The perception of obstacles to innovation along the firm's life cycle

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Abstract

This work focuses on the role of firm's age in attenuating the negative impact of different types of obstacles that can hinder or slow down the firm's innovative activities. In line with some of the most recent contributions, we distinguish between firms facing deterring *vs* revealed barriers to innovation. Using a comprehensive panel of Spanish firms over the period 2004-2010, our empirical analysis shows that different types of obstacles are perceived differently by firms of different ages. Firstly, a clear-cut inverted U relationship between firm's age and firm's assessment of both internal and external lack of funds is identified. Furthermore, firms at the early stages of their life seem to be less sensitive to the effect of lack of qualified personnel when they have to start an innovative project, but more affected by this type of obstacles when they are already engaged in innovation activities. On the other hand, firms in the mature stages of their life are significantly obstructed in their attempt to engage in innovation activity by the lack of qualified personnel. Finally, mature incumbents firms appear to assign more importance to obstacles factors related to market and demand conditions than firms characterized by a lower degree of experience. These results may have important implication for innovation policy

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1. Introduction

According to the Schumpeterian tradition, firm's age, along with firm's size, is considered as a fundamental factor in determining and differentiating a firm's innovation ability, with the degree of novelty and imitation of innovation varying significantly over the life cycle. Indeed, the Austrian scholar in his two most notable works assigns a distinct but equally relevant role to small newly established and large mature firms. Following the so-called 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'. On the other hand, in Schumpeter Mark II (Schumpeter, 1942) the leading contribution in the innovation process is played by large and more experienced firms that, 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, much of the related empirical literature has systematically neglected to investigate the relationship between innovation and firm's age (relevant exceptions are the studies of Klepper, 1996 and Huergo and Jaumandreu, 2004, 2004a). More importantly, there is practically no evidence about the relationship between firm's evolution and the effects (relevance) that certain firms and market factors may have in hindering the firms' innovative process. Indeed, as it is usual within the innovation literature, much more emphasis is given to the analysis of the factors that determine the success of innovation than those that can cause patterns of failure.

Very recently, a new stream of literature has attempted to analyze the role of barriers to innovation in deterring or hampering the innovative effort of firms (Mohnen and Rosa, 2001; Galia and Legros, 2004; Segarra-Blasco et al., 2008; Savignac, 2008)

and give insights about the factors affecting the firm's perception of innovation barriers (Iammarino et al 2009; D'Este et al.; 2012, Hölzl and Janger, 2013, 2014). Interestingly, most of these contributions have mainly focused on the effects of financial constraints on the firm's innovative behaviour (see Hall, 2002 for a review on the subject). Without questioning the fundamental role played by the availability of both internal and external financial resources in determining the firm's innovative decision, other important factors have recently been shown to exert a significant hindrance effect on the firm's innovative process (see for example D'Este et al., 2012; Blanchard et al., 2012; Pellegrino and Savona 2013). Among these, particular attention should be given to factors such as the shortage of adequate skills, the lack of appropriate information on technologies and markets, and the lack/uncertainty of demand.

Crucially, each of these factors might exert a diverse deterring or hampering effect at different stages of the firm's life course: for example, new born or young firms could be more affected than incumbents by the lack of financial resources or the shortage of adequate skills in the implementation of the innovative process, while the lack of/uncertainty on demand could be more important in deterring firms with more experience and that, most probably, operate in a highly saturated market.

Within this context, the main aim of this work is to empirically investigate the role played by firm's age in affecting the firm's perception of the different obstacles to innovation. Furthermore, building on a conceptual framework firstly proposed by D' Este et al. (2012), this particular relationship will be investigated by distinguishing between firms facing revealed and deterring barriers[1]. In doing so, we will perform both

[1] The distinction is based on the relationship between the engagement in innovation activity and the perceived importance of constraints to innovation. Deterring barriers prevent firms from engaging at all in innovation activities; while revealed barriers refer to obstacles that firms face along the innovative process (see Section 2 for a more detailed discussion about revealed and deterring barriers).

univariate and multivariate analyses by drawing on a large longitudinal dataset of manufacturing and services firms and focusing on different phases of the firm's life cycle.

