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STI-DUI innovation modes and firm performance in the Indian capital goods industry: Do small firms differ from large ones?

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Abstract

This paper examines the effect of different innovation strategies followed by small and large firms on their overall performance in the capital goods industry. Following the wider literature on national innovation systems, we categorise the innovation modes as formal Science, Technology and Innovation (STI) and informal learning by Doing, Using and Interacting (DUI) mode. We observe that, in the case of small firms the informal learning and experience based innovation mode is related to improved performance, while the formal STI mode does not have any effect. On the other hand, for large firms, both STI and DUI innovation modes are positively related to its sales growth. Our results indicate that building certain DUI capabilities may act as a pre-condition to enhance the strength of science and technology based innovation strategies.

JEL Codes: O32, O33, L20

Keywords: STI, DUI, Modes of innovation, Capabilities accumulation, Corporate performances, Indian capital goods industry.

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1 Introduction

To begin with, the authors of this paper tried to prepare the traditional "beef ularthiyathu"[1] strictly following the recipe from their grandmothers' cookbook. Even with a very clear description of the exact amount of different ingredients and the procedure, neither of them was able to make it as good as their grandmothers did. It appears that the knowledge that was "codified" in the cookbooks was not enough to replicate the exact dish. To put it differently, the grandmothers had some valuable "tacit knowledge" which was difficult to be codified and transferred. We posit that the case is similar to firms that try to leverage codified knowledge. Firms differ in terms of their capabilities and how much a firm is able to exploit codified knowledge from external parties, in other words, its absorptive capacity, depends on its existing knowledge base and experience in that field.

Firms follow different strategies to learn, acquire knowledge, innovate and grow. Some very successful firms like Google, Apple and Amazon adapted the strategy of constant product innovation, launching every year new products that no one even knew they needed. On the other hand, firms like Piaggio, increased their growth by expanding their existing products to new markets by adapting their products to new market conditions, to capture new customers. For instance, the three-wheeled passenger auto-rickshaw was a product adopted to specific markets, like in India, which currently accounts for a fourth of Piaggo's global turnover. The former example is commonly a result of formal learning and research, while, the latter is more related to informal learning, in this case, understanding the local market conditions. Thus the main question remains whether the performance based on these different innovation and learning strategies are firm-specific, i.e, are some strategies best suited for some firms to help them in achieving better performance?

Even though previous empirical studies have shown that innovative firms outperform its counterparts (Coad, 2009; Audretsch et al., 2014a; Cohen, 2010), yet, not all firms innovate, and not all innovating firms achieve similar performance benefits. Even among innovating firms, some follow a different strategy of learning, innovation and capability accumulation from the other. Recent literature on firm capabilities focus on the type of knowledge flows that can help firms to absorb new inputs and transform them into relevant capabilities such as product expansion, introduction of new production techniques, organisational changes, better distribution and marketing (Rammer et al., 2009; Parrilli and Elola, 2012). Such knowledge flows could occur through different innovation modes. Here we focus on two major innovation modes, namely, the formal science, technology and

[1] A traditional beef fry dish from Kerala (https://en.wikipedia.org/wiki/Kerala_beef_fry).

innovation (STI) based and the informal learning-by-doing, by-using, and by-interacting (DUI) mode. The STI mode involves formal processes of the use and exchange of codified knowledge, mostly investment in science and technology (Griliches et al., 1979; Romer, 1994), while the DUI mode is through informal interactions, by the use and exchange of tacit knowledge (Lundvall, 1992; Jensen et al., 2007). A number of studies (among others, Jensen et al. 2007) has highlighted the standalone and simultaneous effects of STI and DUI modes of innovation strategies. Majority of them claim that a combination of both is optimal for improved innovation and firm performance. However, much of the previous work deal with the link between learning modes and innovation outputs, especially product and process innovations (Parrilli and Heras, 2016). By and large, the effects of STI and DUI learning modes on firm performance have received scant attention (Apanasovich et al., 2016). Understanding the underlying processes of firm innovation strategies and how different strategies are related to firm performance is not only relevant for the management of the firm, but also at the level of the economy, for policy makers to frame national innovation systems to focus on the relevant drivers of innovation and performance.

Firms at different stages of their growth could vary widely in terms of their capabilities and hence could have different effects of the two innovation modes on their performance. It is reasonable to believe that in order to use codified and scientific knowledge effectively, the firms must have to acquire certain prerequisite learning based capabilities which in-turn get reflected in better performance outcomes. Small and large firms likely being on different stages of the "capability escalator" (as termed by Cirera and Maloney, 2017) with differential learning capabilities could have differential performance outcomes from the two innovation modes. Traditional literature has emphasized the role of firm size on innovation; for a detailed discussion on previous works, see Cohen (2010). Among others, Acs and Audretsch (1988); Cohen and Klepper (1996) have shown that, ceteruis paribus, firm size influence innovation within industries, measured in terms of R&D expenditures. Here we investigate whether different innovation modes are related to different performance outcomes among small and large firms in the Indian capital goods sector.

