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The Underlying Internal Learning Processes of Incremental and Radical Innovations

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Abstract – Organizational change is nowadays attracting great interest. However, several domains remain to be explored as far as the relationship between innovation and organization is concerned. Within this framework, the paper investigates whether the introduction of incremental and radical innovation underlies different learning processes in terms of decentralized labor organizational practices, different modes of organizing R&D activity and the nature of employees' competences of innovating firms. The empirical evidence provided points out that incremental innovation seems to be mainly grounded on a problem-solving activity based on *learning by doing* and *learning by using* processes, while in the case of radical innovation *learning by searching* process seems to be at work.

Keywords: internal learning types, incremental innovation, radical innovation, organizational change

JEL Codes: O31, O32, M54,

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1. Introduction

The role of major competence-destroying innovations has been extensively studied by Schumpeter (1934, 1942) in its analysis of technological change as a central feature of the capitalist system. More recent literature (e.g. Abernathy, 1978, Nelson and Winter, 1982, Tushman and Anderson, 1986) has balanced this emphasis on radical innovation by drawing attention to incremental competence-enhancing innovations. Scholars have drawn on this distinction to study different issues such as market entry (e.g. Tushman and Anderson, 1986), firms' investment behavior (e.g. Henderson, 1993) and organizational structure (e.g. Downs and Mohr, 1976). As far as the later issue is concerned, the interplay between economic and organizational theory was already recognized in the work of Williamson (1975), Chandler (1977) and Porter (1980), who highlighted the crucial linkages between firms' technological and organizational change. The relationship between the two has played a strategic role in the history of the capitalist system. Firm's internal organization has traditionally impact on its structure as well as on its innovative and economic performance when understanding organizations as different "bets" on the deconstruction of complex tasks by cognitively limited agents (Jacobides, 2006).

The recent literature on organizational change (see e.g. Lindbeck and Snower, 1996) has documented a shift away from rigid Tayloristic models of production organization towards new models centered on the conception of the firm as a learning organization (Penrose, 1958) in the sense that firms' organizational capabilities are a reflection of routinised practices developed over time. [1]Along these theoretical lines of thought, post-fordist models of production and innovation organization (such as the Swedish (Berggren, 1992) and Japanese (Aoki, 1990) model *vs*. the American (Coriat, 1995) one)[2] are based upon functional flexibility made operational through the active involvement of workers in production activity and their greater responsibility and autonomy (Caroli, 2001). This literature reports that organizational change usually occurs in the form of "cluster" of decentralized labor organizational practices (Milgrom and Roberts, 1995; Ichniowski et al., 1997; Cristini et al., 2003) due to their complementarity. The interest for a flatter internal structure

[1] For a survey on the European experience see Coriat (2001).
[2] See also Dore (2004).

is widely spread in economic, management and sociological studies, which unanimously report trends of decentralization and delayering, collective work and multi-task.

Management scholars have devoted considerable attention to the impact of organization strategy on different innovative activities (Ettile et al., 1984) providing models predicting the adoption of different innovations (Deware and Dutton, 1986) and focusing on the role played by managers in intra-firm organizational structure (e.g. Koberg et al., 2003) as well as on the ability of organizational members to coordinate their activity (Reagans et al., 2005). Although the management literature has greatly contributed to further advance our knowledge about this relationship (for a review see Shane and Ulrich, 2004), several domains remain to be explored as far as the relationship between innovation and organization is concerned (Tushman and Nelson, 1990). In particular, the underlying learning process of firms' innovative activity, still needs to be investigated. In this study, we are interested in *internal* types of learning in the attempt of understanding the role of firms' internal organization in shaping and orienting the learning process underlying their innovative activity. The aim of the paper is to examine whether the application of work practices involving delegation of decisions has an effect on the radicalness of products and process of innovation. The issue is investigated in the context of the Italian province of Reggio-Emilia (Eurostat NUTS 3) hosting industrial districts in mechanicals, ceramics and made-in–Italy sectors, by using a dataset stemming from face-to-face interviews with local manufacturing firms with at least 50 employees. Reggio Emilia is an especially suitable context for analyzing the issue at hand being characterized by 'a "primary" industrial sector with advance technological innovative ability, high wages, and considerable union presence ... and a "secondary" industrial sector, consisting of small firms *sharing* with the "primary" sector its advanced technology, its innovative capacity and its ability to compete on the world market, and at least when business is good paying a similar wages to most of its workforce' (Brusco, 1982, pp. 182–183).

The paper is developed in 5 sections. Next section sets the theoretical framework and discusses the hypotheses. Data collection and the sample of analysis are discussed in section 3, while issues concerning the econometric methodology are addressed in section 4. In section 5, the econometric results are discussed for incremental and radical innovation, in turn. Concluding remarks are put forward in section 6.

2. Theoretical framework

Traditional economic theory has conceptualized technological change as rooted on a costless, easily transferable and readily imitable learning process which reduces average production costs through its innovative output. Although this conceptualization is common to most economists, not all the economic literature shares this view. The evolutionary tradition, initiated by Nelson and Winter (1982) and grounded on Schumpeter's work, has proposed an alternative conceptualization of learning. Without disregarding the public nature of the process, this stream of literature has emphasized the private (or *tacit*) aspect of learning that enables firms to develop unique dynamic capabilities (Teece et al., 1997) mirrored in their managerial and organizational routines throughout their history (path-dependency). Given the heterogeneity of firms (Jovanovic, 1982) in accumulating capabilities and translating them into organizational routines, firms differ across and within industries (Nelson, 1991) in the way they perceive technological opportunities. Firms heterogeneity implies that firms learn in a variety of different ways and, as a consequence, that there are a variety of learning processes each of which is related to a different source and type of knowledge (Malerba, 1992). More specifically, firms' learning may be linked to knowledge developed *internally* to the firm in activities such as production and R&D or sourced *externally* by the firm through its interactions with other firms operating in the same industry, with suppliers and/or customers as well as from science and technology advancements. In any case, the innovation is far to be a linear process where R&D expenditures are the only input. Conversely, innovation is a complex and interactive process involving multiple feedbacks.

As anticipated above, our attention is here confined to the firm's internal learning understood as a collective process in the sense that individual contributions to advances in learning are developed through interactions among firms' workers. Such a collective aspect gains great significance as far as human resource management practices are concerned. As shown by the Japanese experience, for instance, a firm's internal horizontal information structure may prove to be highly competitive (Aoki, 1986).[3] The rotation of workers among various jobs and the encouragement to workers in the shop floor to solve emergent problems by themselves and improvise improvements on designed work process allows firms to train multiskilled workers who understand the entire production process, know who knows what, coordinate their activities and are, therefore, able to respond to unexpected events without calling the supervisors (Edmondson et al., 2001; Carmichael and MacLeod, 1993; Black and Lynch, 2001; Lundvall and Nielsen, 2002). Conversely, strategic decisions (such as R&D investments) are placed under hierarchical control. Thus, collective learning and informal knowledge sharing have been identified as strategic tools in the internal development of potentially useful knowledge by allowing firms to respond timely to a wide variety of changes in the competitive environment (Volberda, 1996; Reagans et al, 2005). The development of new products and services critically depends on the competences developed by employees on-the-job, which in turn depend on the quality of formal education as well as organizational structure and work environment (Arundel *et al*., 2006).

