R&D in raising productivity and growth of nations is well highlighted in the work of Griliches and Terleckyj **(Griliches 1980; Terleckyj 1980).** So, it becomes reasonable to argue that structural change in industrial R&D may lead to structural change in the economy.

The structural transformation in Indian scenario dates back to the inception of second five-year plan when planners grandly and ambitiously sought to transform the structure of the economy. Although broad-based licensing policy was adopted for the import of technology keeping in view the weak technological capabilities of India then, equivalent was the importance assigned to developing India's own technological base in order to build self-reliant industrial system in the long-run. Consequently, R&D expenditures expanded significantly over the first three five year plans and many institutions also came into being, thus highlighting the role of technology and institutional mechanism in transforming the structure of the economy**(Nayar,1983)**. Thus, upholding the role of technical change along with institutional mechanism in structural transformation, the present study therefore adopts the systems of innovation approach to examine the role of various actors, institutions and government in determining the industrialization and structural transformation in Indian scenario.

It is the seminal work of **Christopher Freeman** which provides stark evidence of well establishing the supermacy of 'National Systems of Innovation' in the era of globalization where national education systems, scientific and technical institutes, government policies and interdependence of foreign imports and domestic technical

development are of utmost significance. They derive their importance from the fact of successful overtaking of Britain by Germany and later on, Japan outstripping the American and European economies **(Freeman, 1995 and Nelson, 1993)**.Until now in India, it is the national innovation system perspective being frequently dealt with. However, it is in recent times that that interest has grown to deal with innovations in the manufacturing sector specifically which nonetheless points to the development of sectoral system of innovation in Indian perspective. **Malerba's** concept of Sectoral Innovation System provides multidimensional and integrated view to understand the structure, dynamics and transformation of sectors. Sectoral system is a set of new and integrated products and set of agents carrying out market and non-market transactions for innovating, producing and sale of those products. Here, different sectors operate in different technological and learning regimes and are characterized by specific demand, technologies and networks of relationships among heterogeneous firms and non-firm organizations. In addition, different institutions whether national or sectoral operate in different sectors, thus favoring the growth of some whereas neglecting others. Sectors also undergo transformation through the change in their technological regimes from Schumpeter- mark I pattern to Schumpeter-mark–II and the knowledge base either in the direction of dominant design or drastic change **(Malerba, 2002).Mani (2007)** while providing picture of SSI of pharmaceuticals industry shows that it is one of the most innovative industry in manufacturing sector in India whereby fiscal incentives for R&D, government research institutes, patent regime and price regulation structure have been instrumental for making it innovative. **Joseph (2012)** while dealing with SSI of ICT sector highlights the role of government, trained personnel and technical infrastructure for the remarkable growth of this sector. Further, **Mani (2010)** describes the evolution of SSI of high-tech industry i.e. aerospace industry in India and also throws light on the shift of its activities from defense to civil-oriented later on. It also describes the significant importance being assigned to aerospace industry in manufacturing sector as this industry alone secures 12% of India's gross expenditure on R&D. **Watkins (2015)** attributes the growing innovative activities of high-tech sectors like ICT, biotech and software to the special role being played by industry associations like NASSCOM and biotech industry associations like ABLE and AICBA.

From the above discussion, it can be safely said that the structural transformation of the industrial R&D is relatively neglected area of research. How growth and emergence of these industries affect the structural transformation in industrial R&D has not yet been dealt with and how structural transformation in industrial R&D is related to structural transformation in industrial output? The present study therefore tries to fill this gap by examining these two issues in detail. The rest of the paper is organized as follows. Apart from introduction, the review of relevant literature both of theory and empirical evidence is presented in section two. Data Base and methodology is developed in section three. The empirical evidence containing growth and structural transformation of industrial R&D is presented in section four. Growth and structural transformation of industrial output structure is empirically examined in section five. The relationship between structural change in industrial R&D and industrial output structure is empirically tested in section six. Summary and concluding remarks are presented in the last section.