The capital goods sector which comes under the fabric of engineering industry, on the one hand relies on science and technology based innovation strategies which are primarily based on R&D and external knowledge acquisition. At the same time, the industry is characterised by different types of learning interactions which may not be categorised under the mainstream STI mode. In India, the production and use of capital goods was

formerly regulated through deliberate creation of certain institutions and active state interventions. The liberalisation measures which started from the 1990s emphasized more towards building an innovation system based on more participation of private agents, actors and networks. The capital goods sector plays an important role in the engagement across different sectors such as engineering, construction, infrastructure, and consumer goods and given its importance, the Indian government has been taking active initiatives in this sector. For instance, the recent capital goods policy in 2016 aims to fund technology acquisition, transfer of technology, purchase of IPRs, designs & drawings as well as commercialization of such technologies of capital goods.[2] The characteristics of the sector in terms of its reliance on different innovation strategies and its role in engagement with other sectors makes it interesting to check the effectiveness of different innovation modes on the performance of firms in the sector.

We investigate the relation between different innovation modes and two performance outcomes of firms, namely sales growth and firm profitability, for small and large firms separately. Interestingly, we observe that the relation between different innovation modes and performance differ for small and large firms. For small enterprises, only the informal DUI mode is positively related to performance, both in terms of sales growth and profitability. For large firms, both STI and DUI learning modes contribute to sales growth.

The remaining part of the paper is organised as follows. In section 2, we detail the theory and existing literature, and in section 3, we explain the data. In section 4, we present the methodology and results of the study and in section 5 the conclusion.

2 Theory and literature

Innovating firms could differ in their ways of learning and innovation. Recently, there has been an increased focus on studying how firms create knowledge and engage in learning activities, especially in the evolutionary economics literature (Dosi and Nelson, 2010; Thompson, 2010; Geroski and Mazzucato, 2002). A recent work by Jensen et al. (2007) explains firms' innovativeness regarding different ways of using internal and external knowledge sources by categorizing them into two different modes of innovation, namely, the STI and the DUI mode. Below, we discuss these two modes in detail.

[2]The new Capital Goods Policy was announced by the Ministry of Heavy Industries and Public Enterprises, available at https://dhi.nic.in/writereaddata/Content/NationalCapitalGoodsPolicy2016.pdf.

2.1 The STI mode

The STI mode of innovation refers to the way firms use and develop scientific knowledge to introduce new products and technologies within the firm. This mode of innovation mainly refers to innovation by firms as an after effect of investments in R&D and science and technology. The knowledge generated by this mode of innovation is codified and explicit. Therefore, this mode of innovation heavily relies on investment in R&D, human capital, education of the workforce and cooperation between different actors, like firms and research centres (Rodríguez-Pose and Crescenzi 2008; Isaksen and Karlsen 2010). STI mode of innovation is often done through R&D projects carried out by big R&D laboratories in large firms, sometimes in collaboration with external actors like research centres or universities, where learning is based on the use of codified scientific knowledge. The result of this mode of learning is new codified knowledge, in the form of patents, publications etc which acts as building blocks for further research. Therefore, as Jensen et al. (2007) puts it, STI form of learning use global knowledge all the way through and potentially end up as global knowledge.

Nevertheless, it is important to note that how much ever explicit the knowledge is written down or codified, to pass on to others, or in other words, to be absorbed by potential users, is not automatic. Knowledge transfer does not occur effortlessly (Cohen and Levinthal, 1989), you need some prior knowledge about it (Jensen et al., 2007). Firms' "absorptive capacity", in other words, the ability to assimilate codified knowledge, requires necessary firm capabilities like basic infrastructure, high skilled workers etc, which implies that codified knowledge by itself is not useful if one lacks the complementary capabilities to understand and make use of it. As Powell (1996) argues, organisations can not be passive recipients of knowledge, what can be learned crucially depends on what they have already learned.

Compared to DUI type of learning, which is very difficult to be captured through usual firm level databases, information on formal STI type of innovation is usually available, thanks to detailed micro-level databases and worldwide patent databases. This has led to several studies documenting on STI mode of learning and its effect on firms' innovativeness and performance (among others, Belderbos et al. (2004); Artz et al. (2010); Fitjar and Rodríguez-Pose (2013); Klette and Griliches (2000)). Studies have shown that R&D expenditures by firms is the most influential variable to measure firm's ability to innovate (Dosi, 1988; Freeman and Soete, 1997). In the empirical section of the paper we have used the information on firms' spending on R&D and external technology acquisition to proxy the STI-mode.

2.2 The DUI mode

The innovation strategy of learning by Doing, Using and Interacting mostly refers to informal experienced-based mode of learning. The concept of "learning by doing" got noticed in economics literature by the seminal contribution of Arrow (1962), where he demonstrates that efficiency increase in time with production-based experience. Rosenberg (1982) introduced the concept of "learning by using" where the end-users learn by improving their skill of "using" a product in time. This allows producers to learn from the users, by receiving feedbacks and improving the quality of the product by integrating their feedbacks. In a way, this type of learning comprise of a two-way interaction, which later formalised the concept of "learning by interacting" where interaction between producers and users in innovation enhances the competence of both (Lundvall, 1988). As Von Hippel and Tyre (1995) points out, learning by doing is almost always associated with problem-solving process, which involves interactions between several parties as they seek solutions to specific problems in the production process. Indeed, all these are informal ways of learning, which are difficult to be measured using standard firm-level databases. However we make an attempt here to capture some of these. Here, we focus on "learning by interaction" by looking at both intra-firm and inter-firm interaction.