Different streams of literature have drawn a relationship between the form of work organization adopted by a firm and its innovative style and capacity. Nonetheless, although the recognized significance of more decentralized organizational forms in shaping and directing firms' learning (see e.g. Moch and Morse, 1977), there exists very little quantitative survey-based research focusing on internal organizational environments that promote the introduction of incremental and radical innovations.[4] Conversely, several studies drawing on the managerial literature have investigated the organizational determinants of incremental and radical innovation calling into question the search of a universal theory of innovation (Downs and Mohr, 1976) and testing empirically the role of different model predicting the adoption of the two types of innovation (Deware and Dutton, 1986). On the one hand, emphasis has been placed on strategy and structure consequences of incremental and radical innovation (Ettlie *et al*., 1984; Tushman and Anderson,

[3] It should be, however, borne in mind that the Japanese model experiments a deep crisis in the 1990s (e.g., Dore, 2000).
[4] A notable exception is the work by Laursen and Foss (2003), Jensen et al. (2005), Arundel et al. (2006), Nielesen and Ludvall (2006).

1986).[5] On the other hand, when attention has been given to firm's internal organization, the focus is on the managers' willingness to decentralize the decision process rather than in the actual workers' involvement in the management of the firm (e.g. Koberg et al., 2003; McDermott and Colarelli O'Connor, 2002). Moreover, despite of the interest shown in the distinction between incremental and radical innovation, few studies clearly define the differences between the two. The interest in the level of novelty of innovation dates back to Schumpeter (1934) who claimed that radical technological change can challenge monopolists' power by making the established technology irrelevant and, thus, undermining large firms' competitive advantage. Many empirical studies have tested Schumpeter ideas (Cooper and Schendel, 1976; Anderson and Tushman, 1990; Hederson, 1993) and taxonomies of novelty of innovation span from radical and revolutionary to incremental. The empirical evidence has pointed out that the achievement of radical innovation usually requires considerable investments in R&D with lower chances of success and great rewards. In contrast, radical innovation requires less effort and its performance implications are modest (Marsili and Salter, 2005). However, the lack of common criteria in distinguishing between the two innovations is reflected in different methods used to describe and measure these categories, all of which suffer from limitations (for a review see Dahlin and Beherens, 2005). Given the focus of the paper on internal learning, we draw upon expert panels' method (Dewar and Dutton, 1986) which usually captures both novelty and impact of a set of inventions. Such a method has the advantage that industry experts would be the best to truly judge what technical breakthrough matters to that industry. However, it may suffer from a number of biases such as success, recency and availability (Dahlin and Beherens, 2005) since market successful technologies and technologies one has recently been involved with are likelier to be recalled in details (Kahneman and Tversky, 1984). Despite of these shortcomings, this method seems to suit our research when recalling the distinction in the nature of innovation between "new to market" and "new to firm" product or process innovations. A "new to firm" (but not to the market) innovation may involve *radical* changes to the firm's mix of competences and internal organization. Therefore, on the

[5] It should be, however, pointed out that Henderson and Clark (1990) have questioned this traditional categorisation when analysing market entry and competitive issues, while Henderson (1993) recognised the utility of a careful distinction between the two innovations for the understanding of investment behaviour of incumbents firms.

grounds of expert panels' judgments we understand radical innovation as a new to the firm products and/or processes innovation and incremental innovation as firm's amelioration of existing products and/or processes.[6]

Given this distinction, we explore the underlying learning process of radical and incremental innovation[7] in terms of labor organizational practices, different modes of organizing R&D activity and different employees' competences of innovating firms. Drawing on Malerba (1992), we distinguish three types of internal learning processes according to different sources and types of knowledge: 1) *learning by doing* related to production activity, 2) *learning by using* related to the use of products, machinery and inputs, and 3) *learning by searching* mainly related to formalized activities (i.e. R&D) aimed at generating new knowledge. Within this theoretical framework, we argue that incremental innovation is mainly grounded on a problem-solving activity based on a *learning by doing* and l*earning by using* process. Conversely, radical innovation mainly relies on a problem-solving activity based on learning *by searching* process.

2.1 Hypotheses

Unlike Aghion et al. (1999) who pose that organizational design is a secondary cause of change, a more recent strand of literature inspired to Chandler's (1962, 1977) work contends that the way firms are organized shapes its short- and long-term prospects by affecting productive capabilities (how well it works) as well as dynamic capabilities (how effectively it changes) (Bower and Gilbert, 2005; Jacobides, 2006; Dosi and Gazzi, 2006). As anticipated above, the basic idea of the recent literature on organizational change is that of a progressive shift toward more flexible and heterarchical organizational designs.

The active participation of workers to everyday problem-solving activity related to production issues allows firms to build up "productive capabilities", which, reflected in the firm's productivity, concern its general and specific knowledge of how to do things (Richardson, 1972; Teece et al., 1997)

[6] Although empirical evidence (e.g. Pini and Santangelo, 2005) shows that product and process innovations are quite phenomena also in terms of firms' organisational structure, the rational for folding them together lies in our interest for the *nature* rather than for the *type* of the innovation.

and, in Winter's (2003) words, can be defined as "zero level capabilities" prompting firm's efficiency or effectiveness in engaging in its current business activities. Within the learning curve framework, considerable evidence has been provided on the impact of organizations' production experience on performance both in manufacturing (e.g. Hatch and Mowery, 1998) and services (Pisano et al., 2001). Accumulation of firm productive capabilities typically developed in an organization through a specific path-dependent learning process (Winter, 1988) enhances the ability of the firm to survive in the market by both developing internal problem-solving trajectories and then responding timely to market feedbacks and signals through the amelioration of existing products and/or processes. Thus, we pose that

H1a: The likelihood of introducing incremental innovation is indirectly associated to decentralized labor organizational practices *via* firms' productivity.

Conversely, the introduction of radical innovation is hardly affected by the adoption of decentralized labor organizational practices. Given the competence-destroying nature of radical innovation, decentralized labor organizational practices may have an inertial effect on the innovation process. Although, the exploration of new ways of doing things is localized in the neighborhood of firms' existing knowledge (Atkinson and Stigliz, 1969; Antonelli, 1995; Nelson and Winter, 1982; Dosi, 1988), firms' organizational routines of greater involvements, responsibility and autonomy at the shop floor level may act as rigidities to radical changes. Thus, the introduction of new products and/or processes is likelier not to rely on decentralized labor organizational practices. Thus, we test the following hypothesis

H1b: The likelihood of introducing radical innovation is not associated to decentralized labor organizational practices.

As far as the organization of R&D activity is concerned, firms can conduct it internally or externally (by fully or partially externalizing R&D). If R&D activity is entirely conducted *in-house*, firms develop specific capabilities on selected problems through a firm-specific *learning by searching* process (Richardson, 1972; Nelson and Winter, 1982; Cantwell, 1989) monitored by a formalized

[7] Our focus is on the technological rather than on the administrative nature of innovation. Although we are aware of documented differences in the adoption of the two innovations (Kimberly and Evanisko, 1981).

laboratory aiming at generating new knowledge. Conversely, firms merely relying on market transactions to source knowledge face severe constrains in fully exploiting the potential of the acquired knowledge since they miss the preceding learning process, while firms partially externalizing R&D activity can rely on knowledge produced outside them to the extent that it is complementary to their internal knowledge path and according to their degree of absorptive capacity (Cohen and Levinthal, 1990). Therefore, we pose that

H2: The likelihood of introducing radical innovation is greater for firms conducting *in- house* R&D.

