# Title: What fuels innovation in firms? Exploring linkages of R&D and ICT capabilities with innovation performance of Indian firms

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**Abstract**

*Innovation plays a critical role in the growth of developing economies like India. Existing literature indicates multiple factors that can spur innovation in firms, one of the most important being knowledge capital. Two of the most important knowledge based capabilities that can influence firm level innovation performance and firm productivity include capabilities around research and development (R&D) and information and communication technology (ICT). Firm level innovations can manifest themselves in various forms – product innovation, process innovation, marketing innovation and organizational innovation. The study uses data of firm level surveys in India to examine the linkages of R&D and ICT on innovation outcomes. The study uses a set of tobit regression models, generalised structural equations model and explorative content analysis to examine innovation outcomes of firms. The results indicate that both R&D and ICT parameters play a significant role in influencing innovation outcomes though they are moderated by the size of the firm and sector. The study adds to the existing literature of the resource based view of the firm and also the literature on innovation management in the context of emerging economies.*

**Keywords:** Innovation; R&D; ICT

**JEL:** O30, O32, O34

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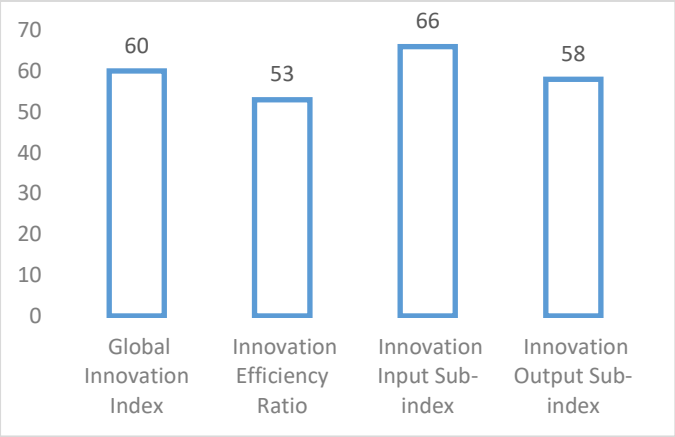
# 1. Introduction

Firms are expected to drive business innovation in emerging economies like India. Economic liberalization in India in the early nineties has increased to motivation for firms to carry out innovations to maximize their gains. However, innovation inputs and innovation capabilities has been found lacking in Indian firms. India lags behind in the Global Innovation Index and is often seen as high on 'jugaad' – a term for an indigenous "frugal, flexible, and inclusive approach to innovation" (Prabhu & Jain, 2015). Understanding this, various programmes have been initiated to fully leverage the innovation potential of the country.

*Figure 1: India's position in the Global Innovation Index 2017*




*Source: Global Innovation Index 2017 Report*

This study examines the role of capabilities around research and development (R&D) and information and communication technology (ICT) in influencing firm level innovations.

A study of this kind is important for several reasons. First, the conclusions shall inform policymakers towards the influencing factors which can impact innovation performance of firms. Second, the study adds to the existing literature of the resource based view of the firm and also the literature on innovation management in the context of emerging economies.

# 2. Theoretical Background

## 3.1 Firm level Innovation

The field of evolutionary economics and strategic management have left a deep influence on the present day innovation discourse. The theory of the firm mentions knowledge as an important driver. In the strategic management literature, the resource based view of the firm views knowledge based capabilities as a competitive asset and a driver for innovation and growth of the firm (Almeida & Phene, 2012). Firms, even with similar resource endowments display a wide heterogeneity in performance (McGahan & Porter, 1997). Some studies attribute the difference in firm performance to certain unobserved or latent factors or capabilities (Rumelt, 1991). In fact certain capabilities play a key role in influencing firm level innovation pathways (Penrose, 1959). Dynamic capabilities focus on capabilities related to change and innovation (Teece, Pisano, & Shuen, 1997). There is also general agreement that innovation requires knowledge, ingenuity and focus and is capable of being practiced (Drucker, The Discipline of Innovation, 2002). Others simply describe innovation as 'ideas that create the future' (Kanter, 2006) or innovation as a tool for business and entrepreneurs to leverage opportunities for a different business or a different service.

## 3.2 Innovation Performance and Interlinkages

The resource based view of the firm holds that R&D is a valuable resource that helps the innovating firm in gaining competitive advantage (Barney, Wright, & Ketchen, 2001). Firm level innovations can manifest themselves in various forms – product/service innovation, process innovation, marketing innovation and organizational innovation.

While product/service innovation, process innovation and organizational innovation has been well documented, there has been fewer studies on marketing innovation. The critical part played by innovation in marketing has been recognized long back by leading experts

like Wroe Alderson. Marketing is often viewed as organized rational innovation (Simmonds, 1986).Leading researchers like Drucker apart from Simmonds also mention innovation as a paradigm of marketing, without which marketing will only be a function without any linkages to innovation (Drucker, Innovation and entrepreneurship: Practices and principles, 1985).