Lundvall and Lorenz (2007) points out that one way in which intra-firm interaction takes place is through active role played by employees. These include work practices that are designed to involve employees in problem solving and at times even decision making. Decentralizing responsibility to lower level employees and forming multi-functional teams is possible through increased learning among employees. Learning among employees indeed helps them not only in improving their skill, but also develops more interaction among employees and between employees and firm management. Here we use employee interaction, measured using spending by firms on staff training and welfare as one of the proxies for DUI mode of innovation.

Inter-firm interactions constitute another informal learning process where both parties engaged in the process learn by interaction between them, which could take different forms. Outsourcing jobs is one way in which such inter-firm interaction takes place, where within-firm processes and functions are relocated to external providers. Outsourcing could create an interdependence between two firms that encourage them to co-operate in solving problems and allows for knowledge sharing during the manufacturing and development phase of the process. It enables firms to create value and improve efficiency by pooling resources, and sharing expertise and knowledge (Ángel López Sánchez et al., 2010). Nevertheless, knowledge-intensive outsourcing alliance also require some minimum

level of knowledge about the outsourcing firm's routines, processes, technologies and its requirements (Brusoni and Prencipe, 2001; Ethiraj et al., 2005). Of course, outsourcing need not always involve knowledge transfer, since, outsourcers could have a strong disincentive to share their private knowledge to the outsourcee as it can be a potential source of competitive differentiation (Matusik, 2002). Still, we presume that if the firm has outsourced one or more of its jobs, then there is some level of interaction that takes place, even though this need not be extensive knowledge transfer.

Market-based learning is another informal process of learning about the market and how marketing strategies are formulated and conceived by the entrepreneur. Recent works have placed importance in the role of marketing and market specific capabilities in overall firm performance (among others, Morgan et al. 2009) and in particular to customer-connecting processes (Day, 1994, 2000). Boussouara and Deakins (1999) points out that using conventional marketing research tools like surveys, focus groups, conjoint analysis etc is paramount for assessing customers' needs and wants. Hence, marketing involves a learning process where firms learn about customer needs which helps them to incorporate these in new or existing product development. Therefore, investment by firms on marketing could be considered as a user-producer interaction within the literature on DUI modes of learning. For instance, the case of Piaggio that we mentioned in the introduction is a good example of tactical marketing, which concerns differentiating and extending existing products. Evidently, innovation by a firm need not necessarily be associated with a high tech product innovation, but simply a marketing innovation where the firm adapts the product to specific market conditions. This requires a certain level of knowledge about the market and customer needs, or in other words, market-based learning by the firm. Here we analyse the effect of market-based learning by firms, an informal learning strategy, on firm performance.

2.3 STI vs DUI mode of innovation and firm performance

Previous works have investigated the effect of the two modes on firm's innovative performance. While some studies show that STI mode is more effective (Parrilli and Elola, 2012; Isaksen and Nilsson, 2013; González-Pernía et al., 2015), some others emphasize the role of the DUI mode (Aslesen et al., 2012), especially in the case of small firms (Thomä, 2017). Several recent studies (Jensen et al., 2007; Isaksen and Karlsen, 2010; Herstad et al., 2015; Amara et al., 2008; González-Pernía et al., 2015) argue that firms that combine both modes are more innovative. Apanasovich (2016) provides a detailed review of the STI-DUI innovation modes. Nevertheless, most of the above mentioned studies focus

on the innovative performance of firms, like product, process or organisational innovations and not on other measures of firm performance.

Further, studies have shown that even though both modes of learning and innovation play an important role, it could be different depending on context (Von Hippel, 1976; Rosenberg, 1982; Pavitt, 1984). If one consider both innovation modes as different kinds of knowledge as pointed out by Jensen et al. (2007), it is reasonable to believe that the effectiveness of each mode is context-dependent. The context could be any firm characteristic like size or growth of the firm, or even geographical location of the firm. Concerning STI modes of innovation, among others, Demirel and Mazzucato (2012); Spescha (2019) show that formal innovation measured by R&D has an effect on firm performance, however size of the firm being a relevant factor in explaining this relationship. Note that, most of these studies investigate the relationship between formal STI mode (measured by firm-level R&D investment or patents) and firm performance (among others, Audretsch et al. 2014b; Capasso et al. 2015; Alfredo and Erasmo 2003; Stam and Wennberg 2009; Coad et al. forthcoming), while there are very few works focusing on the DUI mode. The main reason could be the lack of availability of detailed firm level information on informal modes of learning. An attempt to empirically examine firm-level learning by doing was undertaken by Dosi et al. (2017), where they relate different patterns in learning-by-doing to formal R&D investment by firms.

Cirera and Maloney (2017) building on the capability based theory of the firm, states that firms at different stage of their development possess different capabilities and therefore requires investment of different kinds at different stages of the "capability ladder". Firms accumulate capabilities at each step of the escalator, and climbing up the ladder of capabilities involves patiently expanding their organizational and technological capabilities at each stage. For the use and adoption of codified knowledge as well, firms require some minimum level of capabilities like basic infrastructure, high skilled human capital, knowledge of the market etc. Hence, small firms or firms in the early stage of the growth path might find informal DUI modes more effective than formal STI mode of innovation, since DUI modes of learning at an early stage would facilitate in building capabilities that will help them in achieving benefits from STI mode at a later stage.

