10° WOA
Cagliari, 29-30 Aprile 2009.

Track 10
Enhancing Development, Competitiveness and Innovation: the Role of Creativity

Titolo:
Front end innovation and stakeholder involvement in machine tools sector

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Abstract

Are there differences among companies operating pursuing different types of innovation in the organizational settings and in the combination of internal and external competencies employed to innovate?

In this paper we try to answer to this question focusing on the front end phase of innovation because, although the early stages are well recognized as vital for the subsequent success of the entire innovative process, research on these topic is still very limited.

Our argument is that, since incremental and radical innovation leverage on different knowledge sources, the organizational approach adopted in the front end to realise the full potential of open innovation will be also different.

In particular we concentrate on front end activities that lead to radical/discontinuous and incremental innovations and analyse the different organisational and network arrangements implemented by companies operating in the machine tools industry. We decided to analyse this particular setting because in recent years the sectoral system of innovation in machine tools has experienced important transformations that have led to significant changes in firms' organization and technological performance.

Introduction

Companies do not innovate in isolation. To carry out their innovative activities they leverage on the knowledge and creative potential of outside stakeholders (customers, suppliers, research institutions, etc.), in conjunction to the internal efforts of the employees. Stakeholders differ in the type of knowledge they can and will contribute and the innovative potential of a company largely depends on its ability to identify the right incentives for the right stakeholders. Our question in this paper is therefore the following: are there differences among companies operating with different technologies (for example high-tech vs. low-tech) and pursuing different types of innovation (for example discontinuous vs. incremental), in the organizational settings and in the combination of internal and external competencies that better support the innovative process?

In this paper we try to answer this question by focusing on the front end phase of innovation as, although the early stages are well recognized as vital for the subsequent success of the entire innovative process, research on this topic is still very limited (Verworn et al., 2008).

Our argument is that, since incremental and discontinuous innovations leverage on different types of knowledge, the type of relationships a company should set up with the possible contributors to innovation should also be different.

In particular, we will test our hypotheses on the front end activities that lead to discontinuous and incremental innovations in the machine tools industry. We chose to analyse this particular industry as in the last few years it has progressively moved to the high side of the medium-high tech sectors, including ever more frequently discontinuous innovations.

The paper is structured as follows. In the first section we briefly review the literature on front end innovation, focusing on the contingent view of the front end phases, proposing an integration of the existing frameworks and develop our hypotheses. In the second section we describe the characteristics and the evolution of the machine tools sector; in section 3 we describe the data and the methodology; section 4 presents the results of the statistical analysis; finally section 5 is devoted to the conclusive comments.

1. Effective management of front end phases of innovation: a contingency approach

The front end of innovation or "fuzzy front end" is an expression firstly introduced by Smith and Reinertsen (1991), and describes the first stage of the new product development (NPD) process. According to Murphy and Kumar (1997) the front end phases of the innovation consist of all the activities that range from the generation of an idea to its approval for subsequent development or to the decision of its termination.

Another way to describe the concept is to see the fuzzy front end as that territory leading up to organizational-level absorption of the innovation process (Reid and De Brentani, 2004; Cohen and Levinthal, 1990).

Cooper (1996) distinguishes four phases of the front end stage: the generation of an idea, the initial screening, the preliminary evaluation and the concept evaluation. Khurana and Rosenthal (1997a) include in the front end phase the product strategy formulation and communication, the opportunity identification and assessment, the idea generation, the product definition, the project planning, and the executive reviews.

Some authors extend the concept of "fuzzy front end" to even earlier phases, with the "early front end activities" including problem/opportunity structuring and/or identification/recognition (Reid and De Brentani (2004) Leifer et al., 2000; Urban and Hauser, 1993); information collection/exploration (March, 1991); and ''up-front homework'' (Cooper, 1996).