II. Innovations and Structural Change: A brief review of literature

Kuznets(1966) exhibits the role of epochal innovations and the associated institutional arrangements in modern economic growth during mid-eighteenth to mid-twentieth century, accompanying sectoral shifts with emphasis on changes in the structure of industrial sector. Findings reveal that manufacturing appears to be rapidly growing sub-

division of the industrial sector and within manufacturing, there is a marked shift from consumer to producer goods.The study highlights that technological change is a major determinant of structural transformation and higher the technical change, faster will be rate of structural transformation. **Salter(1960)** while analyzing the sample of 28 British industries, highlight that structural change originate in uneven rates of technical progress and associated potential economies of scale whereby technically progressive industries like electricity, chemicals, cutlery and steel tubes owing to their falling costs and relative prices are able to significantly increase their share in the total output of twenty-eight industries from 10.5% to 42.6% during 1924-50 whereby stagnant industries due to their rising costs and increasing prices are unable to match the performance of the former, thus decreasing their relative importance in the output structure as whole. **Chenery (1960)** empirically investigates the patterns of growth for all sectors of industry, using cross-sectional data for the period 1950-56 and further explains that it is changes in factor proportions which further cause systematic shift in comparative advantage as per capita income (PCY) rises. Results show that as income rises from $100 to $600 per head, share of investment goods in total manufacturing output rises from 12% to 35% whereas consumer goods' share falls from 68% to 35%, with the share of intermediate goods almost remaining constant. **Chenery, Robinson and Syrquin(1986)** while analyzing the **'standard pattern of structural transformation'** shows that structural transformation is analyzed in conjunction with the changes in the final demand, intermediate demand and shifts in comparative advantage as factor proportion changes. Findings show that as PCY rise from level1 $ 140 to level5 $ 2100, share of manufacturing in GDP rises from 15% to 35% whereas that of primary production falls from 38% to 9%, with the share of services remaining unchanged. Within manufacturing, shift occurs from light towards heavy industries. **Kadar(1984)** hints at the modified form of structural change taking place in the world economy during 1970's whereby different driving forces i.e. institutional, technological and military have worked behind this transformation. Findings of the study show marked shifts within manufacturing sector whereby shares of some industries fall and shifts in gravity centre of industries towards low-cost industries is well evident.**Bagchi(1987)** presents the picture of structural transformation in three developing countries i.e. India, China and South Korea and brings out the important fact that the same historical pattern of structural change of developed countries cannot be expected in the developing countries owing to increasing diffusion of innovations to developing countries, changing location of manufacturing activities and changing implication of Engel's law depending on the nature of existing social organization. In addition to plethora of descriptive literature extracting stylized facts of economic development,**Palan and Schmiedeberg (2010)**contributes empirically by testing structural convergence among 14 European countries for 1970-2005 wherein inter-sectoral heterogeneity index reveal significant inter-sectoral convergence as evident from the decline in its value from 0.08 in 1970 to 0.035 in 2004 and results of inter-industry convergence shows the general shift of all countries towards high-tech industries.**Szirmai (2012)** while providing theoretical arguments and empirical evidence on structural transformation, taking into account 67 developing nations and 21 developed countries for the period 1950-2000, brings at forefront the importance of manufacturing as an "engine of growth" in developing nations as evident from the success of East Asian economies.

The above-mentioned studies of structural transformation provide well-marked evidence of the fact that technological change either in one form or another has always been the driving force behind the structural transformation in the economy.Though technological change being earlier considered exogenous in the classical literature failing to provide justification for 'residual'. It is the spurt of endogenous growth theories which embarked on well-establishing the role of R&D, education, human capital, ideas and knowledge in the