Much of the previous work on modes of innovation are in the context of developed economies (Apanasovich, 2016). In our knowledge, this is the first study that looks at the relationship between formal STI and informal DUI modes of innovation and firm performance, with a special focus on small vs large firms in the context of a developing country like India.

3 Data and variable description

The empirical analysis is based on a sample of capital goods producing firms in India compiled by CMIE Prowess IQ database, which is considered as the largest firm level database in India. The time period of the study is from 1988 to 2018. We perform separate analysis for small and large firms. The classification of firm size is based on the new classification by the ministry of small and medium enterprises (MSME). The classification categorizes firms with sales turnover up to 75 crore INR per year as small and the ones that are above that level as large.[3]

The main variables of interest in our work are related to the STI and DUI modes. Other than the usual balance sheet data on firms, CMIE provides several interesting firm-level information, for example, external technology acquisition, different firm collaborations (with client firms, suppliers etc) which helps to proxy formal and informal learning modes. The two variables that we use to proxy the STI mode are i) the dummy indicating if the firm spent on Research and development (R&D) and ii) the dummy indicating if the firm purchased external technology. Concerning the DUI mode, Jensen et al. (2007) provides some guidelines for identifying this, which mostly relates to, yet not limited to, user-producer interactions and customer co-operation. In DUI mode of learning, since the dominant knowledge base remains tacit, knowledge acquisition and exploitation typically calls for interactions with external partners. Since there is no systematic innovation surveys carried out for India (except the World Bank Enterprises Survey for which panel data is not available), taking these aspects into consideration is challenging (Shekar and Paily, 2019). Nevertheless, we are able to identify a number of variables, namely, employee (intra-firm) interaction, market based learning and outsourcing (inter-firm) interaction, which act as the proxy for DUI mode, given the data limitations.

The first DUI indicator is employee interaction, which is defined as the ratio of staff welfare and training expenses to sales turnover. Improved workplace environment and on-job learning help employees to assimilate experience based on practical knowledge, thereby helping employees' ability to deal with complex problem solving tasks. Further, through these skill-generating activities, they also develop a common professional language to smoothly communicate and interact with scientists and engineers within and outside the firm (Thomä, 2017). The second DUI indicator, market based learning is defined in 2 ways: i) the ratio of selling and distribution expenses to sales and ii) market-

[3]The newly approved definition of micro, small and medium firms can be accessed at *https://www.dcmsme.gov.in/meetings/finalAgenda_16th_NBMSME.pdf*.

ing expenses to sales. Spending on selling, distribution and marketing are ways in which firms communicate with potential users on their products and services. Marketing expenses are cost incurred by the firm on presenting their products to potential customers, like advertising, customer surveys, online advertising, printed materials and displays etc. Selling and distribution expenses is more broader in scope; it includes all the costs incurred to deliver the product from the production unit to the end user, like packaging, handling costs at different stages, transportation, promotion expenses etc.

The third DUI indicator, outsourcing interaction is defined as the ratio of outsourcing of manufactured and professional jobs to sales. The outsourcing of jobs and services involves knowledge transfer between the firm and off shore teams to specially design the jobs and services according to the requirement of the firm. It also requires internal training of onshore teams to learn what is being done offshore. Thus, outsourcing jobs involves inter-firm learning and interactions which comes within the broad category of DUI learning mode. The definition of the variables used in our analysis are presented in table 1 and table 2 reports the summary statistics.

Table 1: Definition of variables

Variable	Definition
Sales	Total value of sales in million INR
Firm Age	Number of years since the year of incorporation
Profit Growth	Growth in gross operating margins between 2 consecutive years
Investments	Value of the difference in total assets between 2 consecutive years
R&D Dummy	1 if the firm spend on Research and Development and 0 otherwise
Royalties Dummy	1 if the firm spend on royalties and technical knowhow fees and 0 otherwise
Intra-firm Interaction (Employee interaction)	Ratio of staff welfare and training expenses to sales
Market-based learning 1	Ratio of selling and distribution expenses to sales
Market-based learning 2	Ratio of marketing expenses to sales
Inter-firm interaction (Outsourcing interaction)	Ratio of outsourcing expenses to sales