Notwithstanding the absence of an agreement on the boundaries of this activity, the importance of the early development phases for the success of the innovation process is well recognized in the literature (Ayag, 2005, Booz, Allen, Hamilton, 1982; Dwyer and Mellor, 1991; Atuahene-Gima, 1995; Shenhar et al., 2002). Indeed Cooper and Kleinschmidt (1994) in a study study of 103 new product projects in the chemical industry conclude that "the greatest differences between winners and losers were found in the quality of pre-development activities"(p. 26).

Nonetheless, researchers and practitioners have so far focused their attention on the later phases of the innovation process (new product development and commercialization), because information on these stages is more easy to codify, more reliable and less secret, since the front end stage is very dynamic and generates little amount of documents. Ayag (2005) observes that some researchers still doubt that the early phases of idea generation, called also 'pre-development' (Cooper and Kleinschmidt 1994), 'pre-project activities' (Verganti 1997), or 'pre-phase' (Khurana and Rosenthal 1997a, 1997b), can be managed at all.

Considering the uncertainty around the concept definition and the small number of empirical studies so far, several authors (for example, Kahn et al, 2003, Verworn et al., 2008) identify the front end as an important issue in future research on innovation and product development management.

Recently a contingent view of the management of the front end innovation process has been proposed, suggesting that incremental innovation and discontinuous innovation projects require different approaches towards the front end activities. This idea is based on the theoretical and empirical argument that varying degrees of product innovativeness influence important factors in the NPD process (Avlonitis et al., 2001, Tidd and Bodley, 2002; Verzyer, 1998, Garcia and Calantone, 2002). Discontinuous innovations include the "higher order innovations" that realize technological advances so significant that no increase in scale, efficiency, or design can make older technologies competitive (Tushman and Anderson, 1986; Koberg et al., 2003; Ali, 1994; Garcia and Calantone, 2002). Incremental innovations, instead, typically involve product improvements using existing technologies and target well known markets (Tushman and Anderson, 1986, Garcia and Calantone, 2002). Developing new products creates specific problems because, since prior competences and experiences might be inadequate, firms are forced to use new problem-solving approaches to develop new technical or commercial skills (Garcia and Calantone, 2002) On the other hand, incremental innovations reinforce the capabilities of the organization, but require adequate strategies to enhance organizational learning and cumulative development of knowledge (Lazonick and O' Sullivan, 2000; Tylecote and Visintin, 2008)

Indeed, contingency approaches to front end innovation processes suggest that "incremental and discontinuous innovations differ extensively in the way in which problems are structured and in which information searches are initiated at the fuzzy front end of new product development" (Reid and De Brentani, p. 176). In particular, the most relevant insights that so far have emerged within this perspective could be summarized as follows:

1. During the front end phases of an incremental NPD project the firm performs various activities which do not imply significant reinterpretation of prior knowledge and experience. On the contrary, for discontinuous product innovations, the front end NPD activities will likely require more time and effort and it might be more difficult to acquire the information needed and reduce uncertainties in the fuzzy front end (Song and Montoya-Weiss, 1998; Verzyer, 1998; Verworn et al., 2008).

2. In the case of incremental innovations, problems or opportunities tend to be identified and/or structured by the organization through experimented routines, and to be directed to individuals for information search (Reid and De Brentani, 2004). For example, idea-generation techniques such as brainstorming, perceptual mapping, preference modeling and benefit segmentation build on existing platforms within the firm and are routinized by the organization and delegated to boundary spanning individuals to perform information search. Conversely, in situations of discontinuous innovation, individuals have a central importance. The problem structure is not explicit at the corporate level, as in the case of incremental NPD; rather, it is structured at the individual level. Boundary spanning individuals recognize the problem and decide autonomously to activate search processes and only in a later stage report to the organization to propose the innovation. Therefore, "the directionality of initial decisions regarding new environmental information is "inward", toward the corporate decision-making level, rather than the other way around" (Reid and De Brentani, 2004, p. 177).

