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## Barriers to Innovation: Can Firm Age Help Lower Them?

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# Barriers to innovation: can firm age help lower them?

Gabriele Pellegrino <sup>a b c</sup>

## Abstract

This paper examines how firm age can affect a firm's perception of the obstacles (*detering* vs. *revealed*) that hamper and delay innovation. Using a comprehensive panel of Spanish firms for the period 2004-2011, the empirical analysis conducted shows that distinct types of obstacle are perceived differently by firms of different ages. First, a clear-cut negative relationship is identified between firm age and a firm's assessment of both the internal and external shortages of financial resources. Second, young firms seem to be less sensitive to the lack of qualified personnel when initiating an innovative project than when they are already engaged in such activities. By contrast, the attempts of mature firms to engage in innovation activity are significantly affected by the lack of qualified personnel. Finally, mature incumbents appear to attach greater importance to obstacles related to market structure and demand than is the case of firms with less experience.

**Keywords:** Barriers to innovation, firm age, probit panel data model.

**JEL Classification:** C23, O31, O32, O33.

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## **1. Introduction**

According to the Schumpeterian tradition, firm age, along with firm size, is a fundamental factor in determining and differentiating a firm's innovation ability, with the degree of novelty and imitation of its innovation varying significantly over the firm's life course. Indeed, the Austrian scholar in his two most notable works assigns distinct but equally relevant roles to small, newly established and large, mature firms. In Schumpeter Mark I (Schumpeter, 1934), new entrepreneurial firms, by investing in R&D and launching new radical innovations favour a renewing process of 'creative destruction'. In contrast, in Schumpeter Mark II (Schumpeter, 1942), the main contribution to innovation is made by large, more experienced firms, which, by means of a process of 'creative accumulation', represent the main engine of change (see Malerba and Orsenigo, 1996; Breschi et al., 2000; Acemoglu and Cao, 2010).

Despite the unquestionable influence of Schumpeterian models in innovation studies, surprisingly, the related empirical literature analysing the relationship between innovation and firm age is still underdeveloped with respect to many aspect. More importantly, there is practically no evidence of the relationship between a firm's evolution and the effects (relevance) that certain firm and market factors can have in hindering its innovative process. Indeed, as would appear to be the norm in the innovation literature, much more emphasis is given to analysing the factors that determine the success of innovation than those that can lead to failure.

In recent years, a new stream of literature has begun to analyse the role played by barriers to innovation in deterring or hampering a firm's innovative efforts (Mohnen and Rosa, 2001; Galia and Legros, 2004; Segarra-Blasco et al., 2008; Savignac, 2008) and to examine the factors affecting a firm's perception of these barriers (Iammarino et al., 2009; D'Este et al., 2012; Hölzl and Janger, 2013, 2014). In fact, most have tended to mainly

focus on the impact of financial constraints on a firm's innovative behaviour (see Hall, 2008 for a review of this subject). Without calling into question the fundamental role played by the availability of internal and external financial resources in determining the firm's innovative decision, other factors have recently been shown to be significant hindrances of a firm's innovative process (see, for example, D'Este et al., 2012; Blanchard et al., 2012; Pellegrino and Savona 2013; Coad et al., 2015). Among these, particular attention needs to be paid to such factors as the shortage of adequate skills, the lack of appropriate information on technologies and on markets, and the lack/uncertainty of demand.

Crucially, the deterrent or hampering effect of these factors can vary over the firm's life cycle: for example, new-born or young firms may be more markedly affected than incumbents by a lack of financial resources or a shortage of adequate skills for the implementation of the innovative process, while the lack/uncertainty of demand might be more of a deterrent to firms with more experience and which, in all probability, operate in highly saturated markets.

Within this context, the main aim of this study is to conduct an empirical investigation of the impact of firm age on a firm's perception of the various obstacles to innovation. Building on the conceptual framework first proposed by D'Este et al. (2012), this relationship is examined by distinguishing between firms that face *revealed* barriers and those that face *detering* barriers<sup>1</sup>. To do so, univariate and multivariate analyses are undertaken that draw on a large longitudinal dataset of Spanish manufacturing and services firms and which focus on different phases in their life cycles.

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<sup>1</sup> The distinction is based on the relationship between the engagement in innovation activity and the perceived importance of constraints to innovation. Detering barriers prevent firms from engaging at all in innovation activities; revealed barriers are the obstacles that firms face during the innovative process (see Section 2 for a more detailed discussion).

Results show that different types of obstacle are perceived differently by firms of different ages. While a clear-cut negative relationship is detected between firm age and both the internal and external lack of financial resources, a less obvious pattern is found with respect to the other obstacles. Interestingly, young firms, on average, seem to be less sensitive to the lack of qualified personnel when they have to initiate an innovative project than when they are already engaged in innovation activities. Finally, mature incumbents appear to attach greater importance to obstacles related to market structure and demand than is the case of firms with less experience.

The rest of this paper is organised as follows. Section 2 reviews the theoretical and empirical literature examining barriers to innovation and forwards various hypotheses concerning the main research questions. Section 3 provides a detailed description of the dataset and some descriptive evidence. Section 4 presents the empirical strategy and discusses the main results. Section 5 concludes.

## **2. The literature**

### ***2.1 Barriers to innovation***

Traditionally, innovation and technological change have been identified as fundamental drivers of aggregate economic growth and development (Solow, 1956; Arrow 1962; Griliches, 1979). Within this context, most of the empirical literature based on innovation surveys has, in turn, examined the drivers of innovation activities across firms and sectors, while much less importance has been attached to factors that might impede or delay a firm's engagement in innovation.

Yet, within the emerging branch of innovation literature that has begun to turn its attention to the barriers to a firm's innovation activity, two distinct empirical approaches have been adopted. The first has centred its attention on the impact of what are primarily financial barriers on the propensity and intensity of a firm's innovation activity (see Mohnen and Rosa, 2001; Savignac, 2008; Segarra-Blasco et al., 2008; Blanchard et al., 2012; Pellegrino and Savona, 2013), while the second (and comparatively smaller stream in the literature) has focused its attention on analysing firm and market characteristics that can affect a firm's perception of the importance of different types of barrier (Galia and Legros, 2004; Iammarino et al., 2009; D'Este et al., 2012; Hölzl and Janger, 2013, 2014; D'Este et al., 2014). Here, we seek to contribute to this latter approach and, to this end, the rest of this section examines methodological and conceptual aspects that are crucial to the empirical investigation of the impact of a firm's assessment of the barriers to innovation.

Most empirical studies of innovation barriers report a positive correlation between engagement in innovation and the perception of these barriers. Different explanations have been forwarded to justify this somewhat counterintuitive result. Some authors, for example, interpret this positive link as a signal of a firm's ability to overcome the obstacles to innovation (see Baldwin and Lin, 2002; Galia and Legros, 2004; Mohnen and Röller 2005). In other words, the more innovative a firm is, the more aware it is likely to be of the obstacles to innovation and so the better equipped it will be to overcome them. Recently, Savignac, (2008) has offered a more convincing theory, claiming that the positive spurious correlation between innovation intensity and perception of obstacles can be attributed to an inappropriate selection of the sample used for the empirical analysis. The French scholar suggests restricting analyses to the cohort of so-called 'potential innovators', i.e., those firms that invest in innovation activity (regardless of their success)

and those that do not invest but have experienced barriers to innovation. As demonstrated by later studies (see D'Este et al., 2012; Blanchard et al., 2012; Pellegrino and Savona., 2013), this selection procedure is fundamental to ensure consistent results.