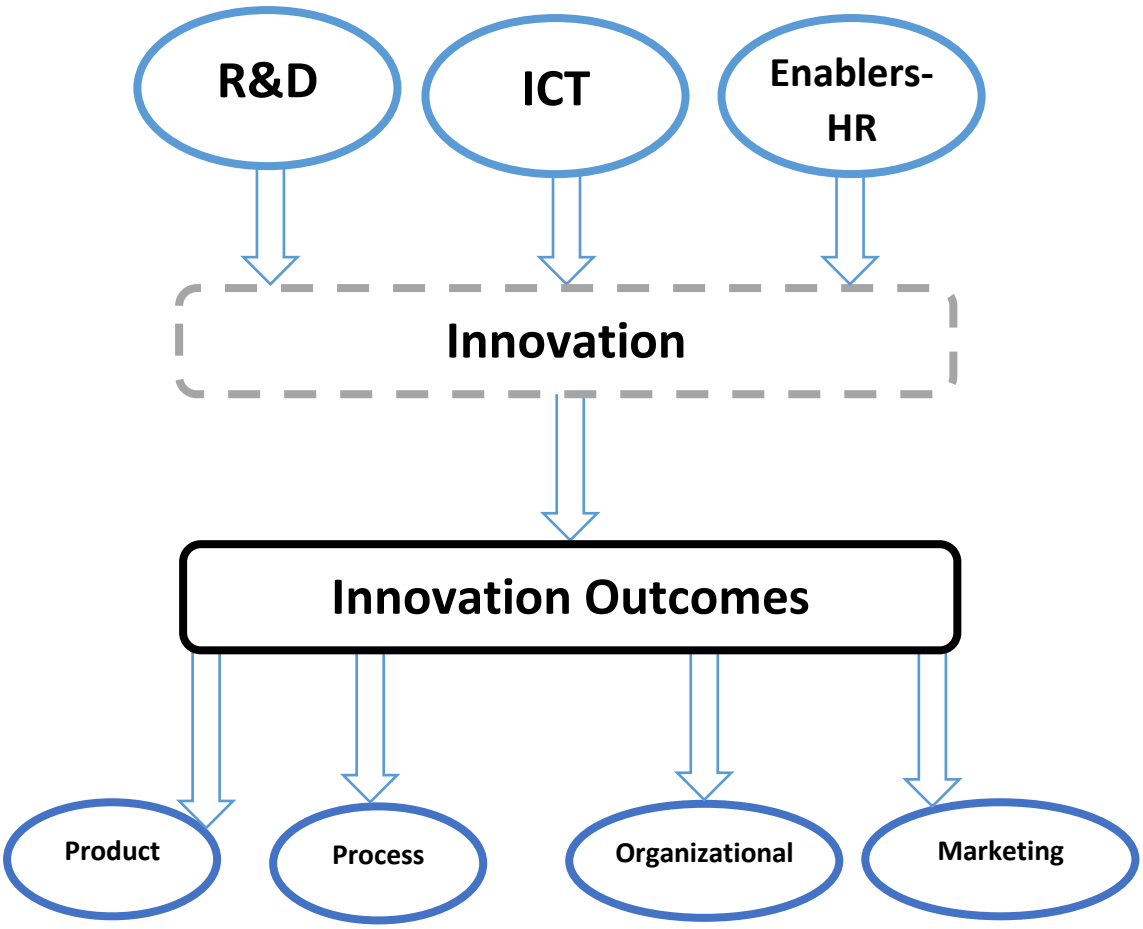
### 3.3 Innovation, R&D and ICT

The study titled 'Patents and R&D at the Firm Level: A First Look' lays the basis for other studies connecting R&D and innovation (Pakes & Griliches, 1984). Few studies have investigated the association of R&D and ICT jointly with innovation. One study reports that high intensity of ICT leads to decrease in R&D efforts (Cerquera & Klein, 2008). Another study draws the conclusion that ICT and innovation are complimentary (Polder, Leeuwen, Mohnen, & Raymond, 2009). Other studies have also concluded the role of ICT in firm level innovation (Arendt & Grabowski, 2018). Studies are available which have treated R&D and ICT as inputs for innovation (Hall, Lotti, & Mairesse, 2012). This study uses R&D and ICT as inputs for innovation and also adds to the literature by differentiating between the various forms of innovation in the emerging markets context.

## 3. Methodology

The study uses data of firm level surveys in India to examine the linkages of R&D and ICT on innovation outcomes. The study uses the well established Crepon–Duguet–Mairesse (CDM) model (Crépon, Duguet, & Mairesse, 1998). The model is modified by classifying different types of innovations as separate outputs.

*Figure 2: Conceptual linkage of constructs*

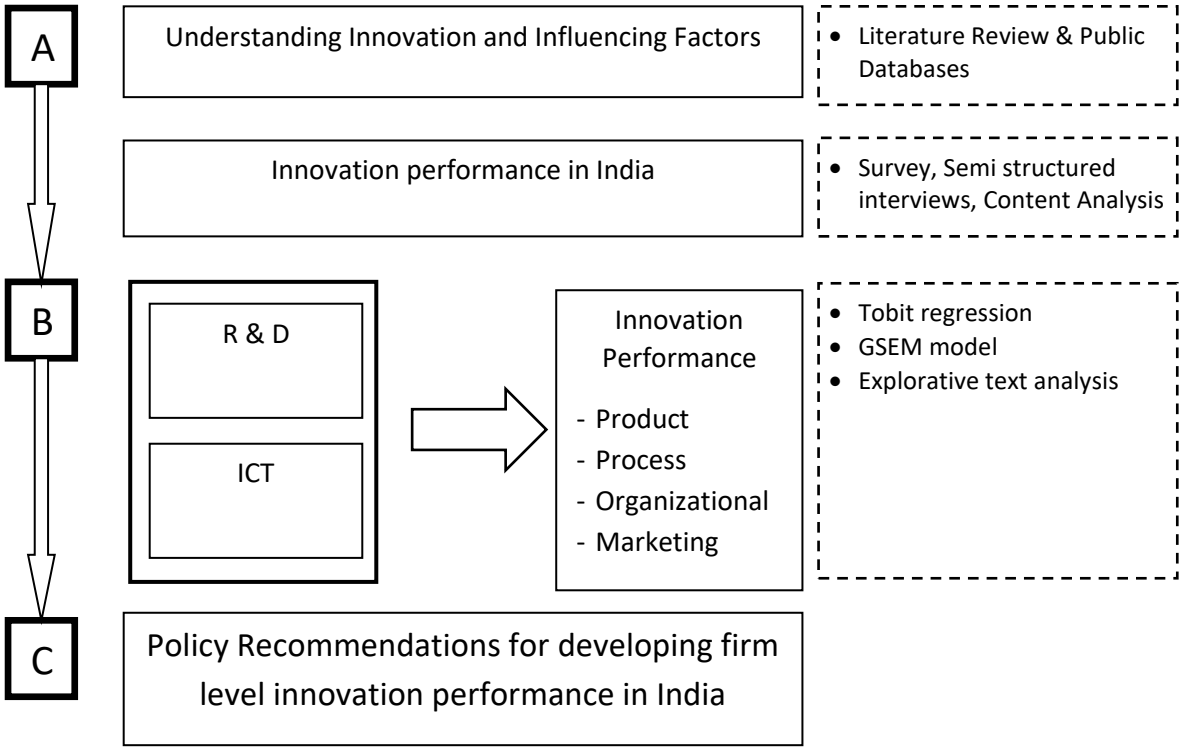



The study uses multiple methods of classification and regression and also develops a frontier function to examine the efficiency of innovation outcomes of firms. The results indicate that both R&D and ICT parameters play a significant role in influencing innovation outcomes though they are moderated by the size of the firm and other interaction terms.

## 3.4 Research Framework

The figure below depicts a proposed research framework to be used for addressing the research questions raised.

*Figure 3: Research Framework*




## 4. Data and Summary Statistics

The study uses firm level survey data from the World Bank's Enterprise Surveys (Enterprise Surveys, The World Bank). The Surveys use standardized survey instruments and a uniform sampling methodology. The survey uses stratified random sampling from the population of firms with the industry sector and the industry size as the stratum. However, the data sets represent only firms that were willing to participate in the survey.

