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# R&D and Productivity in Indian Organized Manufacturing Sector

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**Abstract - This paper is an attempt to analyze the relationship between R&D expenditure considered as knowledge capital and its productivity, to see sectoral differences if any emerge. We use two different industrial databases i.e. CMIE and ASI over the post reform period. we found that R&D has positive and significant impact on productivity, but its elasticity is very less as compare to that of physical capital. As far as employment regressor concern, manufacturing sector shows the positive impact on productivity but again with very low elasticity. While doing sectoral comparison, similar results have been noticed in medium low-tech (MLT), medium high-tech (MHT) & high-tech (HT) industries but low-tech results are largely reversed the nature of R&D negatively impact on productivity. R&D impact on productivity is more in MLT & MHT industries and that of physical capital is more in HT industries. The results suggest that firms' overall capital intensiveness either in form of knowledge capital or physical capital has much impact on productivity but it shows shift in favor of medium-tech sector i.e. MLT & MHT seems to emerge.**

**Keywords: R&D, Productivity, Knowledge capital and physical capital**

## I. INTRODUCTION

The scope of the present study is limited to discuss the relationship between R&D & productivity, looking at whether earlier empirical literature that supporting a positive and significant relationship between R&D and productivity can be confirmed in context of Indian organised manufacturing sector, and to find out any sectoral peculiarities if arise. Nowadays, R&D expenditure and its impact has been becoming focal area of research. However, present study is limited to analysis of productivity and R&D relationship, so we do not deal with R&D returns in terms of rate of return on R&D. thus scope of this paper is not to deal with assessment of how much money invested in R&D activities to yield on one unit of sale or profit. It is just an exercise to analyse the R&D-productivity elasticity by using different datasets (CMIE & ASI) at industry level.

Marsili (2001) and Mairesse & Mohnen (2005) advocated that low-tech industries has more advantage than high-tech industries in terms of productivity gains if they spend even less money in R&D activities as compare to high-tech industries. Low-tech industries have 'latecomer advantage' in catching up. If this is also true in case of Indian organised manufacturing sector, then we can expect a strong R&D-Productivity relationship in low-tech industries as compared to high-tech counterparts. This assumption is contrast with earlier literature that is why our further research question is whether there is ant structural peculiarities arise.

The novel part of this study is that we propose sectoral division by using firm as well as industry level data. This particular approach has not been much used in earlier studies. In our knowledge, we could not find any study with related to R&D-productivity relationship, particularly in context of Indian organised manufacturing sector. This study has been categorized into 5 sections; section 2 deals with brief literature review about this subject, while in section 3, data methodology has been discussed. Section 4 presents empirical analysis and last section 5 conclude the study.

## II. LITERATURE REVIEW

From a long time, the investigation of R&D-productivity link has been central area of research of many researchers. Prominent work of Minasian (1969) & Griliches (1973) on R&D-productivity relationship and further Tesleckyi (1974) work on return on R&D investment laid down the foundation for empirical research on this area. Griliches's (1979) study was further expansion when he developed the framework of measurement, modeling and estimation to perform such empirical work related to 'R&D-productivity'. Other studies also have been established the relationship between R&D and productivity. Some of them are Mairesse & Sassenon (1991), Griliches 1995 & 2000, Mairesse &

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Mohnen 2001, Kortum (2004), loof & Hashmati (2006) & Roger (2006). Most of them established positive relationship between R&D and productivity. In other words R&D investment impacts significantly to enhance the productivity level of any firm. Although there are methodological differences among researchers about estimation and measurement of different datasets, but their central view is similar in nature that R&D helps to increase the productivity level. Due to different methodology, average elasticity of R&D is lies between 0.05 and 0.25. as we earlier said, these studies are generally presents cross-country analysis, some of them are particular sector oriented mostly high-tech sectors.

Verspagen (1995) has used the OECD classification (Hatzichronoglou 1997) and categorized the whole manufacturing sector into 3 segments i.e. low-tech, medium-tech and high-tech. The study presented that it is only high-tech sector which has significant and positive impact of R&D, but in low-tech and medium low-tech sector, R&D do not have significant impact . Similar results have been shown in another study of Kwon & Inui (2003) which is based on more than 3000 firm's data of Japanese manufacturing sector, using Hall & Mairesse's (1995) methodology and estimated that in high-tech firms, R&D impact on labor productivity is significant than that of low and medium-tech firms.