Closely related to this concept of potential innovators is the crucial distinction that has been drawn between *revealed* and *deterring* barriers. This important characterisation, first proposed by D'Este et al. (2012), is based on an analysis of the relationship between a firm's engagement in innovation and its assessment of the barriers to innovation. The authors distinguish two types of firm in their sample of potential innovators: those deterred from engaging in innovation activities and those experiencing barriers that obstruct their undertaking innovative projects. In the case of the former, potential innovators may abandon their efforts to innovate as the barriers are insurmountable. Among these obstacles, a key role is played by financial constraints (both internal and external funds), as well as by the lack of qualified personnel or information on technologies and on the market, and uncertainty or lack of demand for innovative products. However, all these factors, apart from preventing a firm from engaging in innovation, can also play a significant role in slowing down its innovative process. In other words, for some firms, the perception of obstacles to innovation may be sufficient to impede/delay (while not prevent altogether) their engagement in innovation. In line with D'Este et al. (2012), such firms can be characterised as experiencing *revealed* barriers to innovation, because their impact is felt once the firm has begun its innovation activity.

Most of the empirical literature to-date however has failed to identify properly the sample of potential innovators and to disentangle the deterring from the revealed barriers to innovation. And as recent contributions stress (see D'Este et al., 2012; Pellegrino and Savona, 2013), the conceptual and empirical characterisation of the different types of

barrier to innovation and, consequently, of different firm types is fundamental in terms of the broader policy implications. As such, policy interventions might seek to enlarge the population of innovative-active firms (innovation-widening), by removing or alleviating obstacles that prevent firms from engaging in innovation activities; or, alternatively, they might support the existing population of innovative-active firms (innovation-deepening), by removing or alleviating obstacles that prevent the successful completion of innovation projects and hinder adequate returns to innovation investments.

In this paper, building upon D'Este et al. (2012, 2014) and by distinguishing between revealed and deterring barriers, we apply these conceptual frameworks to an examination of the relationship between firm age and a firm's perception of different obstacles to innovation.

## ***2.2 Firm age and barriers to innovation***

As discussed in the introduction, no previous studies provide evidence of the impact of age on a firm's perception of the barriers to innovation. Here, our goal is to go some way to filling this gap in the literature by empirically analysing this particular relationship.

Before moving to the empirical part of the paper, by drawing of different stream of organizational and evolutionary literature, we articulate a theoretical framework useful to characterize the nature of the relationship between age and the multiple types of barriers to innovation.

In a seminal study, Stinchcombe (1965) proposed the influential concept of 'liability of newness', according to which young organizations, for their inherent characteristics, may be in a position of disadvantage with respect to their older counterparts. A critical point of this theory refers to the low level of legitimacy and

reputation typical of young organizations. As suggested by the author (*ibidem*, p. 149), this type of companies needs to learn about the environment in which they operate and gaining legitimacy in the eyes of resource providers, such as finance providers, customers, suppliers and employees (see also Aldrich, 1999; Starr and Macmillan, 1990; Stinchcombe; Stuart, 2000). The lack of legitimacy and reputation in the financial market is particularly relevant for our discussion. Indeed, newly established or young firms, in contrast with more mature incumbents, cannot rely on their having developed a good reputation on the financial markets, since they will only have built a short-term relationship with the banks and their sources of collateral will be limited (see Petersen and Rajan, 1995; Martinelli, 1997; Berger and Udell, 2002). Moreover, more experienced firms are more likely to be able to rely on their own internal funds, given that they will have accumulated more profits over the years. Accordingly, one can expect young firms to be more sensitive than their more mature counterparts to cost factors when seeking to initiate a new innovation project and when wanting to devote more financial resources to an existing one. The empirical literature generally supports these theoretical expectations. Reid (2003), for example, suggests the existence of an inverse relationship between a firm's age and its debt ratio, while Fluck et al. (1997) show that the ratio between external and total finance tends to fall once a firm has been operating for more than seven or eight years. Schneider and Veuglers (2009) attempted to characterise young, highly innovative companies (firms younger than 6 years and specialising in R&D) and found that such firms appear to perceive the internal and external costs of innovation as being more important than do their mature counterparts.

As suggested by Baum and Oliver (1992), the lack of reputation and legitimacy may be a relevant aspect also in determining the so called 'liability of unconnectedness', which refers to the difficulties of establishing network relationships and which may

produce an uneven allocation of the benefits of an alliance in favour of the more established partner (Hill, 1990). Baum and Silverman (2004) stress the important role played by a good firm's network position, through which companies may acquire more valuable information about other organizations and their resources, and consequently enlarging the possible choices of partners. Indeed, for alliances to be formed in a network, firms make a first evaluation of each possible partner based on its observed reputation and credibility. The perceived credibility and reputation of a firm is based on its prior achievements, which for newly established or young firms are scarce by definition (see Powell et al., 1996). Accordingly, it would be reasonable to expect a negative relationship between firm age and obstacles related to the difficulties in finding partners for innovation.

A firm's skill endowment is deemed an important driver of its innovative activity (see Leiponen, 2005; Piva and Vivarelli, 2009) and a skilled workforce is a vital resource for firms dealing with complex activities (including innovation, in general, and R&D, in particular). Cohen and Levinthal (1989, 1990) claim that highly qualified employees are a firm's primary vehicle for absorbing external knowledge and, consequently, for enhancing its absorptive capacity. Florida (2002) argues that a firm's skill base should not be confined to engineering and scientific qualifications, but should incorporate a much wider range of talent (including management, legal and design skills) as each can make a key contribution to creative problem solving. Here, also, it might be expected that young firms will face more obstacles when seeking to hire highly qualified (and costly) personnel. Yet, young firms, because of their greater financial constraints and smaller size, are more likely to turn to alternative sources of innovation (such as acquisition of machinery and equipment and outsourced R&D, see Pellegrino et al., 2012), making the contribution of highly skilled workers less relevant. A different point of view is instead

provided by Baron et al. (2002), which argued that young firms may actually have better access to high-skilled employees because of the dynamic and vibrant work environment in which they operate as compared to their mature counterparts (see also Hannan et al., 1996). Along the same lines, companies with considerable market experience, characterised by well-established organisational routines and production practices, may experience difficulties in adapting and modifying their skills and expertise to change (Nelson and Winter, 1982; Hannan and Freeman, 1984), especially when seeking to initiate an innovative project. Following the same line of reasoning, this type of companies may also be at a disadvantage when having to identify new technological opportunities. As suggested by Cohen and Levinthal (1990) the ability of a firm to use its accumulated knowledge base for further innovation is extremely dependent upon the patterns of communication and distribution of knowledge within the firms. Thus if aging leads to increased rigidity of communication pattern, firms may have more difficulties in recognising, assimilating and exploiting information vital for the implementation of innovative processes (see also Henderson and Clark, 1990).

The inertia and organizational rigidity that characterise more experienced firms might also limit their capacity to react swiftly to changes in demand conditions, in turn making them more sensitive to market barrier factors, especially uncertain demand for innovative goods or services (Nelson and Winter, 1982). On the contrary, young firms, which operate in contexts characterised by high level of uncertainty, are generally more inclined to explore new ideas and technologies and consequently less risk adverse than their mature counterparts (Audretsch, 1995; Coad et al., 2013). However, according to the Schumpeterian tradition (see Schumpeter, 1942; Acs and Audretsch, 1988 and 1990) less experienced companies can be expected to be less able to exploit the benefits deriving

from market concentration and appropriability conditions and, thus, face greater barriers to innovation in markets dominated by established companies.

It is evident from this short discussion that the relationship between firm age and a firm's perception of obstacles to innovation is complex and that it is difficult to hypothesise a clear functional form that captures the exact nature of this relationship. As we see in Section 4, the results of our empirical analyses lend considerable support to these propositions.

