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FIRM-LEVEL DETERMINANTS OF INDUSTRIAL R&D: EMPIRICAL EVIDENCE FROM THE INDIAN R&D INTENSIVE INDUSTRIES

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Abstract

This study examines the firm-level R&D determinants of Indian high R&D intensive industries recognized for their historically weak R&D initiatives and global competitiveness. This study intends to use inflation-adjusted financial balanced panel data for 2001–2021 and apply the random effects Tobit model with bootstrapped standard errors. The study has found that stronger intellectual property regime dummy, export intensity, firm size square, and industry dummies for pharmaceutical, automobile, and electronics industries firm's market power and operational efficiency have positively impacted firm-level R&D intensity. In contrast, the negative and statistically significant impact of raw material import intensity and firm size indicates the requirement for planning and implementing appropriate managerial strategies. A bigger firm size does not stimulate R&D investment and offers a competitive edge to the R&D active firms, so managers may think about launching small R&D subsidiaries for innovation building. Policymakers may also focus on improving the outward orientation of the firm by facilitating exports and discouraging raw material imports.

Keywords: R&D, Manufacturing industries, Intellectual Property Regime, Firm-size.

1. Introduction

R&D strategy is the core strategy as the firm's survival and growth depend on its innovation. R&D investment also helps a firm attain a competitive advantage by developing better products per the changing market demands (Author, 2018). A reasonably large number of studies in innovation economics have investigated the factors that have led to the investment in R&D (Nelson, 1959). As expected, much of the literature on R&D determinants has majorly focused on the Schumpeterian hypothesis and the factors that determine inter-industry R&D activities (Cohen & Klepper, 1996; Crépon, Duguet, & Mairessec, 1998). Significant investigations have been around how characteristics of markets and firms (such as R&D, patents, collaborative innovation, physical and human capital, size of the firm, and sales revenue) influence industrial R&D and its output. Notably, it has also been found that R&D or innovation intensity differs considerably across industries (Patel & Pavitt, 1995).

Indian R&D-intensive firms are relying heavily on their R&D strategy to increase their profits and market share. India is ranked 76th out of 143 economies as per the latest Global Innovation Index (IBEF, 2018). This rank is somewhat encouraging as Indian industries are traditionally not known for their R&D activity but their reverse engineering capabilities. R&D intensity in the Indian economy has been deficient and stagnant at 0.6 to 0.7 percent in the last 20 years, while other economies are spending significantly higher amounts on their R&D activities, such as the USA (2.8%), Israel (4.3%), China (2.1%) and Korea (4.2%) (Economic Survey, 2020-21). With this background information, the present study attempts to investigate what determines R&D investment at a firm-level in R&D intensive manufacturing industries of India for a recent period, i.e., 2000-2020. This paper intends to provide new shreds of evidence in the R&D investment behavior of the firm during a more extended period. The rest of the research article is presented as follows: Section 2 builds a conceptual framework. Section 3 discusses data, methodology, and estimation procedure. Section 4 focuses on results and discussion, while section 5 concludes the study.

2. Conceptual Framework

The dependent variable in the present study is the R&D intensity which considers how much funds a firm will allocate to R&D activity relative to their total sales revenue. Table 1 presents dependent and independent variables.

Table 1. Determinants of Firm-Level R&D Intensity

Variables	**Symbol**	**Description**
Dependent Variable		
Firm-Level R&D Intensity	RDI	Ratio of Firm's R&D expenditure to total sales revenue (in %) at time *t*
Independent Variables		
Industry Effects Variable		
Dummy for Stronger Patent Regime	SPR	Taken as dichotomous variable i.e., attributing the value of 1 for period after 2005, 0 otherwise.
Industry Dummies		
Firm Effects Variables		
Firm's Size	LFSZ	Log of total assets of the firm at time *t*
	LFSZSQ	Squared demeaned Log of total assets of the firm at time *t*
Export Intensity	XI	Ratio of firm's exports to total sales revenue (in %) at time *t*
Debt over Equity Ratio	LEV	Ratio of total debt to total equity of the firm at a time *t*
Past Cash Flow	LCFS	Net cash flow at *t-1*

Source: Author's elaboration

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2.1. Industry Specific Variable

2.1.1. Stronger Patent Regime

Stronger IPRs protection is required for high R&D investment as patents play a significant role in stimulating novel R&D activity (Brekke & Straume, 2009). Intellectual property is also created to cash the fringe benefits than materializing real applications (Author, 2018). The present study hypothesizes that a more robust patent regime may positively impact firm-level R&D activity.

2.1.2. Industry Dummies

Firms in different industries react differently to R&D intensity, so it is hypothesized that industry dummies may positively impact R&D intensity. Against this backdrop, five industrial dummies are considered in the present study.