Turning to the nature of employees' competences and their relationships with the two innovations under analysis, we consider employees' competences new to the innovating firm or existing but reshaped workforce's competences. The innovating firm is here understood as a firm introducing technological and organizational changes along the lines of a recent theoretical and empirical literature focusing on the joint occurrence of both kinds of changes (Pavitt et al., 1989; Milgrom and Roberts, 1990; 1995; Black and Lynch, 2001; Piva et al., 2005). On the one hand, the likelihood of introducing incremental innovations is enhanced by reshaped employees' competences due to the competence-enhancing nature of the innovative process as a result of the firm's need to adjust employees' expertise. For an amelioration of existing product and/or processes to occur, the re-shaping of existing employees competences through their training on the job is likelier to nourish the firm's experience and, furthermore, the introduction of incremental innovation, which requires an adjustment of the firm's competences profile. Thus, the following hypothesis is tested

H3a: The likelihood of introducing incremental innovation is greater for firms adopting technological and organizational innovations requiring the reshaping of existing employees' competences.

On the other hand, radical innovations are likelier to rely on employees' competences new to the innovating firm due to the major breaking generated by the innovative activity which requires a great effort to the firm in terms of diversification of its portfolio of competences. Therefore,

H3b: The likelihood of introducing radical innovation is greater for firms adopting technological and organizational innovations requiring the acquisition of new employees' competences.

Summarizing, our hypotheses suggest that the introduction of incremental innovation underlies a *learning by doing* and *learning by using* process, whereas the introduction of radical innovation underlies a learning *by searching* process. More specifically, the learning process underlying the introduction of incremental innovation by the *i*-th firm can be analytically sketched by the following equations

$$INNO\_INCR_i = f(VADIP_i, x_{i},\ \omega_{i,}\ \gamma_i) \quad (1)$$

$$VADIP_i = f(lop_i,\ x_{i},\ \omega_{i,}\ \gamma_i) \quad (2)$$

where $INNO\_INCR_i$ stands for incremental innovation, $VADIP_i$ stands for firm's productivity, x_i is the vector of independent variables related to different modes of organizing R&D activity, ω_i is the vector of independent variables related to workers' competences, γ_i is a vector of controls, lop_i is the vector of variables related to labor organizational practices.

The learning process underling the introduction of radical innovation by the *i*-th firm can be analytically specified as

$$INNO\_RAD_i = f(VADIP_i, lop_i, x_{i},\ \omega_{i,}\ \gamma_i) \quad (3)$$

where $INNO\_RAD_i$ stands for radical innovation and all other symbols have the meaning specified above.

The two equation model (i.e. equation (1) and (2)) is suggested by *H1a*. Conversely, *H1b* suggests a single equation model given by equation (3). *H2* requires the statistically positive significance of a specific element of vector x_i (i.e. *in-house* R&D) in equation (3). The significance of specific elements of vector ω_i (i.e. the reshaping of existing employees' competence and the acquisition of new employees' competences by innovating firms) is suggested by *H3a* and *H3b*, respectively.

3. Research Methodology

Data on firms' innovative activity, industrial relationships and incentives has been collected through personal structure interviews, which allowed to collect qualitative data for the overall period 1998-2001 in a standardized format suitable for statistical analysis on four main topics: firm's characteristics and employment structure; organizational innovations and human resources management practices; industrial relations; employee evaluation and payment systems. The population to be interviewed concerns all firms located in the Italian province of Reggio Emilia in the year 2001 with at least 50 employees as listed in the Intermediate Census of the National Institute of Statistics (ISTAT, 1999) and in the Chamber of Commerce of Reggio Emilia (Infocamere, 2001) for a total of 257 firms operating in four sectors (i.e. specialized suppliers, scale intensive, resources intensive, labor intensive and science based).[8]

Data collection was started by contacting firms' top managers by phone and sending them the introductory part of the questionnaires by fax in February 2002, asking to answer questions concerning the structural features of the firm and formally requesting a personal interview. Interviewers were sent to accepting firms between May and July 2002. Interviewees are generally top managers and human resources directors. Firms were contacted again, if necessary, to solve problems pertaining their answers or to complete the questionnaire. This process allows to construct a database the provides primary information on 199 firms located in Reggio Emilia. In terms of sectoral distribution, specialized suppliers (39%) and resource intensive (28%) firms are predominant, followed by labor intensive (19%) and scale intensive (14%) ones according to the characteristics of the local economy showing a strong advantage in mechanicals and ceramics. The research method adopted for data collection can pose issues related to non-response bias. In order to address such issues, we compared the two subsets of respondents and non-respondents along two dimensions, such as sector and size (i.e. class of employees' number) (see Table A1). Using a χ^2 test of independence, no statistically significant differences were found between respondents and non-respondents in terms of sector and size, the only exception being firms with more than 999 employees (that are overrepresented in our sample).

For the sake of this study, we focus on firms for which information on economic performance were also available as drawn form their balance sheet submitted at the Chamber of Commerce of Reggio Emilia. More specifically, 166 firms (accounting for 65% of the entire population) were those for which economic performance indicators (for the period 1998-2001) were available. Given the

[8] These sectors are drawn from an OECD (1994) revision of Pavitt's taxonomy, which intends to aggregate industrial sectors according to market orientations, input characteristics, and technological contents for manufacturing firms in order to link sectoral performance with labour markets. However, it should be noted that no science-based firms were recorded.

nature of our data, we perform the Harman's single-factor test (Harman, 1967; Podsakoff and Organ, 1986; Podsakoff et al., 2003) on items included in our econometric model to examine whether common method bias augmented relationships.[9] The results obtained reported good properties, thus supporting the validity of the data.[10]

4. Econometric methodology

In what follows, we firstly discuss the specification of the econometric models and, then, describe the variables adopted, all of which refer to the overall period 1998-2001 unless differently specified, thus preventing us from the use of a dynamic panel structure.

4.1 Model specification

The association between the likelihood of introducing incremental/radical innovations and their drivers may require different estimation models in order to account for the different underlying learning processes. As argued above, a major point is the potential endogeneity of firm productivity. To address the endogeneity concern, we use a weak exogeneity test of firm productivity for models with limited dependent variables as suggested by Smith and Blundell (1986). The test is constructed in two steps involving equation (1) and (2). In the first step, we regress the firm productivity indicator on the instruments and the exogenous variables. In the second step we use the residuals from the first stage regression as additional explanatory variables in equation (1). The test is also performed by substituting *INNO_RAD* to *INNO_INCR* in equation (1) in order to verify that equation (3) correctly specifies the likelihood of introducing radical innovation. Under the null hypothesis of exogeneity, the coefficient of the residuals of the first stage regression is not statistically different from zero at the second stage. According to the results of the test, an instrumental variable (IV) probit model proposed

[9] When common-method bias occurs, either a single factor is extracted from a factor analysis of all measurement items included in the study or a general factor accounts for most of the variance.

[10] We perform a principal component analysis for the cross sectional sample that included all explanatory and control variables, and the dependent variables. Binary variable were firstly standardised in order to avoid complications of running a principal component analysis on a tetrachoric correlation matrix without an automatic computerised routine (missing in statistical packages such as SPSS). This allowed us to perform a principal component analysis on a standard Pearson correlation matrix. The analysis retained 7 factors with

by Newey (1987) or a simple probit estimation is adopted as explained below. In the former case, we use as instruments a set of labor organizational practices indicators. Tests of validity of the instruments are reported in the results section.

4.2 Variables

In equation (1), (2) and (3), the adoption of incremental and radical innovation was captured by two binary variables:

- $INNO\_INCR_i$ is equal to 1 if firm (*i*) has introduced ameliorations on the quality of an existing product and/or process, 0 otherwise.
- $INNO\_RAD_i$ is equal to 1 if firm (*i*) has introduced a new to the firm product and/or process innovation, 0 otherwise.

Productivity was proxied by the average added-value per employee at 2000 constant prices ($VADIP_i$).