### **3. Data**

In this study we draw on firm level data from the Spanish Technological Innovation Panel (henceforth PITEC). PITEC is the result of the joint efforts of the Spanish National Statistics Institute (INE), the Spanish Foundation for Science and Technology (FECYT), and the Foundation for Technical Innovation (COTEC). The data are collected following the Oslo Manual's guidelines (OECD, 1997) and can therefore be considered a Community Innovation Survey or CIS-type dataset. However, one characteristic that distinguishes PITEC from most CIS-type datasets is its panel data structure. Indeed, since 2003, data have been collected systematically, providing highly representative information about the population of Spanish manufacturing and service firms over various time periods. This characteristic represents an important methodological advantage as it allows us to control for unobserved heterogeneity.

In addition to detailed information about a firm's general characteristics (including, main industry of affiliation, turnover, employment, founding year, etc.), PITEC collects data related to a large set of innovation-related aspects: assessments of

engagement in innovation activity, economic and non-economic measures of the effects of innovation, self-reported evaluations of factors hampering or fostering innovation, participation in cooperative innovation activities and complementary innovation activities such as organisational change and marketing<sup>2</sup>.

In this paper, we draw on 8 consecutive waves from 2004 to 2011<sup>3</sup>. The initial sample, comprising 100,016 annual observations (around 12,000 firms every year), was selected according to the following procedure. First, we excluded those firms operating in the primary (1,628 observations), construction (3,914 observations), utilities (720 observations) and sewage/refuse disposal (318 observations) sectors and those firms engaged in processes of mergers or acquisitions (8,543 observations)<sup>4</sup>. Additionally, given the presence of missing values for the variables employed in the empirical specification (see Section 4.2.1), a further 15,289 observations were ruled out.

In line with the discussion presented above (Section 2), we retained in our sample only the ‘Potential Innovators’. In other words, we excluded those firms that, by inference, can be defined as ‘Non innovation oriented firms’. More specifically, we excluded 6,943 observations referring to firms that did not engage in any of the seven innovation activities specified in the questionnaire (see Table A1 in the Appendix) and which, at the same time, did not experience any barriers to innovation during the period

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2 Recent studies using this dataset include López-García et al. (2013), D’Este et al. (2014) and Segarra and Teruel (2014).

3 Following the design of the CIS questionnaire, PITEC data is collected retrospectively over a three year period. This specific characteristic of the dataset may cast doubts about the accuracy of the longitudinal information we use for the empirical analysis. Accordingly, as a robustness check, we estimate equation (1) using a restricted dataset obtained by considering exclusively 3 (not overlapped) waves, namely 2011, 2008 and 2006. The results – available upon request – are not qualitatively different from those reported in Table 5, 6 and 7.

4 These firms were eliminated from the sample in the years following the merger or acquisition.

under analysis (see Table A2 in the Appendix) <sup>5,6</sup>. Thus, we ended up with a sample comprising 62,661 firm-year observations.

Table 1 present the composition of this unbalanced panel taking into account the number of years a given firms is observed. As can be seen, more than 40% of the firms is observed over the entire sample period, 23% for 7 years, and only a marginal percentage (11,83%) for less than 4 years.

**< INSERT TABLE 1 >**

In line with our main research questions, among the potential innovators, we need to distinguish those firms that face deterring barriers from those that face revealed barriers to innovation. Following D'Este et al. (2012, 2014), the former can be identified as those companies that declare no engagement in innovation activity and yet to having faced at least one barrier item, while the latter comprises those firms that have faced at least one barrier item and which claim involvement in at least one of the seven innovation activities<sup>7</sup>. Thus, within the total sample, we identify 43,046 observations referring to firms facing revealed barriers and 18,140 observations referring to firms facing deterring barriers to innovation activity<sup>8</sup>.

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5 As the proposed definition suggests, potential innovators are firms that are willing to innovate, and that either manage to engage in one of the seven innovation activities or fail in their attempt to do so, supposedly due to the effect (among other factors) of the obstacles to innovation they encounter.

6 One may be concerned about the potential problem of sample selection caused by this exclusion procedure, particularly if the age distribution of the sample of not innovation oriented firms considerably differs from that one of the selected sample. However, this does not seem to be case in this study. Indeed, the average age of the sample of not innovation oriented firms is 25.33 (standard deviation 17.16) slightly higher than that one of the selected sample (24.93 with a standard deviation of 20.20).

7 Note that the only difference between the two groups concerns the respective degree of engagement in innovation activity.

8 These figures do not, however, add up to 62,661. Indeed, there are 1,457 firm-year observations that declare involvement in innovation activity but which did not experience any kind of barrier to innovation. Since a firm's innovation activity is central to this paper, we decided not to exclude these firms and to perform our empirical analyses considering both the total sample and the two sub-samples of firms.

## 4. Empirical analysis

### *4.1 Firms' perception of barriers to innovation along their life course*

In this section we provide preliminary univariate evidence for our main research question. Specifically, we use lowess smoothing techniques to obtain non-parametric estimations of the impact of age on a firm's perception of the various obstacles to innovation. Following the PITEC questionnaire design (see Table A1 in the Appendix), we study this relationship by considering three different barrier factors: 1) cost; 2) knowledge; and 3) market, and a total of nine barrier items. However, we focus our attention on just seven of these after excluding the cost factor of 'direct innovation costs too high', and by collapsing two knowledge barrier items into one, namely 'lack of information on technology' and 'lack of information on markets'<sup>9</sup>.

Before discussing the results of the non-parametric analysis, it is useful to report some general insights from the firms' evaluation of barriers to innovation. Table 2 shows the proportion of firms (full sample and the two sub-samples) assessing each of the seven barrier items as highly important. In the case of the total sample, cost factors are, as expected, the category that presents the highest percentages (always above 30%), while market factors are, in general, deemed more important than knowledge factors. As for the two sub-samples, the proportion of firms facing deterring barriers that assess the obstacles to innovation as highly important is always higher than those facing revealed barriers. In line with the evidence provided in D'Este (2012), these figures confirm the importance of taking into account the different nature of the barriers firms face. This would appear to

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<sup>9</sup> We opted to exclude the cost barrier item as it is redundant when considered alongside the other two cost barriers. The same rationale applies to the decision to consider the variables related to lack of information on technology and market jointly. In particular, these two variables appear to be highly correlated (0.85)

be particularly true for the following barrier items: ‘lack of internal funds’, ‘lack of qualified personnel’ and ‘uncertain demand for innovative products’.

**< INSERT TABLE 2 >**

Figures A1 to A3 in the Appendix illustrate the results of the lowest estimations obtained when considering the total sample of firms. As can be seen, the only factor that shows a clear overall linear trend is the cost factor, with the two barrier items (lack of internal and external funds) showing a monotonic decreasing relationship with firm age. The knowledge factor presents a less clear-cut pattern. Of the three barrier items considered, only one (‘difficulties in finding partners for innovation’) presents a negative (albeit not particularly marked) relationship with age. In the case of the market factors, a U-shaped relationship is detected for the item ‘market dominated by established firms’, with a decreasing relationship being recorded until around a firm’s sixtieth year and with mature firms appearing particularly sensitive to this barrier item. This trend is not, however, observed for the second market item ‘uncertain demand for innovative products’, where the curve describing its relationship with age is practically flat.

## ***4.2 Impact of age on firm’s perception of barriers to innovation: a multivariate analysis***

### ***4.2.1 Variables and econometric methodology***

In the two subsections that follow, we investigate further the preliminary evidence discussed above by undertaking multivariate analyses that allow us to determine the impact of firm age on the firm’s perception of obstacles to innovation after controlling for observed and unobserved factors.

For the univariate analysis, we consider seven binary indicators as dependent variables, each identifying firms that assess the selected cost, knowledge and market barriers as highly important. Each of these factors is regressed on a set of control variables and on a set of dummy variables identifying different age classes. Specifically, in selecting the different age thresholds, we sought to represent the different phases in the firm's life course while avoiding any great disparities (in terms of the number of firms) across the different age categories. Thus, we selected the following five age classes: from 1 to 8 years, from 9 to 20 years, from 21 to 30 years, from 31 to 50 years, and more than 51 years<sup>10</sup>.