2.2. Firm-Specific Variables

2.2.1. Market Power-R&D Investment Linkages

The relationship between market power and R&D investment dates back to Schumpeter (1942). Existing empirical studies do not provide extensive evidence regarding firm size and R&D investment linkages. It is hypothesized that larger firms may allocate higher R&D investments than their smaller counterparts.

2.2.2. Financial Variables

Financial variables have always been positively linked with R&D investment in the management research literature. Bougheas et al. (2003) empirically found strong evidence that R&D investments were significantly influenced by the cash flow rather than the external financing arrangements. Bloch (2005) found that R&D investments primarily hinge upon the internal fund because of credit market imperfections. It is hypothesized that cash flow and firm-level R&D intensity may be positively associated, while leverage ratio may negatively influence a firm’s R&D investment.

2.2.3. Outward orientation

2.2.3.1. Export performance

Harris and Moffat (2011) have critically examined the prior art to find evidence of the direct relationship between export orientation and the R&D activities of the firms. The ‘prior art’ suggests that exporters must constantly and rapidly innovate to survive and grow in the competitive foreign markets. Existing studies have found a positive relationship between export orientation and R&D (Baum, 2012, and Yang & Chen, 2012). It is hypothesized that export performance may positively impact R&D investment.

2.2.3.2. Raw material import intensity

Furthermore, export performance is positively linked with raw material import intensity, so it is hypothesized that raw material import intensity may impact R&D intensity positively.

3. Data Sources and Methodology

3.1. Data Sources

The present study has taken the panel data set of 315 domestic manufacturing firms from 2000 to 2020. The study has only considered Indian firms from the top five high R&D intensive manufacturing industries. These industries include pharmaceutical, electrical, electronics, and chemicals, excluding pharmaceuticals and automobiles. The study has used data from PROWESS-IQ of CMIE (Centre for Monitoring Indian Economy). The sample firms are highly representative of R&D-intensive firms in the selected industries. The data have been converted to constant prices before being analyzed.

3.2. Methodology

The study uses a random-effects Tobit model to examine the factors determining the R&D intensity of sampled high R&D intensive Indian manufacturing firms. The Tobit model is the most appropriate model for this research problem due to two main reasons:

1. Firstly, data is unbalanced due to the non-occurrence of firm-level R&D investment for all the years.

2. Secondly, Indian indexed firms are only expected to report those expenses which are more than one percent of the firm's total turnover as per the existing government regulations.

The random effects (RE) Tobit model is chosen over a fixed-effects Tobit model as the fixed effects likelihood estimator in case of the non-linear model is found as inconstant and biased (Greene, 2004; Author, 2018). The Tobit model is specified on the basis of latent dependent variable which is observed only if $RDI_{it}^{*} > 0$ and is not observed if $RDI_{it}^{*} < 0$.

Where $X_{it}^{\prime}$ is a vector of all observed independent variables which are supposed to be determining R&D investment for the firm *i* and at the time period t. β coefficient is the weighted average of the impact of a rise in the explanatory variable on the

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probability of indulging in R&D investment activity above the zero limit. μ_{it} is an error term that captures the unobserved factors that impact R&D investment. Furthermore, bootstrapped standard errors are also used to correct the heteroscedasticity and non-normality of data. The compound Tobit estimates will be interpreted after decomposing its marginal effects. McDonald and Moffitt (1980) decomposition is applied in the present study.

3.3. Estimation Procedure

Descriptive statistics of all variables are observed carefully and presented in table 2.

Table 2. Descriptive Statistics of RDI and R&D Determinants

Variable	Unit of measurement	Observations	Mean	Standard Deviation	Minimum	Maximum
RDI	percentage	5965	1.19	3.17	0	92.88
LFSZ*	million INR	5912	12822.02	39861.89	23.2	657053.7
LFSZSQ	square values	5912	12.21	5.44	1.86	33.84
XI	percentage	5909	22.69	24.07	0	99.93
RMII	percentage	5905	26.16	24.88	0	116.4
LEV	percentage	5904	2.05	27.47	0	1220.6
LCFS**	million INR	5904	71.26	1478.88	-19477.4	34753.7

Note: *Descriptive statistics for LFSZ variables is presented in million INR. Log form of the measurement is not shown in the table for this variable.
**Non-lagged values are used for descriptive statistics.

Source: Author's Own Calculations

A wide heterogeneity is found among the sample units with respect to all the variables. Further, the non-stationarity of the panel was checked. As measured, the Augmented Dickey-Fuller and Phillips-Perron test estimates reject the null hypothesis of absolute non-stationarity of data for all variables. Results are presented in table 3.