economic growth of nations, thus relegating the earlier sources of growth to somewhat minor position **(Solow1957; Lucas1988 and Romer 1990)**.Nevertheless, technical change might be associated with any of these activities, it is mainly R&D expenditure being frequently used as a surrogate for all these activities **(Freeman 1995)**. Today, the economic growth of nations is well gauged from the quantum of resources diverted towards industrial R&D expenditure**(Miozzo and Walsh 2006)**. The rate of growth of nations is positively and significantly affected by the rate of their technological progress **(Fagerberg and Verspagen2002).**Further, **Griliches(1980)** establishes the importance of industrial R&D by providing econometric evidence of positive relationship between R&D and total factor productivity growth of nations. Scholars of technical change have stressed that industrial R&D in developing nations is necessary not only for generating innovations but it also facilitates the assimilation of new technologies developed elsewhere, hence keeping the economy abreast of latest technologies developed elsewhere**(Cohen and Levinthal1989).** In addition,Government provide impetus to industrial R&D by resorting to fiscal incentives also as direct tax incentives are most popular in India **(Mani 1997).**Industrial R&D in India has considerably risen from 97 million in 1990-91 to 376 million in 2000-01 and finally to 1812 million in 2009-10.Further, Major chunk of Gross expenditure on R&D (GERD) in India is allocated to industrial sector only thus ranging from 28% of GERD in 1997-98 to 34.2% in 2009-10.Further, structure of industrial R&D in India highlights its concentrated efforts in few industries only as only ten leading sectors account for 80-85% of total industrial R&D over a period of time **(Research and Development Statistics and Research and Development in Industry, Various issues).**Here, evolutionary approach also stresses the importance of sectoral system of innovation (SIS) which provide conducive environment for the innovative activities of some specific sectors whereas it constrains the innovation in another. In addition, national institutions i.e. patent system, property rights and anti-trust regulations and interactions among various actors of SIS play remarkable role in influencing the innovative activities of sectors **(Malerba 2002).**

Hence, the theory of structural transformation provides well marked evidence of the changes in structure of production and employment and changes within the industrial sector where significance of old industries decline and new ones gain importance. But in the knowledge economy era where role of industrial R&D, education and human capital is gaining importance and relegates the other sources of growth to minor position, there is a need that structural change within industrial R&D should also be tested. Although theoretical framework provides well marked evidence on the growth of industrial R&D over a span of time and the concentrated structure of industrial R&D in India.Hence, this descriptive account of structural transformation in industrial R&D in India needs to be empirically tested over a long period of time. Also, how structural change in industrial R&D is related to structural transformation in industrial output structure.

III. Data Sources and Methodology:

Since the present study aims at analyzing growth and structural change in industrial R&D, OECD industrial classification 2007 based on technological intensity measures fits well in this case wherein industries have been classified into high-tech(H-T), medium high-tech (M-H-T), Medium Low-tech (M-L-T) and Low-tech (L-T) category based on their respective R&D intensity (R&D/value added). This study divides the whole industrial sector into four industrial categories H-T, M-H-T, M-L-T and L-T. Further, Industrial sector consists of private and public sector in India and industries have been classified in both of them on similar lines. Variable such as industrial R&D expenditure is being used for growth

and structural change analysis. Method such as trend growth rate is being used for estimation of industrial R&D expenditure growth rate i.e.$Y_t = Y_0(1 + r)^t$.

Further, while examining structural transformation in industrial R&D, respective shares of each industrial class in total R&D expenditure is being calculated.

Apart from growth and structural change analysis of industrial R&D, the next issue being examined in this study is to find out the relationship between industrial R&D expenditure structure (R&D intensity) and industrial output structure (value added intensity).This will allow us to examine the co-evolution of the structural change in industrial innovation system and industrial production system. In order to examine the relationship between R&D intensity and value added intensity, the methodology suggested by **(Kayal 2016)** is being used wherein Karl Pearson's correlation is employed for this purpose. Further, two indicators are formulated in order to represent industrial R&D expenditure structure and industrial output structure i.e.

Industrial R&D Expenditure Structure	Industrial Output structure
$\frac{IndRDE_i}{ST_i} * 100$ *i refers to each industrial class*	$\frac{NVA_i}{GVO_i} * 100$ *i refers to each industrial class*

where,
IndRDE- Industrial R&D expenditure
ST- Sales Turnover
NVA- Net value Added
GVO- Gross value of output.

Further, suitable price index for freeing the effect of prices to make the R&D expenditure in real terms has been developed because no readily available index exists. Following the tradition, we have used the following method to arrive at a price index while combining the producer price index for an industry and consumer price index for urban non manual workers. The weight assigned is equal to both indexes as follows:

$$R\&DPI = 0.5 * (WPI) + 0.5 * (CPI)$$

For analyzing growth and structural change in industrial R&D, data for industrial R&D expenditure has been collected from NSTMIS (National Science and Technology Management Information System), Department of Science and Technology (DST), New Delhi. Various issues of Research and Development Statistics and Research and Development In Industry are consulted for collecting industrial R&D expenditure data for 1980-81 to 2009-2010. Data for industrial R&D expenditure as a percentage of sales turnover is also collected from NSTMIS, DST, New Delhi. Data for indicators of industrial output structure i.e. Net value added (NVA) and Gross value of output (GVO) is collected from Economic and Political Weekly Research Foundation, EPWRF. Since National Industrial classification changed many times i.e. 1987, 1998, 2004 and 2008 during this thirty-year time-period. EPWRF provides data for Net value added (NVA) and Gross value of output (GVO) till 2004. Consequently, concordance tables provided by EPWRF are used for compilation of this dataset from 2004 till 2010, using concordance tables between NIC 1998 and NIC 2004 and NIC 2004 and NIC 2008.

IV. Growth and Structural Transformation in Industrial R&D

Table-1 shows the trend growth rate of industrial R&D expenditure in public sector, private sector as well as industrial sector as a whole for the period 1980-81-2009-10 as well as for three sub-periods i.e. 1980-81-1989-90, 1990-91-1999-2000 and 2000-01-2009-10. The findings of the public sector R&D highlight that out of all four categories of industrial R&D expenditure, it is M-L-T R&D expenditure recording the highest growth rate of 3.56% during 1980-81-2009-10, followed by H-T (2.37%) and M-H-T(0.10%) whereas negative growth rate of -3.85% is recorded in L-T R&D expenditure. The sub-period analysis exhibit that it is L-T R&D expenditure which registers the highest trend growth rate of 26.77% during Istsub-period and it subsequently turns out to be negative i.e. -8.63% in IIIrd sub-period. M-L-T R&D expenditure records the significant growth rate of 9.76% during 1980-81-1989-90 but this also shows the entirely contrary trend in IIIrd sub-period, thus turning out to be negative i.e. -0.45%. H-T industrial R&D expenditure also grows at considerable growth rate of 9.42% but declines to very small growth rate of 1.26%. However, it is only M-H-T R&D expenditure showing the rise in its growth rate from 4.76% to 7.67% during Ist to IIIrd sub-period. Thus, growth rate of H-T, M-L-T and L-T declines from Ist to IIIrd sub-period, the former shows decline only whereas the latter two declines as well as become negative, allowing only M-H-T R&D to show increase in its growth from Ist to IIIrd sub-period.

Table-1: Trend Growth Rate of Industrial R&D Expenditure in Public Sector, Private Sector and Industrial Sector as a Whole (1980-81-2009-10)

	PUBLIC SECTOR R&D	**(H-T)**	**(M-H-T)**	**(M-L-T)**	**(L-T)**
Years	**1980-81-2009-10**	2.37	0.10	3.56	-3.85
	SUB-PERIODS				
(I)	1980-81-1989-90	9.42	4.76	9.76	26.77
(II)	1990-91-1999-00	0.11	-9.58	0.67	-14.16
(III)	2000-01-2009-10	1.26	7.67	-0.45	-8.63
	PRIVATE SECTOR R&D	**(H-T)**	**(M-H-T)**	**(M-L-T)**	**(L-T)**
Years	**1980-81-2009-10**	12.78	6.65	3.09	1.97
	SUB-PERIODS				
(I)	1980-81-1989-90	6.78	3.65	1.98	11.59
(II)	1990-91-1999-00	14.97	9.37	4.45	8.04
(III)	2000-01-2009-10	12.27	9.48	3.52	-13.69
	INDUSTRIAL SECTOR R&D	**(H-T)**	**(M-H-T)**	**(M-L-T)**	**(L-T)**
Years	**1980-81-2009-10**	8.33	5.15	3.29	1.58
	SUB-PERIODS				
(I)	1980-81-1989-90	8.54	4.03	6.55	13.10
(II)	1990-91-1999-00	7.33	4.80	1.99	6.36
(III)	2000-01-2009-10	9.42	9.19	0.12	-13.53