This study adopts a non-experimental cross sectional, exploratory and confirmatory research design. Firm level survey data from the World Bank was used for this study. The surveys in in India was carried out till 2014.The study considered survey data for 3492 Indian firms. The surveys were carried out across several industrial sectors as provided below in table 1.

*Table 1: Number of Indian Firm level surveys used for this study*

| **No. of employees in firm --->** | **Small >=5 and <=19** | | **Medium >=20 and<=99** | | **Large >=100** | |
|---|---|---|---|---|---|---|
| **Industry Name** | **Manufacturing** | **Services** | **Manufacturing** | **Services** | **Manufacturing** | **Services** |
| Food | 87 | | 78 | 2 | 44 | |
| Tobacco | 12 | | 17 | | 5 | |
| Textiles | 34 | | 86 | | 67 | |
| Garments | 9 | | 50 | | 40 | |
| Leather | 6 | | 21 | | 12 | |
| Wood | 25 | | 16 | | 12 | |
| Paper | 26 | | 30 | | 4 | |
| Publishing, printing, and Recorded media | 14 | | 29 | | 12 | |
| Refined petroleum product | | | 5 | | 3 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Chemicals | 56 | | 122 | | 67 | |
| Plastics & rubber | 82 | | 130 | | 67 | |
| Non metallic mineral products | 58 | | 69 | | 18 | |
| Basic metals | 48 | | 93 | | 85 | 1 |
| Fabricated metal products | 63 | | 122 | 1 | 62 | |
| Machinery and equipment | 92 | | 140 | | 68 | 1 |
| Electronics | 42 | 2 | 97 | | 86 | |
| Precision instruments | 2 | | 14 | | 8 | |
| Transport machines | 44 | 1 | 99 | 1 | 66 | |
| Furniture | 10 | | 12 | | 6 | |
| Recycling | 3 | | 6 | | 1 | |
| Construction | 2 | 23 | 6 | 47 | 8 | 25 |
| Services of motor vehicles | | 10 | | 59 | 1 | 33 |
| Wholesale | | 55 | 1 | 32 | 1 | 10 |
| Retail | 4 | 93 | 2 | 30 | | 13 |
| Hotel and restaurants | | 15 | 2 | 88 | | 47 |
| Transport | | 40 | 2 | 41 | | 9 |
| IT | 1 | 12 | 2 | 37 | 10 | 40 |
| **Total** | **720** | **251** | **1251** | **338** | **753** | **179** |

# 5. Model Specification

The study explores four types of innovation outcomes – product innovation, process innovation, organizational innovation and marketing innovation and explores linkages with three specific inputs – R&D, ICT and Human Capital.

The study takes up parameters of four different innovation outcomes and regresses them on a set of innovation input variables. The input and output variables are provided in annexure I. The basic approach of the well-established CDM model is followed with the addition of two different parameter sets - ICT and Human Capital.

Three different types of modelling approaches are used:

1. A generalized tobit model for 4 different categories of innovation
2. A generalized structural equations model to take care of the feedback and endogenety
3. Content analysis and clustering of textual data

The dependent variables are categorical in nature, which calls for either a set of logit or probit models. However, many innovation studies report a large number of zeroes i.e. the absence of innovation mostly because the innovation project got delayed or abandoned or took a long time to complete which was beyond the timeframe of the survey. Thus the dependent variables in innovation data suffers from left censoring (Beers & Zand, 2014) and inputs which have been harnessed for innovation shows a zero value and cannot take on a negative one to reflect a failed innovation. To address this problem, the CDM model which used only R&D parameters used a Tobit model (Baum, Loof, Nabavi, & Stephan, 2015). In accordance with the relevant literature, this study uses a generalized Tobit model.

The tobit model can be written as:

$$y_i^* = x_i'\beta + u_i \qquad u_i \sim N(0, \sigma^2) \quad i = 1, \ldots\ldots\ldots, n$$

$y_i = y_i^*$ $\quad y_i^* > 0$
$y_i = 0$ $\quad$ otherwise

$x_i$ are a vector of independent variables for the $i$th participant, $y_i$, are observed responses of the $i$th participant and $y_i^*$ is an unobserved continuous latent variable for $y_i$.

The maximum likelihood estimation (MLE) produces consistent estimates of the parameters of tobit model. Homoscedasticity and normality of the error terms are assumed. The likelihood function of the tobit model is as follows:

$$L(\beta,\sigma^2) = \prod_0 \left[1 - \Phi\left(\frac{x_i'\beta}{\sigma}\right)\right] \prod_1 \left[\sigma^{-1}\phi\left(\frac{y_i - x_i'\beta}{\sigma}\right)\right]$$

Four different models are estimated for four different categories of innovation.

Dependent Variables (categorical)

**Model 1 – Product/Service Innovation**: Introduction of any innovative product or service

**Model 2 – Process Innovation**: Innovative methods of manufacturing products or offering services

**Model 3 – Organization Innovation:** Creation of new unit or department for innovation

**Model 4 – Marketing Innovation:** Use the services of a marketing firm, consumer research firm, or advertising firm for innovation

Independent Variables

**R&D Related**

a) Expenses on internal R&D
b) Expenses on external R&D
c) Expenses on employee training for innovation
d) Expenses for purchase of new equipment
e) Expenses on knowledge (purchase of patent, license and others)
f) Non-financial support from government (categorical)

**ICT Related**

g) Percentage of employees using ICT in their jobs
h) Expenses on external ICT consultants
i) Use of ICT for R&D (categorical)

**Human Capital Related**

j) Employees hired specifically for product/service innovation
k) Employees hired specifically for process innovation

Control Variables

l) Firm size
m) Industry sector

In addition, a generalized structural equations model is also estimated

# 6. Results

The study presents results from three different approaches of modelling the innovation data.

First the results of the tobit models are presented.