Our results show that different types of obstacles are perceived differently by firms of different ages. While a clear-cut inverted U relationship between both internal and external lack of financial resources and firm' age is detected, a less obvious pattern is found with respect to the other obstacle factors. Interestingly, firms at the early stage of their life seem to be less sensitive than the average to the effect of lack of qualified personnel when they have to engage in innovation activity, but more affected by this type of obstacle when they are already active in innovation activities. Finally, mature firms appear to assign more importance to obstacles factors related to market and demand conditions than firms characterized by a lower degree of experience.

The paper is organised as follows. Section 2 reviews the theoretical and empirical literature about barriers to innovation and puts forward some hypotheses related to 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 has 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 mainly looks at the peculiarities, drivers and effects of innovation activities across firms and sectors. Much less importance, on the contrary, has been given to the factors that can have a relevant role in blocking or slowing down the firm's engagement in innovation activity.

Within the emerging branch of innovation literature exploring the nature and impact of barriers to firm's innovation activity, two distinct but highly related empirical approaches have been adopted.

A first group of contributions has concentrated the attention on the analysis of the impact of (mainly financial) barriers to innovation on the propensity and intensity of firm's innovation activity (see Mohnen and Rosa, 2001; Savignac, 2008; Segarra-Blasco et al., 2008; Blanchard et al., 2012; Pellegrino and Savona, 2013). A second, comparatively less extended group of contributions, have instead focused the attention on the analysis of those firms and market characteristics that can affect the firms' perception of the importance of different type of barriers (Galia and Legros, 2004; Iammarino et al., 2009; D'Este et al., 2012; Hölzl and Janger, 2013, 2014; D'Este et al., 2014). We aim to contribute to this latter. The remaining of this section is dedicated to the discussion of some methodological and conceptual aspects that are crucial in the empirical investigation of the impact and firm's assessment of the barriers to innovation.

Firstly, most of the empirical studies on innovation barriers have found a positive correlation between engagement in innovation and perception of barriers. Different explanations have been put forward in the attempt to justify this somehow counterintuitive result. Some authors, for example, have interpreted this positive link as a signal of the ability of the firms to overcome the obstacles to innovation that they experience (see Baldwin and Lin, 2002; Galia and Legros, 2004; Mohnen and Röller

2005). That is, the more a firm is innovative, the higher is its consciousness about the obstacles to innovation, the more it is able to overcome them. Recently, (Savignac, 2008) provides another more convincing theory, according to which the positive spurious correlation between innovation intensity and perception of obstacles has to be ascribed to an inappropriate selection of the relevant sample for the analyses. More in detail, the French scholar suggests to restrict the analysis to the cohort of the so called 'potential innovators', that is those firms that invest in innovation activity (regardless the success of this innovation activity), or that do not invest in innovation activity but have experienced barriers to innovations. As demonstrated by subsequent works (see D' Este et al. 2012, Blanchard et al., 2013, Pellegrino et al., 2013), this procedure of selection is fundamental in order to obtain consistent results.

Related to the concept of potential innovators is the crucial distinction between revealed *vs* deterred barriers. This important characterization, firstly proposed by D'Este et al. (2012), is based on the analysis of the relationship between firm's engagement in innovation and their assessment of barriers to innovation. More in detail, the authors propose to distinguish two different types of firms within the sample of potential innovators: firms deterred from engaging in innovation activities and firms experiencing barriers that obstruct their performance in innovative projects. With respect to the former category, potential innovators can give up their attempt to innovate because they are obstructed by some barriers. Among these hindrances, an important role is played by financial constraints (both referred to internal and external funds), lack of qualified personnel or information on technologies and market, uncertainty or lack of demand for innovative products. All these factors however, apart from preventing a firm from engaging in innovation related activities, can have also a relevant role in slowing down the firm's innovative process. In other words, it is possible that for some firms, the

perception of obstacles to innovation could slow down/delay, but not prevent their engagement in innovation activity. Following D'Este et al. (2012), this type of firms can be characterized as experiencing revealed barriers to innovation, because their effect take place after the firm's engagement in innovation activity.