The proposed contingent views of the front end phase tend therefore to focus on information processing and decision making activities, whereas there does not appear to be an explicit attention to a central aspect that is, the type of knowledge involved in the innovation process which, in our view, impacts on the type of relationship a company should develop with its stakeholders.

Incremental innovations leverage on knowledge accumulated over a long period of time, of the product, its architecture and production processes (i.e. firm-specific knowledge), occur within an established paradigm and follow a predictable trajectory (Tylecote and Visintin, 2008). As such, the important stakeholders of the innovation process need to have a close and long-term relationship with the company as any firm-specific investment is risky and will be carried out only if the proper incentives are provided. Employees, customers and suppliers to effectively participate to the front-end innovation process of an incremental innovation will have to be reassured that their investments in the company's firm-specific knowledge will not be wasted (Blair, 1996) . The employees, for example, invest in specific human capital that cannot be fruitfully employed in another firm. Such investment would be largely lost in case of dismissal or if the firm shuts down. "By firm-specific human capital we mean skills or knowledge or networks of personal relationships that are specialised to a given enterprise and are more valuable in that enterprise than they would be in alternative uses. Unlike generic human capital skills that I could take with me to another job or another firm, firm-specific human capital comprises skills that we have or routines or relationships that have developed that are of much less value outside the service of a particular employer" (Blair, 1996, p.8).

In order to favour the investments in firm-specific human capital, the employees need to be included, that is, the strategic decisions of the company need to be aligned (or include) with the goals and interests of the workforce (Blair, 1996; Tylecote and Visintin, 2008). Likewise, also customers and suppliers ought to be reassured that their firm-specific investments will be taken care of, and this can be done through the establishment of close and long-term relationships.

Discontinuous innovations leverage on new knowledge and represent a break with the past. They require profound changes in the technology, culture, processes and routines of the organization and of the market. Very rarely discontinuous innovations originate within established intra and inter-organizational routines (Tushman and Anderson, 1986; Van de Ven et al. 1999); when they originate from the internal environment, they derive from R&D activities and, more generally, from "search processes" which usually require high amounts of slack resources and managers with sufficient power and risk tolerance (Greve, 2003).

Since the above mentioned organizational conditions are not very common, more often discontinuous innovations draw from a technology developed in a different sector e.g. nanotechnologies, biotechnologies, mechatronics, or by start ups which have "nothing to unlearn" (Tylecote and Conesa, 1999). Also research centers and universities, when developing cutting edge technologies is in their mission, may play a central role in triggering processes of discontinuous innovation at the front end.

It follows that when innovations of this type are the result of collaborations, these are hardly “close and long term” but will likely take the form of strategic dalliances, that is “non-committal relationships that companies can 'dip in and out of,' or dally with” (Noke, Perrons, Hughes, p.1, 2008) and are often outside the local domain.

For example, Powell and Owen-Smith (2002) studying the case of the Boston biotechnology industry observed that access to new knowledge is often acquired through strategic partnerships developed within not clearly bounderless social networks. Indeed studies on social networks emphasize the fact that “weak ties” with remote networks provide non redundant information functional to discontinuous innovations. As pointed out by Kijkuit and Ven der Ende (2007) in a recent study on organizational dynamics in the front end stage, “good’ ideas are the result of having non-redundant and heterogeneous contacts that enable actors to generate ideas by combining diverse information (Burt, 2004; Perry-Smith, 2006; Perry-Smith and Shalley, 2003). The underlying assumption is that “non-redundant and heterogeneous contacts increase the range of skills, knowledge and perspectives available to an individual or a group, positively impacting on creative performance” (Kijkuit and Van der Ende, p. 863). This argument is consistent also with established creativity theories (Amabile, 1983, 1996; Woodman et al., 1993) and supported by decision-making literature (Eisenhardt and Schoonhoven, 1996; Haleblian and Finkelstein, 1993).

Close and long-term relationships tend, instead, to perpetuate established routines hindering in this way processes of discontinuous innovation.