Table 3. Test for Stationarity of R&D Determinants

Variables	PP test statistic		ADF test statistic	
	Inverse chi-squared P	Inverse normal Z	Inverse chi-squared P	Inverse normal Z
RDI	1731.89***	-15.10***	1546.73***	-11.74***
LFSZ	403.57**	11.81**	403.57**	11.39**
FSZSQ	579.43**	7.84**	303.82**	15.76**
XI	1366.22***	-6.03***	1084.27***	-6.10**
RMII	1294.40***	-4.57***	831.91***	-2.04**
LEV	3240.25***	-20.64***	1655.61***	-9.82***
LCFS	1090.89***	-75.87***	1009.42***	-43.806***

Note: (i) *** and ** indicates significance at 1%, and 5% respectively.
(ii) Dummy variables are not included.

Source: Author's Own Calculations

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For detecting multicollinearity in variables, VIF values have been estimated. It is noticed that all VIF values are below 4, so the presence of strong collinearity is ruled out. Collinearity and correlation estimates are reported in table 4 and 5 respectively.

Table 4. Collinearity Diagnostics of R&D determinants

Variable	VIF	Tolerance
RDI	1.03	0.98
LFSZ	1.03	0.97
FSZSQ	1.12	0.89
XI	1.46	0.68
RMII	1.43	0.69
LEV	1.00	0.99
LCFS	1.05	0.95
Mean VIF	1.16	
Note: Dummy variables are not included.		

Source: Author's calculations

Table 5: Correlation Statistics of Dependent and Independent Variables (R&D determinants)

Variables	RDI	LFSZ	FSZSQ	XI	RMII	LEV	LCFS
RDI	1						
LFSZ	0.09*	1					
FSZSQ	0.11*	0.99*	1				
XI	0.09*	0.11*	0.09*	1			
RMII	0.05*	0.06*	0.05*	0.55*	1		
LEV	0.01	-0.03	-0.05	0.07	0.80	1	
LCFS	0.06	0.05*	0.06*	-0.03	-0.07	-0.02	1
Note: (i) *shows significance at 5%. (ii) Dummy variables are not included.							

Source: Author's calculations

The econometric model has been estimated by applying random-effects panel Tobit model which is specified as below:

$$RDI_{it} = \beta_0 + \beta_1 LFSZ_{it} + \beta_2 FSZSQ_{it} + \beta_3 XI_{it} + \beta_4 RMI_{it} + \beta_5 LEV_{it} + \beta_6 LCFS_{it} + \beta_7 SPRDUM + \beta_8 \mathrm{ELECTRONDUM} + \beta_9 \mathrm{CHEMDUM} + \beta_{10} ELECDUM + \beta_{11} PHARMDUM + \beta_{12} \mathrm{AUTODUM} + \varepsilon_{it}$$

4. Results and Discussions

Table 6 portrays estimated coefficients of independent variables for RE Tobit estimation and two types of marginal effects as per McDonald-Moffitt decomposition framework.

Table 6. Random Effects Tobit Model-Determinants of Research and Development Intensity (RDI)

Panel A: Random-effects Tobit estimates			
Dependent Variable - RDI			
		McDonald & Moffitt Decomposition	
Independent Variable	**Tobit Coefficient Values**	**E(RDI|RDI>0) = 3.09**	**E(RDI*|RDI>0= 1.831**
LFSZ	-1.59760*** (0.56401)	-0.66609*** (0.23565)	-0.96432*** (0.33356)
FSZSQ	0.32636*** (0.07682)	0.13661*** (0.03231)	0.19393*** (0.04592)
XI	0.01433*** (0.00296)	0.00600*** (0.00120)	0.00851*** (0.00178)
RMI	-0.00776*** (0.00272)	-0.00325*** (0.00114)	-0.00461*** (0.00162)
LEV	0.00119 (0.00152)	0.00049 (0.00064)	0.00071 (0.0009)
LCFS	-0.00002 (0.00002)	-0.00001 (0.00001)	-0.00001 (0.00001)
SPRDUM	0.41076*** (0.10071)	0.169506*** (0.04113)	0.24012*** (0.05819)
ELECTRONDUM	3.01415*** (0.57819)	1.58036*** (0.36965)	2.1972*** (0.48798)
CHEMDUM	0.30694 (0.39861)	0.13091 (0.17323)	0.18616 (0. 24668)
ELECDUM	0.39861 (0.57190)	0.28176 (0.26349)	0.40130 (0.37565)
PHARMDUM	2.52393*** (0.33733)	1.18817*** (0.17988)	1.67707*** (0.24837)
AUTOMDUM	1.70776*** (0.28310)	-0.71230*** (0.11979)	-1.0062*** (0.16831)
Panel B: Test statistics			
Log likelihood	-1297.95		
Wald Chi Square	207.48***		
Total Observations	5304		

Source Author’s calculations
Note: (i) Figures in parentheses are respective clustered standard errors, and
(ii)*** indicates significance at 1% level.