The other variables considered were classified as variables related to: labor organizational practices (lop_i), different modes of organizing R&D activity (x_i), and the nature of workers' competences required by the introduction of technological and organizational innovations (ω_i). We also include a set of variables (γ_i) controlling for sectoral specificities (i.e. scale-intensive (si_i), specialized suppliers (ss_i) and resource-intensive (ri_i)), firm's age (AGE_i) and a further control variable measuring whether the firm operates directly in the output market rather than as a sub-contractor ($output\_market_i$).[11]

Vector lop_i refers to:

- wof_i, which equals 1 if firm (*i*) has adopted a flexible labor organization; 0 otherwise;
- $empsug_i$, which equals 1 if firm (*i*) has established channels for employees' suggestions;
- $empqcm_i$, which equals 1 if in firm (*i*) workers are individually encharged of quality control; 0 otherwise;

egenvalue greater than 1.00 with no factor explained more than 14% of the total variance. Results are available upon request.

[11] Although existing empirical evidence (e.g. Moch and Morse, 1977 and Germain, 1996) has documented the association between radical innovation and size, no statistically significant results were obtaining when controlling for firms' dimension.

– *empev*$_i$, which equals 1 if in firm (*i*) managers formally evaluate employees, 0 otherwise.

In order to account for the fact that labor organizational practices occur jointly as suggested by the recent literature on organizational change and human resource management (Milgrom and Roberts, 1990, 1995; Ichniowski et al., 1997; Cristini et al., 2003), within this vector we also include the following indicators:

– *intro_wp_cumul*$_{i,}$ which ranges from 0 to 7 according to the number of practices (i.e. team work, total quality projects, job rotation, autonomy in problem-solving, structured channels for workers' suggestions on organizational topics, structured channels for workers' suggestions on quality topics, permanent education) firm (*i*) has introduced;

– *wop_cumul*$_i$, which ranges from 0 to 5 according to the number of labor organizational practices (i.e. team work, quality circles, just-in-time, job rotation, total quality management) adopted by firm (*i*).

Vector x_i refers to:

– *R&D*$_i$, which equals 1 if firm (*i*) conducts *in-house* R&D through an internal R&D function, 0 otherwise;

– *fullR&Dext*$_{i,}$ which equals 1 if firm (*i*) externalizes R&D and has not an internal R&D function, 0 otherwise;

– *partialR&Dext*$_i$, which equals 1 if firm (*i*) externalizes R&D and has an internal R&D function, 0 otherwise.

Vector ω_i relates to:

– *compres*$_{i,}$ which equals 1 if firm (*i*) has introduced technological and organizational innovations requiring training of the existing work-force, 0 otherwise;

– *newcomp*$_i$, which equals 1 if firm (*i*) has introduced technological and organizational innovations requiring the recruitment of workers with new competences, 0 otherwise.

Table A.2 provides a summary of the variables described above, while the relative descriptive statistics and correlation matrix are reported in Table 1.

5. The econometric results

The results of the Smith-Blundel (see Table 2 and 3) provide support to the hypothesis of an undirected association between incremental innovations and decentralized labor organizational practices *via* productivity (*H1a*).

More specifically, the Smith-Blundell test does not reject the hypothesis that firm's productivity is weakly exogenous for radical innovation (Table 3), thus the model is appropriately specified with all explanatory variables as exogenous, as outlined in equation (3), and a single probit model can be appropriately used. Conversely, the weak exogeneity test reject the null hypothesis that firm's productivity in equation (1) is exogenous, making the use of a single probit model inappropriate for the likelihood of introducing incremental innovation (Table 2). To control for endogeneity we use a fully specified instrumental variables (IV) probit estimation routine by adopting Newey's (1987) method as implemented in STATA by Harkness (2003). Such a method allows to generate consistent estimates for non-linear models via Amemiya Generalized Least Squares when addressing estimation bias due to endogeneity and omitted characteristics instrumenting the independent variables in the model that are thought to be endogenous.[12]

In what follows, the results obtained for each of the two models are discussed.

5.1 Incremental Innovation

The ivprobit results concerning incremental innovation are reported in the last column of Table 2. The likelihood of introducing incremental innovation is positively associated to the firm's average added-value per employee instrumented with the labor organization practices indicators ($VADIP_i$ is statistically positive significant at $p \leq 0.05$). Therefore, firms showing a greater productivity (i.e. accumulation of problem-solving capabilities through experience in productive activity) as a result of the adoption of more decentralized labor organizational practices are likelier to introduce amelioration of existing products and/or processes as suggested by the literature on the Japanese firm (Aoki, 1990; Coriat 1991; Womack et al., 1990). Workers' involvement in production issues amplifies the firm's

[12] STATA ivprobit command estimates the endogenous variable as a linear function of the instrumental variables and corrects the second step standard errors (Wooldridge, 2002).

ability to build up productive capabilities which, in turn, increase the likelihood of introducing incremental innovation. Problem-solving activity in the production realm enables experience accumulation which generates *learning by doing* (Arrow, 1962; David, 1975; Rosenberg, 1976). This is in line with the analytical (Fudenberg and Tirole, 1983) and empirical (e.g. Hatch and Mowery, 1998) findings on the implications of *learning by doing* on market performance as a result of the building-up of firms' core competences that makes them more capable in dealing with market pressure. Similarly, the repeated use of products, machinery and inputs enables workers to accumulate experience generating *learning by using*. This result emphasizes the significance of knowledge acquired by workers and their problem-solving activity in the generation of incremental innovation. Incremental innovations rely on a *learning by doing* and *learning by using* process grounded on a problem-solving activity of production issues where the everyday workers' experience is a crucial aspect.

Along the same lines, the successful introduction of incremental innovation is associated with the reshaping of competences already present in the firms as shown by the positive statistically significance of the variable capturing the nature of workers competences required by the introduction of technological and organizational innovations ($compres_i$ is statistically positive significant at $p \leq 0.05$) (*H3a*). Given the competence-enhancing nature of incremental innovations, employees' competences already present in the firms but, somehow, reshaped through training on the job gain great significance in the likelihood of introducing this innovation by allowing the adjustment of the firm's competences' profile according to the learning trajectories related to production activity and the use of products, machinery and inputs. Similarly, firms producing directly for the output market introduce incremental innovations to a lesser extent than firms operating as sub-contractors, ($ouput\_market_i$ is statistically negative significant at $p \leq 0.01$) reflecting the role of firms interactions in orienting technological trajectories in Reggio Emilia industrial districts. Sub-contracting relationships seem to matter more than user-producer relationships for the sake of incremental innovation at least in the context under investigation (see also Mazzanti et al. 2006).

5.1.1 Validity of instruments

As anticipated above, the variables adopted as instruments refer to labor organizational practices indicators exposed above (i.e. wof_i, $empsug_i$, $empqcm_i$, $empev_i$, wop_cumul_i and $intro\_wp\_cumul_i$). Good instruments are correlated with the endogenous variables but not with the dependent variables. Therefore, we expected these variables to be strong predictors of firm productivity, but not of the likelihood of introducing incremental innovation. Valid instruments must be orthogonal to the error process in the structural equation. Therefore, we expected these variables to be uncorrelated with the unobservable factors affecting $INNO\_INCR_i$ in the structural equation.

The relevance of the selected instruments is tested by computing the F-statistics on the excluded variables (i.e. instruments) in the firm productivity equation (whose results are reported in the second column of Table 2) in order to test their joint insignificance (Bound test). The first stage seems to explain fairly well firm productivity and the Bound test rejects the null hypothesis that the instruments are all joint insignificant. We also compute a standard probit model for incremental innovation including the labor organizational practices indicators (first column of Table 2) in order to test for their separate and joint insignificance, which is confirmed by the econometric results.