As for the employees, the sources of discontinuous innovations at the front end, are more likely to be young professionals with non-firm specific competencies acquired outside of the organization, hired with this specific task. Close and long-term relationships would be redundant and even counter productive (Tylecote and Visintin, 2008). At the same time, the inclusion of the other sections of the workforce could still be useful to encourage the prompt suggestion of new ideas (Getz and Robinson, 2003).

On the basis of these arguments, this research attempts to extend the contingent view of front end innovation focusing on the relationship between the innovative performance of a company and the type of relationships with the various stakeholders of the early phases of NPD. In particular we will analyze whether the involvement of different stakeholders in the front end of innovation and the type of involvement, have any impact on the success of the firm in bringing different types of innovation to the market.

2. The machine tools sector. Traditional and emergent features

The machine tools sector is composed basically by firms engaged in productions of two kinds of machines: metal-cutting tools and metal-forming tools. The leading machine tools producing countries are Japan, Germany, Italy and United States (Wengel and Shapira, 2004; Tylecote and Visintin, 2008). The industry has experienced several transformations during the last decade. Traditionally the sector has been characterized by incremental innovations, since the latest technological breakthrough was the introduction of Computer Numeric Control Systems in the late seventies – early eighties. Related features have been the intensive user-supplier relationships, where production engineers and technicians of the user firms are close partners of the design engineers of the supplier firm during the phases of new product development, and where employees on the shop floor play a significant role in the discovery of new solutions to meet the needs of the customers. Thus innovation dynamics in this sector have been traditionally characterised by a high importance of local, mainly tacit, knowledge. For example, the role of customization within the local system has been especially relevant for the competitive advantage of Italian machine tools SMEs, which developed distinctive capabilities in the adaptation of "standard" foreign technologies (for example of Japanese or American origin) to the very specific needs of local customers. Acting as interface between large foreign suppliers and local users, these small firms specialized in accurately interpreting and meeting customer demands, through intense exchanges of information and interactive learning processes (Delmestri, 1998; Albertini and Visintin, 2002).

In recent years, however, some significant developments have been observed among the machine tools producers. According to Wengel and Shapira (2004) these transformations can be summarized as follows:

1. The spatial boundaries of the sectoral innovation system have shifted, in response to competitive and technological changes. Beyond regionally bounded networks of machine tools producers and users based on close and long-term ties, the sectoral systems of innovation have extended to national and international loosely coupled networks, embodying a wider array of enterprises and research institutions with complementary skills in new technology and system integration. For example, Italian districts of machine tools producers are experiencing major restructuring in their systems of relationships, by combining and re-combining new and diverse actors. Many leading machine tools producers have started to develop links with universities and research centers (Delmestri, 1998, Malerba and Montobbio, 2004). In Ger-

many, the federal government has supported in the last two decades the constitution of cross-sectoral consortia and joint-projects for the development of new and promising technologies.

2. The number of technological breakthroughs has risen and the sector has been experiencing more frequently than in the past the introduction of discontinuous innovations, particularly as adaptations of innovations occurred in other sectors. For example, the importance of IT in the functioning of a machine tool is continuously growing and new developments in microelectronics and micro-system technologies are forcing changes in the manufacturing equipment. Emerging technologies seem to depend increasingly on the application of material sciences, simulation and modelling and integrated software development (Wengel and Shapira, 2004)3. Although tacit information flows and personal relationships remain a critical source of innovation, progressive processes of knowledge codification and "ubiquitification" (originating both by the ICT revolution and the globalisation of the markets) are allowing companies to interact with other actors without the need of sharing the same local language, culture and history (Wengel and Shapira, 2004).

Table 1 provides a synthesis of the emerging trends in the sector.

