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Industry- and firm-specific factors of innovation novelty

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Industry- and firm-specific factors of innovation novelty

Abstract

This paper investigates the underlying factors that might shape the firm's choices with respect to degrees of innovation novelty. Using a sample of 2983 firms observed under the Portuguese Community Innovation Survey, we assess the relative relevance of a set of firm- and industry-specific factors in explaining firms' choices about incremental or radical innovation. The results indicate that both the firm's idiosyncratic historical factors giving rise to heterogeneous R&D capabilities and the industry context have power to shape the firm's innovation choices, even though firm-specific factors appear to be more powerful. The estimated impacts on firm's innovation novelty are, nonetheless, significantly moderated by the type of firm and industry.

JEL Classification: L21, L10, O31

Keywords: radical and incremental innovation, competitive environment, R&D capabilities.

1. Introduction

Firms may pursue different innovation strategies. One possible indicator of firms' innovation strategy is the degree of novelty of innovation output. Radical or drastic innovation refers to products that are new for the firm, market and industry and to technological breakthroughs, whereas incremental or non-drastic innovation refers to small changes of existing products or processes.

Radical innovation is likely to be more important than incremental innovation because it is the foundation of firms' competitive advantages by rendering the established technology irrelevant and conferring a temporary monopolist position to the innovator (Schumpeter, 1934). Radical innovation can create new markets and destroy old ones. It also creates opportunities to outsiders to access new markets and it can bring down large incumbents that fail to innovate (e.g. Henderson, 1993; Chandy and Tellis 1998, 2000; Czarnitzki and Kraft, 2004; Acemoglu and Cao, 2010).

However, radical innovation is riskier and demands more resources than incremental innovation, making it less common and underscoring the importance of incremental innovation (Treacy, 2004; Varadarajan, 2008). Regarding incremental innovation there are at least two ways through which it can play an important role in achieving and maintaining competitive advantages, namely through product differentiation (e.g. Filson and Gretz, 2004) and cost-efficiency gains from better production processes (e.g. Ghosal, 2009).

Although innovation novelty may affect differently firms' and industries' performance, our current knowledge about the underlying factors that may determine different types of innovation output is still scarce. Firms' incentives to engage in innovation have been the topic of a long debate and scrutiny. Yet, theoretical and empirical contributions do not provide consensual results regarding its main determinants and they hardly distinguish radical from incremental innovation. Nonetheless, the distinction between radical and incremental innovation may well be a useful key to disentangle the lack of consensual results (Henderson, 1993; Czarnitzki and Kraft, 2004). This paper contributes to fill this gap by looking at the firm's innovation output in terms of its degree of novelty in assessing the role of industry- and firm-specific factors in shaping firms' innovations decisions.

Our motivation derives from the growing evidence reporting persistently different firm-level innovation decisions (e.g. Camacho and Rodriguez, 2008; Brusoni and Sgalari, 2006; Ghosal, 2009; Forsman, 2011). This heterogeneity relates not only to interindustry differences but also to intra-industry differences across similar firms, hence making it difficult to devise empirical regularities relating firms' innovation decisions. As such, the purpose of this paper is twofold. First, it aims to understand the role of industry factors on firms' decision to introduce in the market a radical or an incremental innovation, a theme that has been neglected to some extent by previous empirical studies (Duguet, 2006; Vega-Jurado et al., 2008). Second, it investigates in what extent and which sources of firms' heterogeneous R&D capabilities are relevant to explain different degrees of innovation novelty. By doing so, this paper brings new empirical evidence to the still scarce literature on the drivers of radical and incremental innovation at firm-level. Further, instead of looking at a one specific factor – the more common empirical approach -, this paper assesses simultaneously the relative relevance of industry-specific factors and firms' idiosyncratic historical factors giving rise to their heterogeneous capabilities.

Understanding the drivers of firms' decisions in terms of innovation novelty is important for two reasons. First, it is reasonable to assume that radical and incremental innovations are driven by different processes (see, e.g. Duguet, 2006; Thornhill, 2006). For instance, conventional wisdom is that the creation of incremental innovations is variously explained in terms of 'rational' responses to markets, dynamics of technological regimes, dominant design, etc., whereas radical innovations, in contrast, are explained in terms of serendipity, chance or haphazard scientific discoveries (Godoe, 2000). However, other studies contradict this view and note that radical innovations are to a higher degree more dependent on existing knowledge than non-radical innovations (Sternitzke, 2010; Shoenmakers and Duysters, 2010). Naturally, understanding the main drivers of radical and incremental innovation has implications for the study of firm dynamics and innovation strategy (Eiriz, et al., 2013). Thus, knowing the main sources of radical and incremental innovation, either related to industry- or firm-specific factors, will help to explain diversity of firms' innovative strategy.

Second, a direct result from the latter is that diversity in strategies generates diversity in firms' market shares, which in turn will impact upon firm and industrial dynamics (Llerena and Oltra, 2002). That is, intra-industry differences in innovative strategy and output are expected to play an important role in explaining firm and industry evolution (Gort and Klepper, 1982; Hopenhayn, 1994; Jovanovic and MacDonald 1994; Klepper 1996).

The remainder of the paper is organized as follows. Section 2 provides an overview of the theoretical contributions to the modelling of the relationship between industry-and firm-specific factors and firms' choices regarding innovation novelty, and proposes the hypotheses to be investigated. Section 3 describes the data and the empirical variables, and presents the econometric decisions. Section 4 presents and discusses the results. Section 5 draws the conclusions and discusses the limitations of the paper.

2. Theoretical background and hypotheses

2.1. The role of industry-specific factors on radical and incremental innovation

Two opposite views have characterized the debate on the role of incentives on innovation. The Schumpeterian view is that monopoly power may be a precondition for innovation (Schumpeter, 1934). This view is driven by the argument that a firm possessing market power has more financial resources, faces less market uncertainty and can more easily appropriate returns from its R&D investment. By contrast, the Arrow (1962) perspective argues that firms in competitive markets have always more incentives to invest in innovation. This result applies whether the innovation is radical, or incremental. The explanation for this lies in what is known as the Arrow effect or replacement effect: the established monopolist suffers a rent replacement effect.

Gilbert and Newbery (1982) contradicted Arrow's result by arguing that if the innovation is incremental, that is, if the older technology remains a viable substitute for the new, then it pays a monopolist to pre-empt potential competitors because by remaining a monopolist it can earn a flow of profit in excess of the sum of the profits in other industry structure. However, if the innovation is radical, then both incumbents and entrants have equivalent incentive to invest in it.

On the other hand, Reinganum (1983, 1985a) reinstated Arrow's (1962) result in the case of radical innovation. She argues that under uncertainty, the incumbent does less research than any other entrant because of the fear of cannibalizing current profits, leading to a process of continuous leapfrogging between firms (Reinganum, 1983; 1985a). In these models second-mover advantages are also possible (Reinganum, 1985b). In the case of incremental innovation the final outcome is a function of the relative strength of the fear of cannibalization and the incentive to extend market power (Reinganum, 1989).

Recently, Acemoglu and Cao (2010) provided conciliation between these opposite views by focusing on the interplay between new entrants and incumbents. Specifically, they extended the basic Schumpeterian endogenous growth model by allowing incumbents to undertake innovations to improve their products, while entrants engage in more "radical" innovations to replace incumbents. Their contribution involves simultaneous innovation by new and existing establishments therefore emphasizing the role of creative destruction by new firms in economic growth, but also the importance of large (here incumbents) firms in innovation (see Schumpeter 1934, and Schumpeter 1942).

The management literature presents an alternative explanation for differences between an incumbent and a challenger. Chandy and Tellis (1998) argued that size is not the important variable, but firms' willingness to cannibalize their own investments. This depends on firms' specialized investments, size of internal markets and size of future markets. According to Christensen and Bower (1996) leading firms tend to address the foreseeable needs of their current customers, so the effective resource allocation procedure in experienced organizations is driven by innovations known to be demanded by current customers in existing markets. Radical innovations are then more plausibly developed by challengers, who entered the market recently. In this case, post-entry and post-innovation monopoly conditions may increase the incumbent's incentives to respond to new competitors' innovation events as incumbents may face a greater risk of losing market share and a heightened survival pressure (Lee et al., 2000). Thus we expect that as the intensity of new entry at industry-level increases, the greater the likelihood the firm will attempt at generating radical innovation.

Hypothesis 1: The net entry rate of an industry has a positive and increasing impact on innovation novelty.

Regarding the effect of competition on innovation, the literature also provides contradictory theoretical predictions. There is no consensus on how competition or its lack shapes firms' innovation activity (Gilbert, 2006). Whereas some models show that competition in the current product market reduces the level of innovation (Dasgupta and Stiglitz, 1980; Asker and Baccara, 2010), others argue the opposite (Reinganum, 1983, 1985a, 1985b; Hoernig, 2003). Schmutzler (2010) offers an overview of a number of theoretical settings and assumptions and their implications for the relationship between market competition and firms' innovation activities. For instance, Vives (2008) demonstrated that competitive pressure fosters innovation, but it depends on the measure of competition that is used and the type of innovation. This suggests that an avenue that helps to conciliate these seemingly contradictory results lies in the heterogeneity on competition nature across industries and types of innovation.

With respect to industries' heterogeneity, some studies suggest that the effect of competition on innovation will vary upon the protection regime of the industry (Hoernig, 2003; Lee, 2005; Fershtman and Markovich, 2010). For instance, Lee (2005) predicted a positive relationship between market concentration - a measure of competition - and industry R&D intensity for low-appropriability industries, that is, industries where imitation is easier. A negative or an inverted U-shaped relationship emerges for high-appropriability industries.

Industry heterogeneity concerning its technological sophistication level may also explain differences in the incentives to innovation. Aghion et al. (2005) argued that more competition might foster innovation in industries where incumbent firms are operating at similar technological levels. In this in case, R&D investments aim at "escaping competition". On the other hand, in industries where innovation is made by laggard firms with already low initial profits, an increase in competition may erode post-innovation profits, thus discouraging innovation.

As such, several other studies have abandoned the search for a general relationship between competition and innovation and instead they tackle the question of how market competition affects different types of innovation. Most of them look at the different effects of competition on product innovation from those on process innovation, but a fruitful analysis would be based on the distinction between radical and incremental innovation. Although academic research directs most attention to product or process innovations, firms and industries evolution is also shaped by as much or more effort is allocated to radical or incremental innovations.