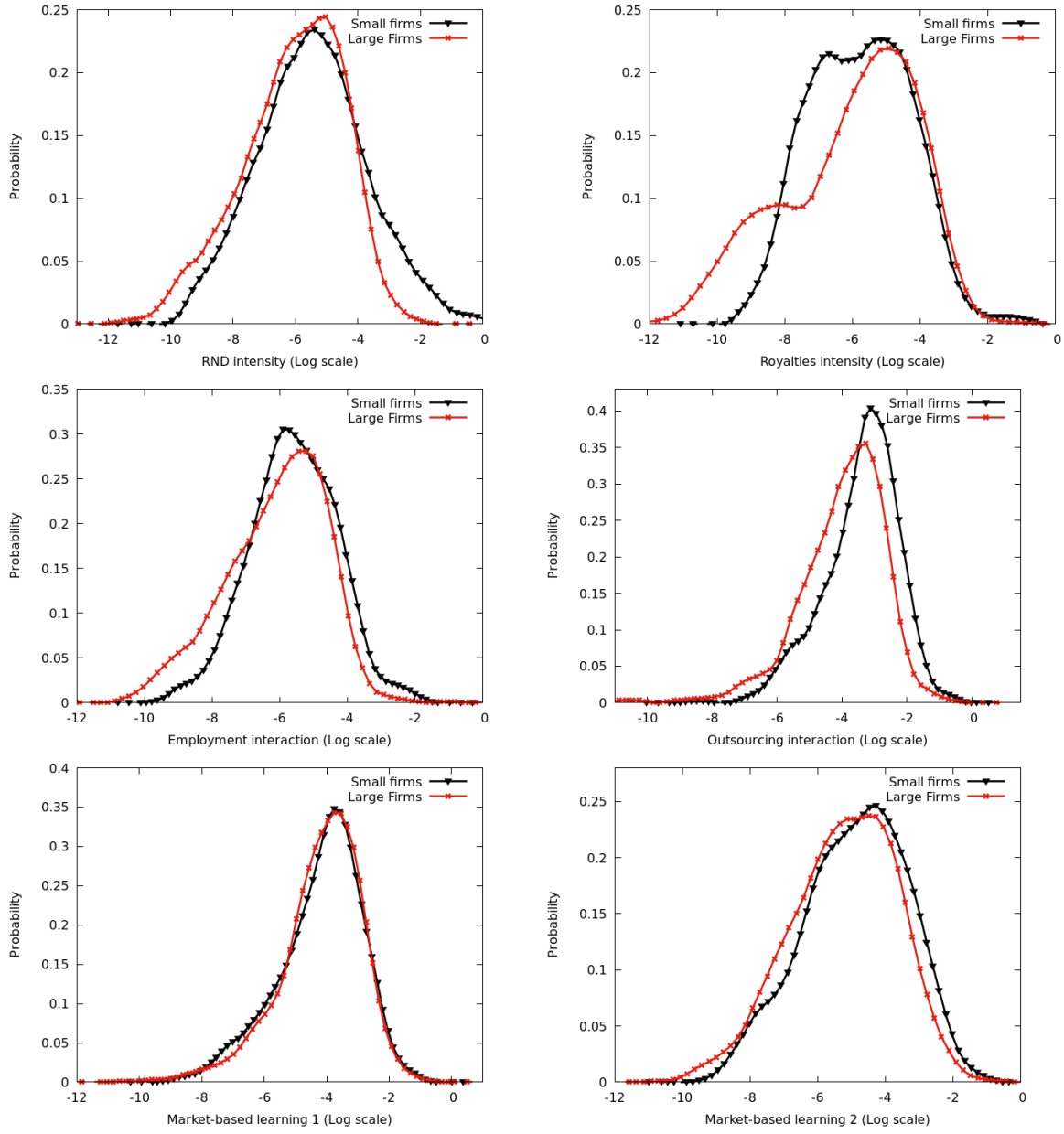
Table 2: Comparative summary statistics for small and large firms

	Small Firms		Large Firms	
Variable	Mean	Std. Dev	Mean	Std. Dev
Sales	328.53	176.50	19051.07	58469.33
Firm age	25.40	25.10	36.43	21.44
Profit growth	0.177	0.890	0.154	0.807
Investments	76.53	157.92	3460.41	12780.98
R&D expenditure	2.619	6.95	149.31	884.211
Royalties expenditure	3.57	3.987	346.37	1993.72
Intra-firm interaction	0.009	0.010	0.0069	0.0093
Market-based learning 1	0.039	0.065	0.038	0.041
Market-based learning 2	0.023	0.034	0.018	0.034
Inter-firm interaction	0.041	0.039	0.036	0.030

As already discussed, innovation and its effect differ between the small and large firms (Acs and Audretsch, 1988; Cohen and Klepper, 1992; Audretsch, 2001; Tether, 1998). In figure 1 we present the distributional plots of STI and DUI variables for small and large firms. The first two plots represent STI related variables, namely, R&D and technology purchases,[4] while the rest four are DUI variables. While it is difficult to visually detect differences between small and large firms for STI related variables, some DUI variables, namely, employee interaction, outsourcing and market-based learning 2 (defined in terms of marketing intensity) show some interesting patterns. The distributions of these DUI variables for small firms (marked black) are shifted towards the right of the red distributions which represent the large firms. This indicates that, on an average, small firms focus more on these three types of DUI interactive learning modes. In the next section, we move on to empirically analyze which innovation modes are effective for small and large firms respectively.

[4]Here, we use R&D and royalties intensities (measured in terms of their values over total sales) to show the distributional graphs.

Figure 1: Distributions of STI and DUI variables for small vs large firms



4 Empirical Specification and Results

In this section, we investigate the relationship between different innovation modes and firm performance. We focus on two firm performance outcomes, namely, sales growth and profitability. Sales growth is measured as the difference between the logarithmic value of sales in two consecutive years (Coad, 2009; Bottazzi et al., 2010). Profitability is measured as the log of the ratio of profit after tax to sales turnover.