The validity of the selected instruments is tested through a test of overidentification. Since the direct application of Sargan (1958) and Basmann's (1960) instrumental variable method to nonlinear errors-in-variables models fails to yield consistent estimators, Lee (1992) shows that the Newey's (1987) minimized distance (or minimum-χ^2) for the ivprobit estimator provides a test of overidentifying restrictions. The Amemiya-Lee-Newey minimum χ^2 statistic is performed through the overid STATA module (Baum *et al*. 2006). Like Sargan and Basmann statistics, the test statistic is distributed as χ^2 with (L-K) degrees of freedom (where L is the number of instruments, K the number of regressors and L-K the number of overidentifying restrictions) under the null that the instruments are valid. The results of the test confirm the validity of our selected instruments, as shown in the third column of Table 2.

5.2 Radical Innovation

Turning to radical innovation and drawing upon the results gathered from the Smith-Blundell test, discussed above, we run a simple probit model where firms' productivity and indicators related to labor organizational practices were all exogenous independent variables. The results obtained reported in Table 3 confirm that the likelihood of introducing radical innovation is not associated to labor organizational practices (*H1b*). Conversely, the existence of an R&D function within the firm enhances the firm's likelihood of introducing radical innovation ($R\&D_i$ is statistically positive significant at $p \leq 0.05$) (*H2*). Such a function enables firms to learn and generate technological advance in specific directions coherently with firms' past history of searching. Off-line R&D and experimental research play a powerful role in facilitating the evolution of technological change. As noted by Nelson (2003), the uneven advance of human know-how across fields can be traced back to the unevenness of advance of sciences behind various technologies. Thus, basic off-line research in specialized facilities separated from where the technology is being employed informs and strengthens science and engineering disciplines, allowing for rapid technological change. In this sense, a formalized R&D activity allows a *learning by searching* process. Similarly, the introduction of technological and organizational innovations promoting the recruitment of employees with new competences is positively associated to the likelihood of introducing radical innovation ($newcomp_i$ is statistically positive significant at $p \leq 0.01$) (*H3b*). This is not surprising given the competence-destroying nature of the innovation under analysis. The recruitment of new competences creates the conditions to wider the firms' competence portfolio and, therefore, to enhance the opportunities for radical change. These results seem to suggest that the nature of this innovation seems to underlie a *learning by searching* process relying on a more structured R&D function and fed by new employees' competences which enable the firm to deal with the new rules of the game required by the innovative process.

6. Conclusions

This paper has investigated the *internal* learning processes underlying incremental and radical innovation in terms of labor organizational practices, R&D organizational modes and the nature of employees' competences of the innovating firms in Reggio-Emilia industrial districts. The econometric results point out that the likelihood of introducing incremental innovation is indirectly associated to decentralized labor organizational practices via firms' productivity while decentralized labor organizational practices do not seem to affect the likelihood of introducing innovation radical to the firm. Conversely, the likelihood of introducing such a kind of innovation is greater for firms conducting *in-house* R&D. The empirical evidence also suggests that firms introducing technological and organizational innovations requiring the reshaping of existing employees' competences are likelier to innovate incrementally, while firms adopting technological and organizational innovations requiring the acquisition of new employees' competences are likelier to introducing new to the firm products and processes.

Our interpretation of the results is that the discriminating factor between the introduction of the two innovations seems to lie in the nature of the problem-solving activity at work. As discussed above, in the case of incremental innovation, the innovative process is fed by a problem-solving activity based on *learning by doing* and *learning by using* process realized through workers active participation in the firm's production issues which enhances the firm's ability to survive the market ameliorating existing products and/or processes. The innovative process concerning radical innovation is, instead, related to an R&D laboratory structured within the firm, carrying out a problem-solving activity oriented to *learning by searching* and fed by employees' competences new to the firm.

The study confirms the heterogeneity of innovative activity as far as incremental and radical innovations are concerned and contributes to advance our knowledge on the relationship between innovation and organization. If the distinction between these two innovations can be traced back to Schumpeter's work, very few quantitative survey-based studies have addressed the relationships between internal organizational environment and the introduction of incremental and radical innovation due to constrains on data availability. The value-added of such a kind of study lies in the fact that they allow to considered innovation indicators relevant to understand the role of organizational structure in the development of different types of knowledge, otherwise neglected in studies adopting secondary data such as material (e.g. R&D expenditures) and human capital inputs (e.g. available pool of skills based on the number of years of education) which miss to capture how these resources are used and organized within the firm. Moreover, our results cast doubts on the success of the Japanese model for innovation creation, suggesting that the success of such a model should be evaluated according to the level of novelty yielded by the innovation process. If factors blocking or slowing down innovation may be located downstream reflecting rigid organizational frameworks that limits employees' participation and contribution to the innovation process, decentralized organizational practices may be a solution to the extent that the final target is incremental innovation. Conversely, centralization of R&D activity appears to be the route to follow when targeting a greater level of innovation novelty.

This bears important implications for the management of innovation by providing managers with some guidelines for the organization of the firms according to the type of innovation projects they intend to adopt. Decentralized management techniques are the key organizational strategy if short-term revenues associated to incremental innovation are sought, while the adoption of more ambitious innovation projects calls for off-line and experimental research centralized in a internal R&D function which can freely search around and beyond the firm's current knowledge.

The study suffers from some drawbacks that need to be considered. First, for each firms all the questionnaire's answers were provided by the same person, this entailing potential common method bias. We control for this limitation performing the Harman's single-test and submitting the questionnaire through face-to-face interviews. Future research should attempt to overcome the limitations of self-reported data. Second and linked to the above, we acknowledge the shortcoming of adopting perceptual instruments to measure the novelty of innovation rather than more objective measures, which poses identification and validating problems. Thirdly, the different types of internal learning are captured indirectly rather than through direct measurements, which would be difficult to build due to the complexity and multidimensional nature of the phenomenon under analysis. Finally, future research should be aimed at extending the time span covered by the data in order to allow longitudinal studies.

References

Abernathy, W. J. (1978) *The Productivity Dilemma*. (John Hopkins University Press, Baltimore).

Aghion, P., Caroli, E., García-Peňalosa, C. (1999) "Inequality and economic growth: the perspective of the new growth theories". *Journal of Economic Literature*, Vol. 37, pp.1615-1660.

Anderson, P. and Tushman, M. (1990) "Technological discontinuities and dominant designs. A cyclical model of technological change". *Administrative Science Quarterly*, Vol. 35, pp. 604-633.

Antonelli, C. (1995) *The Economics of Localised Technological Change and Industrial Dynamic*s. (Dordrecht, Kluwer Academic Press).

Aoki, M. (1986) "Horizontal vs. vertical information structure for the firm". *American Economic Review*, Vol. 76, No. 5, pp. 971-983.

Aoki, M. (1990) *Information, Incentives and Bargaining in the Japanese economy*. (Cambridge, Cambridge University Press).

Arrow, K. (1962) "The economic implications of learning by doing". *The Review of Economic Studies*, Vol. 29, No. 3, pp. 155-173.

Arundel, A. , Lorenz, E., Lundvall, B-A, Valeyre, A. (2006) "The organization of work and innovative performance: a comparison of the EU-15". *DRUID Working Paper* No. 06-14.

Atkinson, A. B. and Stiglitz, J. E. (1969) "A new view of technological change". *The Economic Journal*, Vol. 69, pp. 573-578.

Basmann, R.L., (1960) "On Finite Sample Distributions of Generalized Classical Linear Identifiability Test Statistics". *Journal of the American Statistical Association*, Vol. 55, Issue 292, pp. 650-59.