Table 1. Traditional and emerging features of the sectoral innovation system in machine tools. Source: adapted from Wengel and Shapira (2004)

Feature	Traditional	Emerging
Product development	Incremental	Systematic - discontinuous
Nature of knowledge	Tacit	Tacit and codified
Technological basis	Mechanical	Information intensive and multi-discipline
Protection of innovation	Secrecy – long term relationships	Patents
Form of inter-organizational relationships	Informal and stable	Formalized and open-flexible
Nature of inter-organizational relationships	Producers linked with users	Partnerships of producers, users, research centres
Work organization	Internal informal collaboration/participation	Increasing formalization and external cooperation

On the basis of the above arguments we may assume that the traditional features of the machine tool sector are predominantly associated with incremental innovations whereas emerging features include also more discontinuous innovations. As suggested above, this distinction affects, in turn, the dynamics of the front-end phases of innovation, the type of networks created and the actors involved in the innovation process.

3. Research Hypotheses

Drawing upon the described perspective, we propose a series of hypotheses aimed at testing a contingency framework which explains the front end stages of innovation in machine tool firms, distinguishing between incremental and discontinuous innovation outputs.

In particular, we test for the impact of the involvement in the idea generation phase of different actors (with different types of relationships) on the innovativeness of a company.

Starting with the employees, we will test whether the inclusion of the shop floor employees in the front end phases of innovation is positively associated with incremental innovation processes in the machine tools sector. As mentioned above, a large section of the workforce can contribute to innovation, giving suggestions, identifying problems and solutions and exploiting the knowledge acquired in the production processes if they have the proper incentives to invest in firm-specific human capital. For example, the incorporation of new elements in existing machines or the adaptation of new technologies to specific needs of the customers usually leverage on a deep knowledge of the product and on the marginal adaptation of existing processes.

In the machine tools sector, however, the inclusion of shop-floor employees is important also for discontinuous innovations because the latter often derive by the adaptation of innovations produced in other sectors to existing products (as it has been the case with CNCs) and might not consist on a complete redefinition of the production concept and architecture. An organization's absorptive capacity, that is the ability to acquire external knowledge and exploit it in internal innovation projects (Cohen and Levinthal, 1990), depends crucially on the employees' firm-specific competences and motivation; indeed high levels of "employee driven" absorptive capacity have been recently shown to be positively related to both incremental and discontinuous innovations (Lund Vinding, 2006).

On the basis of the previous arguments we propose the following:

Hypothesis 1 The involvement of the shop floor employees in the front end phases sector increases the propensity to innovate and it is positively related to incremental innovations. Also the number of discontinuous innovations is positively related to the involvement of shop floor workers.

User firms are also important for new product development, especially on a cumulative basis. The role of the user in the innovation process has been emphasized by several studies on the management of innovation (e.g. Von Hippel, 1988, 1994; Foxall, 1986; Rothwell, 1986). According to these views, the user often generates the idea for a new product and initiates the stages of development. Therefore, the user may be regarded as a primary actor in the front end phases of the innovation.

Traditionally, machine tool users have shown a distinctive function in fostering product innovation, both through their influences on the development activity of specialised producers, by way of "demand pull" mechanisms, and through the joint development of new machines and services (Lee, 1996; Lindblom et al., 2003). The interactions between users and specialised suppliers, which usually take the form of strong tie relationships and informal flows of information between design engineers and production engineers, can be interpreted as a learning process. The process implies a huge variety of improvements, modifications in design, building and operational use of machines, components and concomitant software (Grosse, 1994; Lee, 1996). The learning process has a cumulative and continuous dimension and generates over time a shared knowledge base, leading, in turn, to innovative outputs, which are predominantly incremental. As observed in the previous section, this is true in particular for the relationships between customers and suppliers belonging to the same local context.

The previous arguments allow us to propose the following:

Hypothesis 2 Relationships with local user firms in the front end phases are positively related to incremental innovations.

As we observed in the previous section, a clear emerging feature of the machine tools sector is the increasing importance of firms' contacts and relationship outside their local contexts to reach different "cognitive domains". As highlighted in section 2, the major interactions of machine tool firms outside their local domain occur within networks of international partners. We may thus formulate the following:

Hypothesis 3 Participation of international "strategic partners" in the front end phases is positively related to discontinuous innovation.