One relevant distinction between radical and incremental innovation is that the latter retains elements of the pre-innovation market competition, while radical innovation may result in post-innovation monopolies for the innovating firm (Gilbert and Newbery, 1982). In this sense, one would expect that the payoff from radical innovation is invariant to pre-innovation market competition but the replacement effect is lower for competitive firms (Gilbert, 2006). This suggests that firms that are protected from product market competition have lower incentives to generate radical innovations, compared to firms in competitive markets.

In the case of incremental product innovations, in which the existence of old products alters the behaviour of new-products sellers, Greenstein and Ramey (1998) concluded that increasing competition in the old-product market may provide smaller incentives for innovation. When competition from firms producing the old product reduces the payoff of introducing the new product, innovation is relatively less attractive under competition. A reason why a competitive firm might invest less is that, even after innovation, it still faces the pressure from the fringe firms. Thus, it will earn less after the innovation than the monopolist who carries out the same innovation. The net effect is a function of the relative strength of the replacement effect that captures the positive effect of ex-ante competition on innovation and the Greenstein-Ramey negative effect of ex-post competition. But, on the other hand, incremental innovations may be a way to soften competition by increasing product differentiation. In this case, one would expect an increasingly competitive environment to induce incremental innovation. Given these arguments the hypothesis to be tested is:

Hypothesis 2: Increasing product market competition affects positively innovation novelty.

Other works (e.g. Boone, 2001; Dubey and Wu, 2002; Dinlersoz and MacDonald, 2009; D'Aspremont et al., 2010) suggest that the incentives to innovation will ultimately depend upon innovation- and industry-specific characteristics, namely technological level and technological regime of the industry. As such, two additional industry-level factors are important to understand the drivers of radical and incremental innovation: industry life-cycle and technological opportunities.

Industry and product life-cycle models provide an explicit and formal account of the relationship between innovation and industry dynamics (Utterback and Abernathy, 1975; Gort and Klepper, 1982; Klepper and Graddy, 1990; Hopenhayn, 1992; Jovanovic and MacDonald, 1994; Klepper, 1996). These approaches suggest that an industry starts with a radical product innovation where successful entrants introduce new products and grow. Thereafter, competing firms engage in radical innovation until a dominant design emerges. As the product market matures, technological opportunities decline, and innovations increasingly shift to minor product incremental innovations and to cost reduction. The number of new firms declines as more competitive firms win out over less competitive firms. A large number of firms may end up exiting the industry until leadership in the industry stabilizes with large firms dominating the market.

Various studies have found empirical evidence corroborating the propositions of industry life-cycle models (e.g., Stadler, 1991; Carree and Thurik, 2000; Braguinsky et al., 2007). Others, however, have argued that the industry life-cycle approach provides a fruitful starting point to understand the evolution of industries as innovation evolves but does not explain certain empirical facts such as those observed in high-tech mature industries (McGahan and Silverman, 2001; Filson, 2001; Brusoni and Sgalari, 2006; Dinlersoz and MacDonald, 2009).

These studies challenge the notion that industry evolution is driven by a single major innovation and argue that different technological evolutions may occur during the various life-cycle phases. This is consistent with the view that in mature industries that are still technologically intensive, entry may be less about radical innovation and possibly more about filling market niches (Audretsch and Agarwal, 2001). Based on these premises, we argue that the life-cycle stage of the industry in which the firm operates are an important determinant of innovation novelty and we propose the following hypotheses:

Hypothesis 3: The industry's maturity is negatively related to innovation novelty, but it may be moderated by industry technological characteristics.

2.2. The role of firm-specific factors on radical and incremental innovation

R&D activities are seen as the key input in the knowledge production function where innovation depends upon current and lagged R&D investment (Pakes and Griliches, 1984). The amount devoted to R&D by each firm will in turn depend upon firm-specific differences in the private productivity of research effort caused by either variation in appropriability environments, opportunities, or differences in managerial ability. Such differences will, in general, be transmitted to differences in research expenditures and firms with more productive research departments will invest more in research.

The view that firms have different knowledge stocks and R&D capabilities, which in turn shape innovation decisions, is central in various theoretical approaches. Furthermore, it helps to explain intra-industry heterogeneity with respect to firms' innovation novelty. Dasgupta and Stiglitz (1980) were the first to advance this argument in order to justify why incumbents may have an advantage over new entrants. Since then, several contributions have reinstated the assumption that firms display different R&D capabilities (e.g. Grossman and Saphiro, 1987; Doraszelski, 2003; Etro, 2004; Chang and Wu, 2006; Fershtman and Markovic, 2010).

Differences in R&D capabilities may result from first-mover advantages (Grossman and Saphiro, 1987, Etro, 2004), differences on accumulated stock of knowledge (Doraszelski, 2003), differences in production experiences (Chang and Wu, 2006) and past innovative successes, or differences in features of R&D activities (Brusoni and Sgalari, 2006). Brusoni and Sgalari (2006) found that differences in the intensity and organization of R&D activities were critical in explaining the presence of heterogeneous innovation strategies as well as radical innovation in the tire manufacturing industry. Another important characteristic of R&D activities is that they not only generate new information, but also enhance the firm's ability to assimilate and exploit existing information, which will therefore influence the firm's incentive to invest in R&D (Cohen and Levinthal, 1989).

The relationship between R&D activities and learning as a source of innovation patterns and heterogeneous innovation decisions has been explored in more-depth by contributions from evolutionary (Dosi, 1988; Malerba, 1992) and organizational approaches (Llerena and Oltra, 2002; Henderson, 2006, Forsman, 2011, Herrmann and Peine, 2011). In these approaches, technological change results from cumulative forms of knowledge and is firm-specific. Thus firms may learn and innovate in a variety of different ways, because of their idiosyncratic historical factors, such as past innovative success and R&D activities, giving rise to different knowledge bases and competencies, that is, R&D capabilities.

Recent empirical evidence on the role of sources of knowledge on innovation novelty reveals some ambiguous results (e.g. Amara et al. 2008; Vega-Jurado 2008; Santamaría et al. 2009). Overall, the evidence shows that the firm's knowledge sources are important to determine technological competences and that their importance varies across industries hence corroborating previous contributions (Malerba, 1992; Breschi et al. 2000).

This evidence reveals differences relating the relative importance of internal and external sources. Duguet (2006), Amara et al. (2008), Cefis et al. (2009), Santamaría et al. (2009) and Forsman (2011) found that external sources, namely those derived from cooperation in R&D activities, are more important to generate radical innovation than internal sources, particularly so in the low-and medium-technology industries and in the services industries.

However, Vega-Jurado et al. (2008) found that radical innovations are mainly the output of internal R&D activities, whereas external R&D, such as cooperation R&D, seems more oriented towards innovation of incremental nature. These ambiguous results suggest that one should not overlook the productiveness of R&D cooperation in terms of radical innovation, as neither should one for in-house R&D activities in the case of incremental innovations.

The possible complementary relationship between both R&D types may explain the diversity of results, which, in turn, may be moderated by differences on the industry technological and protection regime as well as firm size. For instance, certain firms rely on in-house R&D exclusively in order to develop new products and processes whereas other firms are more outward-oriented and enter into R&D collaboration agreements in order to access external knowledge and accelerate the innovation process.

Based on these contributions we consider the following effects. The first is that a greater effort in R&D activity increases the firm´s possibilities of generating new knowledge to develop new or improved products. The second is that both internal and external of sources knowledge contribute to increase the firm´s technological competences and innovative output but their relative importance might by mediated by industry- and firm-specific effects. The third effect is that external sources, namely cooperation, may impact more strongly on innovation novelty than each R&D activities (intra-mural and extra-mural), which can be explained by two effects. First, because there is an indirect effect from increased absorptive capacity derived from internal or intra-mural R&D activities, which makes it easier for the firm to exploit externally available knowledge (Cohen and Levinthal, 1989). Second, because in general radical inventions are based on a relatively large number of knowledge domains, compared to non-radical inventions (Schoenmakers and Duysters, 2010) therefore firms that cooperate with other agents are more likely to increase their knowledge base and technological competences thereby increasing their chance of success in radical innovation. Thus we propose the following hypothesis:

Hypothesis 4: R&D activities affect firm's innovation novelty positively.

Although R&D activities can be measured looking at different sources of knowledge, we should not expect a contradictory direction on the relationship between each type of R&D activities and innovation novelty. In fact, intra-mural (in-house) R&D and extra-mural (external) R&D investments is expected to affect firm's innovation novelty positively, even though their relative effect may be mediated by industry- and firm-specific characteristics. In a similar vein, cooperation in R&D is likely to have a positive effect on firm's innovation novelty, but industry- and firm-specific characteristics may accentuate or not this relationship.

Firm size is another firm-specific characteristic found to be relevant in explaining innovation novelty. There is the view that large established firms have an advantage over entrants in the pursuit of incremental innovations, whereas small firms may be better positioned to explore radical innovations. Henderson (1993) argued that this is so because incremental innovation builds upon existing knowledge and capabilities, but these resources can simultaneously reduce substantially the effectiveness of their attempts to exploit radical innovation.

The literature on the nature of innovation, as for example, Ettlie et al. (1984), Acs and Audretsch (1988), Czarnitzki and Kraft (2004), documents how established and large firms are the main source of innovations that improve existing products, while new firms invest in more radical and original innovations. Recent work by Akcigit and Kerr (2010) provides empirical evidence from the US Census of Manufacturers that large firms engage more in exploitative R&D, while small firms perform exploratory R&D (defined similarly to the notions of incremental and radical R&D here). Given these predictions and evidence, we expect that firm size is a driver of innovation and we formulate the next hypothesis:

Hypothesis 5: Firm size is more likely to be positively correlated with incremental innovation than with radical innovation.

The firm's incentives to introduce an incremental or radical innovation may also vary across the firm life-cycle. However, the relationship between firm life-cycle and innovation novelty has received less attention than other firm-specific factors. The firm life-cycle hypothesis proposed by Mueller (1972), and Grabowski and Mueller (1975) imply that as the firm matures it might loose the capacity to repeatedly innovate. This happens because with growth and diversification the firm tends to become less efficient at handling information, which is crucial to continually generate innovative ideas. Also, as the firm matures, managers avoid risk, thus activities with lower innovativeness, and imitative behaviour of other firms drives profits down.