Source: Author's Own Calculations

The private sector industrial R&D growth scenario brings at forefront the fact that out of all the categories, H-T R&D expenditure is dominant thus recording highest trend growth rate of 12.78% during 1980-81-2009-10, followed by M-H-T (6.65%), M-L-T (3.09%) and L-T (1. 97%).Whereas sub-period trend shows that H-T R&D expenditure grows at 6.78% during Ist sub-period and its growth rate almost doubles i.e. 12.27% as evident in IIIrdsub-

period. The growth rate of M-H-T R&D expenditure is nearly 3.65% whereby three-fold rise in its growth is observed in IIIrd sub-period amounting to 9.48%.M-L-T R&D expenditure on the other hand grows at relatively low growth rate of 1.98% in Ist sub-period and its growth rate also increases significantly (3.52%) in IIIrd sub-period but still remains relatively much lower compared to H-T and M-H-T growth rate in IIIrd sub-period. L-T R&D expenditure although registering the highest growth rate of 11.59% in Ist sub-period, thus subsequently turns out to be significantly negative rate of -13.69% in IIIrd sub-period. Contrary to H-T, M-H-T and M-L-T which shows rise in their growth rate from Ist to IIIrdsub-period, L-T R&D expenditure shows slippage in its growth rate by considerable extent.

The findings of the industrial sector R&D as a whole show that it is H-T R&D expenditure which here maintains its leading position by recording significant higher growth rate of 8.33% in 1980-81-2009-10.M-H-T R&D expenditure on the other hand records 5.15% growth rate followed by M-L-T (3.29%) and L-T (1. 58%).H-T and M-H-T industrial R&D expenditure registers a rise in its growth rate from 8.54% to 9.42% and 4.03% to 9.19% during Ist to IIIrd sub-period respectively. Although these two categories i.e. H-T and M-H-T records a rise in their growth rate from Ist to IIIrd sub-period but the rise in H-T growth rate is quite smaller compared to M-H-T which registers more than two-fold rise in its growth rate. M-L-T R&D expenditure while registering quite remarkable growth rate of 6.55% in Ist sub-period shows considerable slippage in its growth, thus coming down to mere 0.12% of growth in IIIrd sub-period. L-T R&D expenditure comes out to be registering the highest growth rate of 13.10% in Ist sub-period but then declines and turns to be negative i.e. -13.53% in IIIrdsub-period.

Table-2 shows the structural change in industrial R&D in public sector, private sector as well as industrial sector as a whole for the period 1980-81 to 2009-10 in India. Industrial R&D expenditure has been classified into High-tech (H-T), Medium high-tech (M-H-T), Medium Low-Tech (M-L-T) and Low-tech (L-T) R&D expenditure. A glance at public sector R&D reveals that high-tech (H-T) R&D expenditures constitute 39.10% of total industrial R&D expenditure in 1980-81 which after a decline in 1990-91, considerably increases its share to 50.55% in 2005-06 but finally decreases to 36.55% in 2009-10. Out of total industrial R&D expenditure, M-H-T also has a considerable share of 40.42% in 1980-81 but its share decreases throughout and finally shrink to 33.88% in 2009-10.Contrarily, the share of M-L-T R&D expenditure in total R&D expenditures shows considerable rise from 19.32% in 1980-81 to 28.99% in 2009-10.Lastly, L-T R&D expenditure has a very trivial share amounting to 1.17% in total industrial R&D expenditure in 1980-81 which further declines to merely 0.58% in 2009-10.

Within private sector R&D, it is clearly evident that H-T industrial R&D expenditure contributes only 15.82% in total industrial R&D expenditure in 1980-81.The share of H-T in total R&D continues to increase throughout and shows very significant rise in total industrial R&D in the year 2005-06 which approximates to 48.88%.Although the share of H-T declines slightly from 48.44% to 44.95% from 2005-06 to 2009-10 but its share has risen very considerably from 15.82% in 1980-81 to 44.95% in 2009-10.The share of M-H-T constitutes very significant proportion of total industrial R&D expenditure i.e. 57.79% in 1980-81 but its share finally decreases to 47.26% in 2009-10.It is clearly revealed that although the share of M-H-T in total industrial R&D expenditure shows decline but it still constitutes considerable proportion of total R&D. Whereas the share of M-L-T as well as L-T R&D expenditure in total industrial R&D expenditure shows discernible fall from 12.24% to 4.86% and 14.15% to 2.93% respectively during 1980-81-2009-10.Together, H-T and M-H-T has been able to secure a major chunk of industrial R&D i.e. 92.21% in total industrial R&D, thus relegating

the share of M-L-T and L-T R&D expenditure to a very minor position nearing about 7.79% in 2009-10.