Other sources of cognitive variation can be those with external professionals, universities and research institutions, which often provide access to recent discoveries and applications at the technological frontier. This reasoning allows us to express the following:

Hypothesis 5 Contacts with universities and research institutions in the front end phases is positively related to discontinuous innovation.

Hypothesis 6 Contacts with external professionals in the front end phases are positively related to discontinuous innovation.

4. Data and methodology

The data refer to a subsample of the firms included in the 8th survey on the Italian manufacturing enterprises carried out in the year 1998 by the Italian merchant bank Mediocredito Centrale. The survey collects a wide range of information on the profile and the financial and competitive performance of a representative sample of 5000 Italian large and small-medium firms. We extracted from the database a subsample of 175 firms operating in the machine tools sector. Between May and September 2004, the extracted firms were contacted by phone and 158 firms agreed to take part to the research.

A survey was carried out through a 10 minute structured phone interview with the CEO or with a member of top management team, on the basis of a questionnaire aimed at collecting information on: (1) general data and profile of the enterprise; (2) innovative performance in the past three years; (3) major sources of technological knowledge and ideas. 153 questionnaires were completed.

Measures

The innovative performance was measured through the mean value of three items which measure on a seven point Likert scale: (1) the degree of novelty of the products realised in the last three years with respect to those realised in the previous three years, (2) the degree of novelty with respect to the products realised by the competitors, (3) the degree of novelty of the product technology with respect to the industry. Firms which obtained scores between 0 and 2,5 are classified as non innovative; firms with scores higher than 2,5 and up to 5 are classified as incrementally innovative, firms with scores higher than 5 are considered to innovate discontinuously. Reliability of the measure was assessed through a factor analysis and the Cronbach Alpha evaluation. Factor analysis of the three items resulted in a single factor explaining 69,5% of the variance; loadings of the items range from 0,761 to 0,897. The Cronbach Alpha of the measure is 0,78.

The independent variables measure the involvement of various actors in the processes of generation of new ideas in the areas of product technology and product development. The actors considered are: employees, local customers, universities and research institutions, external professionals, international partners. Involvement of each actor is assessed through a series of dichotomous variables which assume value 1 if the actor is involved in the front end phase, 0 otherwise.

A number of control variables was included in the analysis namely: R&D investment (expressed as percentage of turnover); firm size, since dimension could be positively correlated with the amount of investments devoted to innovation; firm age, since in younger and founder led firms the innovative posture tends to be more pronounced.

Model

Differences in the actors' involvement for each typology of innovative performance are preliminarily assessed through an univariate analysis of variance. Subsequently, the hypotheses were tested through three binomial logistic regression models which estimate the impact of the explanatory variables on the likelihood to introduce: 1) no innovations vs. discontinuous innovations, 1) discontinuous vs. incremental innovations, 3) incremental innovations versus no innovations.

5. Results

The analysis of variance indicates that significant differences exist in the categories of actors involved in the front end phases for each type of innovative performance (Table 2). Observed differences in explanatory variables are consistent with our hypotheses, except for the role of international strategic partners that appears to be more relevant (although not significantly) in firms that introduce incremental innovations.

Table 2. ANOVA for differences in explanatory and control variables among different innovative performances

	No innovation (n=48)	*Incremental (n=59)*	*Discontinuous (n=46)*
Age (years)	28,4 (4,3)	36,2 (7,3)	33,3 (8,4)
Size (Number of employees)**	81,2 (53,2)	109,4 (63,6)	138 (66,5)
R&D investment*	0,035 (0,036)	0,045 (0,044)	0,056 (0,037)
Employees***	0,23 (0,42)	0,81 (0,39)	0,68 (0,47)
Customers**	0,41(0,50)	0,54(0,50)	0,25 (0,49)
International partners*	0,27 (0,45)	0,57(0,50)	0,40 (0,49)
Research institutions*	0,04 (0,21)	0,18 (0,39)	0,21 (0,42)
Professionals**	0,01 (0,07)	0,09 (0,29)	0,25 (0,43)