Baum, C.F., Schaffer, M.E., Stillman, S., Wiggins, V. (2006) "overid: Stata module to calculate tests of overidentifying restrictions after ivreg, ivreg2, ivprobit, ivtobit, reg3". http://ideas.repec.org/c/boc/bocode/s396802.html

Berggren, C. (1992) *Alternatives to Lean Production*. (Ithaca-New York, ILR Press).

Black, S.E. and Lynch, L.M. (2001) "How to compete: the impact of workplace practices and information technology on productivity". *Review of Economics and Statistics,* Vol. 83, No. 3, pp. 434-445.

Bower, J. L. and Gilbert, C. (2005) *From Resource Allocation to Strategy*. (Oxford, Oxford

University Press)

Brusco, S. (1982) “The Emilian model: productive decentralisation and social integration”. *Cambridge Journal of Economics*, Vol. 6, No. 2, pp. 67-184.

Cantwell, J. A. (1989) *Technological Innovation and Multinational Corporation*. (Oxford; Basil Blackwell).

Carmichael, H. L. and MacLeod, W. B. (1993) “Multiskilling technical change and the Japanese firm”. *The Economic Journal*, Vol. 103, No. 416, pp. 142-160.

Caroli, E. (2001) “New technologies, organisational change and the skill bias: what do we know?” in Petit, P. Soete, L. (eds.) *Technology and the Future of European Employment*. (Cheltenham; Edwar Elgar).

Chandler, A. (1962) *Strategy and Structure*. (Cambridge, MIT Press).

Chandler, A. (1977) *The Visible Hand*. (Harvard, Harvard University Press).

Cohen, W. M. and Levinthal, D. A. (1990) “Absorptive capacity: a new perspective on learning and innovation”. *Administrative Science Quarterly*, Vol. 35, pp. 128-152.

Cooper, A. and Schendel, D. (1976) “Strategic responses to technological threats”. *Business Horizon*, Vol. 19, pp. 61-69.

Coriat, B. (1991) *Penser à l’envers: travail et organisation dans l’entreprise Japonaise*. (Paris, Christian Bourgois).

Coriat, B. (1995), “Incentives, bargaining and trust: alternative scenarios for the future of work”. *International Contribution to Labour Studies*, Vol.5, Special Issue, pp.131-151.

Coriat B. (2001), “Organisational Innovation in the European Firms: a Critical Review of the Survey Evidence” in Archibugi D. and Lundval B. (eds.) (2001) *Globalization and the Knowledge Based Society*, Cambrige, Cambrige University Press.

Cristini, A., Gaj, A., Labory, S. and Leoni, R. (2003) “Flat hierarchical structure, bundles of new work practices and firm performance”. *Rivista Italiana degli Economisti*, Vol. 8, pp. 313-341.

Dahlin, K. B. and Behrens, D. M. (2005) „When is an invention really radical? Defining and measuring technological radicalness”. *Research Policy*, Vol. 34, pp. 717-737.

David, P. (1975) *Technical Choice, Innovation and Economic Growth*. (Cambridge; Cambridge University Press).

Deware, R. D. and Dutton, J. E. (1986) "The adoption of radical and incremental innovations: an empirical analysis". *Management Science*, Vol. 32, No. 11, pp. 1422-1433.

Dosi, G. (1988) "Sources, procedures and microeconomic effects of innovation". *Journal of Economic Literature*, Vol. 36, pp. 1126-1171.

Dosi, G. and Gazzi, M. (2006) "Technologies as problem-solving procedures and technologies as input–output relations: some perspectives on the theory of production". *Industrial and Corporate Change*, Vol. 15, No. 1, pp. 173-202.

Dore, R. (2000) *Stock market capitalism: welfare capitalism: Japan and Germany versus the Anglo-Saxons*. (Oxford, Oxford University Press).

Dore, R. (2004) *New Forms and Meanings of Work in an Increasingly Globalised World*. (Geneva, International Institute for Labour Studies, ILO).

Downs, G. W. and Mohr, L. B. (1976) "Conceptual issues in the study of innovation". *Administrative Science Quarterly*, Vol. 21, pp. 700-714.

Edmondson, A., Bohmer, R. and Pisano, G. (2001) "Disrupted routines: team learning and new technology implementation in hospitals". *Administrative Science Quarterly*, Vol. 46, pp.685-716.

Ettlie J. E., Bridges, W. P. and O'Keefe, D. (1984) "Organisation Strategy and Structural Differences for Radical versus incremental innovation". *Management Science*, Vol. 30, No. 6, pp. 682-695.

Fudenberg, D. and Tirole, J. (1983) "Learning-by-doing and market performance". *The Bell Journal of Economics*, Vol. 14, No. 2, pp. 522-530.

Germain, R. (1996) "The role of context and structure in radical and incremental logistics innovation adoption". *Journal of Business Research*, Vol. 35, pp.117-127.

Harkness, J. (2003) "Instrumental variables probit and tobit using Amemiya Generalized Least Square" Stata Corp. Baltimore MD.

Henderson, R. M. (1993) "Underinvestment and incompetence as responses to radical innovation: evidence from the photolithographic alignment equipment industry". *The RAND Journal of Economics*, Vol. 24, No. 2, pp. 248-270.

Henderson, R. M. and Clark, K. B. (1990) "Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms". *Administrative Science Quarterly*, Vol. 35, No. 1, pp. 9-30.

Ichniowski, C., Shaw, K. and Prenushi, G. (1997) "The effects of Human Resource Management practices on productivity: a study of steel finishing lines". *American Economic Review*, Vol. 87, pp.219-313.

Infocamere (2001) *Registro delle imprese*. (Reggio Emilia, Camera di Commercio).

ISTAT (1999) *Censimento intermedio dell'industria e dei servizi 1996*. (Roma, ISTAT).

Harman, H. H. (1967) *Modern Factor Analysis*. (Chicago, IL: University of Chicago Press).

Hatch, N. and Mowery, D. (1998) "Process innovation and learning by doing in semiconductor manufacturing". *Management Science*, Vol. 44, pp. 1461-1477.

Jacobides, M. G. (2006) "The architecture and design of organizational capabilities". *Industrial and Corporate Change*, Vol. 15, No. 1, pp. 151-171.

Jensen, M., Johnson, B., Lorenz E., Lundval, B-A (2005) "Forms of knowledge, modes of innovation and innovation system", paper presented a the 2005 Globelics Conference, Beijing.

Jovanovic, B. (1982) "Selection and the evolution of industry". *Econometrica*, Vol. 50, pp. 649-670.

Kahneman, D. and Tversky, A. (1984) "Choices, values and frames". *American Psychologist*, Vol. 39, pp. 341-350.

Kimberly, J. R. and Evanisko, M. J. (1981) "Organisational innovation: the influence of individual, organisational, and contextual factors on hospital adoption of technological and administrative innovations". *The Academy of Management Journal*, Vol. 24, No. 4, pp. 689-713.

Koberg, C. S. Detienne, D. R. and Heppard, K. A. (2003) "An empirical test of environmental, organisational, and process factors affecting incremental and radical innovation.". *Journal of High Technology Management Research*, Vol. 14, pp. 21-45.

Lee, L. (1992) "Amemiya's Generalized Least Squares and Tests of Overidenfication in Simultaneous Equation Models with Qualitative or Limited Dependent Variables". *Econometric Reviews*, Vol. 11, No. 3, pp. 319-328.

Lindbeck, A. and Snower, D. (1996) "Reorganization of firms and labor-market inequality". *American Economic Review*, *AEA Papers and Proceedings*, Vol. 86, pp.315-321.