The idea that large, mature and established firms are more likely to introduce incremental innovations than radical ones has been widely advocated in the literature (e.g. Nelson and Winter, 1977; Henderson, 1993). According to this view mature firms are characterized by organizational inertia, i.e., they have more difficulty in adjusting their organizational capabilities (e.g. skills, routines, processes, and structures) since this is a difficult and costly process. Hence, once they make an initial investment, firms do not find it economically optimal to engage in large adjustments to their capabilities.

On the other hand, several arguments sustain the view that mature firms have more capabilities to invest in innovation. These capabilities relate to financial funds, higher degree of market power (Gilbert and Newbery, 1982; Aghion et al. 2009), organizational capabilities (Dewar and Dutton, 1986; Chandy and Tellis, 1998, 2000) and experience (Klette and Kortum, 2004). The latter has been associated with learning-by-doing hence with a decrease in the marginal cost of production (e.g. Malerba, 1992). Furthermore, innovative activities may be subject to learning effects in that they improve over time (Cohen and Levinthal, 1989; Fershtman and Markovic, 2010).

Empirical evidence on the relationship between firm life-cycle and innovation novelty is both scarce and inconclusive. Sørensen and Stuart (2000) found that mature firms generate more innovation overall but they also found a negative relationship between maturity and innovation novelty in semiconductors but a positive one in biotechnology. Balasubramanian and Lee (2008) found that maturity is negatively related to technical quality, and that this effect is greater in technologically active areas. Whereas this evidence suggests a negative relationship between firm's maturity and innovation novelty, anecdotal evidence shows that mature firms are the most innovative in intensive technology industries (Dewar and Dutton, 1986; Chandy and Tellis, 2000; Filson and Gretz, 2004; Brusoni and Sgalari, 2006; Aghion et al., 2009).

The arguments and evidence exposed above suggest that start-up and mature firms are more prone at introducing radical innovation, while firms at other stages of growth may pursue incremental innovations. However, small firms often lack access to factors crucial to pursue further a radical course of innovation, namely financial resources. One way to solve the lack of access to crucial resources is to grow through incremental innovations in order to become a routinized mature firm with specialised research units that have the focus and commitment to pursue innovation. For those routinized mature firms, radical innovation is a very likely output of their R&D activities. In order to investigate whether the firm's decisions regarding innovation novelty varies over the firm life-cycle we test the following hypothesis:

Hypothesis 6: Firm's innovation novelty varies over the firm life-cycle. Start-up and mature firms are more productive in terms of radical innovations than firms in other stages of growth.

3. Data, variables and econometric model

3.1. The data and empirical variables

The empirical analysis makes use of data from the Portuguese part of the Community Innovation Survey (CIS) of the European Commission. The CIS provides information on firms' innovation activities (e.g. different types of innovation, sources of innovation, effects of innovation) and it follows the OECD recommendations published in the Oslo Manual (OECD/Eurostat, 2005). Nowadays the CIS data has been widely used and the validity of its innovative indicators recognized by researchers (see, e.g., Kleinknecht et al., 2002; Mairesse and Mohnen, 2002; Mairesse and Mohnen, 2010). An advantage of the CIS data is that much of its innovative indicators are based on subjective perceptions of respondents, which means that on one hand they are less informative than other quantitative data, but on the other hand they are less affected by measurement errors (Mairesse and Mohnen, 2010).

A major disadvantage of this data is that it is very difficult to construct panel data samples by merging consecutive innovation surveys because they are performed every four years in most countries and every two years in only a few of them. As such, the cross-section nature of the data limits the possibility of doing a proper analysis of causality that would require structural modelling in a dynamic setting (Mairesse and Mohnen, 2010).

In Portugal the CIS survey has been conducted several times since the mid-1990s.[1] The survey is approximately representative of the Portuguese manufacturing and service industries (EUROSTAT/GPEARI, 2007), hence can be considered globally valid for the manufacturing and services population of firms. Firms with 10 or more employees were sampled randomly by industry and size strata[2]. The data regarding innovation activities is made up of retrospective answers that cover the three years preceding the survey.

In this paper we focus the analysis on the most recent survey for which data is available, which is the CIS6. The CIS6 comprises data on 4,721 Portuguese manufacturing and services firms for the period 2004-2006. In order to obtain data on each firm's turnover growth and past innovation activities and to construct lagged explanatory variables we had to use data from three CIS waves (i.e. data from CIS3, CIS4 and CIS6 surveys). The dependent variable (innovation novelty) was constructed from the CIS6 survey, while most of the firm-specific explanatory variables are based on the CIS4 survey.

Each sampled firm is given a code number that allow us to identify and follow each firm along the various CIS surveys. However, a given firm may not appear in all CIS surveys either because it may have not been selected during the sampling procedure or the firm may have not answered the survey. Thus, and after excluding observations due to missing values, we ended up with a sample of 2983 firms.

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[1] The available surveys for Portugal are: CIS2 (1995-1997); CIS3 (1998-2000); CIS4 (2002-2004); CIS6 (2004-2006). In this paper we could not use the CIS2 for two reasons. First, the questionnaire employed in this survey is rather different from the questionnaire employed in the following waves making it difficult, and in some cases not possible, to link the data among surveys. Second, firm identification numbers used in CIS2 are not coherent with those of the following waves, thus making it unreliable to link the data among surveys. Each three-year period indicates the period for data, while data collection took place after that.

[2] In the stratified sample of CIS6 there are three size-classes: 10–49 employees, 50–249 employees, and more than 250 employees. The industrial stratification is by NACE at the 2-digit level. When a stratum size was too small for sampling a census was done within the specific stratum.

This sample size reduction could bring a potential risk of biased results if the observed firms differ on average substantially from the full CIS6 sample. In order to investigate whether there is sample bias between the full CIS6 sample (N=4,721 firms) and the sample used in this study (N=2,983) we ran some descriptive statistics of selected variables for these two samples. Table A1 in the Appendix shows a comparison between the full CIS6 sample (N=4,721 firms) and the sample used in this study (N=2,983). It is clear that, on average, the characteristics of the firms are almost identical across samples, leading us to conclude that there is not any bias in the reduced sample.

In order to assess innovation novelty we needed data on the distinction between radical and incremental innovation. The survey distinguishes the products and/or services that are 'new-to-market' (i.e., new not only to the firm but also to the market) and 'new-to-firm' (i.e. introduced by the firm for the first time but not new to the market). This distinction can be seen to represent different degrees of novelty and it is used to construct our measure of radical and incremental innovation. Hence, the question is likely to pick up rather precisely what firms consider a major or radical innovation and a minor or incremental one.

Unfortunately, the survey does not make the same clear distinction with respect to process innovation. As such, we did not include process innovations in the analysis, which removes a significant portion of innovative activity. Moreover, it was only considered innovation activities that have been successful, i.e., firms that report having actually introduced an innovation in the market during the period 2004-2006. From the CIS surveys we also collected data on the firm's economic activity classification, turnover, R&D expenses and data about the firm's cooperation in innovation activities.

These data were then complemented with industry-level data collected from the *Quadros de Pessoal* database. The *Quadros de Pessoal* database is a comprehensive survey conducted on an annually basis by the Portuguese Ministry of Employment, covering all firms and establishments employing paid labour (either permanent or temporary workers). Given its compulsory nature, it can be seen as representing the population. Each firm and establishment in this database has a unique identifier, which allows us to follow each firm and establishment over time. Moreover, it collects data on firms' employees, turnover, and economic activity classification. This classification was used to construct several industry-specific variables, namely the industry growth rate, the net entry rate, the industry age and the industry concentration index, which are then matched with the CIS firm-level data through the code of firms' economic activity classification.

The dependent variable used to measure the firm's innovation novelty is INNOV. It can take three possible values depending on the novelty of the product innovation developed: 0, if the firm did not introduce any new or improved products into the market during the period 2004–2006; 1, if the firm reports having introduced a product into the market in that period that was new to the firm, i.e., an incremental innovation; and 2, if the product introduced into the market was new to the market, i.e., a radical innovation. Firms that have both kind of innovative output in the observed period are not considered as they are different from the ones that are only engaged in one of them, as has been suggested by the works that deal with ambidextrous organizations.

A major advantage of this measure relatively to other traditional measures, such as R&D expenses or patents, is that it enables us to observe successful introduction of product innovations, thus excluding the attempts to innovate that turned out to be unsuccessful. Indeed, one limitation of previous empirical studies of incentives to innovation has been the way innovative output is measured and the distinction between a radical and incremental innovation (Filson, 2001). Until now a few studies have used this variable to study innovation novelty in manufacturing industries (Duguet, 2006; Vega-Jurado et al., 2008) and services industries (Mansury and Love, 2008). However, a shortcoming of this measure of innovation outputs is that it does not give an idea about the intensity level of the innovation activities.

Based on our measure of the firm's innovation novelty, Table 1 presents the number and percentage of no-innovating and innovating firms by innovation novelty and for different types of firms and industries. Out of 2,983 firms 19.01% introduced an incremental innovation and 7.34% firms introduced a radical one during the period 2004-2006, indicating that incremental innovation is clearly a more common phenomenon than radical innovation. Nonetheless, the percentage of innovating firms – that is, those that report having introduced a product in the market - is slightly above 25%, implying that a quite large number of Portuguese firms were not successful at introducing a product in the market during the observed period. However, it does not mean that no-innovating firms are firms with no innovation activities at all.

[Table 1 here]

Interestingly, the distribution of incremental and radical innovators is fairly similar across industries (manufacturing versus services) and types of firms. Nonetheless, these empirical distributions appear to suggest that manufacturing firms are slightly more likely to be innovators than service firms and, if so, they are more likely to be incremental innovators. A similar finding is observed for firms in the high growth-stage. Large or cumulative innovating firms – that is, firms that report having introduced an innovation in the recent past years – appear to be those more prone to be radical innovators, while non-cumulative innovators and low growth firms are the less likely to engage in radical innovation. This first approximation to the data seems to contradict the preposition from the innovation regimes literature that radical innovation is introduced by firms who did not innovate before (Malerba, 1992, Breschi et al., 2000).