Table 3 shows the composition of the different samples by age category, while Figure A4 in the appendix shows the proportion of firms that assess the seven obstacles as highly important by age category and by sub-sample (i.e., revealed vs. deterring). In line with the results from the non-parametric estimations, a clear negative relationship is found between firm age and a firm's perception of cost barriers to innovation, with a notable difference being recorded between the percentages reported by the first and last age categories. In contrast, the differences between the five age classes are much less marked for the other two barrier factors. Interestingly, and in line with the theoretical discussion previously proposed (see Section 2.2), in the case of firms facing deterring barriers, the market factor 'uncertain demand for innovative goods' appears to be more relevant for more experienced firms than for those in the early stages of their life.

**< INSERT TABLE 3 >**

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<sup>10</sup> In selecting the cut-off for the first age class we referred to recent contributions that, in order to identify and explore the innovative peculiarities of young companies, use a threshold of 8 years (see Pellegrino et al., 2012, and García-Quevedo et al., 2014; see also Van Praag and Versloot, 2007). Robustness checks were performed assuming alternative thresholds or different age groups. Results – available upon request – are consistent (both in terms of the sign and statistical significance of the estimated coefficients) with those discussed in Section 4.2.2.

Apart from these five age classes, we consider other control variables that may affect the firm's perception of the different obstacles to innovation. The choice of these additional controls was made taking into account both the information obtained from the questionnaire and the main insights provided in the literature.

First, we control for firm size by taking the natural logarithm of a firm's total number of employees. Previous evidence shows that larger firms are less sensitive to barriers to innovation than are their smaller counterparts (see D'Este et al., 2012; D'Este et al., 2014). Indeed, large companies are able to rely more fully on internal funds, enjoy easy access to external funds and a high level of appropriability and are able to exploit economies of scale; all of which are important in alleviating the negative impact of obstacles to innovation (Schoonhoven et al., 1990; Katila and Shane, 2005). Since, these same favourable effects may apply to firms that form part of an industrial group (see Mairesse and Mohnen, 2002), we include a variable that identifies such enterprises.

Second, we control for the degree of internationalisation achieved by a firm by considering a variable that is equal to 1 if the firm's most significant destination market is international and 0 otherwise. As D'Este et al. (2012) show firms operating in foreign countries may be less affected by knowledge-related obstacles to innovation as a result of the so-called learning-by-exporting process (see Clerides et al., 1998), but more affected by market-related obstacles as they are exposed to fiercer competition.

We also control for appropriability conditions, by identifying those firms that make use of patents and informal methods to protect their innovations, and for the possible beneficial effects of public policy instruments, by singling out those companies that have received public subsidies for their innovation activity.

Finally in order to check for possible macroeconomic trends and for sectoral peculiarities we also consider a set of industry and year dummies.

Table 4 shows the descriptive statistics (mean and standard deviation) for the above variables for the pooled sample and for the two sub-samples of firms facing deterring or revealed barriers, respectively. As expected, the two groups of firms present some notable differences. Specifically, firms that have experienced revealed obstacles are much more oriented to foreign markets, more likely to use formal and informal methods of protection and present a higher probability of receiving public subsidies than firms that have experienced deterring barriers. All in all, these descriptive statistics further corroborate the importance of taking into account the different nature of the barriers firms face.

**< INSERT TABLE 4 >**

In order to verify how the above variables might affect a firm's assessment of the barriers to innovation we estimate the following equation:

$$Y_{jit} = I [\beta'X_{it} + \sum \delta'_k Age_{kit} + c_i + \varepsilon_{it} > 0] \quad (1)$$

where  $I[\cdot]$  is an indicator function that takes a value of 1 if the argument in brackets is true, and zero otherwise,  $Y_{jit}$  ( $j = 1, \dots, 7$ ) denotes the seven binary obstacle variables,  $X_{it}$  is the vector of control variables described above,  $Age_{kit}$  ( $k = 1, \dots, 5$ ) represents the set of dummies identifying the five age categories,  $c_i$  is the unobserved time-invariant individual effect, and  $\varepsilon_{it}$  an idiosyncratic error term.

Equation (1) is estimated by applying a standard random effect probit model<sup>11</sup>. As is standard, to avoid the dummy trap problem associated with the inclusion of the set of age dummies a reference category should be dropped, its effect on the dependent variables being captured by the intercept. However, in the case of more than one set of mutually exclusive dummies<sup>12</sup>, the intercept captures the aggregate effect of all the excluded dummy variables, so that the separate effects of the various excluded dummy variables cannot be estimated. Further, the results of the estimations are sensitive to the choice of the ‘left-out’ reference category. Taking into account that the effect of firm age is central to our analysis, to deal with these problems we use the well-known methodology proposed by Suits (1984). According to this simple approach, once the equation has been estimated, a value  $k$  can be chosen and added to each of the coefficients of the age dummies and subtracted from the constant term (including of course the zero coefficient of the ‘left-out’ industry)<sup>13</sup>. The effect of each age category can thus be interpreted as a deviation from the average age effects.

#### **4.2.2 Results**

Tables 5, 6 and 7 show the econometric results of the random effect probit model for the total sample and the two sub-samples of firms experiencing deterring and revealed barriers to innovation<sup>14</sup>.

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11 Alternatively we could have considered a fixed effect specification. However, due to the small degree of variation in the dependent variables, the use of this econometric model would have notably reduced the sample of firms considered for analysis. Indeed, on average, a considerable percentage of firms experiencing any of the seven obstacles to innovation considered in any year  $t$ , retain this status in  $t+1$ . In particular, this percentage ranges from 68% in the case of the obstacle barrier item labelled ‘uncertain demand for innovative goods/services’ to 78% in the case of the obstacle ‘Lack of available finance within the firm’. Therefore, we preferred to have a larger (and more representative) sample and implement random effects only.

12 The econometric specification includes a set of eight time and 34 industry dummies.

13 The value  $k$  is chosen so that the new age dummy coefficients average zero. Estimating the equation with all the age dummies and this restriction would produce identical statistical properties as the original estimation (see Suits, 1984, for more details).

14 As a robustness check, in order to control for any correlation among the error terms of the regressors for the different obstacle variables we implement a multivariate probit regression. The wald test reject the null hypothesis of

The most obvious outcome reported in Table 5 (total sample) is the negative relationship between firm age and a firm's assessment of the cost factor. Indeed, in line with the discussion above (see Section 2.2), young firms (up to 20 years) report the lack of internal and external financial resources a significant obstruction to their innovative activity, whereas firms in the last three age categories appear to be considerably less hampered by these barrier items. This evidence is even more pronounced if we look at the magnitude of the coefficients of the 5 age categories, which show a clear-cut monotonic decrease. In particular, it is worth noticing the considerable difference in magnitude between the coefficients of the first and the second age class, with the former being four times greater than the latter. Interestingly enough, comparing the results of table 6 and 7, it emerged that the youngest group of firms are particularly sensitive to the deterring *vs* revealed effect of the cost obstacles. Indeed, although always highly significant, the coefficients of the first age class (1 to 8 years) appear to be substantially higher in magnitude for the subsample of firms experiencing deterring barriers to innovation. Besides demonstrating the importance of distinguishing between different groups of firms when analysing barriers to innovation, these results confirm our hypothesis that newly created firms are especially hampered in their efforts to innovate by a lack of internal and external funds.