Laursen, K. and Foss, N. (2003) "New human resources management practices, complementarities and the impact on innovation performance". *Cambridge Journal of Economics*, Vol. 27, pp. 243-265.

Lundvall, B. and Nielsen, P. (2002) "Innovation, learning organisation, and industrial relations". *DRUID Working Papers* No.03-07.

Malerba, F. (1992) "Learning by firms and incremental technical change". *The Economic Journal*, Vol. 102, No.413, pp.845-859.

Marsili, O. and Salter, A. J. (2005) "Is innovation democratic? Skewed distributions and the returns to innovation in Dutch manufacturing". *Economics of Innovation and New Technology*; Vol. 14, No. 1-2, pp. 83-102.

Mazzanti, M. Montresor S. and Pini, P. (2006) "The General Profile of the Outsourcing Firm: Evidence for a Local Production System of Emilia Romagna". DRUID Working Paper No. 06-20.

McDermott, C. M. and Colarelli O'Connor, G. (2002) "Managing radical innovation: an overview of emergent strategy issues". *The Journal of Production Innovation Management*, Vol. 19, pp. 424-438.

Milgrom, P. and Roberts, J. (1990) "The economics of modern manufacturing: technology, strategy and organisation". *American Economic Review*, Vol. 80, pp. 511-528.

Milgrom, P. and Roberts, J. (1995) "Complementarities and firms: strategy, structure and organisational change in manufacturing". *Journal of Accounting and Economics,* Vol. 19, pp. 179-208.

Moch, M. K. and Morse, E. V. (1977) "Size, centralisation and organisational adoption of innovations". *American Sociological Review*, Vol. 42, No. 5, pp. 716-725.

Nelson, R. R. (2003) "On the uneven evolution of human know-how". *Research Policy*, Vol. 32, pp. 909-922.

Nelson, R. R. (1991) "Why do firms differ, and how does it matter?". *Strategic Management Review*, Vol. 12, pp. 61-74.

Nelson, R. R. and Winter, S. G. (1982) *An Evolutionary Theory of Economic Change*. (Cambridge, Mass., Harvard University Press).

Newey, W. (1987) "Efficient estimation of limited dependent variable models with endogenous explanatory variables". *Journal of Econometrics*, Vol. 36, pp.231-250.

Nielsen, O. and Lundvall, B-A (2006) "Learning organisations and industrial relations: how the Danish economy learns", in Lorenz, E: and Lundvall, B-A (eds.) *How Europe's Economies Learn: coordinating competing models*. (Oxford, Oxford University Press).

OECD (1994) *The OECD job study*. (Paris, OECD).

Pavitt, K., Robson, M., Townsend, J. (1989) "Technological accumulation, diversification and organization in UK companies, 1945-1983". *Management Science*, Vol. 25, pp.81-99.

Penrose, E. T. (1958) *The Theory of the Growth of the Firm*. (Oxford: Basil Blackwell).

Pini, P. and Santangelo, G. D. (2005) "Innovation types and labour organisational practices: A comparison of foreign and domestic firms in the Reggio Emilia industrial districts". *Economics of Innovation and New Technology*, Vol. 14, No. 4, pp. 251–276.

Pisano, G. P., Bohmer, M. J. And Edmondson, A.C. (2001) "Organisational differences in rates of learning: Evidence from the adoption of minimally invasive cardiac surgery". *Management Science*, Vol. 47, pp. 752-768.

Piva, M., Santarellli, E. and Vivarelli, M. (2005) "The skill bias effect of technological and organisational change: Evidence and policy implications". *Research Policy*, Vol. 34, pp.141-157.

Podsakkoff, P.M., MacKenzie, S.B. and Lee J-Y (2003) "Common Method biases in behavioral Research: a critical review of the literature recommended remedies". *Journal of Applied Psychology*, Vol. 88, No. 5, pp.879-903.

Podsakoff, P. M., and Organ, D. W. (1986) "Self-reports in organizational research: problems and prospects". *Journal of Management,* Vol. 12, pp. 531-44.

Porter, M. (1980) *Competitive Strategy*. (New York, Free Press).

Reagans, R., Argote, L. and Brooks, D. (2005) "Individual experience and experience working together: predicting learning rates from knowing who knows what and knowing how to work together". *Management Science*, Vol. 51, pp. 896-881.

Richardson, G. B. (1972) "The organisation of industry". *The Economic Journal*, Vol. 82, pp. 883-896.

Rosenberg, N. (1976) *Perspectives on Technology*. (Cambridge and New York, Cambridge University Press).

Sargan, J.D. (1958) "The Estimation of Economic Relationships Using Instrumental Variables". *Econometrica*, Vol. 26, pp. 393-415.

Schumpeter, J. A. (1934) *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle*. (Oxford and New York, Oxford University Press).

Schumpeter, J. A. (1942) *Capitalism, Socialism and Democracy*. (Allen and Unwin, London).

Shane, S.A. and Ulrich, K.T. (2004) "Technological innovation, product development, and entrepreneurship in Management Science". *Management Science*, Vol. 50, pp.133-144.

Smith, R: J. and Blundel, R. (1986) "AN exogeneity test for a simultaneous equation Tobit model with an application to labor supply". *Econometrica*, Vol. 54, pp.679-686.

Teece, D. J., Pisano, G. and Shuen, A. (1997) "Firm capabilities, resources, and the concept of strategy". *Strategic Management Review*, Vol. 18, No. 7, pp. 509-533.

Tushman, M. L. and Anderson, P. (1986) "Technological discontinuities and organisational environments". *Administrative Science Quarterly*, Vol. 31, no. 3, pp. 439-465.

Tushman, M. L. and Nelson, R. R. (1990) "Introduction: Technology, organisations , and innovation". *Administrative Science Quarterly*, Vol. 35, no. 1, pp. 1-8.

Volberda, H. W. (1996) "Toward the flexible form: how to remain vital in hypercompetitive environments". *Organization Science*, Vol. 7, No. 4, pp. 259-374.

Williamson, O.E. (1975) *Markets and Hierarchies: Analysis and Antitrust Implications*. (New York, The Free Press).

Winter, S. (2003) "Understanding dynamic capabilities". *Strategic Management Journal*, Vol. 24, No. 10/11, pp. 981-997.

Winter, S. (1988) "On Coase competence, and the corporation". *Journal of Law and Economics and Organization,* Vol. 4, pp. 163-180.

Womack, J. P., Jones, D. T. and Roos, D. (1990) *The Machine that Changed the World*. (New York, Rawson Associates).

Wooldridge, J. (2002) *Econometric Analysis of Cross Section and Panel Data*. (Cambridge, MA, MIT Press).