## 6.1 Regression models

Model 1 – Product/Service Innovation

*Table 2: Model 1 results*

| **Tobit regression** | | **Number of obs** | = | 3492 |
|---|---|---|---|---|
| | | **LR chi2(12)** | = | 1071.42 |
| | | **Prob > chi2** | = | 0 |
| **Log likelihood =** | -3072.9415 | **Pseudo R2** | = | 0.1485 |

| **Prod/Service Innovation** | **Coef.** | **Std. Err.** | **t** | **P>t** | **[95% Conf.** | **Interval]** |
|---|---|---|---|---|---|---|
| | | | | | | |
| Internal R&D | 9.12E-09 | 3.88E-09 | 2.35 | 0.001 | 1.50E-09 | 1.67E-08 |
| External R&D | 2.67E-09 | 1.84E-09 | 1.45 | 0.146 | -9.32E-10 | 6.28E-09 |
| Employee Training | 3.50E-08 | 1.84E-08 | 1.9 | 0.058 | -1.14E-09 | 7.11E-08 |
| New Equipment | 5.23E-11 | 9.95E-11 | 0.53 | 0.599 | -1.43E-10 | 2.47E-10 |
| Knowledge Acquisition | 3.74E-08 | 1.15E-06 | 0.03 | 0.974 | -2.22E-06 | 2.30E-06 |
| Government Support | 0.0644222 | 0.0248712 | 2.59 | 0.01 | 0.0156586 | 0.1131857 |
| ICT usage | 0.000804 | 0.0004744 | 1.69 | 0.09 | -0.0001261 | 0.001734 |
| External ICT Support | -1.79E-09 | 3.76E-09 | -0.48 | 0.634 | -9.17E-09 | 5.59E-09 |
| ICT for R&D | 0.0904213 | 0.0234637 | 3.85 | 0 | 0.0444174 | 0.1364253 |
| Recruitment for product/service innovation | 0.7384026 | 0.0239523 | 30.83 | 0 | 0.6914407 | 0.7853646 |
| Recruitment for process innovation | -0.3183919 | 0.0240611 | -13.23 | 0 | -0.3655672 | -0.2712165 |
| Firm Size | -0.008459 | 0.0149254 | -0.57 | 0.571 | -0.0377223 | 0.0208044 |
| Industry Sector | 0.2238387 | 0.0270108 | 8.29 | 0 | 0.1708801 | 0.2767973 |
| Constant | 0.1428255 | 0.0393884 | 3.63 | 0 | 0.0655988 | 0.2200522 |
| /sigma | 0.5889136 | 0.0097144 | | | 0.5698671 | 0.6079601 |

| **Model** | **Obs** | **ll(null)** | **ll(model)** | **df** | **AIC** | **BIC** |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| | 3492 | -3608.654 | -3072.942 | 14 | 6173.883 | 6260.098 |

Obs. summary: 1217 left-censored observations at hb1<=0
2275 uncensored observations
0 right-censored observations

The likelihood ratio chi-square of 1071.42 with a p-value of 0 indicates that the tobit model significantly fits better than one without predictors. The results indicate that for product/service innovation the following parameters are significant – Spending on Internal R&D, Spending on ICT for R&D, Recruitment for product/service innovation, Recruitment for process innovation. The coefficient of the last parameter i.e. recruitment for process innovation in negative indicating that if focus is provided on employing for process innovation, then product innovation may suffer. The influence of industry sector is significant indicating that it has a significant influence on product/service innovation.

Model 2 – Process Innovation

*Table 3: Model 2 results*

| **Tobit regression** | | **Number of obs** | = | 3492 |
|---|---|---|---|---|
| | | **LR chi2(12)** | = | 680.09 |
| | | **Prob > chi2** | = | 0 |
| **Log likelihood =** | -3342.8012 | **Pseudo R2** | = | 0.0923 |

| **Process Innovation** | **Coef.** | **Std. Err.** | **t** | **P>t** | **[95% Conf.** | **Interval]** |
|---|---|---|---|---|---|---|
| Internal R&D | -2.01E-09 | 4.51E-09 | -0.45 | 0.656 | -1.08E-08 | 6.83E-09 |
| External R&D | 1.55E-09 | 2.13E-09 | 0.73 | 0.466 | -2.63E-09 | 5.74E-09 |
| Employee Training | 1.57E-08 | 2.14E-08 | 0.73 | 0.464 | -2.62E-08 | 5.75E-08 |
| New Equipment | 2.40E-10 | 1.15E-10 | 2.09 | 0.036 | 1.53E-11 | 4.65E-10 |
| Knowledge Acquisition | 1.28E-06 | 1.33E-06 | 0.96 | 0.336 | -1.33E-06 | 3.88E-06 |
| Government Support | -0.047131 | 0.0294338 | -1.6 | 0.109 | -0.1048403 | 0.0105784 |
| ICT usage | -0.0001113 | 0.0005654 | -0.2 | 0.844 | -0.0012198 | 0.0009972 |
| External ICT Support | 6.47E-09 | 4.37E-09 | 1.48 | 0.139 | -2.09E-09 | 1.50E-08 |
| ICT for R&D | 0.0301216 | 0.0275078 | 1.1 | 0.274 | -0.0238115 | 0.0840548 |
| Recruitment for product/service innovation | -0.0815352 | 0.0281269 | -2.9 | 0.004 | -0.136682 | -0.0263884 |
| Recruitment for process innovation | 0.6703774 | 0.0273402 | 24.52 | 0 | 0.6167729 | 0.7239819 |
| Firm Size | 0.0486855 | 0.0174906 | 2.78 | 0.005 | 0.0143926 | 0.0829785 |
| Industry Sector | 0.1702701 | 0.031356 | 5.43 | 0 | 0.1087921 | 0.2317482 |
| Constant | -0.010654 | 0.0465946 | -0.23 | 0.819 | -0.1020095 | 0.0807015 |
| /sigma | 0.6830917 | 0.0118485 | | | 0.659861 | 0.7063223 |

| Model | Obs | ll(null) | ll(model) | df | AIC | BIC |
|---|---|---|---|---|---|---|
| | 3492 | -3682.848 | -3342.801 | 14 | 6713.602 | 6799.818 |

Obs. summary: 1379 left-censored observations at hc1<=0
2113 uncensored observations
0 right-censored observations

The likelihood ratio chi-square of 680.09 with a p-value of 0 indicates that the tobit model significantly fits better than one without predictors. The results indicate that for process innovation the following parameters are significant – Recruitment for product/service innovation, Recruitment for process innovation. What is surprising is that none of the R&D parameters are considered significant for process innovation. Firm size and industry sector are both significant indicating that they have a significant influence on process innovation.