An interesting relationship is also found between firm age and the barrier item labelled 'lack of qualified personnel'. The parameter estimates in column 3 of Table 6 show that this knowledge factor is significantly less important in deterring engagement in innovation among those firms in the early stages of their life (1 to 8 years) than it is

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independence of the equations. However, the results, available upon request, are in line with those reported in Tables 5, 6 and 7.

among those firms with ages around the sample mean. In contrast, the only category of firms for which the lack of qualified personnel appears to be a relevant deterrent to their innovative efforts are those in the last age category (more than 51 years). In this case, in fact, the coefficient of this variable appears to be positive significant and considerably high in magnitude. In line with the theoretical discussion put forward in Section 2.2, this result suggests that mature firms (typically characterised by well-established organisational and production practices) are at a disadvantage when it comes to reorganising themselves and adopting the skills and expertise required to initiate a new innovative project. New-born and young companies, on the other hand, that enter the market with an innovative idea appear to be well-equipped in terms of skilled workers and human capital. Different results, however, are detected among the sample of firms facing revealed barriers to innovation. In this case, while the parameter for firms in business for more than 51 years is no longer significant, a positive (albeit barely significant) association between the youngest firms (1 to 8 years) and the barrier item 'lack of qualified personnel' is detected.

In the case of the two market factors, the only notable result is the highly significant association between firms in the last age category facing revealed barriers and the barrier item labelled 'uncertain demand for innovative goods/services'. In particular, the high magnitude of the coefficient clearly demonstrates how relevant is the impact of type of obstacles in hampering the innovative activity of the most experienced firms. Once again, this evidence corroborate the proposed theoretical framework: more experienced firms, being characterised by an high level of organizational rigidity and inertia, are less capable than their younger counterparts to react swiftly to changes in demand conditions and to operate efficiently in context characterized by an high level of uncertainty.

As for the other firm characteristics, large firms and firms belonging to an industrial group appear, as expected, to perceive the various obstacles to innovation as being less relevant than do their counterparts. In addition, the 'subsidy' variable is mainly positive and significantly correlated with a greater degree of importance being attached to barriers to innovation.

No effects are detected among firms facing deterring barriers in relation to appropriability conditions. But both patent and informal protection appear to be positively associated with higher levels of relevance of the various obstacle items in the case of firms facing revealed barriers.

Finally, firms with a greater foreign market orientation seem not to suffer so greatly the effects of a 'lack of qualified personnel', indicating perhaps the beneficial effects of learning from direct experience of the exporting mechanism. Interestingly, these firms seem to be more strongly affected than their counterparts by the lack of external funds.

**< INSERT TABLES 5, 6 AND 7 >**

## **5. Conclusions**

The main objective of this article was to empirically investigate the impact of firm age on the perception of obstacles to innovation. By building on a theoretical framework first proposed by D'Este et al. (2012), this specific relationship has been investigated by distinguishing between firms that face either revealed or deterring barriers. In so doing, we have performed both univariate and multivariate analyses of a large representative sample of Spanish manufacturing and services firms for the period 2004-2011.

Our results, in addition to confirming the need to distinguish between deterring and revealed barriers, show that different obstacle types are perceived differently by firms of different ages.

First, a clear-cut negative relationship has been identified between firm age and a firm's assessment of both the internal and external shortage of financial resources, especially in the group of firms facing revealed barriers to innovation. As such, this result confirms the importance of policy interventions that seek to finance the innovative projects of newly created firms, but at the same time it points to the need for policy schemes that can financially sustain firms already engaged in innovation activity and that have recently entered the market (less than 20 years ago). In particular, specific attention should be devoted to programmes geared towards the promotion of remarkably risky projects conducted by young innovative companies. Public authorities should spur the creation and diffusion of some form of private financial intermediation, most notably Venture Capitalists. The complementarity between private and public risk financing is a particularly important objective for policy makers to consider as our results have shown the importance of access to finance hampering young firm's innovative activities. Such

mixed interventions could be desirable in order to render the policy instruments more effective and to avoid usual deadweight and substitution effects.

Another result stemming from the econometric analysis, points to some dissimilarities in the level of perception of the knowledge obstacle ‘lack of qualified personnel’ of firms of different ages. In this respect, firms in the early stages of their life seem to be less sensitive to this type of obstacle when having to initiate an innovative project, but more markedly affected by an obstacle of this type when already engaged in innovation activities. In contrast, mature firms are significantly affected in their attempts to engage in innovation activity by a lack of qualified personnel. It would seem that this outcome might be linked to the organisational rigidity and structured routines that come to characterise incumbents and which might lead to a certain degree of resistance when having to adjust staff skills and expertise.

These findings clearly suggest the need to contrast different systemic failures associated with deficiency in terms of education, training and human capital that affect different types of firms at different stages of their life. Accordingly, along with long-term structural policies aimed at improving the educational level of a country and its higher education system, more targeted policies should be set in order to address specific issues. This includes, for example, support and tax incentives for hiring high qualified personnel to be involved in specific innovative projects and policies aimed at improving the interactions between firms and public research centres. In accordance with our results, such programmes should be designed to sustain in particular new born innovative companies and firms at the mature stage of their life that want to start a new innovative project.

Finally, from the empirical evidence, it seems that mature firms attach greater importance to obstacles related to market structure and demand than is the case of firms with less experience. These findings seem to confirm the relevance of demand as a crucial incentive to innovative, specifically for established firms. In this respect, concrete policies may be put forward in order to boost consumption and enhancing market's reaction to the introduction of new products. The range of instruments that can be implemented in order to reach this goal is ample. Along with the different types of the traditional public procurement schemes, mainly directed at encouraging a broader demand, more focused programmes that are specifically oriented towards private demand should be put into practice. Government or public institutions could, for example, promote price-based measures in the form of demand subsidies and specific policies aimed at directly reducing prices of certain innovative products. Along the same lines, labelling and information campaigns could be implemented in order to enhance the awareness for an innovation and security for its use, in turn accelerating its diffusion. Other possible measures could go in the directions of improving user involvement in innovation production (user-driven), or defining new functional requirements for products and services (such as market approval and recycling requirements). All these instruments may be central in ensuring markets for new goods and services for specific categories of firms.

Overall, the findings offered by this study appear to be quite relevant from an innovation policy perspective, as they allow the identification of the nature and the best timing of policy intervention and strategic decision in relation to the firm's life course. Indeed, the design of proper and effective policy instruments can be achieved only by identifying why and to what extent different type of companies are excluded from the "innovation arena". More specifically, policy makers might give more relevance to the enlargement of the population of innovative-active firms, by removing or alleviating

barriers that prevent firms from engaging in innovation activities; or strengthen the innovation capacity of the existing population of innovative active firms, by removing or attenuating obstacles that obstruct successful completion of innovation projects and adequate returns to innovation investments.

Future research should certainly look beyond the simple distinction that assigns firms to different age groups and explore more deeply the relationship between firm age and firm perception of obstacles to innovation. This might be tackled by employing non-parametric techniques, which would allow us to consider the entire age distribution without assigning any particular functional form to the relationship of interest. Furthermore, to complement the present findings, it would also be interesting to examine the impact the various obstacles to innovation have in hindering the innovation activity (on both the input and output sides) of firms of different ages.

Overall, the growing interest among policy makers and the paucity of contributions on the subjects call for more research into the nature, effects and determinants of barriers to innovation faced by firms and also for collecting more refined statistical information on these barriers.