On the explanatory variables side, we constructed most of the variables corresponding to the beginning of the observation period in order to give them a pre-determined nature and hence to mitigate potential endogeneity problems. The exception is the R&D cooperation variable. The use of a lagged dummy variables taking the value one if the firm indicated that it was or had been engaged during 2002-2004 in active R&D cooperation would imply the assumption that R&D cooperative efforts require time to translate into innovation outcome and, hence, cooperative R&D have its main impact on innovation outcome in the following 3-years period. However, as Belderbos et al. (2004) pointed out, some R&D cooperation may have a more contemporary and relatively quick impact on innovation outcome. Thus, R&D cooperation in 2004 or 2005 may impact on innovation outcome reported in 2006. If so, a lagged R&D cooperation variable could fail to pick up this effect or offer empirical results that underestimate the impact of cooperation. In order to account for these arguments and allow for an different speed of the cooperation effects, the R&D cooperation variable combines information on the two subsequent periods and takes the value one if the firm reports having engaged in cooperation in innovative activities during the period 2002-2004 or 2004-2006, and zero otherwise. Table 2 provides survey of our hypotheses, the empirical variables used to test them, and the way each variable was operationalized.

[Table 2 here]

Complementary, Table 3 presents some descriptive statistics of the empirical variables used to estimate the model of innovation novelty. Some interesting features can be pointed out. Whereas the average industry growth rate over the period 2002-2004 was positive (3.2%), the net entry rate was negative for all observed industries, suggesting that the observed period is characterized by a reduction on the number of active firms. On the other hand, the average industry concentration, measured by the Herfindhal index at the 2-digit level aggregation, is low but exhibiting a considerable variability.

[Table 3 here]

Another interesting finding is the distribution of firms across the defined stages of firm's growth. Nearly 40% of the firms are in the decline phase – that is, report negative annual turnover growth rate over the period 2002-2004 – which represents more than twice the number of firms in the high growth (13%) or the low growth (17%) phases. This reinforce the previous finding that the observed period have reported a decline in the economic activity.

The percentage of firms that reported having engaged in cooperation in innovative activities during the period 2004-2006 is 21.4%, which contrasts considerably with the high percentage of firms that reported having introduced an innovation in the previous years. This finding suggests that there are a significant number of Portuguese innovating firms but they seem to favour more other R&D activities than using cooperation as an external source of knowledge. Looking at R&D intensity separated by intramural and extramural R&D expenses, on average the Portuguese firms appear to invest more in external sources of knowledge than in intramural R&D investments. The data also indicates that there is strong heterogeneity across firms with respect to R&D intensity, even when the distinction between internal or external sources of knowledge is accounted for.

3.2. The econometric model

Given the nature of the dependent variable, which represents the individual choice of each firm in terms of innovation outcome (non innovation, radical innovation or incremental innovation), discrete choice models offer the best approach to assessing the determinants of the observed innovation choices at firm level.

A firm will choose the innovation outcome *j* if and only if it renders the highest expected payoff. The reduced-form of the payoff of firm *i*, operating in industry *k*, expected from obtaining the innovation outcome *j* is

$$\pi_{ikj} = z_k'\alpha + x_i'\beta + \varepsilon_{ij}, \text{ with } j=0, 1, 2 \quad (1)$$

where the vector $\mathbf{z}_k$ comprises observed industry-specific characteristics, the vector $\mathbf{x}_i$ comprises observed firm-specific characteristics, and $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are the compatible vectors of unknown parameters to be estimated. The ε_{ij} is the stochastic term associated with each choice and firm. Here, the stochastic term aims at capturing unobserved firm-specific characteristics, such as firm management capabilities, that may also determine whether or not a firm engages on innovation activities, and unobserved choice-specific attributes.

The parameters of interest (**α** and **β**) should be read with caution. In fact, they should not be interpreted as measuring a causal effect of industry- and firm-specific factors on innovation novelty, but rather as capturing correlations of which the causal effect is but one possible interpretation. The cross-section nature of the innovation survey data prevent us to carry out a proper analysis of causality given that it is quite tricky to deal with potential econometric endogeneity problems (Mairesse and Mohnen, 2010). In order to mitigate this econometric problem explanatory variables are lagged relatively to the 2004-2006 period, which is the period that relates to the dependent variable.

Given the stochastic nature of the payoff function and the ordinal nature of the dependent variable – innovation novelty -, the probability that innovation outcone *j* is selected by a firm *i* can be written as

$$P_{ikj} = P(y_{ik} = j \mid z_k, x_i) = F(\kappa_{j+1} - z_k'\alpha - x_i'\beta) - F(\kappa_j - z_k'\alpha - x_i'\beta) \quad (2)$$

.

where $\kappa_1, \ldots, \kappa_{j+1}$ are threshold values and it is understood that $\kappa_1=-\infty$ and $\kappa_{j+1}=+\infty$. The ordered probit model is obtained by substituting for F the standard normal distribution.

The standard ordered models are, sometimes, quite restrictive. They usually assume equal thresholds for all individuals or firms and, hence, the estimated coefficients of explanatory variables are not allowed to vary over the all outcomes J. This assumption neglects possible heterogeneous effects of some explaining factors and generate restrictive marginal effects given that their relative magnitude is not allowed to vary over the outcomes and their signs are entirely determined by the distribution function F (Boes and Winkelmann, 2004).

Relaxing the assumption of equal thresholds for all firms and allowing indices to differ across the outcomes leads to a generalized ordered probit model. It is a very flexible model – similarly to the multinomial probit model – that uses the ordering information by making the threshold parameters, κ_j, linear functions of the explanatory variables. Let $\kappa_{ij} = \tilde{\kappa}_j + z_k'\gamma_j + x_i'\delta_j$, j=1, ..., J where the vector $\mathbf{z}_k$ comprises observed industry-specific characteristics, the vector $\mathbf{x}_i$ comprises observed firm-specific characteristics as in equation (1) and (2). Entering that threshold equation into the probability that innovation outcone *j* is selected by a firm *i* leads to a likelihood contributions of the form

$$\begin{aligned} P(y_{ik} = j \mid z_k, x_i) &= F(\tilde{\kappa}_{j+1} + z_k'\gamma_{j+1} + x_i'\delta_{j+1} - z_k'\alpha - x_i'\beta) - F(\tilde{\kappa}_j + z_k'\gamma_j + x_i'\delta_j - z_k'\alpha - x_i'\beta) \\ &= F(\tilde{\kappa}_{j+1} - z_k'\alpha_j - x_i'\beta_j) - F(\tilde{\kappa}_j - z_k'\alpha_j - x_i'\beta_j) \end{aligned} \quad (3)$$

where $\alpha_j=\alpha-\gamma_j$ and $\beta_j=\beta-\delta_j$. The generalized probit model contains J-1 parameter vectors for β and for α plus J-1 constants $\tilde{\kappa}$ that can be estimated jointly by maximum likelihood. Let $y_{ikj}=1$ if $y_{ik}= j$ and $y_{ikj}=0$ else. For a sample of n independent observations (y_{ik}, z_k, x_i) the log-likelihood function is given by

$$\ln L(\alpha, \beta, \kappa_2, ..., \kappa_j; y, z, x) = \sum_{i=1}^{n} y_{ikj} \ln P(y_{ik} = j \mid z_k, x_i)$$

This specification allows for individual heterogeneity in the parameter vectors that leads to heterogeneity across outcomes, implying that the effects of explanatory variables on the log-odds are now outcome specific.

Similarly to other non-linear models, we can estimate the marginal effects of the explanatory variables on the probabilities. Since our main objective is to explain the driving forces of firms' choices with respect to innovation output, we will mostly base the discussion of the results on the estimated marginal effects on the probabilities and their standard errors, as they are a more direct interpretation of the effects of explanatory variables on the probability of choosing an innovation outcome. The marginal effects of changes in the explanatory variables has now a substantially more flexible form $ME_{jl}(g_i) = f(\tilde{\kappa}_j - g_i'\lambda_j)\lambda_{jl} - f(\tilde{\kappa}_{j+1} - g_i'\lambda_{j+1})\lambda_{j+1,l}$, with g=(z, x) and λ=(α, β). A consistent estimator of the marginal effects is obtained by replacing the parameters with their maximum likelihood estimators and averaging over the sample.

The greater flexibility in modelling ordered responses with generalized thresholds has a practical consequence as it increases considerably computation time and the number of parameters to be estimated, along with other restrictions. In this sense, the fully flexible approach could again be a very strong assumption. However, in most cases theory does not provide adequate guidance to determine which explanatory variables should have invariant parameters across outcomes. Thus, the specific structure of the distributional effects is determined by data using the automated selection mechanism implemented by Williams (2006). The assumption of equal thresholds will only be relaxed for those explanatory variables where it is violated. That is, variables which pass the statistical tests – i.e. variables whose effects do not significantly differ across outcomes – have proportionality constraints imposed.

4. Estimation Results

The generalized ordered probit estimates of the marginal effects of industry- and firm-specific characteristics on the probability of firm's choices on innovation novelty (non innovation, radical innovation or incremental innovation) are presented in Table 4. In all estimated models a set of industry dummies at a different level of aggregation than the structural industry characteristics is included as an attempt of controlling for industry-fixed effects. The industry dummies are based on Pavitt (1984) taxonomy.

[Table 4 here]

Overall, the results suggest that industry-specific as well as firm-specific characteristics are differently correlated with firms' innovation choices, indicating that the firm's heterogeneous R&D capabilities and industry factors are relevant to explain different degrees of innovation novelty. More interestingly, if we look at the statistical contribution of each factor group (decomposing the adjusted R^2 and assuming a linear probability model), we find that firm-specific factors have a higher contribution, explaining approximately 12% of the aggregate variability on firms' innovation choices, than industry-specific factors, which explain around 2% of the aggregate variability on firms' innovation choices. Nonetheless, this result should be read with caution. It is based on a simple and limited statistical procedure, on a broad definition of industry and it would be misguided to separate the influence of idiosyncratic historical factors giving rise to firm-specific factors from the industry and competitive contexts in which firms operate.

Looking at the predicted probability (p_j) of each innovation outcome and comparing it with the observed frequency (f_j), the specified models perform well in determining firm's innovation choices, even though its goodness-of-fit varies slightly across the three specified ordered innovation outcomes. Overall, the model over-predicts the probability of non-innovation and tends to under-predicted the probability of incremental and radical innovation. One possible explanation may be grounded on the low rate of innovative firms (Table 1 shows that only 26.46% of the firms are innovative). The other measures of goodness of fit also confirm that the specified model have power to explain firm's innovation novelty.

In order to test the hypothesis, Section 4.1 discusses the results on industry- and firm-specific factors as drivers of firms' innovation novelty, using the entire sample and pooling all firms and industries. Section 4.2 summarizes and discusses the results of several robustness checks, using sub-samples based on different types of industries and firms, which might reveal some more detailed knowledge.