Model 3 – Organization Innovation

*Table 4: Model 3 results*

| **Tobit regression** | | **Number of obs** | = | 3492 |
|---|---|---|---|---|
| | | **LR chi2(12)** | = | 620.51 |
| | | **Prob > chi2** | = | 0 |
| **Log likelihood =** | -2827.5675 | **Pseudo R2** | = | 0.0989 |

| **Organizational Innovation** | **Coef.** | **Std. Err.** | **t** | **P>t** | **[95% Conf.** | **Interval]** |
|---|---|---|---|---|---|---|
| Internal R&D | -3.86E-09 | 7.24E-09 | -0.53 | 0.595 | -1.81E-08 | 1.03E-08 |
| External R&D | -1.03E-08 | 9.15E-09 | -1.13 | 0.261 | -2.82E-08 | 7.64E-09 |
| Employee Training | -5.57E-08 | 4.92E-08 | -1.13 | 0.257 | -1.52E-07 | 4.07E-08 |
| New Equipment | 2.26E-10 | 1.81E-10 | 1.25 | 0.211 | -1.28E-10 | 5.80E-10 |
| Knowledge Acquisition | 1.01E-06 | 2.39E-06 | 0.42 | 0.672 | -3.67E-06 | 5.70E-06 |
| Government Support | 0.1913778 | 0.050889 | 3.76 | 0 | 0.0916025 | 0.2911531 |
| ICT usage | 0.001854 | 0.0009626 | 1.93 | 0.054 | -0.0000334 | 0.0037413 |
| External ICT Support | 7.94E-10 | 6.98E-09 | 0.11 | 0.909 | -1.29E-08 | 1.45E-08 |
| ICT for R&D | 0.1107452 | 0.0501919 | 2.21 | 0.027 | 0.0123366 | 0.2091537 |
| Recruitment for product/service innovation | 0.12182 | 0.0483357 | 2.52 | 0.012 | 0.0270509 | 0.2165891 |
| Recruitment for process innovation | 0.2461042 | 0.0474507 | 5.19 | 0 | 0.1530701 | 0.3391382 |
| Firm Size | 0.6960623 | 0.0360517 | 19.31 | 0 | 0.6253776 | 0.7667469 |
| Industry Sector | 0.0475586 | 0.0554683 | 0.86 | 0.391 | -0.061195 | 0.1563122 |
| Constant | -2.12005 | 0.1054632 | -20.1 | 0 | -2.326826 | -1.913275 |
| /sigma | 1.048845 | 0.0259641 | | | 0.9979391 | 1.099752 |

| Model | Obs | ll(null) | ll(model) | df | AIC | BIC |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| | 3492 | -3137.824 | -2827.567 | 14 | 5683.135 | 5769.35 |

Obs. summary: 2335 left-censored observations at hd3a<=0
1157 uncensored observations
0 right-censored observations

The likelihood ratio chi-square of 620.51 with a p-value of 0 indicates that the tobit model significantly fits better than one without predictors. The results indicate that for organizational innovation the following parameters are significant – Government support, Recruitment for process innovation. Firm size is significant indicating that it has a significant influence on organizational innovation.

Model 4 – Marketing Innovation

*Table 5: Model 4 results*

| **Tobit regression** | | **Number of obs** | = | 3492 |
|---|---|---|---|---|
| | | **LR chi2(12)** | = | 232.33 |
| | | **Prob > chi2** | = | 0 |
| **Log likelihood =** | -2396.3011 | **Pseudo R2** | = | 0.0462 |

| **Marketing Innovation** | **Coef.** | **Std. Err.** | **t** | **P>t** | **[95% Conf.** | **Interval]** |
|---|---|---|---|---|---|---|
| Internal R&D | -5.63E-09 | 1.02E-08 | -0.55 | 0.581 | -2.56E-08 | 1.43E-08 |
| External R&D | 2.76E-09 | 4.46E-09 | 0.62 | 0.536 | -5.98E-09 | 1.15E-08 |
| Employee Training | 1.23E-07 | 4.26E-08 | 2.9 | 0.004 | 3.99E-08 | 2.07E-07 |
| New Equipment | 3.51E-10 | 2.37E-10 | 1.48 | 0.139 | -1.14E-10 | 8.16E-10 |
| Knowledge Acquisition | 0.0000138 | 2.79E-06 | 4.95 | 0 | 8.35E-06 | 0.0000193 |
| Government Support | -0.1733328 | 0.074197 | -2.34 | 0.02 | -0.3188068 | -0.0278589 |
| ICT usage | 0.0030776 | 0.0013128 | 2.34 | 0.019 | 0.0005037 | 0.0056514 |
| External ICT Support | 1.59E-09 | 9.76E-09 | 0.16 | 0.871 | -1.76E-08 | 2.07E-08 |
| ICT for R&D | 0.4141228 | 0.0722086 | 5.74 | 0 | 0.2725473 | 0.5556983 |
| Recruitment for product/service innovation | -0.0701682 | 0.0690121 | -1.02 | 0.309 | -0.2054765 | 0.06514 |
| Recruitment for process innovation | 0.3323137 | 0.0660873 | 5.03 | 0 | 0.2027398 | 0.4618876 |
| Firm Size | 0.2814447 | 0.0436397 | 6.45 | 0 | 0.1958827 | 0.3670067 |
| Industry Sector | -0.4723282 | 0.0729297 | -6.48 | 0 | -0.6153175 | -0.3293389 |
| Constant | -1.610674 | 0.1273122 | -12.65 | 0 | -1.860288 | -1.36106 |
| /sigma | 1.333706 | 0.0415113 | | | 1.252317 | 1.415095 |

| **Model** | **Obs** | **ll(null)** | **ll(model)** | **df** | **AIC** | **BIC** |
|---|---|---|---|---|---|---|
| . | 3492 | -2512.469 | -2396.301 | 14 | 4820.602 | 4906.817 |

Obs. summary: 2711 left-censored observations at he2a<=0
781 uncensored observations
0 right-censored observations

The likelihood ratio chi-square of 232.33 with a p-value of 0 indicates that the tobit model significantly fits better than one without predictors. The results indicate that for marketing innovation the following parameters are significant – Knowledge acquisition, ICT for R&D, Recruitment for process innovation. Firm size and industry sector are both significant indicating that they have a significant influence on marketing innovation.