Taiwan country has also experienced the similar trends as in OECD countries and Japan. Tsai & Wang (2004) also presented the similar picture by using similar methodology (Cobb-Douglas production function). Study has also confirmed that R&D impact on productivity is positively significant. It also confirmed that R&D is more useful in terms of productivity growth in high-tech industries as compare to others. Similarly Harhoff (1998) also provided similar trends. This study categorized 443 German manufacturing firms into high-technology and other firms. It shows higher impact of R&D investment on productivity in high-technology firms as compare to other firms. In high-technology firms, R&D elasticity was lie between 0.125-0.176, while in other than high-tech firms it is between 0.090-0.096.

Through Cobb-Douglas production function, Wakelin (2001) have regressed productivity on R&D investment of 170 firms of UK manufacturing firms for the period of 1988-92. Study found positive and significant impact of R&D investment on productivity growth. Moreover R&D expenditure of other firms in the same sector has higher impact on productivity than that of weighted R&D expenditure of innovation-supplying firms.

Another study of Rincon & Vecchi (2003) using Cobb-Douglas Production Function, to estimate R&D impact on productivity at firm level. This cross country analysis for the period of 1991-2001 presents that R&D reporting firms enjoy more productivity gain than non-R&D reporting firms. A positive and significant impact of R&D on productivity has been registered in US and EU firms except three European countries (Germany, France & UK) where return from R&D decreased in manufacturing sector.

Our key area of research in this paper is manufacturing sector, thus we do not touch R&D impact in services sector. In brief , we can say, many researchers such as Blasco (2010); Crepon et.al. (1998); Segarra & Teruel (2011) & Bogiacino & piñata (2011), have performed simultaneous analysis of service as well as manufacturing sector and reiterated that R&D impact is significantly positive in high-tech industries and services.

From the above empirical evidences, assumption of positive impact of R&D on productivity has been confirmed. In our knowledge, none of the study is based on Indian organised manufacturing sector. We could not find even one study which states the R&D impact on productivity at sectoral basis. We attempt to find whether Indian organised manufacturing sector support the above mentioned hypothesis of significant and positive impact of R&D on productivity and determine the magnitude of any sectoral peculiarities if emerged.

## III. DATA METHODOLOGY

Although significant and positive relationship between R&D and productivity has been established by previous literature, but we find no study that provide empirical evidences of such relationship on sectoral basis particularly with context of Indian manufacturing sector. To fill this gap, we do penal analysis of R&D expenditure on productivity in Indian organised manufacturing sector, using ASI & CMIE database together. Correlation analysis and pooled ordinary least square (POLS) with FE (fixed effect) and RE (random effect) method has been used to estimate such relationship. Key components that required to analyze such relationship has been discussed follow.

Generally many assumptions are there to estimate capital stock that employed in manufacturing process. There is not one ideal method. Nevertheless PIM (perpetual inventory method) is consider as practical for capital stock estimation of 3 digit industries in manufacturing sector at 2004-05 prices. The net fixed capital (NFC) calculated at book value after depreciation whereas net capital formation (NCF) is at current prices. For estimating rate of depreciation, previous study of Goldar (1986) has been referred. Study assumed that total life of fixed asset is generally 25 years. Thus rate of depreciation could be 2.5 percent. So we have also taken 2.5 percent (0.025) annual rate of depreciation in this chapter. Thus capital stock estimation is estimated as follow.

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$K_t = I_t + (K_{t-1} - 0.025\ K_{t-1})$

$K_T = K_0 + \sum_{t-1}^{n} I_t$

Knowledge capital has been used in this paper by capitalizing R&D expenditure in which R&D expenditure data has been transformed in to stock by using perpetual inventory method (PIM). The characteristic of this method is to make annual stock and subtract the obsoleteness or depreciation of existing stock. In equation form, it is as follow…

$K_R^{t+1} = (1-\delta)K^t + R^t$

$K_R^{t+1}$ is amount of R&D stock of the next year (t+1), $\delta$ is a rate of depreciation. $K^t$ is R&D capital stock of current year (t) and $R^t$ is R&D expenditure of current year (t). 15 % rate of depreciation has been taken in the study. Further nominal R&D expenditure has been converted into real R&D expenditure by deflating with GDP deflator.

A standard production function as referred by other empirical studies in this literature i.e. Griliches (1986), Lichtenberg et.al (1989), Hall et.al (1995) and Verspagen (1995), has been followed for econometrics analysis, written as…

$$In\left(\frac{Y}{E}\right) = \alpha + \beta\ In\left(\frac{R}{E}\right) + \gamma\ In\left(\frac{C}{E}\right) + \delta\ In(E) + \mu$$

In above equation, Y is output (real gross value added), E is employment (total person engaged). Our first pivotal impact variable is knowledge capital (R) per person (R&D stock per person) and second pivotal variable is physical capital (C) per person (capital stock per person), E is employment as control variable (total person engaged) and u is error term.