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**Table 1. Composition of the panel**

Time obs.	N° of firms	%	% Cum.	N° of obs.
1	370	3.80	3.80	370
2	366	3.76	7.57	732
3	414	4.26	11.83	1242
4	533	5.48	17.31	2132
5	679	6.98	24.29	3395
6	938	9.65	33.93	5628
7	2,238	23.01	56.95	15,666
8	4,187	43.05	100	33,496
<b>Total</b>	<b>9,725</b>	<b>100</b>		<b>62,661</b>

**Table 2. Proportion of firms assessing obstacles to innovation as highly important**

	Total	Deterring	Revealed	Mean comp. test
Cost obst.(int.)	0.33	0.36	0.33	0.02*** (5.09)
Cost obst.(ext.)	0.32	0.31	0.33	-0.02*** (-5.09)
Know obst.(skill)	0.12	0.15	0.11	0.04*** (11.61)
Know obst.(info.)	0.13	0.13	0.12	0.01** (2.61)
Know obst.(coop.)	0.12	0.14	0.12	0.02*** (6.83)
Mkt. obst.(incum.)	0.20	0.21	0.20	0.01 (1.52)
Mkt. obst.(demand)	0.23	0.26	0.23	0.03*** (8.06)
Observations	62,661	18,140	43,046	

**Table 3. Descriptive statistics (mean, sd) for the pooled sample and for the two sub-samples**

	Total sample		Deterring		Revealed	
	Mean	SD	Mean	SD	Mean	SD
Foreign markets	0.63	0.48	0.48	0.50	0.70	0.46
Industrial group	0.36	0.48	0.31	0.46	0.38	0.48
Informal protection	0.24	0.42	0.11	0.31	0.29	0.46
Patent	0.12	0.33	0.02	0.14	0.17	0.38
ln(Size)	4.09	1.56	4.05	1.67	4.08	1.50
Subsidy	0.36	0.48	0.05	0.22	0.49	0.50
Observations	62,661		18,140		43,046	

**Table 4. Composition of the different samples by age category**

Firm age (years)	Total sample		Deterring		Revealed	
	Freq.	%	Freq.	%	Freq.	%
1-8	7,844	12.52	1,544	8.51	6,124	14.23
9-20	24,359	38.87	7,774	42.86	16,061	37.31
21-30	14,132	22.55	4,654	25.66	9,147	21.25
31-50	11,420	18.23	3,046	16.79	8,084	18.78
>51	4,906	7.83	1,122	6.19	3,630	8.43
Total	62,661	100	18,140	100	43,046	100

**Table 5. Probit random effect estimations for the whole sample**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Cost.(int.)	Cost.(ext.)	Know.(skill)	Know.(info)	Know.(coop)	Mkt.(incum.)	Mkt.(uncer.)
1-8	0.258*** (0.031)	0.216*** (0.030)	0.031 (0.039)	0.042 (0.038)	0.049 (0.035)	0.051 (0.034)	-0.026 (0.031)
9-20	0.065*** (0.021)	0.054*** (0.020)	-0.007 (0.026)	0.043 (0.026)	-0.015 (0.024)	-0.009 (0.023)	-0.038 (0.020)
21-30	-0.084*** (0.023)	-0.069*** (0.022)	0.016 (0.029)	0.042 (0.028)	-0.013 (0.027)	-0.017 (0.025)	-0.020 (0.022)
31-50	-0.132*** (0.029)	-0.088*** (0.028)	-0.040 (0.035)	-0.059* (0.035)	-0.005 (0.033)	-0.047 (0.031)	-0.012 (0.027)
>51	-0.106*** (0.047)	-0.114*** (0.045)	-0.000 (0.057)	-0.068 (0.056)	-0.017 (0.052)	0.022 (0.050)	0.097** (0.044)
Foreign markets	0.039 (0.025)	0.100*** (0.025)	-0.105*** (0.032)	-0.014 (0.031)	-0.034 (0.029)	0.025 (0.028)	0.046* (0.025)
Industrial group	-0.232*** (0.029)	-0.218*** (0.028)	-0.268*** (0.036)	-0.187*** (0.035)	-0.259*** (0.033)	-0.171*** (0.031)	-0.140*** (0.028)
Informal protection	0.074*** (0.022)	0.107*** (0.022)	0.078*** (0.028)	0.076*** (0.028)	0.064** (0.027)	0.077*** (0.024)	0.087*** (0.022)
Patent	-0.001 (0.030)	0.066** (0.029)	-0.012 (0.039)	0.052 (0.037)	0.133*** (0.036)	0.018 (0.033)	0.009 (0.030)
ln(Size)	-0.247*** (0.012)	-0.184*** (0.011)	-0.085*** (0.014)	-0.107*** (0.014)	-0.138*** (0.013)	-0.107*** (0.012)	-0.133*** (0.011)
Subsidy	0.042** (0.020)	-0.052*** (0.019)	-0.032 (0.026)	0.103*** (0.025)	0.018 (0.024)	-0.006 (0.022)	0.021 (0.020)
Constant	0.161 (0.101)	-0.113 (0.095)	-1.779*** (0.122)	-1.743*** (0.120)	-1.193*** (0.106)	-1.293*** (0.110)	-1.278*** (0.099)
Year Dummies	Yes						
Sectoral Dummies	Yes						
Obs	62,661	62,661	62,661	62,661	62,661	62,661	62,661
lnL	-29,342.81	-29,902.75	-17,563.16	-17,922.78	-18,495.99	-24,000.03	-27,260.02
Sigma	1.389*** (0.019)	1.288*** (0.017)	1.396*** (0.025)	1.374*** (0.024)	1.222*** (0.022)	1.373*** (0.021)	1.214*** (0.017)
Rho	0.659***	0.624***	0.661***	0.654***	0.599***	0.653***	0.596***
LR test rho	16,051.335	14,465.923	9,457.699	9,564.103	7,779.108	13,021.988	11,610.164
p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

**Table 6. Probit random effect estimations for the sample of firms experiencing deterring barriers to innovation**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Cost.(int.)	Cost.(ext.)	Know.(skill)	Know.(info)	Know.(coop)	Mkt.(incum.)	Mkt.(uncer.)
1-8	0.349*** (0.059)	0.263*** (0.058)	-0.160** (0.072)	-0.049 (0.073)	-0.011 (0.069)	0.067 (0.063)	-0.061 (0.059)
9-20	0.030 (0.036)	0.037 (0.036)	-0.020 (0.044)	0.014 (0.045)	0.025 (0.042)	-0.072** (0.040)	-0.061* (0.036)
21-30	-0.088** (0.041)	-0.059 (0.040)	0.011 (0.049)	-0.007 (0.050)	0.016 (0.047)	-0.067 (0.044)	-0.002 (0.040)
31-50	-0.156*** (0.050)	-0.156*** (0.049)	-0.062 (0.060)	-0.032 (0.062)	-0.011 (0.058)	-0.055 (0.055)	0.059 (0.049)
>51	-0.136* (0.081)	-0.085 (0.079)	0.231*** (0.093)	0.074 (0.099)	-0.019 (0.094)	0.128 (0.086)	0.065 (0.078)
Foreign markets	0.035 (0.044)	0.096** (0.044)	-0.133** (0.054)	-0.085 (0.056)	-0.020 (0.051)	-0.035 (0.049)	0.097** (0.044)
Industrial group	-0.463*** (0.052)	-0.436*** (0.051)	-0.433*** (0.065)	-0.415*** (0.067)	-0.486*** (0.062)	-0.375*** (0.058)	-0.385*** (0.052)
Informal protection	0.007 (0.056)	0.056 (0.055)	-0.004 (0.069)	0.002 (0.071)	0.001 (0.068)	-0.056 (0.062)	0.087 (0.056)
Patent	-0.009 (0.111)	0.117 (0.108)	-0.299* (0.153)	-0.197 (0.151)	-0.058 (0.139)	-0.053 (0.129)	-0.216* (0.115)
ln(Size)	-0.211*** (0.018)	-0.159*** (0.017)	-0.067*** (0.021)	-0.089*** (0.022)	-0.119*** (0.020)	-0.058*** (0.019)	-0.134*** (0.018)
Subsidy	0.040 (0.068)	-0.117* (0.068)	0.008 (0.086)	0.195** (0.086)	0.051 (0.082)	0.068 (0.077)	0.082 (0.068)
Constant	0.304** (0.148)	-0.119*** (0.145)	-1.509*** (0.182)	-1.470*** (0.185)	-1.299*** (0.170)	-1.349*** (0.169)	-1.046*** (0.151)
Year Dummies	Yes						
Sectoral Dummies	Yes						
Obs	18,140	18,140	18,140	18,140	18,140	18,140	18,140
lnL	-9,141.34	-8,975.99	-6,009.37	-5,621.47	-6,042.00	-7,517.59	-8,593.64
Sigma	1.392*** (0.035)	1.329*** (0.034)	1.441*** (0.044)	1.454*** (0.047)	1.309*** (0.042)	1.435*** (0.040)	1.288*** (0.034)
Rho	0.659***	0.638***	0.675***	0.679***	0.631***	0.673***	0.624***
LR test rho	3,436.704	3,059.805	2,573.406	2,357.487	1,967.900	3,055.102	2,862.483
p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