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Table 1 – Descriptive Statistics and correlation matrix

	Mean	Std. Dev.	$INNO\_RAD_i$	$INNO\_INCR_i$	$VADIP_i$	wop_cumul_i	$intro\_wp\_cumul_i$	$empev_i$	wof_i	$empqcm_i$	$empsug_i$	$R\&D_i$	$fullR\&Dext_i$	$partialR\&Dext_i$	$compres_i$	$newcomp_i$
$INNO\_RAD_i$	.542	.500	1.00													
$INNO\_INCR_i$	.867	.340	-.110	1.000												
$VADIP_i$	105.135	62.906	-.016	-.013	1.000											
wop_cumul_i	1.331	1.272	.231	.074	.238	1.000										
$intro\_wp\_cumul_i$	2.699	1.837	.205	.101	.260	.497	1.000									
$empev_i$	.428	.496	.183	.015	.054	.216	.136	1.000								
wof_i	.723	.449	.079	.115	.074	.024	-.021	.100	1.000							
$empqcm_i$	.542	.500	.005	.069	.011	.069	.100	.086	-.083	1.000						
$empsug_i$	.783	.413	.015	.010	.052	.207	.105	.130	.099	.133	1.000					
$R\&D_i$	.578	.495	.048	.206	.018	.204	.139	-.002	.098	-.026	.054	1.000				
$fullR\&Dext_i$	.048	.215	.150	.005	-.032	-.103	-.101	.147	.139	.037	.050	-.207	1.000			
$partialR\&Dext_i$	.108	.312	-.068	.079	-.063	.046	.026	.051	-.001	-.107	.137	.298	.012	1.000		
$compres_i$	.855	.353	.276	.193	.059	.216	.213	.113	.090	.069	.199	.100	.013	.033	1.000	
$newcomp_i$	.596	.492	.205	.222	.071	.196	.106	.140	.094	-.066	.014	.118	.185	.011	.290	1.000

Table 2 – Probit and ivprobit estimations for the likelihood of introducing incremental innovation

Variables	***Specification***											
	PROBIT				*FIRST STAGE*				*IVPROBIT*			
	dF/dx	***Robust Std. Err.***	***Z***		***Coef.***	***Std. Err.***	***t***		***dy/dx***	***Std. Err.***	***Z***	
VADIP$_i$	-.001	.001	-.880						.017	.008	2.130	**
wof$_i$	.049	.099	.490		10.646	10.787	.990					
empsug$_i$	-.100	.107	-.920		-1.237	12.145	-.100					
empqcm$_i$	-.056	.087	-.640		-1.813	9.661	-.190					
empev$_i$	.094	.089	1.060		2.180	9.915	.220					
wop_cumul$_i$	.073	.045	1.620		5.905	4.581	1.290					
intro_wp_cumul$_i$	.034	.029	1.190		7.047	2.986	2.360	**				
R&D$_i$	.072	.095	.770		-7.951	10.546	-.750		.333	.304	1.090	
fullR&Dext$_i$	.368	.117	1.970		-.388	23.506	-.020		1.149	.719	1.600	
partialR&Dext$_i$	-.154	.148	-1.020		-20.658	16.349	-1.260		.006	.497	.010	
newcomp$_i$	.343	.117	2.570		4.331	10.520	.410		.222	.306	.730	
compres$_i$	.098	.093	1.040	**	-4.669	14.569	-.320		.939	.431	2.180	**
specialized suppliers$_i$	.053	.136	0.390		1.904	14.822	.130		.094	.438	.220	
scale intensive$_i$	-.065	.167	-.390		39.892	17.500	2.280	**	-.896	.604	-1.480	
resource intensive$_i$	-.039	.143	-.270		20.770	15.316	1.360		-.483	.467	-1.040	
age$_i$	.004	.003	1.280		.486	0.320	1.520		.000	.010	.030	
output_market$_i$	-.003	.001	-2.280		.319	.150	2.130	**	-.015	.005	-2.690	***
	No of obs.	166			No of obs.	166			No of obs.	166		
	Log pseudolikelihood	-93.882			R2	.190						
	LR chi2(17)	41.180	***		Adj R2	.103			Wald chi2(11)	21.24	**	
	Pseudo R2	.180										
	Smith-Blundell test chi2(1)	8.180	**									
	Bound test	10.29			Bound test	2.32	**		Amemiya-Lee-Newey minimum chi2 statistic chi2(5)		1.407	

*** Significant at $p \leq 0.01$

** Significant at $p \leq 0.05$

Table 3 – Probit estimations for the likelihood of introducing radical innovation

Variables	*dF/dx*	*Robust Std. Err.*	*Z*	
$VADIP_i$	.000	.000	-1.230	
wof_i	.054	.055	1.070	
$empsug_i$	-.038	.044	-.780	
$empqcm_i$	.066	.046	1.560	
$empev_i$	-.010	.044	-.230	
wop_cumul_i	-.014	.021	-.660	
$intro\_wp\_cumul_i$	.017	.012	1.390	
$R\&D_i$	.094	.052	1.980	**
$fullR\&Dext_i$	-.039	.130	-.340	
$partialR\&Dext_i$	.055	.050	.840	
$newcomp_i$	.146	.062	2.740	***
$compres_i$	.056	.080	.800	
age_i	.002	.001	1.220	
$output\_market_i$	.000	.001	-.430	
$specialized\ suppliers_i$	.052	.060	.840	
$scale\ intensive_i$	.085	.041	1.440	
$resource\ intensive_i$	.031	.054	.540	

obs. P	.867	
pred. P	.915	(at *x*-bar)
No of obs.	166	
Log pseudolikelihood	-53.186	
LR chi2(17)	34.21	***
Pseudo R2	.1809	
Smith-Blundell test chi2(1)	.295	

*** Significant at $p \leq 0.01$

** Significant at $p \leq 0.05$

Table A.1 - Sample representativeness

Dimension	*Total firms in the population*	*Respondent*	*Non-Respondent*	χ^2 *test*	
Sector					
Labor intensive	48	33	15	2.546	
Resource intensive	73	58	15	0.238	
Scale intensive	35	30	5	1.591	
Specialized Suppliers	101	78	23	1.217	
Size					
50-99	117	86	31	1.896	
100-249	76	57	19	0.365	
250-499	33	26	7	0.040	
500-999	16	15	1	2.600	
>999	15	15	0	4.643	**

** Significant at $p \leq 0.05$

Table A.2 - Description of the variables

Variables	*Definition*
$INNO\_RAD_i$	equals to 1 if firm (*i*) has introduced a new to the firm product and/or process innovation, 0 otherwise.
$INNO\_INCR_i$	equals to 1 if firm (*i*) has introduced ameliorations on the quality of an existing product and/or process, 0 otherwise.
$VADIP_i$	average added-value per employee at 2000 constant prices.
Variables related to labour organisational practices	
wof_i	equals 1 if firm (*i*) has adopted a flexible labour organisation, 0 otherwise.
$empsug_i$	equals 1 if firm (*i*) has established channels for employees' suggestions, 0 otherwise.
$empqcm_i$	equals 1 if in firm (*i*) workers are individually encharged of quality control, 0 otherwise.
$empeval_i$	equals 1 if in firm (*i*) managers formally evaluate employees, 0 otherwise.
wop_cumul_i	ranges from 0 to 5 according to the number of labour organisational practices (i.e. team work, quality circles, just-in-time, job rotation, total quality management) adopted by firm (*i*).
$intro\_wp\_cumul_i$	ranges from 0 to 7 according to the number of practices (i.e. team work, total quality projects, job rotation, autonomy in problem-solving, structured channels for workers' suggestions on organisational topics, structured channels for workers' suggestions on quality topics, permanent education) firm (*i*) has introduced.
Variables related to different modes of organizing R&D activity	
$R\&D_i$	equals 1 if firm (*i*) conducts *in-house* R&D through an internal R&D function, 0 otherwise.
$fullR\&Dext_i$	equals 1 if firm (*i*) externalizes R&D and has not an internal R&D function, 0 otherwise.
$partialR\&Dext_i$	equals 1 if firm (*i*) externalizes R&D and has an internal R&D function, 0 otherwise.
Variables related to the nature of employees' competences required by innovating firms	
$compres_i$	equals 1 if firm (*i*) has introduced technological and organisational innovations requiring the training of the existing work-force, 0 otherwise.
$newcomp_i$	equals 1 if firm (*i*) has introduced technological and organisational innovations requiring the recruitment of workers with new competences, 0 otherwise.