## 6.2 Generalized Structural Equations Model (GSEM)

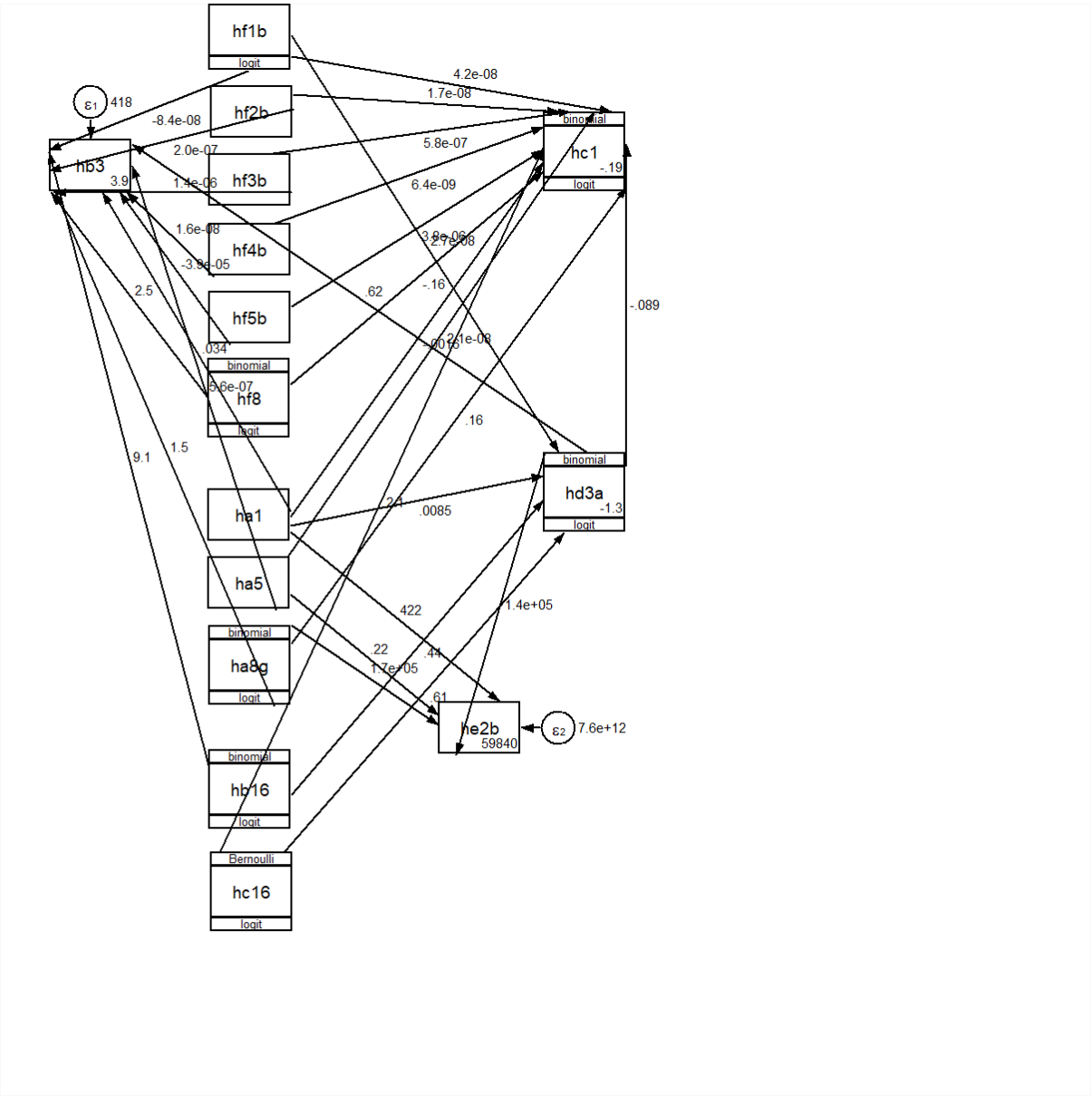
The study evaluates several dependence–independence relationships. Instead of using several multiple regression analyses, generalized structural equation modelling (GSEM) was used. A GSEM model is implemented in stata 13.1 to understand the simultaneous effect of inputs on outputs and also to provide feedback loops for organizational innovation to other categories of innovation. Compared to the tobit model, two changes have been made to the innovation output parameters to use continuous variables which are not censored and closely reflect the true innovation outcome. The outcome indicator for product innovation is percentage of total sales represented by sales from all innovative products or services and that for marketing innovation is payment for external services for innovation. The model is presented below.

The results indicate that for percentage sales from innovative products or for product innovation the following factors are significant - Internal R&D, External R&D, Employee Training, New Equipment and External ICT Support. External R&D and Government Support have significant influence on process innovation. For marketing innovation, ICT support plays a key role and organizational innovation is significantly impacted by process innovation.

*Table 6: GSEM Results*

| | Coef. | Robust Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| hb3 <- | | | | | | |
| hd3a | .6209755 | .3912597 | 1.59 | 0.112 | -.1458794 | 1.38783 |
| hf1b | -8.45e-08 | 4.48e-09 | -18.86 | 0.000 | -9.33e-08 | -7.57e-08 |
| hf2b | 1.99e-07 | 1.70e-09 | 116.73 | 0.000 | 1.96e-07 | 2.02e-07 |
| hf3b | 1.41e-06 | 2.99e-07 | 4.73 | 0.000 | 8.27e-07 | 2.00e-06 |
| hf4b | 1.63e-08 | 4.15e-10 | 39.34 | 0.000 | 1.55e-08 | 1.71e-08 |
| hf5b | -.0000386 | .0000354 | -1.09 | 0.275 | -.0001078 | .0000307 |
| hf8 | 2.483715 | 1.468938 | 1.69 | 0.091 | -.3953499 | 5.36278 |
| ha1 | .0335012 | .020454 | 1.64 | 0.101 | -.0065879 | .0735903 |
| ha5 | 5.61e-07 | 2.89e-08 | 19.38 | 0.000 | 5.04e-07 | 6.17e-07 |
| ha8g | 1.459296 | .8662598 | 1.68 | 0.092 | -.2385419 | 3.157134 |
| hb16 | 9.144871 | 1.134426 | 8.06 | 0.000 | 6.921437 | 11.36831 |
| _cons | 3.929596 | .6197666 | 6.34 | 0.000 | 2.714876 | 5.144316 |
| hc1 <- | | | | | | |
| hd3a | -.0886743 | .0644898 | -1.38 | 0.169 | -.215072 | .0377233 |
| hf1b | 4.20e-08 | 7.18e-08 | 0.58 | 0.559 | -9.87e-08 | 1.83e-07 |
| hf2b | 1.66e-08 | 5.47e-09 | 3.03 | 0.002 | 5.85e-09 | 2.73e-08 |
| hf3b | 5.80e-07 | 3.47e-07 | 1.67 | 0.095 | -1.00e-07 | 1.26e-06 |
| hf4b | 6.43e-09 | 4.37e-09 | 1.47 | 0.141 | -2.14e-09 | 1.50e-08 |
| hf5b | 3.80e-06 | 2.85e-06 | 1.34 | 0.182 | -1.78e-06 | 9.39e-06 |
| hf8 | -.1586198 | .0383446 | -4.14 | 0.000 | -.2337739 | -.0834657 |
| ha1 | -.0015602 | .0010526 | -1.48 | 0.138 | -.0036233 | .0005029 |
| ha5 | 2.07e-08 | 3.60e-08 | 0.57 | 0.565 | -4.99e-08 | 9.12e-08 |
| ha8g | .1611449 | .0557994 | 2.89 | 0.004 | .0517801 | .2705097 |
| hc16 | 2.117142 | .2485633 | 8.52 | 0.000 | 1.629967 | 2.604317 |
| _cons | -.1866416 | .0242687 | -7.69 | 0.000 | -.2342073 | -.1390758 |
| he2b <- | | | | | | |
| hd3a | 142281 | 126788.7 | 1.12 | 0.262 | -106220.3 | 390782.2 |
| ha1 | 421.6024 | 3080.392 | 0.14 | 0.891 | -5615.854 | 6459.059 |
| ha5 | .2201425 | .0008802 | 250.11 | 0.000 | .2184174 | .2218676 |
| ha8g | 173720.7 | 148775.5 | 1.17 | 0.243 | -117873.8 | 465315.3 |
| _cons | 59839.98 | 77916.12 | 0.77 | 0.442 | -92872.82 | 212552.8 |
| hd3a <- | | | | | | |
| hf1b | 2.70e-08 | 1.99e-08 | 1.35 | 0.176 | -1.21e-08 | 6.61e-08 |
| ha1 | .0084571 | .0041359 | 2.04 | 0.041 | .0003508 | .0165633 |
| hb16 | .4353651 | .1514389 | 2.87 | 0.004 | .1385504 | .7321799 |
| hc16 | .6064239 | .0789629 | 7.68 | 0.000 | .4516594 | .7611885 |
| _cons | -1.338782 | .7616147 | -1.76 | 0.079 | -2.83152 | .1539551 |
| var(e.hb3) | 417.8469 | 33.19728 | | | 357.5943 | 488.2517 |
| var(e.he2b) | 7.59e+12 | . | | | . | . |