**Table 7. Probit Random Effect estimations for the sample of firms experiencing revealed barriers to innovation**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Cost.(int.)	Cost.(ext.)	Know.(skill)	Know.(info)	Know.(coop)	Mkt.(incum.)	Mkt.(uncer.)
1-8	0.227*** (0.039)	0.200*** (0.037)	0.088* (0.047)	0.046 (0.046)	0.059 (0.043)	0.041 (0.041)	-0.031 (0.038)
9-20	0.106*** (0.027)	0.075*** (0.025)	-0.000 (0.033)	0.048 (0.032)	-0.028 (0.030)	-0.002 (0.029)	-0.029 (0.025)
21-30	-0.099*** (0.030)	-0.087*** (0.028)	0.037 (0.037)	0.080** (0.035)	-0.039 (0.034)	-0.043 (0.032)	-0.049* (0.028)
31-50	-0.144*** (0.037)	-0.071** (0.034)	-0.025 (0.044)	-0.082** (0.043)	0.000 (0.040)	-0.051 (0.039)	-0.028 (0.034)
>51	-0.090 (0.059)	-0.117** (0.055)	-0.099 (0.070)	-0.092 (0.068)	0.008 (0.063)	0.054 (0.060)	0.138*** (0.053)
Foreign markets	0.047 (0.033)	0.119*** (0.031)	-0.083** (0.041)	0.009 (0.040)	-0.013 (0.037)	0.061* (0.036)	0.027 (0.032)
Industrial group	-0.172*** (0.036)	-0.165*** (0.034)	-0.196*** (0.045)	-0.109** (0.043)	-0.192*** (0.041)	-0.102*** (0.039)	-0.064* (0.035)
Informal protection	0.082*** (0.026)	0.102*** (0.025)	0.116*** (0.034)	0.104*** (0.032)	0.085*** (0.031)	0.100*** (0.028)	0.091*** (0.026)
Patent	-0.009 (0.033)	0.068** (0.032)	0.011 (0.043)	0.089** (0.040)	0.156*** (0.039)	0.038 (0.036)	0.030 (0.033)
ln(Size)	-0.277*** (0.016)	-0.213*** (0.015)	-0.088*** (0.019)	-0.136*** (0.018)	-0.139*** (0.017)	-0.148*** (0.016)	-0.143*** (0.015)
Subsidy	0.065*** (0.024)	-0.062*** (0.023)	0.024 (0.031)	0.119*** (0.030)	0.075*** (0.028)	0.036 (0.026)	0.058** (0.024)
Constant	0.285** (0.132)	0.145 (0.123)	-2.000*** (0.160)	-1.882*** (0.158)	-1.215*** (0.136)	-1.222*** (0.143)	-1.400*** (0.130)
Year Dummies	Yes						
Sectoral Dummies	Yes						
Obs	43,046	43,046	43,046	43,046	43,046	43,046	43,046
lnL	-20,045.61	-20,699.53	-11,526.93	-12,275.36	-12,412.60	-16,362.09	-18,426.70
Sigma	1.553*** (0.026)	1.420*** (0.023)	1.515*** (0.033)	1.476*** (0.031)	1.321*** (0.028)	1.503*** (0.028)	1.320*** (0.023)
Rho	0.707***	0.669***	0.697***	0.686***	0.636***	0.693***	0.635***
LR test rho	11,728.104	10,727.916	6,294.189	6,699.466	5,376.083	9,419.943	8,321.637
p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

## Appendix

**Table A1. PITEC questionnaire: barriers to innovation**

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During the three years period ---- how important were the following factors as constraints to your innovation activities or influencing a decision to innovate?

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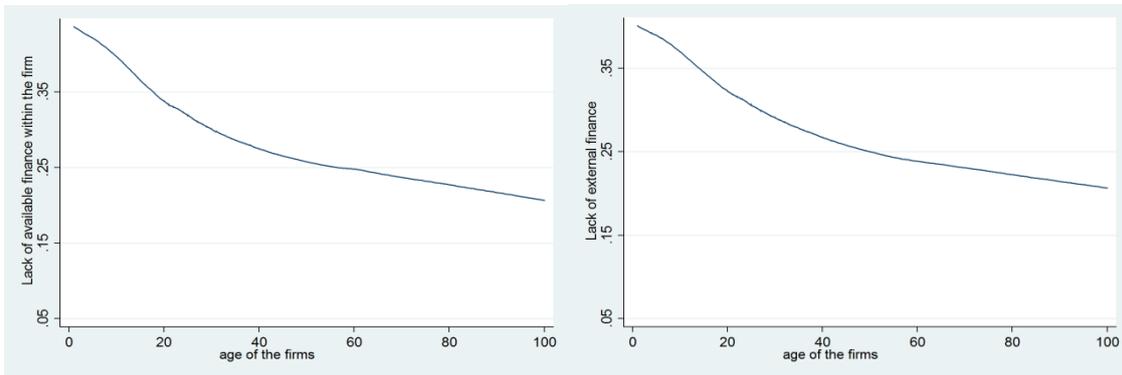
Barrier factors	Barrier items	Factors not exp.	Degree of importance		
			Low	Med	High
Cost factors	Lack of available finance within the firm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Lack of available finance from other organizations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Direct innovation costs too high	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Knowledge factors	Lack of qualified personnel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Lack of information on technology	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Lack of information on markets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Difficulties in finding partners for innovation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Market factors	Market dominated by established enterprises	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Uncertain demand for innovative goods or services				