Table-2: Structural Change in Industrial R&D: Public, Private and Industrial Sector (1980-81 to 2009-10)

PUBLIC SECTOR R&D					
Years	**(H-T)**	**(M-H-T)**	**(M-L-T)**	**(L-T)**	**TOTAL**
1980-81	39.10	40.42	19.32	1.17	5523.91
1985-86	35.32	39.74	22.15	2.79	8652.56
1990-91	28.80	37.61	31.06	2.53	10103.06
1995-96	37.07	30.96	30.62	1.35	7809.44
2000-01	47.66	19.75	31.25	1.34	10632.25
2005-06	50.55	18.40	30.61	0.44	11409.91
2009-10	36.55	33.88	28.99	0.58	14397.04
PRIVATE SECTOR R&D					
Years	**(H-T)**	**(M-H-T)**	**(M-L-T)**	**(L-T)**	**TOTAL**
1980-81	15.82	57.79	12.24	14.15	7718.70
1985-86	18.55	54.40	9.77	17.28	9906.80
1990-91	18.50	55.64	12.40	13.46	11124.90
1995-96	20.14	61.37	6.79	11.70	23862.07
2000-01	28.81	52.69	6.51	11.99	29117.20
2005-06	48.88	44.95	3.11	3.05	49953.00
2009-10	44.95	47.26	4.86	2.93	55277.83
INDUSTRIAL SECTOR R&D					
Years	**(H-T)**	**(M-H-T)**	**(M-L-T)**	**(L-T)**	**TOTAL**
1980-81	25.53	50.54	15.20	8.73	13242.48
1985-86	26.37	47.57	15.54	10.53	18559.36
1990-91	23.40	47.06	21.28	8.26	21227.96
1995-96	24.30	53.84	12.66	9.21	31691.15
2000-01	33.85	43.88	13.12	9.14	39749.44
2005-06	49.19	40.02	8.22	2.57	61365.64
2009-10	43.79	45.08	8.65	2.48	68759.70

Note(I) Data of Industrial R&D expenditures is given in millions.
(II) Data of Industrial R&D expenditures is at 2004-05 constant prices.
Source: Author's Own Calculations

Within Industrial sector R&D as a whole, it is noticeable that H-T R&D expenditure has a share of 25.53% in total industrial R&D expenditure in 1980-81.Its share has risen by significant amount (almost 70%) i.e. 43.79% in 2009-10 in total R&D. M-H-T R&D expenditure shows a slight fall in its share from 50.54% in 1980-81 to 45.08% in 2009-10.Despite this, H-T and M-H-T continue to maintain their dominant position in total industrial R&D expenditure, thus together contributing a share of about 88.87% in total industrial R&D expenditure in 2009-10.Whereas the share of other two categories i.e. M-L-T and L-T in total R&D expenditure has slipped from 15.20% to 8.65% and 8.73% to 2.48% respectively during 1980-81 to 2009-10.

V. Growth and Structural Transformation in Industrial Value added

Table-3 Trend Growth Rate of Industrial Value Added (1980-81-2009-10)

	INDUSTRIAL SECTOR	(H-T)	(M-H-T)	(M-L-T)	(L-T)
Years	1980-81-2009-10	8.81	7.97	8.9	5.97
SUB-PERIODS					
(I)	1980-81-1989-90	10.54	6.98	5.55	5.67
(II)	1990-91-1999-00	9.21	9.90	9.11	6.72
(III)	2000-01-2009-10	14.41	13.46	17.5	8.77

NOTE (I) Data of industrial value added is given in millions.
(II) Data of industrial value added is given in 2004-05 constant prices.
Source: Author's Own Calculations

Table-3 shows the trend growth rate in industrial value added for the period 1980-81-2009-10 and also for three sub-periods for four industrial categories i.e. H-T, M-H-T, M-L-T and L-T. A glance at table-3 shows that M-L-T category ranks top (8.9%), followed by H-T (8.81%) and M-H-T (7.97%) with the L-T registering 5.97% growth rate in 1980-81-2009-10.The sub-period trend shows that H-T category registers highest growth rate i.e. 10.54% in sub-period-I followed by M-H-T (6.98%) whereas growth rate of M-L-T and L-T approximates 5%-6%.The growth rate of H-T shows rise from 10.54% to 14.41% during I^{st} to III^{rd} sub-period. The growth rate of M-H-T and M-L-T records more than twofold and three-fold expansion i.e. from 6.98% to 13.46% and from 5.55% to 17.5% respectively. Finally, the growth rate of L-T also shows considerable increase from 5.67% to 8.77%. The growth rate of all industrial categories shows continuous increase from I^{st} to II^{nd} and then to III^{rd}sub-period except H-T category whose growth rate declines slightly in II^{nd} sub-period.