It is important to understand that we have experimented two different data sources to perform the above function. Due to lack of data of required variable in one data source, we have been compelled to use two datasets. Output data in terms of gross value added (GVA), employment data in terms of total person engaged (TPE), data values of fixed capital, investment and depreciation to make capital stock has been taken from ASI dataset. One constraint of non-availability of R&D data in ASI data series, forced us to move CMIE's Prowess database. It provide R&D expenditure data but at firm level. To get aligned with existing industry level data of other variables, we aggregated the firm level data into respective industries. Since our objective of the study is to distinguish different segments i.e. low-tech (LT), medium low-tech (MLT), medium High-tech (MHT) and high-tech (HT) industries, we followed OECD classification (Hatzichronoglou 1997) to label different industries (see appendix 1).

## IV. EMPIRICAL ANALYSIS

Table 1 presents the preliminary correlation results shows that productivity is significantly and highly correlated with physical capital with p of 0.8593 in total manufacturing sector. it is important to note that it is highly correlated with productivity in all section also i.e. low-tech (0.7811), medium low-tech (0.8943), Medium high-tech (0.7954) and high-tech (0.8486). We have provided earlier in the last chapter that capital plays pivotal role in determination of employment and this table shows similar picture with regard to productivity.

**Table 1: Correlation Matrices**

| Total Manufacturing | | | | Low-Tech Industries | | | | Medium Low-Tech Industries | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In (Y/E) | In (RD/E) | In (CS/E) | | In (Y/E) | In (RD/E) | In (CS/E) | | In (Y/E) | In (RD/E) | In (CS/E) |
| In (Y/E) | 1 | | | In (Y/E) | 1 | | | In (Y/E) | 1 | | |
| In (R/E) | 0.6368 (0.000) | 1 | | In (R/E) | 0.3787 (0.000) | 1 | | In (R/E) | 0.6847 (0.000) | 1 | |
| In (C/E) | 0.8593 (0.000) | 0.5127 (0.000) | 1 | In (C/E) | 0.7811 (0.000) | 0.3063 (0.000) | 1 | In (C/E) | 0.8943 (0.000) | 0.3784 (0.000) | 1 |

| Medium High-Tech Industries | | | | High-Tech Industries | | | |
|---|---|---|---|---|---|---|---|
| | In (Y/E) | In (RD/E) | In (CS/E) | | In (Y/E) | In (RD/E) | In (CS/E) |
| In (Y/E) | 1 | | | In (Y/E) | 1 | | |
| In (R/E) | 0.6422 (0.000) | 1 | | In (R/E) | 0.1720 (0.117) | 1 | |
| In (C/E) | 0.7954 (0.000) | 0.5096 (0.000) | 1 | In (C/E) | 0.8486 (0.000) | -0.1845 (0.092) | 1 |

***Source:*** Author's Calculations.

***Note:*** p-values in parentheses. Y represents output (GVA), R R&D, C capital stock and E employment (total person engaged).

However productivity is also highly significant correlated with knowledge capital with p of 0.6368 in total manufacturing sector. Some variations have been noticed in all four sections (LT, MLT, MHT and HT) of manufacturing sector. In low-tech it is low at

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0.3787 but in medium low-tech industries, R&D per employee highly correlated with productivity with p of 0.6847 whereas in medium high-tech it is considerable at 0.6422. It has been seen that in high-tech industries the relationship between knowledge capital and productivity is insignificant with very low p of 0.1720. It is hard to believe that productivity does not have much impact of R&D in high-tech sector because high-tech sector has relatively high R&D intensity as compared to other sector.

To confirm above evidences econometrically, we attempted to tested specification (1) in Table (4) by using POLS (pooled ordinary least square) with FE (fixed effect) and RE (random effect) models. POLS estimates are shown in the Table 2, to present the complete picture of results whereas FE and RE estimates have been used for further explanation of results.