4.1 All firms and industries

With respect to industry-specific effects, most of the explanatory variables are statistically significant. The estimates confirm the hypothesis H1, given that an increase in the net number of active firms appears to increase firms' innovation activities, either incremental or radical, suggesting an 'escape competition effect' as posited by Aghion et al. (2005) and Reiganum (1983, 1985a). Nonetheless, the estimates do no confirm an increasing impact of net entry rate on innovation novelty. In fact, the results suggest that an increase in the net number of active firms affect positive but more strongly the probability of a firm engaging in incremental innovation than in radical innovation.

Hypothesis H2 is not confirmed as firms operating in industries with large levels of concentration – and, hence, less market competition – seem to be more prone to engage in incremental innovation. The positive correlation of higher levels of industry concentration – and, hence, lesser market competition - on innovation seems to argue in favour of the Schumpeterian effect and some innovation race models in which firms with market power have more resources and incentives to invest in innovation, particularly on incremental instead of radical innovation (Gilbert and Newbery, 1982). The Vives (2008) hypotheses that competitive pressure fosters innovation is not confirmed.

Support for hypothesis H3 on industry's maturity is partially provided, as firms operating in older industries are less stimulated to engage in innovation, either incremental or radical innovation. The estimates also provide evidence that, holding everything else constant, high levels of industry growth are associated with lower probabilities of firms' incremental and radical innovation. This seems to indicate that firms operating in growing industries have lower incentives for innovation due to the lessening of competitive pressure. They seem to understand the competitive environment less tough and, hence, they are less motivated to root their performance in innovation activities. On the other hand, industries with high growth rates may be the result of the exploitation of previous innovations. Thus, there would be fewer incentives to introduce new products in the market. Decreases in industry growth suggest a trajectory to its maturity stage and, comparably to high growth industries, an increase in market competition and, hence, in the incentives to innovate. Firms operating in mature industries, which usually report a declining or low growth rates, appear to have more incentives to engage in incremental or radical innovation than firms in growing industries. Therefore, as an industry approaches its maturity stage firms seem to be more prone to introducing new products in the market as a way to invert the growth trajectory and to overcome the possible obsolescence of older products. This result is consistent with previous finding on the relationship between industry life-cycle and innovation (see, e.g., Agarwal and Gort, 2002).

On the side of firm-specific characteristics, results strongly support hypothesis H4. Firms are asymmetric in terms of R&D capabilities, which appear to be grounded on R&D cooperation with other agents and investments in R&D, in particular extramural R&D investments. The results strongly suggest that firms engaging in R&D cooperation increase substantially the probability of performing incremental or radical innovation. However, our estimates do not corroborate the argument and the evidence that found external sources to be more important to achieve radical innovation than incremental innovation (e.g. Amara et al. 2008, Vega-Jurado et al., 2008; Forsman, 2011). Instead, our findings are in line with Malerba (1992) who found that external sources of knowledge play a relevant role in generating incremental technical change.

On the other hand, holding everything else constant, the probability of engaging in incremental or radical innovation is higher when firms invest in R&D, reinforcing the relevance of R&D heterogeneous capabilities to explain innovation outcomes. However, extramural R&D investments appear to be the driving force of innovation for Portuguese firms. Moreover, our estimates appear to provide some support to a common assumption that radical innovations build on a higher degree on basic research than incremental innovations and are based less on existing knowledge (Laukkanen et al., 2008; Vega-Jurado et al., 2008; Sternitzke, 2010).

On the other hand, previous successful innovation outcomes seem to not generate upgrading in the firm's R&D capabilities that, in turn, would foster incremental or radical innovation. This is an unexpected result as one would expect that firms would benefit from learning from their own past innovation outcomes. Nevertheless, this result is consistent with the view that some innovations depend less on cumulative knowledge and experience (e.g. Fudenberg et al., 1983; Grossman and Shapiro, 1987). Another possible explanation for this result might be the way the variable PAST INNOVATION was measured because it includes any type of innovation, i.e., product or process, whereas the dependent variable only relates to product innovation. More importantly, the results seem to suggest that, after innovation in the previous period, firms have less incentives and need to introduce new products in the market than when their did not. This suggests a fixed cost and a rent exploitation aspect to introducing new products in the market so that a financially constrained firm may be induced to not keep on introducing new products in the markets.

The lack of statistical significance of the variable SIZE suggests that firm size is not necessarily a determinant of innovation, in general, and product innovation novelty, in particular. It provides evidence of not supporting hypothesis H5. Nonetheless, if we look at the probability of radical innovation, this result is in line with various authors who have argued that organizational and strategic factors, namely willingness to cannibalize firms' own investments, seem to be more relevant to explain the ability to innovate radically (Chandy and Tellis, 1998, 2000; Henderson, 1993; 2006) than firm size. A similar result was found with the variables associated to the firm's growth stages. Firms with different levels of growth appear to have no differences in the probability of engaging in innovation, either incremental or radical innovation. Hence, the firm's growth stages hypothesis, H6, is not supported by empirical results.

4.2 Robustness checks

In this section, we discuss estimates of our model applied to different sub-samples to explore the robustness of our results and to reveal some more detailed knowledge on the drivers of innovation novelty. In particular, we are looking for evidence on different circumstances that may challenge the unidirectional relation put forward in most of our hypothesis. It would allow us to evaluate whether there is some ambiguity about the direction of the effect of industry- and firm-specific factors on innovation novelty as suggested in the literature.

4.2.1 Industry-types

A potential source of concern with our estimates is the inclusion of several industries whose technological opportunities and protection regimes may be significantly different. The importance of technological regimes in explaining innovation patterns across industries as put forward by the evolutionist approach (Dosi, 1988; Malerba, 1992; Breschi et al., 2000) has been widely recognized in the literature. We have checked the robustness of our results to this concern by breaking the sample into more homogenous groups of industries. Estimates using sub-samples of firms operating in manufacturing industries and in services industries are reported in Table 5, while estimates for firms operating in industry-types based on the Pavitt (1984) taxonomy are reported in Table 6.

[Table 5 and Table 6 here]

The relevance of market concentration in shaping the firm's innovation choices appears to be confined to firms operating in service industries. In fact, the innovation choices of firms operating in manufacturing industries seem not to be driven by the level of industry concentration. They appear to be more driven by industry dynamics, measured by the net entry rate, than the actual level of competition. Moreover, an increase in actual market competition seem to discourage firms operating in service industries to engage in incremental innovation, while, holding everything else constant, increases in competition brought by entry of new firms appear to foster radical innovation. A similar effect is found for scale-intensive industries (see Table 6), either manufacturing or services firms, even though the estimates show a less degree of statistical significance.

More interestingly, in the case of supplier dominated industries, the intensity of new entrants, which can also be seen as an increase in market competition, appear to have a positive effect on innovation novelty, suggesting that firms operating in supplier dominated industries "escape competition" through mainly incremental innovation. Conversely, firms operating in science-based industries appear to corroborate the Schumpeterian effect, in which market power – gained through lower actual market competition – provides incentives to incremental innovation. In turn, variations in market competition due to entry of new firms seem not to affect those firms' incentives to innovate.

Among industry-types, these dissimilar incentives to innovation associated to market competition provide support for hypothesis H2. They may be well explained by differences in the protection regime among different industries as have pointed out, among others, by Lee (2005), and Fershtman and Markovich (2010). In the case of low-appropriability industries, such as service industries, high levels of market concentration are positively correlated with incremental innovation. However, for other types of low-appropriability industries, such as supplier dominated industries, a similar relationship between market competition and innovation are not found, suggesting that other factors may be at work. In this case, a possible explanation may well be based on differences in technological level among firms operating in the same industry-type as posited by Aghion et al. (2009). Overall, the results show that the way market competition affects innovation novelty varies across industries, whose analysis requires fine details on market structure and firms' heterogeneity.

The hypothesis that industry's maturity is negatively related to innovation novelty does not pass the robustness check based on industry-types. Hypothesis H3 is only confirmed for the case of firms operating in the manufacturing industry. More interestingly, the estimates suggest that the incentives for firms operating in supplier-dominated industries or scale intensive industries introducing new products in market, holding everything else constant, are mainly driven by market competition. This is consistent with anecdotal evidence that Portuguese textile and apparel industries as well as the footwear industry have been able to adjust to market competition through innovation. Thus, this evidence contradicts the view of industry-life effects and it adds to the growing evidence showing that innovation is being done in traditional industries by established firms as a way to become more competitive (Filson, 2001; Brusoni and Sgalari, 2006; Dinlersoz and McDonald, 2009).

The effect of market size variations – measured by industry growth – on innovation novelty appears to be mostly robust to the distinction between manufacturing and service industries, which is in line with the results found by Forsman (2011). However, it does not pass the robustness check based on Pavitt industry-types. Only in science-based industries firm's innovation choices appear to be driven by industry growth, suggesting that, holding everything else constant, firms have lower incentives for innovation, either incremental or radical, when the industry have previous high growth rates, which may be due to the lessening of competitive pressure. This result is consistent with the evidence showing that innovation in science-based industries like pharmaceuticals is largely driven by the size of the market (e.g. Dubois et al., 2011).

On the firm-specific characteristics side, the robustness checks based on industry-types provide additional evidence on the different circumstances that drives firms' innovation novelty. In particular, the estimates show that in some cases the firm's innovation novelty may well vary over a firm life cycle – hypothesis H6 – but it depends on the type of the industry. That is, the way the life-cycle of the firm influences its choices regarding incremental and radical innovation seems to depend on the industry in which the firm operates. In particular, declining firms operating in the service industries or in science-based industries appear to be more prone to engage in innovation, either incremental or radical, to escape to this growth stage.

On the importance of R&D activities, the estimates show that it varies across industries, as it has been widely recognized. The role of R&D cooperation for radical innovation appears to be relevant in most of the industries, while the role of extramural R&D intensity appear to be an additional and important driver of incremental innovation in the case of manufacturing industries. However, when we split the sample according to Pavitt's taxonomy, extramural R&D intensity only plays a role in explaining innovation radicalness for scale intensive and science based industries, corroborating previous empirical evidence which presents an ambiguous relationship between innovation outcomes and R&D intensity.