Most of the empirical literature has failed to properly identify the sample of potential innovators and to disentangle the deterring from the revealed barriers to innovation. As emphasized by recent contributions (see D'Este et al., 2012; Pellegrino and Savona, 2013), the conceptual and empirical characterization of the different types of barriers to innovation and consequently of the different types of firms is fundamental in terms of policy implications. In this respect, policy interventions could be oriented towards the enlargement of the population of innovative-active firms (innovation-widening) by removing or alleviating obstacles that prevent firms from engaging in innovation activities; or could support the existing population of innovative-active firms (innovation-deepening) by removing or alleviating obstacles that obstruct successful completion of innovation projects and adequate returns to innovation investments.

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

2.2 Firm's age and barriers to innovation

As mentioned in the introduction, no previous studies have provided evidence about the role played by age in affecting the firm's perception of the barriers to innovation. In this paper we try to cover this gap in the literature by going beyond the

simplistic distinction between new entrants and incumbents and try to focus on distinct phases of the firm's life cycle. In doing so, we do not propose any a priori hypotheses regarding the underling research question, in the belief that no particular functional form can be assigned to the relationship between firm's age and the relevance of the different obstacles to innovation perceived by the firms. Having said that, it is useful to give some insights drawing on some related streams of literature.

Firstly, it could be plausible to expect that firms in the early stages of their life show an higher level of sensitivity than more experienced firms to cost and financial factors both when they want to start a new innovative project and devote more financial resources in an existing one. Different arguments can be offered in supporting this assertion. Firstly, more experienced firms can rely more on internal funds since more profits are accumulated with the time goes by. In this respect, Reid (2003) calls for an inverse relationship between a firm's age and its debt ratio, while Fluck et al. (1997), in accordance with this evidence, show that the ratio of external finance to total finance tends to fall once a firm has been operating for more than seven or eight years. Moreover, newly established or young firms, in contrast with more mature incumbents, cannot generally count on a well-developed reputation on the financial market since they do not have developed an established, long-term relationship with banks and their sources of collateral are typically limited (see Petersen and Rajan, 1995; Martinelli, 1997; Berger and Udell, 2002). In a recent contribution, Schneider and Veuglers (2009) try to provide some characterization of the so called young innovative companies (firms younger than 6 years and highly intensive in R&D) and find that this type of firms appear to perceive as more important both the internal and external cost related obstacles to innovation than their mature counterparts.

Firm's skill endowment is regarded as an important driver of innovation activity (see Leiponen, 2005; Piva and Vivarelli, 2009). Skilled workers are indeed a vital resource for firms dealing with complex activities (such as innovation activity in general and R&D in particular). In this respect, as suggested by Cohen and Levinthal (1989, 1990) high qualified employees represent the main firms' vehicle to absorb external knowledge and consequently to enhance the absorptive capacity of a given organization. Moreover, as suggested by Florida (2002) a skill base cannot be confined to just engineering and scientific qualifications, but refers to a much more ample range of expertise (such as management, law, design etc.) each of them giving an important contribution to the creative problem solving process. Also in this case, one may expect that firms in the first stages of their life could have more difficulties in hiring high qualified (and costly) personnel. On the other hand, it also likely that young firms, due to their higher financial constraints and small size, rely more on alternative sources of innovation (such as acquisition of machinery and equipment and outsourced R&D, see Pellegrino et al. (2012)), for which the contribution of high skilled workers could be less relevant.

On the other hand, large mature firms being characterized by a well-established and more routinized organizational and production practices could experience some difficulties in adapting and modifying competencies and expertise to environmental changes (Nelson and Winter, 1982; Hannan and Freeman, 1984), in particular when they want to start an innovative project. For the same reasons, more experienced firms may be in a position of disadvantage at identifying new technological opportunities, thus being significantly affected by some kind of knowledge related obstacles (i.e. lack of information and technology and on markets). However, according to the Schumpeterian tradition (see Schumpeter, 1942, Acs and Audretsch, 1988 and 1990)

young firms could be expected to be less able to exploit the benefits deriving by market concentration and appropriability conditions so facing higher barriers to innovate in market dominated by established companies.