*Figure 4: GSEM Path Diagram*

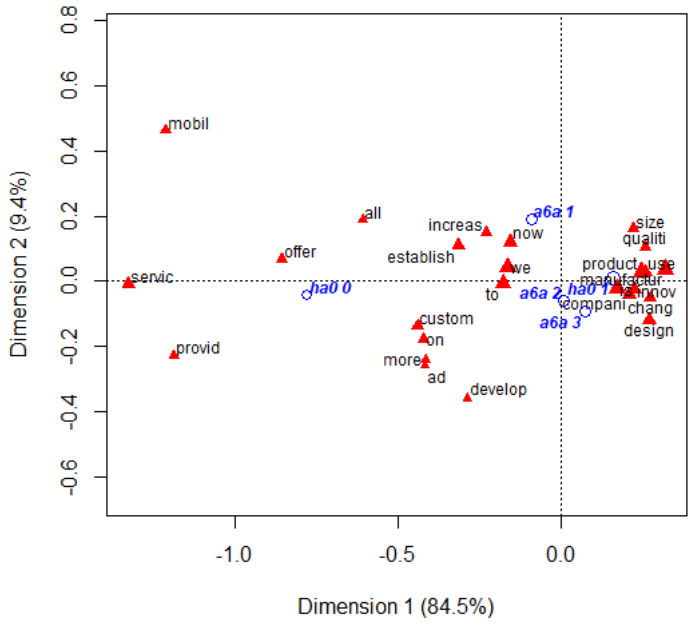



## 6.3 Explorative Content Analysis and Clustering

The innovation survey tried to capture the details of both product and process innovation through free flowing text inputs. These are important for the study, as apart from various innovation input and output parameters already considered, these text fields provide us a sense of keywords participants associate with innovation.

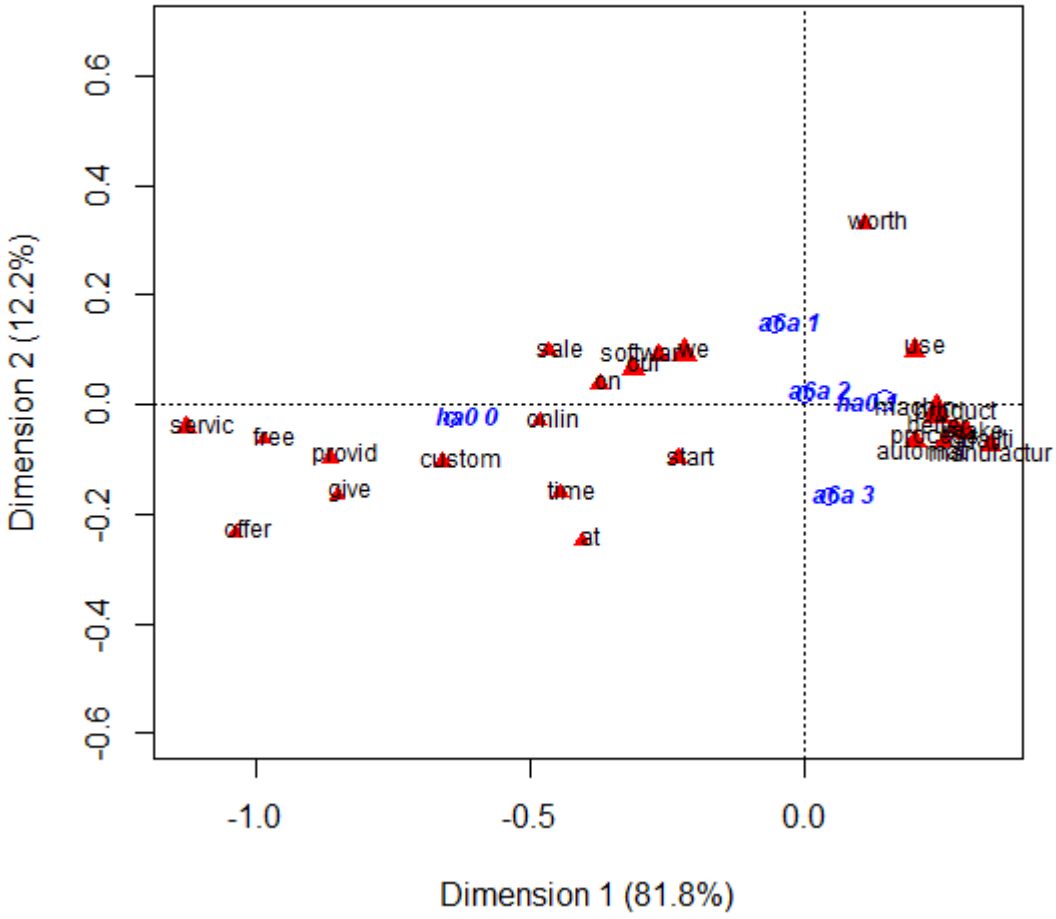
Our text analysis explores high frequency words both in product and process innovation. These were subject to Chi square tests to identify those words that occur with more frequency than the normative dataset. These were then clustered to identify dimensions associated with each word cluster. The standard process of lemmatization and word stemming were carried out. The results are presented below for both product/service innovation and process innovation and classified according to size of the firm. The results indicate some keywords which are associated with product/service and process innovation according to firm size and sector.