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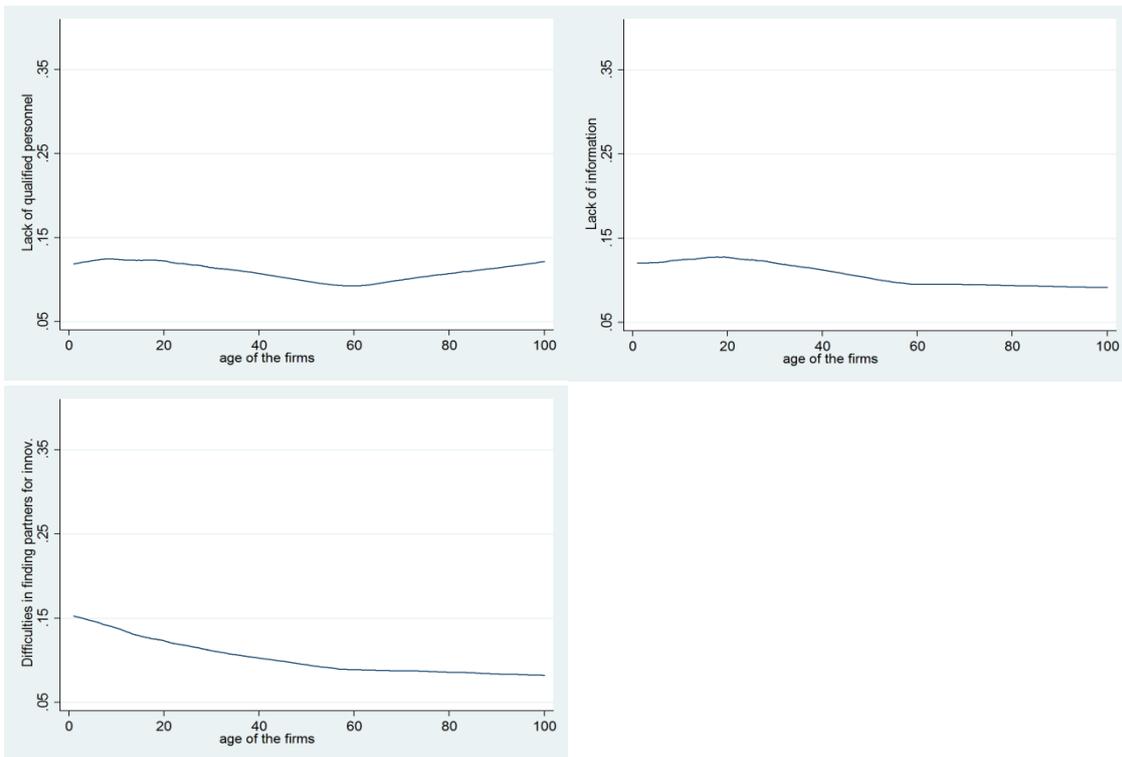
**Table A2. PITEC questionnaire: engagement in innovation activity**

<i>During the three-year period, did your enterprise engage in the following innovation activities?</i>	YES	NO
<b>Intramural (in-house) R&amp;D</b> Creative work undertaken within your enterprise on an occasional or regular basis to increase the stock of knowledge and its use to devise new and improved goods, services and processes.	<input type="checkbox"/>	<input type="checkbox"/>
<b>Acquisition of R&amp;D (extramural R&amp;D)</b> Same activities as above, but purchased by your enterprise and performed by other companies (including other enterprises within your group) or by public or private research organisations.	<input type="checkbox"/>	<input type="checkbox"/>
<b>Acquisition of machinery, equipment and software</b> Acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved goods, services, production processes, or delivery methods.	<input type="checkbox"/>	<input type="checkbox"/>
<b>Acquisition of external knowledge</b> Purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other enterprises or organisations.	<input type="checkbox"/>	<input type="checkbox"/>
<b>Training</b> Internal or external training for your personnel specifically for the development and/or introduction of innovations.	<input type="checkbox"/>	<input type="checkbox"/>
<b>All forms of design</b> Expenditure on design functions for the development or implementation of new or improved goods, services and processes. Expenditure on design in the R&D phase of product development should be excluded.	<input type="checkbox"/>	<input type="checkbox"/>
<b>Market introduction of innovations</b> Activities for the market preparation and introduction of new or significantly improved goods and services, including market research and launch advertising.	<input type="checkbox"/>	<input type="checkbox"/>

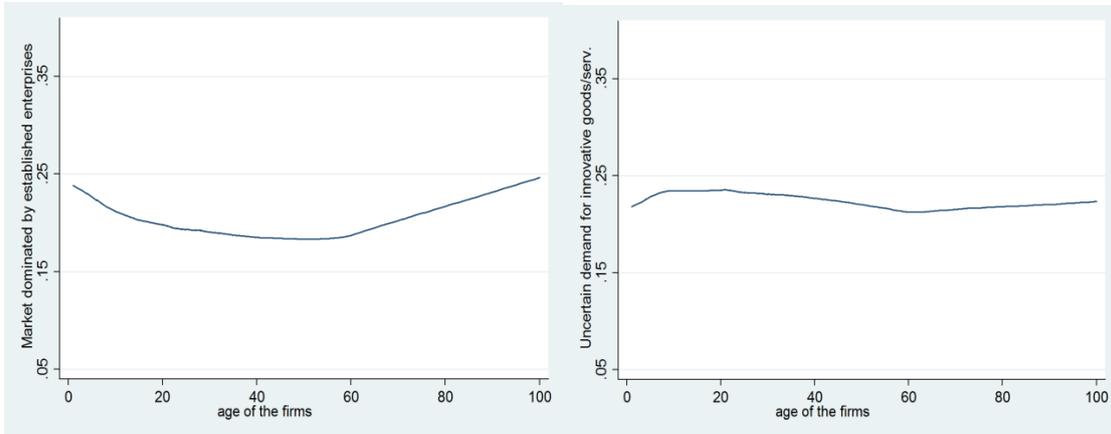
**Figure A1. Local linear smoothing (lowess): relationship between firm age and cost obstacles**



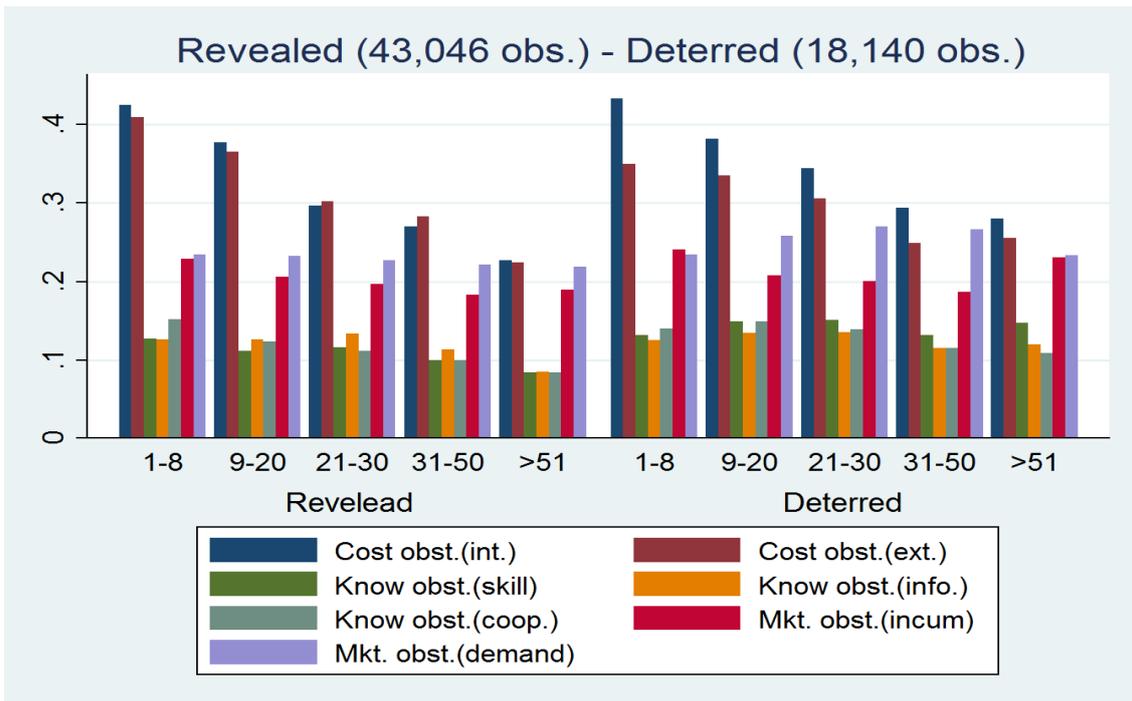
**Figure A2. Local linear smoothing (lowess): relationship between firm age and knowledge obstacles**



**Figure A3. Local linear smoothing (lowess): relationship between firm age and market obstacles**



**Figure A4. Average firm's perception of obstacles to innovation by age category (revealed and deterring samples)**



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