4.2.2 Firm-types

Another potential source of concern with our estimates is related to firms' heterogeneity and its impact on innovation drivers. We have checked the robustness of estimates to this concern by breaking a sample into more homogenous groups of firms. Estimates using sub-samples of firms with different sizes are reported in Table 7, while estimates for firms that regularly innovate – cumulative innovators – and other firms – non-cumulative innovators – are reported in Table 8. A firm is classified as a cumulative innovator if it reports having introduced an innovation in the two previous CIS waves and non-cumulative innovator otherwise.

[Table 7 and Table 8 here]

Looking at more homogenous groups of firms with respect to size and past innovative experience, we found that the role of actual level of market competition in discriminating innovation choices between small and large firms appear to be weak, but it seems to be an important one for non-cumulative innovators. In fact, our findings suggest that an increase in actual market competition seem to discourage non-cumulative innovators to engage in incremental innovation, while, holding everything else constant, increases in competition brought by entry of new firms appear to foster non-cumulative innovators to carry out radical innovation. A similar pattern of effects is found to large firms, suggesting that noteworthy industry dynamics and the associated increase in market competition force large firms to upgrade on innovation novelty.

On the other hand, the estimates suggest the rejection of hypotheses H6. That is, among cumulative or non-cumulative innovators firm growth stage appears not to drive firm's innovation choices. However, firms' grouping by size provides a dissimilar finding, suggesting that the impact of the firm's life-cycle on innovation novelty also varies with firm's size. The positive and statistically significant association between the declining growth and incremental innovation in small firms seems to provide some evidence to the view that small firms have less organizational constraints than large ones, which facilitate their innovation activity (e.g. Henderson, 1993) and they use incremental rather than radical innovation to overcome this growth stage.

In turn, the estimates do not corroborate the idea that large and low growth firms are more likely to introduce incremental innovations than radical ones. Holding everything else constant, the estimated probability of large and low growth firms to engage in incremental innovation does not differ from that of other firms. Overall the results suggest that the relationship between firm growth level and innovation novelty requires a more fine detailed analysis and possibly an alternative methodology.

Our findings provide some support for that R&D intensity play an important role in discriminating innovation choices of non-cumulative innovators from cumulative innovators. Cumulative innovators seem to be successful by rooting their R&D investment on extramural expenses while non-cumulative innovators appear to base mainly their innovation novelty on intramural R&D expenses. The impact of R&D intensity on innovation outcomes also appear to vary with firm size. R&D capabilities of small firms appear to be grounded on cooperation, while the evidence on large firms pointed out the importance of internal sources of knowledge, along with R&D collaboration, on innovation outcomes.

5. Conclusion

This paper provides evidence on the main drivers of firms' choices regarding innovation novelty. Using a discrete measure of innovation output, the results corroborate the importance of industry- and firm-specific factors in revealing deeper insights into the different levels of opportunities in radical and incremental innovation at the firm level. Whereas previous literature has pointed out that there is diversity in firms´ choices regarding innovation both across and within industries, this paper supplements this evidence by showing a richer picture of the drivers of this diversity. Specifically, we analyze with more depth the role of industry-specific characteristics than previous studies as well the interplay between these characteristics and firm-specific characteristics.

The strong correlations between industry's growth and innovation novelty, as well as between the net entry rate and innovation novelty, suggest that the industry dynamics is an important factor underlying firms' innovation decisions in terms of novelty. Market competition seems to shape firms' innovation novelty but it appears to be moderated by differences in the protection regime among industries and in intra-industry technological level. These findings challenge previous evidence that has neglected the importance of industry characteristics on innovation novelty (Duguet, 2006; Vega-Jurado et al., 2008). Therefore, there seems to be an important role for managers and policy-makers as they should closely monitor the industry's characteristics evolution such as net entry rate, growth, and concentration, because such factors help to understand firms' innovation decisions. That is, since it is expected that significant changes in these factors may impact on innovation, they should anticipate those changes and, consequently, their innovation decisions.

Regarding firm-specific characteristics our results strongly suggest that R&D capabilities play a central role as driver of both radical and incremental innovation. When discriminating between internal and external sources, cooperation in R&D activities, which provide external sources of knowledge, seem to be the most consistent driver of product innovation, a result that is in line with previous empirical evidence (e.g. Duguet, 2006; Vega-Jurado, 2008). However, results also show that internal sources, i.e., the firm´s R&D intensity, has a larger effect on the probability of firms introducing a radical innovation in the market than cooperation itself. Furthermore, the relative importance of external sources of knowledge on innovation outcomes, as compared with internal ones, is moderated by firm size, with large firms accentuating the relevance of internal sources, namely intra-mural R&D activities. Also, among innovators, intra-mural R&D investment has the largest effect on innovation non-cumulative innovation. Altogether these results support the idea that both type of knowledge sources are important to Portuguese firms and in-house R&D activities not only generate new knowledge, but also promote the use of external sources, as proposed by Cohen and Levinthal (1989).

We also found that the importance of each type of R&D capabilities varies across industries. Whereas R&D cooperation seems to be the most important driver of both radical and incremental innovation in the services industries, it clearly plays a minor role in determining radical innovation among manufacturing industries. Similar results emerge when we discriminate the sample across Pavitt (1984) sectoral taxonomy. That is, the relative importance of each R&D capability varies across industries. R&D cooperation seems to have an equal effect on each type of innovation in the scale-intensive industries but exert a minor effect on radical innovation in the science and supplier dominated industries. Simultaneously, extra-mural R&D activities are also relevant to both types of innovation in scale-intensive and science-based industries. In sum, these results suggest that the use the knowledge generated by in-house R&D activities does not substitute for knowledge obtained through cooperation or from an external source and that their relative importance varies across technological regime and appropriability conditions.

Another interesting result emerging from our data is that the firm´s growth stages also play a role in determining innovation choices. It became apparent that firms in the declining stage in the services and science-based industries, as well as small firms in general, are investing in innovation. This is an important contribution of this paper because results support the idea that managers should consider to invest in innovation as a means to overcome a decline in growth. Another important contribution from this paper is that managers should pay more attention to enhance their own in-house R&D activities and their external sources of knowledge than to their past innovation activities.

The results have also important implications for innovation policy in the Portuguese and other similar contexts. On one hand, policies should strengthen the firm´s R&D competences because these are the main driver of innovation either radical or incremental. In addition, innovation policy should contribute to enhance R&D cooperation between agents on innovation activities. In fact, cooperation in R&D depends on the will of the parties involved but also on public policies in areas such as education, technology infrastructure, and SMEs support. Public policies should also take into account the size of the firm. Given the large impact that in-house R&D has on large firms´ innovation outcome, these policies should be designed to enhance smaller firms' in-house R&D capabilities.

On the other hand, public policies should be primarily directed to promote the entry of new firms in the market as this is a main driver of firms´ innovation outcome. Thus policies should aim at creating attractive business conditions that facilitate firms´ entry. Regarding competition, public policies should take into account the specific characteristics of the industries, as results are sensitive to the type of each industry.

The findings are subject to some limitations due to the cross-section nature of data. In fact, the estimates do not measure causal effects, but rather they capture correlations of which the causal effect is but one possible interpretation. Nevertheless, they provide some important hints on how innovation takes place in Portuguese firms. Furthermore, they show that models incorporating industry- and firm-specific factors as well as the interplay between them explain innovative performance better than models that include just one type of factors. It contributes also for a better understanding of which factors may affect innovation novelty at the firm-level.

Finally, the paper reveals an under-researched issue, suggesting that firm's innovation novelty varies over the firm life-cycle, even though such variation depends on the industry type. Clearly much more attention should be devoted to understand which are the main incentives and innovation strategies of firms in different growth stages. This would contribute to a better understanding of the conditions and ways under which firms in different growth stages develop and implement different innovation strategies.

This question is beyond the scope of this paper but it certainly deserves further research.

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Table 1: Incremental and radical innovation, 2004-2006, by types of firms and industries

	All firms		Non-innovators		Incremental		Radical		Total
	No.	%	No.	%	No.	%	No.	%	%
Industry									
Manufacturing	1,412	47.33	1,014	71.84	299	21.18	99	7.01	100.00
Services	1,571	52.67	1,183	75.30	268	17.06	120	7.64	100.00
Total	2,983	100.00	2,197	73.65	567	19.01	219	7.34	100.00
Small, medium and large firms									
Small firms	761	25.51	559	73.46	145	19.05	57	7.49	100.00
Medium firms	1,469	49.25	1,092	74.34	277	18.86	100	6.81	100.00
Large firms	753	25.24	546	72.51	145	19.26	62	8.23	100.00
Total	2,983	100.00	2,197	73.65	567	19.01	219	7.34	100.00
Cumulative versus non-cumulative innovating firms									
Cumulative innovators	1,468	49.21	1,057	72.00	291	19.82	120	8.17	100.00
Non-cumulative innovators	1,515	50.79	1,140	75.25	276	18.22	99	6.53	100.00
Total	2,983	100.00	2,197	73.65	567	19.01	219	7.34	100.00
Firm-growth stage									
High growth	394	13.21	276	70.05	88	22.34	30	7.61	100.00
Moderate growth	902	30.24	666	73.84	167	18.51	69	7.65	100.00
Low growth	496	16.62	373	75.20	90	18.15	33	6.65	100.00
Decline	1,191	39.93	882	74.06	222	18.64	87	7.30	100.00
Total	2,983	100.00	2,197	73.65	567	19.01	219	7.34	100.00

Table 2: Hypotheses and explanatory variables

Industry-specific variables	
H1	NET ENTRY RATE: the number of firms new firms minus the number of firms that decide to exit from the industry divided by the total number of firms in industry in 2003
H2	CONCENTRATION: the Herfindahl index on the 2-digit industry level and is calculated as the sum of squares of turnover shares of all firms in the industry in 2003.
H3	GROWTH: the industry annual turnover growth rate over the period 2002-2004 AGE: measured by the logarithm of the age of the oldest firm in the industry in 2003.
Firm-specific variables	
H4	R&D COOPERATION: dummy variable that takes the value one if the firm reports having engaged in cooperation in innovative activities during the period 2002-2004 or 2004-2006, and zero otherwise. R&D INTENSITY: total R&D expenses divided by total turnover in 2004. INTRAMURAL R&D INTENSITY: intramural R&D expenses divided by total turnover in 2004 EXTRAMURAL R&D INTENSITY: extramural R&D expenses divided by total turnover in 2004 PAST INNOVATION: dummy variable that takes the value one if the firm reports having introduced an innovation of any type (i.e., product, service or process innovation) in the past years from 1998 to 2004, and zero otherwise.
H5	SIZE: the log of total turnover in 2004.
H6	HIGH GROWTH: dummy variable that takes the value 1 if the firm's annual turnover growth rate over the period 2002-2004 is larger than 0.5 and zero otherwise. LOW GROWTH: dummy variable that takes the value 1 if the firm's annual turnover growth rate over the period 2002-2004 is greater than 0 and less than 0.1 and 0 otherwise. DECLINE, dummy variable that takes the value 1 if the firm's annual turnover growth rate over the period 2002-2004 is negative and 0 otherwise.