*Figure 5: Classification of keywords for product/service innovation*




| Size | Sector | Keywords |
|---|---|---|
| **Small** | Manufacturing | quality, product, manufacture |
| | Services | mobile, increase, offer |
| **Medium** | Manufacturing | manufacture, innovation |
| | Services | service |
| **Large** | Manufacturing | develop, customize, advertise |
| | Services | design, change |

*Figure 6: Classification of keywords for process innovation*




| Size | Sector | Keywords |
|---|---|---|
| **Small** | Manufacturing | machine, worth |
| | Services | sales, software |
| **Medium** | Manufacturing | machine, product, better, process |
| | Services | online, service, time, customer |
| **Large** | Manufacturing | quality, automation |
| | Services | offer |

## 7. Discussions and Implications

The study started with the objective of understanding various factors that influenced different types of innovation in Indian firms. The study has reached several important conclusions which will be of benefit to firms and government as well as informing the academic debate about factors that influence innovation. First, the study finds that to encourage product/service innovation, firms may spend on internal R&D, ICT and recruiting personnel specifically for innovation. Second, firms have to maintain a clear demarcation of focus between product/service innovations or process innovation as both these may work at cross purposes. Third, to strengthen the earlier result, none of the R&D

parameters influence process innovation, which is solely driven by recruitment and nurturing of knowledgeable workforce. Fourth, organization innovation is highly influenced by government support and human resource recruitment. Fifth, the significant factors that influence marketing innovation include knowledge acquisition, ICT for R&D, recruitment for process innovation. Sixth, the exploratory text analysis reveals that small, medium and large firms have a different perspective about both product/service innovation and process innovation. Finally, the GSEM model with feedbacks from organizational innovation finds that both external and internal R&D, employee training, harnessing ICT and developing an innovation ecosystem by purchasing innovation equipment and platforms significantly influence product/service innovation.

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## ANNEXURE

*Table 7: Model input and output and data summary*

| MODEL Inputs & Outputs | Parameter Description | Variable Type/ Unit | Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|---|---|---|
| **DEPENDENT VARIABLES** | **Product Innovation** | | | | | | | |
| | Introduction any innovative product or service (2010/2011 thru 2012/2013) | Yes/No | hb1 | 3492 | 0.651489 | 0.476567 | 0 | 1 |
| | Number of innovative products or services (2010/2011 thru 2012/2013) | No. | hb2 | 3492 | 1.206186 | 2.204884 | 0 | 50 |
| | In 2012/2013, percentage of total sales represented by sales from all innovative products or services (2010/2011 thru 2012/2013) | % | hb3 | 3492 | 9.402348 | 21.16093 | 0 | 100 |
| | In 2012/2013, percentage of total sales was represented by sales from the main innovative product or service | % | hb4 | 3492 | 22.35281 | 25.59553 | 0 | 100 |
| | **Process Innovation** | | | | | | | |
| | Any innovative methods of manufacturing products or offering services (2010/2011 thru 2012/2013) | Yes/No | hc1 | 3492 | 0.605097 | 0.4889 | 0 | 1 |
| | Any innovative logistics, delivery, or distribution methods for inputs, products, or services (2010/2011 thru 2012/2013) | Yes/No | hc2 | 3492 | 0.475086 | 0.49945 | 0 | 1 |
| | Any innovative supporting activity for processes, such as maintenance systems or operations for purchasing, accounting, or computing (2010/2011 thru 2012/2013) | Yes/No | hc3 | 3492 | 0.495991 | 0.500056 | 0 | 1 |
| | **Organizational Innovation** | | | | | | | |
| | Create a new unit or department (2010/2011 thru 2012/2013) | Yes/No | hd3a | 3492 | 0.331329 | 0.470758 | 0 | 1 |
| | Contract other firms to perform any activities previously done in-house (outsourcing -2010/2011 thru 2012/2013) | Yes/No | hd7 | 3492 | 0.187572 | 0.390426 | 0 | 1 |
| | **Marketing Innovation** | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Use the services of a marketing firm, consumer research firm, or advertising firm (2010/2011 thru 2012/2013) | Yes/No | he2a | 3492 | 0.223654 | 0.416753 | 0 | 1 |
| | Payment in total for those services (2010/2011 thru 2012/2013) | INR | he2b | 3492 | 261238.6 | 2826248 | 0 | 7.00E+07 |
| **INDEPENDENT VARIABLES** | **R&D** | | | | | | | |
| | Total cost of internal R&D (2010/2011 thru 2012/2013) | INR | hf1b | 3492 | 240563.8 | 2897410 | 0 | 1.00E+08 |
| | Total cost of external R&D (2010/2011 thru 2012/2013) | INR | hf2b | 3492 | 158115 | 5434279 | 0 | 2.50E+08 |
| | Spending on formal training to any of its employees specifically for the development and/or introduction of innovative products or services and processes (2010/2011 thru 2012/2013) | INR | hf3b | 3492 | 65599.86 | 551158.4 | 0 | 2.73E+07 |
| | Spending on the purchase of that new equipment, machinery, or software (2010/2011 thru 2012/2013) | INR | hf4b | 3492 | 8377362 | 1.09E+08 | 0 | 4.20E+09 |
| | Spending on purchase or license of any patented or non-patented inventions, or other types of knowledge (2010/2011 thru 2012/2013) | INR | hf5b | 3492 | 1168.958 | 9183.547 | 0 | 100000 |
| | Receive any non-financial support from the government for innovation-related activities (2010/2011 thru 2012/2013) | Yes/No | hf8 | 3492 | 0.237686 | 0.425727 | 0 | 1 |
| | **ICT** | | | | | | | |
| | Percentage employees who regularly use computers in their jobs, including management | % | ha1 | 3492 | 22.96363 | 23.56884 | 0 | 100 |
| | Total cost of external computer consultant or software consultants (2010/2011 thru 2012/2013) | INR | ha5 | 3492 | 124773.9 | 2807570 | 0 | 1.00E+08 |
| | Use ICT to do research and develop ideas on new products and services | Yes/No | ha8g | 3492 | 0.674112 | 0.468773 | 0 | 1 |
| | **Human Capital** | | | | | | | |
| | Employees hired specifically for the purpose of developing the main innovative product or service | Yes/No | hb16 | 3492 | 0.290664 | 0.454134 | 0 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Employees hired specifically for the purpose of developing the most important innovative process | Yes/No | hc16 | 3492 | 0.317297 | 0.465491 | 0 | 1 |
| **CONTROLS** | Size | Micro, Small, Medium, Large | a6a | 3492 | 1.988832 | 0.738235 | 1 | 3 |
| | Manufacturing or services | Yes/No | ha0 | 3492 | 0.780069 | 0.414259 | 0 | 1 |