Table-4 Structural Change in Industrial Value Added (1980-81-2009-10)

Years	(H-T)	(M-H-T)	(M-L-T)	(L-T)	TOTAL
1980-81	6.17	26.52	30.07	37.24	480894
1985-86	7.37	27.80	29.95	34.88	659428
1990-91	7.36	29.90	29.00	33.74	1003509
1995-96	7.77	35.81	28.73	27.69	1672537
2000-01	8.10	29.99	28.06	33.84	1712841
2005-06	8.42	30.16	36.66	24.76	3059250
2009-10	9.88	31.29	36.48	22.30	4644089

Source: Author's own estimates.

Table-4 shows the structural change in industrial value added for four industrial categories i.e. H-T, M-H-T, M-L-T and L-T for the period 1980-81-2009-10. The share of H-T in total value added is 6.17% in 1980-81 which increases throughout and finally rises to 9.88% in 2009-10. M-H-T constitutes a significant proportion of industrial value added i.e. 26.52% in 1980-81, its share continues to increase and shows a significant rise to 35.81% in 1995-96. The share of M-H-T although registering a decline to 29.99% in 2000-01, starts increasing afterwards and finally becomes 31.29% in 2009-10.The share of H-T and M-H-T together increases from 32.69% in 1980-81 to 41.17% in 2009-10.M-L-T contributes nearly 30.07% in total value added and its share after a decline till 2000-01,finally increases to 36.48% in

2009-10. Although L-T category initially has a major chunk in industrial value added i.e. 37.24% in 1980-81 finally shows a significant drop to mere 22.30% in 2009-10.

VI. Relationship between Industrial R&D Expenditure and Industrial Structure

After examining Growth and Structural change in industrial R&D, the next issue being examined is to find out the relationship between industrial R&D structure and industrial output structure. The literature in this regard provides well-marked evidence that there exists positive relationship between industrial R&D structure (R&D intensity) and industrial output structure (value added intensity) where higher R&D intensity industries should have higher value added and industries characterized by higher value added should have higher R&D intensities. Therefore, it is hypothesized in the present study that there would be positive relationship between R&D intensity and value added intensity. In order to empirically examine the relationship between R&D intensity and value added intensity, the methodology suggested by **Kayal (2016)** is being pressed for use wherein Karl Pearson's correlation coefficient is employed.

Table 5: Relationship between Industrial R&D Expenditure and Industrial Structure (1980-81 to 2009-10)

Sr. No.	INDUSTRIES	Whole Period (1980-81-2009-10)	Sub-Period-I (1980-81-1989-90)	Sub-Period-II (1990-91-1999-00)	Sub-Period-III 2000-01-2009-2010)
1	**H-T**	.420*	.702*	.019	-.439
2	**M-H-T**	.190	-.330	-.491	.016
3	**M-L-T**	-.266	-.206	-.505	-.415
4	**L-T**	.205	-.140	-.095	.302

Note*Correlation is significant at 0.05 level.
Source: Author's Own calculations.