*Differences significant at p-values * 0,1; ** 0,05; *** 0,01.*

Among the control variables, only differences in a firm's age turned out not to be significant, whereas as expected the amount of resources invested in R&D is significantly higher in firms engaged in discontinuous and incremental innovations than in non-innovative firms. The size of firms which pursue discontinuous innovation strategies is also significantly higher than the size of non-innovative firms.

Binary logistics regressions allowed us to test the hypotheses, by jointly considering the specific effects of the explanatory variables on the likelihood to introduce different typologies of innovation.

Hypothesis 1 is supported by the data analysis; an involvement of shop floor employees in the front end phases has a positive impact on the likelihood to introduce both incremental innovations versus no innovations (Table 4) and discontinuous innovations versus no innovations (Table 5).

Hypothesis 2 is confirmed (Table 3): the involvement of customers with close and long term relationships with the firm favours the introduction of incremental innovations over discontinuous innovations.

Table 3
Binary logistics estimations for the likelihood to introduce incremental innovations versus discontinuous innovations[1];

	Coefficients	*Wald*	*Sig.*
Constant	0,625	0,321	0,571
Age (years)	0.004	0,724	0,395
Size (Number of employees)	0,003	1,302	0,164

R&D investment	-3,614	0,272	0,602
Employees	0,732	1,386	0,239
Customers	1,171	4,017	0,045**
International partners	0,693	0,593	0,242
Research institutions	-0,138	0,332	0,003***
Professionals	-1,242	2,842	0,034**
Nagelkerke R-square	0,258		
Omnibus test for model coefficients	26,8 (sig.,000)		
Percentage of correct predictions	63,1		

*(1) positive coefficients indicate positive impact on the likelihood to introduce incremental vs. discontinuous innovations. Coefficients significant at p-levels: *** 0,01; ** 0,05; *0,1*

Hypothesis 3 is not supported; the contribution of international strategic partners to the front end phases of innovation is not significantly related to discontinuous innovative performance, both in comparison to incremental innovators and to not innovators (Table 3 and 5). This result is rather disappointing but could be explained by the low number of international partnerships the firms in the sample have.

Table 4
Binary logistics estimations for the likelihood to introduce incremental innovations versus no innovations[2];

	Coefficients	*Wald*	*Sig.*
Constant	0,625	0,412	0,521
Age (years)	0.003	0,352	0,553
Size (Number of employees)	0,004	0,887	0,346
R&D investment	6,201	3,345	0,072*
Employees	2,491	7,805	0,000***
Customers	0,144	,572	0,449
International partners	0,373	,198	0,657
Research institutions	7,648	,090	0,149
Professionals	1,056	,412	0,521
Nagelkerke R-square	0,508		
Omnibus test for model coefficients	25,9 (sig. ,000)		
Percentage of correct predictions	81,8		

*(2) positive coefficients indicate positive impact on the likelihood to introduce incremental vs. no innovations. Coefficients significant at p-levels: *** 0,01; ** 0,05; *0,1*

Hypothesis 5 and Hypothesis 6 receive support by the data. Contribution of research institutions and professionals have a positive and significant impact on the likelihood to introduce discontinuous innovations in comparison to no innovations (Table 5), and also on the likelihood to introduce discontinuous changes versus incremental innovations (Table 3). No significant role is played by these contacts to introduce incremental innovations (Table 4).