Table 3: Descriptive statistics of the empirical variables for all firms

Variable	Obs	Mean	Std. Dev.	Min	Max
Innovation outcome	2983	0.337	0.609	0	2
Industry-specific characteristics					
NET ENTRY RATE	2983	-0.301	0.125	-0.899	-0.081
CONCENTRATION	2983	0.032	0.065	0.002	0.604
GROWTH	2983	0.032	0.140	-0.315	0.571
AGE	2983	4.856	0.507	2.773	5.986
Firm-specific characteristics					
R&D COOPERATION	2983	0.214	0.410	0	1
R&D INTENSITY	2983	0.022	0.067	0	0.990
INTRAMURAL R&D INTENSITY	2983	0.005	0.027	0	0.509
EXTRAMURAL R&D INTENSITY	2983	0.016	0.058	0	0.973
PAST INNOVATION	2983	0.492	0.500	0	1
SIZE	2983	14.756	1.856	8.700	22.294
HIGH GROWTH	2983	0.132	0.339	0	1
LOW GROWTH	2983	0.166	0.372	0	1
DECLINE	2983	0.399	0.490	0	1

Table 4: Estimated marginal effects on the probability of each firm's innovation decisions for all firms

	Model 1			Model 2		
	No-innovation	Incremental innovation	Radical innovation	No-innovation	Incremental innovation	Radical innovation
Industry-specific characteristics						
NET ENTRY RATE	-0.480*** (0.088)	0.289*** (0.055)	0.191*** (0.036)	-0.480*** (0.088)	0.289*** (0.055)	0.191*** (0.036)
CONCENTRATION	-0.476*** (0.162)	0.522*** (0.136)	-0.046 (0.097)	-0.477*** (0.162)	0.522*** (0.136)	-0.046 (0.097)
GROWTH	0.335*** (0.064)	-0.202*** (0.039)	-0.133*** (0.026)	0.334*** (0.064)	-0.201*** (0.039)	-0.133*** (0.026)
AGE	0.041* (0.022)	-0.025* (0.013)	-0.016* (0.009)	0.041* (0.022)	-0.025* (0.013)	-0.016* (0.009)
Firm-specific characteristics						
R&D COOPERATION	-0.284*** (0.023)	0.199*** (0.021)	0.085*** (0.015)	-0.284*** (0.023)	0.199*** (0.021)	0.085*** (0.15)
R&D INTENSITY	-0.323*** (0.110)	0.195*** (0.067)	0.128*** (0.044)	-	-	-
INTRAMURAL R&D INTENSITY	-	-	-	-0.369 (0.263)	0.222 (0.159)	0.147 (0.105)
EXTRAMURAL R&D INTENSITY	-	-	-	-0.312** (0.130)	0.188** (0.079)	0.124** (0.052)
PAST INNOVATION	0.028* (0.017)	-0.017* (0.010)	-0.011* (0.007)	0.028* (0.017)	-0.017* (0.010)	-0.011* (0.007)
SIZE	0.007 (0.004)	-0.004 (0.003)	-0.003 (0.002)	0.007 (0.004)	-0.004 (0.003)	-0.003 (0.002)
HIGH GROWTH	-0.023 (0.025)	0.014 (0.015)	0.010 (0.011)	-0.023 (0.026)	0.014 (0.15)	0.009 (0.011)
LOW GROWTH	0.007 (0.024)	-0.005 (0.015)	-0.003 (0.009)	0.007 (0.024)	-0.004 (0.015)	-0.003 (0.009)
DECLINE	-0.009 (0.019)	0.006 (0.012)	0.004 (0.008)	-0.009 (0.019)	0.005 (0.011)	0.004 (0.008)
Industry dummies		Yes			Yes	
Log-Likelihood		-2039.5			-2039.4	
χ^2		292.7***			293.4***	
AIC		4114.9			4116.9	
p_j	75.1	18.4	6.5	75.1	18.4	6.5
f_j	73.7	19.0	7.3	73.7	19.0	7.3
Sample Size		2983			2983	

Notes: Figures in parentheses are robust standard errors. *, ** and *** mean that coefficients are statistically significant at 10%, 5% and 1% level, respectively. The indicator p_j measures the predicted probability for choice j, while f_j reported the observed frequency for choice j. The reference category in firm's stages of growth is moderate growth, meaning firms with annual growth between 0.1 and 0.5.

Table 5: Estimated marginal effects on the probability of each firm's innovation decisions for firms operating in manufacturing industries and in service industries

	Manufacturing			Services		
	No-innovation	Incremental innovation	Radical innovation	No-innovation	Incremental innovation	Radical innovation
Industry-specific characteristics						
NET ENTRY RATE	-0.990*** (0.165)	0.636*** (0.113)	0.355*** (0.062)	-0.419*** (0.130)	0.255*** (0.080)	0.163*** (0.052)
CONCENTRATION	0.734 (0.492)	-0.471(0.317)	-0.263 (0.177)	-0.725*** (0.198)	0.650*** (0.155)	0.075 (0.115)
GROWTH	0.299** (0.127)	-0.192** (0.083)	-0.107** (0.046)	0.592*** (0.105)	-0.361*** (0.067)	-0.231*** (0.043)
AGE	0.101** (0.047)	-0.101*** (0.036)	-0.001 (0.020)	0.042 (0.027)	0.026 (0.017)	-0.016 (0.011)
Firm-specific characteristics						
R&D COOPERATION	-0.275*** (0.034)	0.220*** (0.031)	0.055*** (0.019)	-0.262*** (0.030)	0.136*** (0.015)	0.126*** (0.0175)
INTRAMURAL R&D INTENSITY	-0.431 (0.488)	0.277 (0.314)	0.154 (0.175)	-0.235 (0.298)	0.143 (0.182)	0.092 (0.116)
EXTRAMURAL R&D INTENSITY	-0.643*** (0.239)	0.711*** (0.246)	-0.068 (0.127)	-0.220 (0.175)	0.134 (0.107)	0.086 (0.069)
PAST INNOVATION	0.036 (0.025)	-0.023 (0.016)	-0.013 (0.009)	0.017 (0.023)	-0.010 (0.014)	-0.007 (0.009)
SIZE	0.006 (0.006)	-0.004 (0.004)	-0.002 (0.002)	0.003 (0.006)	-0.002 (0.004)	-0.001 (0.002)
DECLINE	0.040 (0.028)	-0.026 (0.018)	-0.014 (0.010)	-0.047* (0.026)	0.028* (0.016)	0.019* (0.011)
HIGH GROWTH	-0.024 (0.037)	0.015 (0.023)	0.009 (0.014)	-0.016 (0.035)	0.010 (0.020)	0.007 (0.014)
LOW GROWTH	0.003 (0.036)	-0.002 (0.023)	-0.009 (0.013)	0.019 (0.0312)	-0.012 (0.019)	-0.007 (0.012)
DECLINE	0.040 (0.028)	-0.026 (0.018)	-0.014 (0.010)	-0.047* (0.026)	0.028* (0.016)	0.019* (0.011)
Industry dummies		Yes			Yes	
Log-Likelihood		-967.4			-1031.0	
χ^2		185.8***			169.01***	
AIC		1976.8			2095.9	
p_j	74.0	20.2	5.8	77.1	17.0	5.9
f_j	71.8	21.2	7.0	75.3	17.1	7.6
Sample Size		1412			1571	

Notes: Figures in parentheses are robust standard errors. *, ** and *** mean that coefficients are statistically significant at 10%, 5% and 1% level, respectively. The indicator p_j measures the predicted probability for choice j, while f_j reported the observed frequency for choice j. The reference category in firm's stages of growth is moderate growth, meaning firms with annual growth between 0.1 and 0.5.

Table 6: Estimated marginal effects on the probability of each firm's innovation decisions for firms operating in industry-types based on the Pavitt (1984) taxonomy

	Scale-intensive			Science-based			Supplier dominated		
	No-innovation	Incremental innovation	Radical innovation	No-innovation	Incremental innovation	Radical innovation	No-innovation	Incremental innovation	Radical innovation
Industry-specific characteristics									
NET ENTRY RATE	-0.710** (0.367)	0.419* (0.219)	0.291* (0.152)	-0.302 (0.215)	0.179 (0.128)	0.123 (0.088)	-0.559*** (0.173)	0.387*** (0.124)	0.172 (0.055)
CONCENTRATION	-0.554 (0.438)	0.327 (0.260)	0.227 (0.180)	-1.222*** (0.352)	1.093*** (0.288)	0.129 (0.161)	0.442 (0.308)	-0.306 (0.217)	-0.136 (0.093)
GROWTH	0.190 (0.331)	-0.112 (0.195)	-0.078 (0.136)	0.682*** (0.127)	-0.404*** (0.081)	-0.278*** (0.056)	0.129 (0.158)	-0.089 (0.111)	-0.040 (0.048)
AGE	0.016 (0.056)	-0.049 (0.040)	0.034 (0.027)	-0.010 (0.048)	0.006 (0.028)	0.004 (0.019)	0.036 (0.047)	-0.025 (0.033)	-0.011 (0.014)
Firm-specific characteristics									
R&D COOPERATION	-0.249*** (0.036)	0.124*** (0.018)	0.125*** (0.022)	0.296*** (0.044)	0.228*** (0.040)	0.068** (0.029)	-0.185*** (0.040)	0.116*** (0.024)	0.070*** (0.019)
INTRAMURAL R&D INTENSITY	-0.236 (0.446)	0.139 (0.263)	0.097 (0.183)	-0.287 (0.391)	0.170 (0.231)	0.117 (0.159)	-0.192 (0.572)	0.132 (0.396)	0.059 (0.176)
EXTRAMURAL R&D INTENSITY	-0.530* (0.294)	0.312* (0.174)	0.217* (0.121)	-0.444* (0.253)	0.263* (0.150)	0.181* (0.105)	-0.201 (0.170)	0.139 (0.120)	0.062 (0.052)
PAST INNOVATION	0.006 (0.029)	-0.003 (0.017)	-0.002 (0.012)	0.047 (0.034)	-0.028 (0.020)	-0.019 (0.014)	0.002 (0.026)	-0.002 (0.018)	-0.001 (0.008)
SIZE	0.007 (0.008)	-0.004 (0.005)	-0.003 (0.003)	0.005 (0.009)	-0.003 (0.006)	-0.002 (0.004)	0.006 (0.007)	-0.004 (0.005)	-0.002 (0.002)
HIGH GROWTH	-0.015 (0.043)	0.009 (0.025)	0.006 (0.018)	-0.068 (0.055)	0.038 (0.030)	0.029 (0.025)	0.003 (0.040)	-0.002 (0.028)	-0.001 (0.012)
LOW GROWTH	0.046 (0.040)	-0.029 (0.025)	-0.018 (0.015)	-0.073 (0.051)	0.041 (0.028)	0.031 (0.023)	0.012)	-0.008 (0.025)	-0.004 (0.011)
DECLINE	0.017 (0.032)	-0.010 (0.019)	-0.007 (0.013)	-0.131*** (0.042)	0.075*** (0.024)	0.056*** (0.019)	0.036 (0.029)	-0.025 (0.021)	-0.011 (0.009)
Industry dummies		No			No			No	

Table 6: Estimated marginal effects on the probability of each firm's innovation decisions for firms operating in industry-types based on the Pavitt (1984) taxonomy (cont.)