Table-5 exhibits the relationship between industrial R&D expenditure structure and industrial output structure in all four industrial categories i.e. H-T, M-H-T, M-L-T and L-T through Karl Pearson's correlation coefficient for 1980-81-2009-10 and also for three sub-periods i.e. 1980-81-1989-1990,1990-91-1999-2000 and 2000-01-2009-10. Findings of the Karl Pearson's correlation shows that H-T category shows significantly positive correlation(.420*) between industrial R&D expenditure structure and industrial output structure during 1980-81-2009-10, followed by L-T (.205) and M-H-T (.190).Contrarily, M-L-T shows the negative correlation between industrial R&D expenditure and industrial output structure i.e.-.266. However, the relationship between industrial R&D expenditure and industrial output structure as exhibited by four industrial categories during different sub-periods brings out the picture that H-T category although showing highly significant positive correlation (.702*) during I^{st} sub-period (1980-81-1989-1990), thus later on shows low correlation (.019) in II^{nd} sub-period (1990-91-1999-2000) and subsequently turns out to be negative i.e. -.439 in III^{rd}sub-period (2000-01-2009-10).M-H-T category on the other hand is found to have negative correlations between industrial R&D expenditure and industrial output structure during I^{st} and II^{nd} sub-periods i.e. -.330 and -.491 respectively and low correlation (.016) in III^{rd} sub-period. Medium Low-tech (M-L-T) thus shows negative correlation between industrial **R&D** expenditure and industrial output structure in all three sub-periods i.e. -.206, -.505 and -.415 respectively. Lastly, L-T shows low negative

correlation in Ist and IInd sub-period i.e. -.140 and -.095 respectively and positive (.302) in IIIrd sub-period.

Table-6: Relationship between structural change in Industrial R&D and Industrial value added: Karl Pearson's correlation coefficient.

INDUSTRIES	Correlation coefficient
H-T	0.74*
M-H-T	0.29
M-L-T	-0.74*
L-T	0.83**

*****Correlation is significant at 0.05 level
******Correlation is significant at 0.01 level

Table-6 shows the relationship between structural change in industrial R&D and industrial value added for all four industrial categories. Evident from the table that there exists a significant positive relationship (0.74*) between structural change in industrial R&D and industrial value added for H-T industrial category as the share of both H-T R&D in total manufacturing R&D and H-T output in manufacturing output has increased. M-H-T category records a low positive correlation (0.29) between structural change in industrial R&D and industrial output. It is only M-L-T category where the relationship between structural change in industrial R&D and industrial output is found to be negative of the order i.e. -0.74* as the share of M-L-T R&D in manufacturing R&D has shown decline whereas share of M-L-T output in manufacturing output has shown rise. The last industrial category i.e. L-T shows a highly significant positive correlation (0.83*) between structural change in industrial R&D and industrial output. The reason for such high positive correlation is that the share of both L-T R&D in manufacturing R&D and L-T output in manufacturing output has shown a significant decline respectively.

Table-7: Relationship between structural change in Industrial R&D and industrial value added (Lagged Effects)

INDUSTRIES	Correlation coefficient
H-T	0.93*
M-H-T	-0.27
M-L-T	-0.64
L-T	0.71

* Correlation is significant at 0.05 level.

Table-7 shows the lagged relationship between industrial R&D and industrial output in all four industrial categories where H-T category shows a very significant positive correlation i.e. 0.93*. Other two industrial categories i.e. M-H-T and M-L-T show a negative correlation i.e. -0.27 and -0.64 respectively. Lastly, a positive relationship is found in L-T category i.e. 0.71.It can be gauged from the table structural change in industrial R&D has its positive lagged impact on structural change in industrial output in H-T and L-T industrial categories only whereas negative relationship is found in the remaining two categories i.e. M-H-T and M-L-T.

VII Conclusion

The contribution of the present study to existing literature lies in the fact that it has endeavored to examine two relatively neglected areas of research. It provides empirical insights about how structural transformation in industrial innovation system takes place in India. It also examines the co evolution of the structural change in industrial innovation system and industrial output system. The empirical evidence suggests that structural transformation in industrial R&D has taken place. The shares of H-T and M-H-T industrial R&D in total industrial R&D shows rising trend, whereas M-L-T and L-T industrial R&D shows decline in their respective shares in total industrial R&D. The study further concludes that broad structural transformation is witnessed in industrial output structure also. While examining co-evolution of the structural change in industrial innovation system and industrial output system, it is noticeable that structural change in industrial R&D is positively correlated with structural change in industrial output structure in three industrial categories i.e. H-T(0.74*), M-H-T (0.29) and L-T (0.83*) respectively whereas negative relationship is found in M-L-T category to the order of -0.74%. The major public policy implication that emerges from this study is that strengthening innovation system will help to determine the future industrial structure. This study also helps us to identify future areas of research where scholars should draw their attention to examine co-evolution of innovation system and industrial and trade structure of a developing economy.

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