Table 5
Binary logistics estimations for the likelihood to introduce discontinuous innovations versus no innovations[3];

	Coefficients	*Wald*	*Sig.*
Constant	9,575	0,038	0,845
Age (years)	-0,022	0,123	0,753
Size (Number of employees)**	0,015	4,151	0,042**
R&D investment	16,439	5,260	0,022**
Employees	1,514	5,320	0,033**
Customers	-1,436	2,409	0,121
International partners	0,253	0,077	0,781
Research institutions	2,900	3,148	0,076*
Professionals	1,563	3,412	0,061*
Nagelkerke R-square	0,508		
Omnibus test for model coefficients	25,9 (sig. ,000)		
Percentage of correct predictions	81,8		

*(3) positive coefficients indicate positive impact on the likelihood to introduce discontinuous vs. no innovations. Coefficients significant at p-levels: *** 0,01; ** 0,05; *0,1*

Among the control variables, firm size has positive effects on the likelihood to introduce discontinuous innovation in comparison to no innovations; however the value of the coefficient is negligible. Coefficient of R&D investments is instead relevant both for "incremental innovators" and "discuontinuous innovators" in comparison to "non innovators"

6. Discussion and conclusion

In this work we analyse the importance of different actors and different types of relationships at the front end stage of innovation and test our hypotheses in the machine tools sector. The sector in the past few decades has witnessed important transformations from the point of view of innovation, particularly as a consequence of frequent processes of incorporation of technological breakthroughs originating in other sectors to the traditional machines. The management of innovation in the machine tools companies has also changed, strengthening the importance of new actors and eclipsing that of the traditional ones.

The study was carried out through a binary logistic analysis considering as dependent variable the type of innovation eventually carried out by the companies (no innovation; incremental innovation; radical innovation). In particular we assess the role played by a number of stakeholders (namely employees, customers, suppliers, external professionals, research centers and universities) with different types of relationships with the companies in the process of generation of ideas related to product technology and product development, under the main hypothesis that discontinuous and incremental innovations differ in the characteristics of the main catalysts of innovation, prone to routine-breaking the first and more conservatory and operating along a predefined trajectory the second.

Data confirm that the contribution of included employees at the front end is essential to exploit external knowledge and promote innovation. This is evident, at a first place, in the comparison between incremental innovation and no innovation. In the two situations the role of close and long-term customers is similar, but in the innovative firms the joint contribution of the employees seems to be crucial in transforming external knowledge flows in product changes, whereas non-innovators seem to be "passive" receptors of customers' technological inputs.

In incremental innovations shop floor employees play a central role thanks to their firm-specific and long-term knowledge. As for more discontinuous innovations, they play an important role in the front end phase by identifying ways of incorporating the radical innovations in the existing products and in downwards along the innovation value chain in favouring the change management process.

Customers confirmed their role as central actors in the incremental types of innovation. Incremental innovations are thus basically transformations of products and technologies to satisfy specific user needs.

As for discontinuous innovations instead, close and long-term customers are too much integrated into the existing paradigm to be able to systematically trigger breakthrough innovations.

The external professionals, the universities, the research centres and the strategic partners are other actors that we include in the analysis. As expected, the first and the second groups have a positive impact on the success of a company in carrying out discontinuous innovations (as for professionals, they have a significant and positive impact). The international strategic alliances, instead, do no appear to play any role in triggering breakthrough innovations. This may be because of the small number of partnerships of this type in the sample.

Finally, also formalised internal efforts (i.e. R&D investments) have, as expected, a positive impact on the propensity to innovate; this is particularly true for discontinuous innovations.

The study has several limitations that need to be addressed in future researches. One of the main limits stems from the simple form of the explanatory variables; dichotomous measures provide us with little information on the relative importance of the various actors and types of relationships.

We are also aware that this kind of study underestimates the complex and processual nature of the phenomena we attempted to analyse. In the study of front end phases of innovation, dimensions such as the creativity, the organizational dynamics which affect the "life cycle" of ideas, the motivation of groups and individuals are fundamental variables that need to be considered for a thorough evaluation of the theme.

Future research is needed to refine and better articulate the explanatory variables, also with the support of in-depth analyses which employ qualitative methodologies.

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