Firm size

Quite contrary to existing studies, firm size is found negatively yet significantly related to firm-level R&D investment. An increase in size decreased direct R&D investment along with the probability of being engaged in R&D activities, as explained by the McDonald and Moffit decomposition estimates. A significantly positive impact of FSZSQ is found on R&D intensity. A negative relationship between R&D activity and firm size implies that smaller firms invest more in R&D than advertising, as R&D investment fits their growth and survival strategy in the long run, so they promote a higher growth rate through fostering innovation (Ortega-Argilés, Vivarelli, & Voigt, 2009).

Export Intensity

Positive and significant export intensity-R&D investment linkage is found for the sample firms. If estimates from McDonald–Moffitt decomposition for marginal effects are considered, it is evident that the increase in a firm's exports favors R&D active firms more than the firms which may probably pursue the R&D activity. This positive relationship is consistent with the existing studies that exporting firms become more efficient and innovative due to knowledge spillover from the global market entry and survival (Baum, 2012, and Yang & Chen, 2012).

Raw Material Import Intensity

Higher import intensity showed a negative yet significant impact on the R&D intensity of the R&D intensive manufacturing Indian firms. The findings imply that the firms which are into extensive importing of raw materials may have a low level of technological capabilities, which makes them rely on imported raw materials.

Debt over Equity Ratio and Past Cash Flow

Both of these financial variables have exercised a non-significant and negligible impact on firm-level R&D investment. These findings imply that financial variables do not play significant roles in determining R&D intensity or probability of being engaged in R&D activity.

Stronger Patent Regime

A stronger patent regime dummy has exercised a significant and positive impact on R&D investment. This finding implies that after the introduction of a stronger patent regime in India, the innovative ability and capacity of high technology-intensive manufacturing firms were enhanced and improved a lot, contrary to popular belief. A significant shift from a weaker patent regime to a stronger one has stimulated firm-based R&D activity.

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Industry Dummies

Industry dummies have demonstrated mixed results. Dummy variables for the electronics industry, automobile industry, and pharmaceutical industry are found to be related to firm-level R&D intensity and probability of engaging in R&D activity in a robust, positive, and significant manner. This finding implies that the firms operating in these industries are more inclined towards R&D investment than firms operating in the chemical and electrical industries.

5. Conclusion, Policy Implications, and Recommendations

The present paper contributes to the existing literature as it enhances the understanding of what determines R&D intensity in the firms operating in Indian high R&D intensive industries. Firm size is found in a negative relationship with R&D intensity which is quite contrary to traditional Schumpeterian knowledge, while FSZSQ showed a positive association. The negative relationship can be attributed to the loss of interest on the part of bigger firms in dedicating resources towards innovative activities due to the setbacks and constant failure so far to come up with something substantive which could provide hope. These companies have now, in effect, opened up small R&D companies to eliminate the impact of very low output of R&D on the firm's share prices and also to take advantage of tax benefits and other incentives. The positive effects of FSZSQ suggest a threshold level of firm size for making a positive impact on R&D investment due to its nonlinear association with firm size. Outward orientation of the domestic pharmaceutical firms also made a significant impact on firm-level R&D intensity. The effect of outward direction was measured using two variables: export intensity and raw material import intensity of the firm. The positive and statistically significant impact of export intensity of the firm on R&D intensity suggests that overseas exposure enhances the probability of such a firm investing more in R&D for the reason that overseas markets may have specific requirements about the manufacturing products. Arguably, the overseas exposure may also result in a knowledge spillover effect, which may require further R&D to absorb the knowledge. Interestingly, one of the variables, i.e., Import Intensity, was found to have an adverse bearing on the R&D intensity. It may be mentioned here that higher import intensity may lead to efficiency gains for the firm on account of the import of cheaper quality inputs and intermediaries but may not have any positive influence on R&D intensity. On the other hand, the firms which are low in R&D may have a greater probability of resorting to more imports. The analysis has several important implications. In particular, it provides novel insights by examining the impact of a firm's outward orientation and stronger patent regime dummy on the firm's R&D investment behavior. By using the latest dataset, this paper investigates the broader period after the implementation of a stronger intellectual property regime and records the paradigm shifts in the industrial R&D activity. It gives a conceptual framework for analyzing the impact of the proposed managerial and strategic actions on R&D investment decisions.

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The larger size does not provide the competitive edge to R&D active firms, and managers may focus on starting up small R&D subsidiaries to focus on innovation specifically. Export orientation and import intensity also facilitate R&D investment due to knowledge spillover and global exposure. Future research may focus on additional variables, such as investigating the linkages between R&D activity and mergers and acquisitions. Future researchers may also analyze the type of firm-level R&D activities.

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