**Table 2: Sectoral decomposition: Indian Organised Manufacturing Sector**

| | | In (R&D/Emp) | | In (Physical stock/Emp) | | In (Emp) | | Constant | | Rsq (overall) | Rsq (between) | Rsq (within) | Hausman test (p-value) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Low-Tech** | POLS | 0.038*** | (0.000) | 0.433*** | (0.000) | -0.005 | (0.777) | 2.128*** | (0.000) | 0.631 | -- | -- | |
| | FE | -0.042*** | (0.008) | 0.647*** | (0.000) | 0.146*** | (0.000) | 0.496 | (0.315) | 0.519 | 0.483 | 0.671 | 13.46 (0.003) |
| | RE | -0.027* | (0.065) | 0.62*** | (0.000) | 0.125*** | (0.000) | 0.755* | (0.096) | 0.546 | 0.518 | 0.67 | |
| **Medium Low-Tech** | POLS | 0.145*** | (0.000) | 0.67*** | (0.000) | -0.167*** | (0.000) | 5.185*** | (0.000) | 0.864 | -- | -- | |
| | FE | 0.127*** | (0.002) | 0.465*** | (0.000) | 0.154** | (0.044) | 0.945 | (0.318) | 0.724 | 0.758 | 0.58 | 12.3 (0.006) |
| | RE | 0.113*** | (0.001) | 0.569*** | (0.000) | 0.004 | (0.934) | 2.851*** | (0.000) | 0.837 | 0.901 | 0.572 | |
| **Medium High-Tech** | POLS | 0.141*** | (0.000) | 0.547*** | (0.000) | 0.157*** | (0.000) | 1.063*** | (0.001) | 0.754 | -- | -- | |
| | FE | 0.104*** | (0.010) | 0.703*** | (0.000) | 0.309*** | (0.000) | -0.408 | (0.450) | 0.729 | 0.8 | 0.692 | 4.3 (0.231) |
| | RE | 0.12*** | (0.000) | 0.65*** | (0.000) | 0.265*** | (0.000) | 0.009 | (0.985) | 0.741 | 0.814 | 0.691 | |
| **High-Tech** | POLS | 0.069*** | (0.001) | 0.875*** | (0.000) | 0.113** | (0.012) | 2.258*** | (0.000) | 0.845 | -- | -- | |
| | FE | 0.045 | (0.513) | 0.882*** | (0.000) | 0.513 | (0.145) | 1.776 | (0.109) | 0.842 | 0.952 | 0.797 | 11.6 (0.008) |
| | RE | 0.069*** | (0.001) | 0.875*** | (0.000) | 0.113*** | (0.010) | 2.258*** | (0.000) | 0.845 | 0.970 | 0.796 | |
| **Total Manufacturing** | POLS | 0.094*** | (0.000) | 0.61*** | (0.000) | 0.005 | (0.693) | 2.847*** | (0.000) | 0.79 | -- | -- | |
| | FE | 0.038** | (0.016) | 0.664*** | (0.000) | 0.153*** | (0.000) | 1.037*** | (0.001) | 0.739 | 0.772 | 0.638 | 12.81 (0.005) |
| | RE | 0.055*** | (0.000) | 0.646*** | (0.000) | 0.117*** | (0.000) | 1.481*** | (0.000) | 0.763 | 0.803 | 0.637 | |

Notes: P values are in parenthesis(); * significance at 10%, ** at 5% and ***at 1%.

Source: Author's own calculations based on ASI and CMIE database.

In Table 2, results related to total manufacturing sector show that though R&D has positive & significant impact on productivity, but its elasticity is very less (0.04/0.05) as compare to that of physical capital (0.07/0.06). Results are mostly consistent as we have already mentioned that physical capital impact on productivity more than that of knowledge capital. As far as employment regressor concerned, manufacturing sector shows the positive impact on productivity but with very low elasticity of 0.1.

*Table 3 Hausman Test for Determination of Model (Fixed or Random Effect)*

| | Hausman Test | p-Value | Decision | Model Used |
|---|---|---|---|---|
| **Low-tech** | $13.46^{***}$ | 0.003 | Reject $H_0$ | Fixed Effect |
| **Medium Low-tech** | $12.3^{***}$ | 0.006 | Reject $H_0$ | Fixed Effect |


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| | | | | |
|---|---|---|---|---|
| **Medium High-tech** | 4.3 | 0.231 | Accept $H_0$ | Random Effect |
| **High-tech** | $11.6^{***}$ | 0.008 | Reject $H_0$ | Fixed Effect |
| **Total Manufacturing** | $12.8^{***}$ | 0.005 | Reject $H_0$ | Fixed Effect |

Notes: *** means significant at 1% and ** means significant at 5%.

Source: Based on Table 2.