In order to empirically examine the effect of different innovation modes on firm performance, we estimate an OLS and Fixed Effect Regression. Our baseline models with

dependent variables of firm growth and profitability are as follows.

$$SalesGrowth_{i,t} = \alpha + \beta 1\, Size_{i,t-1} + \beta 2\, SqSize_{i,t-1} + \beta 3\, Age_{i,t-1} + \beta 4\, PftGr_{i,t-1} + \beta 5\, Investments_{i,t-1} + \beta 6\, STI_{i,t-1} + \beta 7\, DUI_{i,t-1} + Controls + \epsilon_{i,t} \quad (1)$$

Likewise,

$$Profitability_{i,t} = \alpha + \beta 1\, Size_{i,t-1} + \beta 2\, SqSize_{i,t-1} + \beta 3\, Age_{i,t-1} + \beta 4\, PftGr_{i,t-1} + \beta 5\, Investments_{i,t-1} + \beta 6\, STI_{i,t-1} + \beta 7\, DUI_{i,t-1} + Controls + \epsilon_{i,t} \quad (2)$$

Here, our variables of interest are the STI and DUI indicators. We use R&D dummy and Royalties dummy to proxy for STI mode. Informal DUI mode is measured by inter-firm, intra-firm and user-producer interaction. We proxy inter-firm interaction through outsourcing, intra-firm interaction through employee training and user-producer interaction or market-based learning through selling and distribution and marketing expenses. For detailed definition of these variables, please refer to table 1. We use a set of firm specific control variables, namely, firm size (defined as the log of total sales), firm age (defined as number of years since incorporation), investments (defined as the log of additions to total assets) and profitability growth (defined as growth in profit margins) to control for the growth momentum of the firm. We also control for a non-linear relationship of firm size by adding a quadratic term. Sector and time dummies are used to control for industry and time effects. The independent variables are lagged by one year.

Tables 3 to 6 presents the results. In each table, we show four models with alternate DUI indicators: intra-firm interaction, both variables proxying market-based learning and inter-firm interaction. Therefore, model 1 concerns with the role of employee interactions in sales growth/profitability along with STI indicators and other firm and industry-level controls. Similarly, Model 2 and 3 refers to market-based learning (with selling/distribution expenses and marketing expenses) and model 4 refers to outsourcing interaction. The first 4 columns in each table refers to results from a fixed effects estimation and the last 4 columns correspond to results from an OLS estimation. The analysis is performed separately for small and large firms.

We observe that the effect of STI and DUI innovation modes on firm performance are different for small and large firms. In tables 3 and 4 we report the results of the regressions for small firms. We find that the DUI mode is positively related to firm performance for small firms, while the STI mode do not have any effect. The coefficients of employee

Table 3: Small Firms - Sales Growth: Fixed Effects and OLS Regression

	(1) FE	(2) FE	(3) FE	(4) FE	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Size	-0.468**	0.025	-0.064	-0.306	0.022	-0.032	-0.042	0.072
	(0.204)	(0.123)	(0.158)	(0.236)	(0.138)	(0.094)	(0.111)	(0.168)
Squared log of Sales	0.004	-0.029**	-0.022	-0.008	-0.016	-0.009	-0.009	-0.020
	(0.019)	(0.012)	(0.015)	(0.022)	(0.013)	(0.009)	(0.011)	(0.016)
Age	0.012	-0.049	-0.055	0.008	-0.001	-0.001*	-0.001	-0.001
	(0.095)	(0.091)	(0.099)	(0.107)	(0.001)	(0.000)	(0.001)	(0.001)
Profitability Growth	-0.017	-0.002	-0.002	-0.009	0.004	0.013*	0.014*	-0.006
	(0.010)	(0.008)	(0.008)	(0.014)	(0.011)	(0.008)	(0.008)	(0.014)
Log of Investments	0.075***	0.069***	0.073***	0.078***	0.076***	0.073***	0.072***	0.082***
	(0.010)	(0.007)	(0.007)	(0.013)	(0.010)	(0.006)	(0.006)	(0.012)
R&D Dummy	-0.089	-0.072	-0.080	-0.286	-0.084	-0.079	-0.070	-0.012
	(0.107)	(0.109)	(0.110)	(0.181)	(0.084)	(0.080)	(0.081)	(0.113)
Royalties Dummy	-0.031	-0.013	-0.017	-0.065	0.008	0.012	0.008	-0.005
	(0.041)	(0.024)	(0.024)	(0.052)	(0.023)	(0.014)	(0.015)	(0.028)
Employee Interaction.	3.007**				2.213**			
	(1.228)				(1.015)			
Market-based Learning 1		0.264**				0.368***		
		(0.108)				(0.102)		
Market-based Learning 2			0.739***				0.642***	
			(0.273)				(0.208)	
Outsourcing Interaction.				-0.013				0.637*
				(0.488)				(0.346)
Time & Sector Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	610	1147	1069	397	610	1147	1069	397
R^2	0.749	0.664	0.667	0.751	0.258	0.263	0.257	0.315

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Column 1 to 4 refers to Fixed Effects and Column 5 to 8 refers to OLS Regression