Log-Likelihood		-780.9			-542.5			-518.5	
χ^2		86.0***			130.9***			65.05***	
AIC		1591.9			1116.9			1064.9	
p_j	73.1	19.9	7.1	74.1	19.1	6.9	82.4	14.0	3.6
f_j	71.9	19.9	8.2	71.9	19.8	8.3	80.9	14.5	4.7
Sample Size		1081			794			925	

Notes: Figures in parentheses are robust standard errors. *, ** and *** mean that coefficients are statistically significant at 10%, 5% and 1% level, respectively. The indicator p_j measures the predicted probability for choice j, while f_j reported the observed frequency for choice j. The reference category in firm's stages of growth is moderate growth, meaning firms with annual growth between 0.1 and 0.5.

Table 7: Estimated marginal effects on the probability of each firm's innovation decisions for small firms and large firms

	Small firms			Large firms		
	No-innovation	Incremental innovation	Radical innovation	No-innovation	Incremental innovation	Radical innovation
Industry-specific characteristics						
NET ENTRY RATE	-0.549*** (0.169)	0.338*** (0.109)	0.212*** (0.066)	-0.403** (0.172)	0.243** (0.105)	0.159** (0.069)
CONCENTRATION	0.106 (0.256)	-0.065 (0.157)	-0.041 (0.098)	-0.428 (0.374)	0.704** (0.304)	-0.276 (0.201)
GROWTH	0.131 (0.128)	-0.081 (0.079)	-0.051 (0.049)	0.348*** (0.121)	-0.210*** (0.075)	-0.138*** (0.050)
AGE	0.122*** (0.045)	-0.112*** (0.037)	-0.010 (0.021)	0.057 (0.046)	-0.035 (0.028)	-0.023 (0.018)
Firm-specific characteristics						
R&D COOPERATION	-0.358*** (0.052)	0.251*** (0.049)	0.107*** (0.036)	-0.205*** (0.037)	0.114*** (0.021)	0.091*** (0.019)
INTRAMURAL R&D INTENSITY	-0.218 (0.416)	0.134 (0.256)	0.084 (0.161)	-3.427*** (0.955)	2.071*** (0.600)	1.356*** (0.392)
EXTRAMURAL R&D INTENSITY	-0.237 (0.238)	0.146 (0.147)	0.091 (0.091)	-0.264 (0.306)	0.159 (0.185)	0.104 (0.121)
PAST INNOVATION	0.029 (0.035)	-0.018 (0.022)	-0.011 (0.013)	0.030 (0.036)	-0.018 (0.022)	-0.012 (0.015)
SIZE	0.032 (0.026)	-0.020 (0.016)	-0.012 (0.010)	0.016 (0.0134)	-0.010 (0.008)	-0.007 (0.006)
HIGH GROWTH	-0.023 (0.065)	0.065 (0.060)	-0.042** (0.018)	-0.024 (0.051)	0.014 (0.030)	0.010 (0.021)
LOW GROWTH	0.015 (0.049)	-0.009 (0.031)	-0.006 (0.018)	0.043 (0.048)	-0.027 (0.030)	-0.016 (0.017)
DECLINE	-0.022 (0.038)	0.065** (0.031)	-0.044** (0.020)	-0.034 (0.038)	0.020 (0.023)	0.014 (0.016)
Industry dummies		Yes			Yes	
Log-Likelihood		-510.9			526.0	
χ^2		95.0***			80.34***	
AIC		1065.8			1088.1	
p_j	75.1	18.7	6.1	74.2	19.3	6.6
f_j	73.5	19.1	7.5	72.5	19.3	8.2
Sample Size		761			753	

Notes: Figures in parentheses are robust standard errors. *, ** and *** mean that coefficients are statistically significant at 10%, 5% and 1% level, respectively. The indicator p_j measures the predicted probability for choice j, while f_j reported the observed frequency for choice j. The reference category in firm's stages of growth is moderate growth, meaning firms with annual growth between 0.1 and 0.5.

Table 8: Estimated marginal effects on the probability of each firm's innovation decisions for cumulative innovating firms and non-cumulative innovating firms

	Cumulative innovators			Non-cumulative innovators		
	No-innovation	Incremental innovation	Radical innovation	No-innovation	Incremental innovation	Radical innovation
Industry-specific characteristics						
NET ENTRY RATE	-0.424*** (0.129)	0.247*** (0.077)	0.178*** (0.055)	-0.559*** (0.115)	0.354*** (0.075)	0.205*** (0.045)
CONCENTRATION	-0.192 (0.233)	0.112 (0.136)	0.080 (0.098)	-0.675*** (0.218)	0.839*** (0.203)	-0.165 (0.139)
GROWTH	0.352*** (0.095)	-0.205*** (0.056)	-0.148*** (0.041)	0.353*** (0.088)	-0.224*** (0.057)	-0.129*** (0.033)
AGE	0.082*** (0.032)	-0.048*** (0.019)	-0.034*** (0.013)	0.002 (0.030)	-0.002 (0.019)	-0.001 (0.011)
Firm-specific characteristics						
R&D COOPERATION	-0.210*** (0.027)	0.147*** (0.024)	0.063*** (0.017)	0.458*** (0.041)	0.336*** (0.042)	0.121*** (0.031)
INTRAMURAL R&D INTENSITY	0.023 (0.292)	-0.0135 (0.170)	-0.010 (0.122)	-1.279* (0.746)	0.811* (0.476)	0.469* (0.275)
EXTRAMURAL R&D INTENSITY	-0.287** (0.134)	0.167** (0.078)	0.120** (0.057)	-0.761 (0.650)	1.158** (0.600)	-0.397 (0.275)
PAST INNOVATION	-	-	-	-	-	-
SIZE	0.005 (0.006)	-0.003 (0.004)	-0.002 (0.003)	0.007 (0.007)	-0.004 (0.004)	-0.003 (0.002)
HIGH GROWTH	-0.012 (0.034)	0.007 (0.020)	0.005 (0.014)	-0.043 (0.040)	0.026 (0.024)	0.016 (0.016)
LOW GROWTH	0.035 (0.034)	-0.021 (0.021)	-0.014 (0.013)	-0.023 (0.035)	0.014 (0.021)	0.009 (0.013)
DECLINE	-0.022 (0.028)	0.013 (0.016)	0.009 (0.012)	-0.007 (0.027)	0.004 (0.017)	0.002 (0.010)
Industry dummies		Yes			Yes	
Log-Likelihood		-1059.8			-949.8	
χ^2		126.9***			210.6***	
AIC		2153.5			1939.5	
p_j	73.3	19.5	7.2	77.0	17.5	5.5
f_j	72.0	19.8	8.2	75.3	18.2	6.5
Sample Size		1468			1515	

Notes: Figures in parentheses are robust standard errors. *, ** and *** mean that coefficients are statistically significant at 10%, 5% and 1% level, respectively. The indicator p_j measures the predicted probability for choice j, while f_j reported the observed frequency for choice j. The reference category in firm's stages of growth is moderate growth, meaning firms with annual growth between 0.1 and 0.5.

Appendix

In order to investigate whether there is some sort of sample bias between the full CIS6 sample (N=4,721 firms) and the sample used in this study (N=2,983) some descriptive statistics of selected variables for these two samples are provided in the Table A1. An inspection of Table A1 shows that this study sample is about two thirds of the full sample in size and that the average characteristics are almost identical, therefore there is not any apparent bias in the reduced sample. Of particular interest is the proportion of innovative firms, which only decreases marginally, and the R&D and cooperation variables, which are almost identical. Regarding the representativeness of the manufacturing and services industries they are equally represented in both samples, although the proportion of the services industries have increased slightly in this study, from 51% to 52% of the firms in the sample.

Table A1: Descriptive statistics of selected variables for the full CIS6 and this study samples

	Full CIS6 sample: 4,721 firms				This study sample: 2,983			
	Mean	Std. Dev.	Min.	Max	Mean	Std. Dev.	Min.	Max.
Variable								
INNOVATION OUTCOME	0.362	0.627	0	2	0.337	0.609	0	2
R&D COOPERATION	0.254	0.436	0	1	0.250	0.433	0	1
R&D INTENSITY	0.017	0.063	0	0.927	0.016	0.057	0	0.871
INTRA-MURAL R&D INTENSIY	0.005	0.032	0	0.927	0.004	0.024	0	0.457
EXTRA-MURAL R&D INTENSITY	0.012	0.051	0	0.871	0.012	0.049	0	0.871
SIZE	14.989	1.826	8.475	20.565	14.967	1.807	8.475	20.565
MANUFACTURING	0.493	0.500	0	1	0.481	0.500	0	1
SERVICES	0.507	0.500	0	1	0.519	0.500	0	1

Note: All variables relate to the year 2006. Except for the innovation outcome variable, the values of the statistics are different from those presented in Table 3 which are used in model estimations because the latter refer to the lagged value of the explanatory variables.

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