Hence, Hausman test has been used in the analysis to determine fixed or random effect model to find out relationship of R&D investment and productivity that shown in Table 3. According to hausman test results null hypothesis ($H_0$) is rejected in most of segments of manufacturing sector except MHT industries. Therefore fixed effect is more active in LT, MLT, HT & total manufacturing sector. In all these segments p value is considerably low but in case of MHT, random effect is active than fixed effect because p value is 0.231.

While doing sectoral comparison, it is seen that similar trend has come in. Similar results have been noticed in three sections of manufacturing sector i.e. medium low-tech, medium high-tech and high-tech industries, but for low-tech results are largely reversed the nature of R&D negatively impact on productivity. It is well established that high-tech industries is more R&D intensive than others. But results show that R&D impact on productivity is more in medium low-tech and medium high-tech industries than high-tech industries. In case of physical capital higher impact has been noticed in high-tech industries. These results confirm that relatively high-technology intensive industries are more efficient to translate their physical and knowledge capital in to higher productivity.

## V. Conclusion

Although significant and positive relationship between R&D and productivity has been established by previous literature, but we find no study that provide empirical evidences of such relationship on sectoral basis particularly with context of Indian manufacturing sector. To fill this gap, we do penal analysis of R&D expenditure on productivity in Indian organised manufacturing sector, using ASI & CMIE database together. Correlation analysis and pooled ordinary least square (POLS) with FE (fixed effect) and RE (random effect) method has been used to estimate such relationship.

We find our results are similar with earlier literature in terms of coefficient magnitude and its nature. In other words we have also estimated a positive and significant relationship between R&D expenditure and productivity. Thus positive link between the two has been confirmed in case of Indian organised manufacturing sector. In this paper, we talked about labour productivity because our prime concern is employment generation in manufacturing sector as well. POLS with FE and RE model further provide us that though R&D has positive & Significant related with productivity but its elasticity is less than that of physical capital. It is important to note that in low-tech industries, R&D and productivity has negative relationship. This shows that those manufacturing industries are relatively more technology intensive tend to achieve more productivity gains with R&D investments than other low-tech counterparts. This has raised the question about usefulness R&D expenditure in manufacturing sector. It is also confirmed that manufacturing sector particularly high-tech sector is getting productivity gains from physical capital investment.

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**Appendix- I**

| Code | Industry | Code | Industry |
|---|---|---|---|
| **Low Technology** | | 271 | Basic iron and steel |
| 151 | Meat, fish, fruit vegetables, oils and fats | 272 | Basic precious and other non-ferrous metals |
| 152 | Dairy products | 281 | Structural metal products, tanks, reservoirs and steam generators |
| 153 | Grain mill products and animal feeds | 289 | Other fabricated metal products |
| 154 | Other food products | 351 | Building and repair of ships & boats |
| 155 | Beverages | **Medium High Technology** | |
| 160 | Tobacco product | 241+233 | Basic chemicals + Processing of nuclear fuel |
| 171 | Spinning, weaving and finishing of textiles | 242-2423 | Other chemical products except pharmaceuticals |
| 172 | Other textiles | 291+300 | General purpose machinery + Office, accounting and computing machinery. |
| 173 | Knitted and crocheted fabrics | 292 | Special purpose machinery |
| 181 | Wearing apparel, except fur apparel | 293 | Domestic appliances, n.e.c. |
| 191 | Tanning and dressing of leather | 311 | Electric motors, generators and transformers |
| 192 | Footwear | 312+313 | Electricity distribution and control apparatus |
| 201 | Saw milling and planing of wood | 314 | Accumulators, primary cells and primary batteries |
| 202 | Wood, cork, straw and plaiting | 341 | Motor vehicles |
| 210 | Paper and paper products | 342 | Bodies for motor vehicles |
| 221 | Publishing | 351 | Ships and boats |
| 222 | Printing | 352 | Railway locomotives and rolling stock |
| 361 | Furniture | 353 | Air and spacecraft machinery |
| **Medium Low-tech Industries** | | 359 | Transport equipment n.e.c. |
| 231 | Coke oven products | **High Technology** | |
| 232 | Refined petroleum products | 321 | Electronic valves and tubes and other electronic components |
| 251 | Rubber products | 323 | Television and radio receivers, sound or video recording etc. |
| 252 | Plastics products | 331+333 | Medical appliances etc + watches and clocks |
| 261 | Glass and glass products | 332 | Optical instruments and photographic equipment |
| 269 | Non-metallic mineral products n.e.c. | 2423 | Pharmaceuticals |
| *OECD (1997) classification* | | | |

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