Table 4: Small Firms - Profitability: Fixed Effects and OLS Regression

	(1) FE	(2) FE	(3) FE	(4) FE	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Size	-0.216	-0.396	-0.048	0.540	-0.013	-0.186	-0.202	-0.570
	(0.824)	(0.561)	(0.735)	(0.828)	(0.577)	(0.433)	(0.515)	(0.628)
Squared log of Sales	0.036	0.026	-0.002	-0.031	-0.019	0.005	0.008	0.054
	(0.075)	(0.053)	(0.068)	(0.076)	(0.055)	(0.042)	(0.049)	(0.061)
Age	1.154***	1.252***	1.339***	1.184***	-0.001	-0.003	-0.001	-0.003
	(0.383)	(0.416)	(0.460)	(0.374)	(0.003)	(0.002)	(0.002)	(0.004)
Profitability Growth	0.038	0.025	0.022	0.018	0.024	0.021	0.019	0.015
	(0.042)	(0.035)	(0.037)	(0.048)	(0.044)	(0.035)	(0.036)	(0.052)
Log of Investments	0.138***	0.060*	0.047	0.084*	0.153***	0.186***	0.175***	0.139***
	(0.042)	(0.031)	(0.033)	(0.045)	(0.040)	(0.027)	(0.029)	(0.045)
R&D Dummy	0.057	-0.313	-0.319	0.176	0.395	0.239	0.197	0.194
	(0.434)	(0.498)	(0.510)	(0.637)	(0.352)	(0.371)	(0.374)	(0.423)
Royalties Dummy	-0.100	-0.135	-0.163	-0.178	0.191**	0.044	0.050	0.083
	(0.167)	(0.108)	(0.112)	(0.183)	(0.095)	(0.065)	(0.068)	(0.103)
Employee interaction.	11.391**				7.846*			
	(4.968)				(4.241)			
Market-based Learning 1		1.184**				0.633		
		(0.494)				(0.472)		
Market-based Learning 2			2.824**				1.836*	
			(1.268)				(0.961)	
Outsourcing Interaction.				4.994***				1.576
				(1.715)				(1.289)
Observations	610	1147	1069	397	610	1147	1069	397
R^2	0.728	0.606	0.598	0.745	0.141	0.119	0.112	0.210

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Column 1 to 4 refers to Fixed Effects and Column 5 to 8 refers to OLS Regression

Table 5: Large Firms - Sales Growth: Fixed Effects and OLS Regression

	(1) FE	(2) FE	(3) FE	(4) FE	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Size	-0.370***	-0.339***	-0.330***	-0.492***	-0.070***	-0.064***	-0.070***	-0.085**
	(0.039)	(0.031)	(0.033)	(0.071)	(0.023)	(0.020)	(0.021)	(0.034)
Squared log of Sales	0.009***	0.009***	0.008***	0.013***	0.001	0.000	0.001	0.002
	(0.002)	(0.002)	(0.002)	(0.004)	(0.001)	(0.001)	(0.001)	(0.002)
Age	0.012	0.017	0.019	0.032	-0.001***	-0.001***	-0.001***	-0.001***
	(0.016)	(0.016)	(0.018)	(0.025)	(0.000)	(0.000)	(0.000)	(0.000)
Profitability Growth	0.001	0.000	0.000	0.003	0.005	0.004	0.004	0.005
	(0.004)	(0.003)	(0.004)	(0.006)	(0.004)	(0.003)	(0.004)	(0.006)
Log of Investments	0.041***	0.042***	0.043***	0.034***	0.052***	0.052***	0.050***	0.050***
	(0.003)	(0.003)	(0.003)	(0.006)	(0.003)	(0.003)	(0.003)	(0.005)
R&D Dummy	0.086***	0.085***	0.073**	0.154***	0.084***	0.078***	0.073**	0.125***
	(0.031)	(0.031)	(0.034)	(0.045)	(0.028)	(0.027)	(0.030)	(0.037)
Royalties Dummy	0.033***	0.031***	0.033***	0.032	0.003	0.008	0.009	0.010
	(0.012)	(0.010)	(0.011)	(0.021)	(0.007)	(0.006)	(0.006)	(0.010)
Employee interaction	8.082***				4.235***			
	(0.456)				(0.360)			
Market-based Learning 1		1.642***				0.733***		
		(0.101)				(0.069)		
Market-based Learning 2			1.764***				1.014***	
			(0.108)				(0.085)	
Outsourcing interaction				-0.549				-0.136
				(0.379)				(0.167)
Time & Sector Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3266	4000	3675	1582	3266	4000	3675	1582
R^2	0.490	0.456	0.463	0.476	0.234	0.230	0.236	0.194

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Column 1 to 4 refers to Fixed Effects and Column 5 to 8 refers to OLS Regression

Table 6: Large Firms - Profitability: Fixed Effects and OLS Regression

	(1) FE	(2) FE	(3) FE	(4) FE	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Size	-0.018	-0.342**	-0.438***	-0.291	-0.566***	-0.528***	-0.557***	-0.703***
	(0.166)	(0.136)	(0.145)	(0.300)	(0.106)	(0.098)	(0.103)	(0.156)
Squared log of Sales	-0.003	0.011	0.017**	0.012	0.023***	0.021***	0.023***	0.033***
	(0.009)	(0.007)	(0.008)	(0.016)	(0.006)	(0.005)	(0.006)	(0.008)
Age	0.096	0.101	0.126	0.086	0.001	0.001	0.001	0.001
	(0.068)	(0.070)	(0.078)	(0.105)	(0.001)	(0.001)	(0.001)	(0.001)
Profitability Growth	0.007	0.025*	0.025	-0.034	0.011	0.024	0.024	-0.026
	(0.017)	(0.015)	(0.016)	(0.026)	(0.018)	(0.017)	(0.017)	(0.027)
Log of Investments	0.076***	0.064***	0.064***	0.067***	0.171***	0.174***	0.178***	0.165***
	(0.015)	(0.013)	(0.014)	(0.024)	(0.014)	(0.012)	(0.013)	(0.021)
R&D Dummy	0.085	0.086	0.047	0.145	0.281**	0.289**	0.255*	0.418**
	(0.133)	(0.137)	(0.148)	(0.191)	(0.132)	(0.131)	(0.146)	(0.169)
Royalties Dummy	-0.053	-0.053	-0.065	-0.094	0.041	0.052*	0.036	0.016
	(0.051)	(0.045)	(0.048)	(0.088)	(0.031)	(0.028)	(0.029)	(0.046)
Employee interaction	-3.012				3.624**			
	(1.956)				(1.696)			
Market-based Learning 1		-0.527				-0.133		
		(0.444)				(0.332)		
Market-based Learning 2			-0.392				-0.036	
			(0.475)				(0.406)	
Outsourcing Interaction				-1.775				0.183
				(1.597)				(0.756)
Time & Sector Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3267	4001	3676	1583	3267	4001	3676	1583
R^2	0.504	0.469	0.471	0.504	0.101	0.107	0.109	0.116

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Column 1 to 4 refers to Fixed Effects and Column 5 to 8 refers to OLS Regression

interaction and market-based learning are positive and significant while considering both measures of firm performance, which is consistent across the OLS and Fixed Effects regressions. We could not find any significant effect of inter-firm (outsourcing) interaction for firm performance. Our findings are consistent with Thomä (2017) which validates the contribution of DUI modes of innovation especially in the context of small enterprises.

Tables 5 and 6 report the results for large firms, for sales growth and profitability respectively. As reported in table 5, we observe that, for large firms, both STI and

DUI indicators are related to firm growth, except for outsourcing interaction.[5] As we mentioned earlier, note that outsourcing need not always be associated with knowledge transfer, since the outsourcing firm could have a strong disincentive to share their knowledge to the outsourcee since it could be a potential competitor (Matusik, 2002). This could be a deterrent factor leading to less learning and innovation through this interaction.

Concerning profitability, as reported in table 6, for large firms, the DUI variables are positive and significant with a fixed effects regression, while the STI variables are not.[6] The relationship between innovative activity (measured by patents or R&D) and profitability might be complex. Studies claim that the effect of innovation on profitability could depend on several factors, for instance, the reaction of competing firms (Koellinger, 2008). The sooner the rivals are able to imitate, the less time an innovating firm has to reap the benefits from innovation, in other words, the appropriability problem (Geroski, 1995). Hanel and St-Pierre (2002) show that in industries with high appropriability, like effective patent protection, the relationship between R&D and profitability is higher. The appropriability might vary greatly among industries (Cohen et al., 2000). Let us recall that, here we are looking at one specific industry and these results might not hold for other industries.

Broadly, the results we observe are in line with the idea of "capability escalator" presented by Cirera and Maloney (2017). For small firms, which are probably in the lower steps of the escalator, it is more effective to accumulate more informal learning and innovation capabilities which will help them to engage in more complex activities in higher stages of the escalator. In other words, the informal DUI learning modes which includes employee training to strengthen the human capital, market-based learning to understand better the market conditions etc. could help firms at a later stage to introduce and reap the benefits from formal STI modes.

5 Discussion and Concluding Remarks

In this work we empirically examine the relation between different innovation modes and performance of small and large enterprises. We find that, for small firms, only the informal

[5]Royalties dummy is not significant with OLS specification and with fixed effects while using inter-firm interaction as an explanatory variable. Note that, in the above mentioned case, there is a reduction in the number of observations, which might be a reason for the coefficient not being significant.

[6]The coefficients are not significant with a fixed effect regression and are significant at $p<0.05$ with an ordinary least squares regression.

DUI modes of learning are related to performance, while for large firms, both modes are effective. This implies that small firms with less managerial and technological capabilities might not benefit from formal investment in R&D or external technology acquisition before building the necessary underlying management capabilities that are required for the same. Aforementioned results are in line with a capability-based theory of the firm (Teece et al., 1994, 1997). The intuition behind is that firms build on existing capabilities, in other words, climbing up the "ladder of capabilities" (Cirera and Maloney, 2017) involves patiently accumulating and expanding their organizational and technological capabilities.

These findings have relevant policy implications. Conventionally, much of the science, technology and innovation policy focused mainly on formal modes of innovation and placed very less or no importance to informal modes of learning and innovation. In fact, the relative importance of each of the innovation modes for firm performance calls for different innovation policies. While the STI mode calls for a supply driven policy aimed at commercialising research results, DUI mode calls for demand driven policies, such as development of new products or services to specific markets (Isaksen and Nilsson, 2013). Jensen et al. (2007) identifying the importance of both STI and DUI mode, calls for public policy that supports DUI-mode in STI-dominated firms and the STI-mode in DUI-dominated firms.

The results presented here would suggest different policies for small and large firms: for small firms, policies should aim to build appropriate firm capabilities which would later stimulate formal R&D, whereas for large firms, both the modes of innovation should be encouraged. Therefore, while for the latter, policies to increase the R&D capacity of organizations would be an optimal one, for the former, the right policy might be to support on-the-job organizational learning or joint innovation projects between different actors in the value chain.

This is one of the few works that investigate the effect of different modes of innovation on performance of small and large firms in the context of a developing country. Our work is based on a sample of Indian firms in the capital goods industry; a further validation for other sectors and countries would be an interesting future work.

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