It is evident from this short discussion that the relationship between firm ' s age and firm's perception of different obstacles to innovation is quite complex and that it is difficult to hypothesis a clear functional form that depicts the nature of this relationship. As we will show in Section 4, the results of our empirical analyses give important support to these propositions.

3. Data

In this work we use firm level data from the Spanish Technological Innovation Panel (henceforth PITEC). PITEC represents the result of the joint effort 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 be therefore considered as a Community Innovation Survey (CIS) –type dataset. However, one relevant peculiarity that distinguishes PITEC from most of the CIS-type datasets is its panel data structure. Indeed, since 2003 a systematic data collection methodology has been carried out, allowing a consistent representativeness of the population of Spanish manufacturing and service firms over a number of time periods. This characteristic represents an important methodological advantage because allows us to control for unobserved heterogeneity.

Along with detailed information about some general firm's characteristics (such as main industry of affiliation, turnover, employment, founding year), PITEC collects data concerning a very large set of innovation-related aspects measuring the firms'

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 some complementary innovation activities such as organisational change and marketing[2].

In this paper, we use data refer to the period 2004-2011. The initial sample, made up of 100,016 year observations, has been selected according to the following procedure. Firstly we drop those firms operating in the primary (1,628 observations), construction (3,914 observations), utilities (720 observations), sewage/refuse disposal (318 observations) sectors and those firms which experienced processes of M\&A (8,543 observations)[3].

Furthermore, due to the high presence of missing values for the variables employed in the empirical specification (see Section 4.2.1) 15,289 observations have been ruled out.

In addition, according to the discussion presented in Section 2, we retain just the sample of 'Potential Innovators'. In other words, we exclude from the final sample those firms that, by inference, can be defined as 'Not innovation oriented firms'. As already pointed out (see Section 2), this filtering procedure permits to correct for a clear anomaly that characterizes the design of the CIS questionnaire, where all the firms (regardless of their willingness to innovate) are asked to reply to the questions regarding the obstacles to innovation. More specifically, we exclude 6,943 observations referred to firms that did not engage in any of the seven innovation activities specified in the questionnaire (see Table A1 in the Appendix) and that at the same time did not experience any barriers to innovation during the period under analysis (see Table A2 in

[2] Recent examples of work using this dataset are López-García, et al. (2013), D'Este et al (2014) and Segarra and Teruel (2014)

[3] These firms were eliminated from the sample in the years following the merger or acquisition.

the Appendix)[4], finally ending up with a sample made up of 62,661 firms-year observations.

In accordance with our main research questions, within the potential innovators, it is necessary to distinguish those firms that experience deterring barriers from those facing revealed barriers to innovation. Following D'Este et al. (2012, 2014) the former group is identified by considering those companies that declare no engagement in innovation activity and to confront at least one barrier item, while the latter is made up by those firms experiencing at least one barrier item and claiming involvement in at least one of the 7 innovation activities[5]. Following this approach, within the total sample, we can single out 43,046 observations referred to firms facing revealed barriers and 18,140 observations regarding firms confronting deterring barriers to innovation activity[6].

< INSERT TABLE 1 >

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

[5] Note that the only difference between the two groups regards the degree of engagement in innovation activity.

[6] As can be noted, these figures do not sum to 62,661. Indeed, there are 1,457 firm-year observations that declare involvement in innovation activity but did not experience any kind of barrier to innovation. Since firm's innovation activity is central in this paper we decide to not 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 Univariate analysis

In this section we provide preliminary univariate evidence regarding our main research question. In particular, we use lowess smoothing techniques to obtain non-parametric estimations of the impact of age on the firm's perception of the different obstacles to innovation. Following the PITEC questionnaire design (see Table A1 in the Appendix), we study this relationship considering 7 different barrier items that refer to 3 different factors: 1) cost factors; 2) knowledge factors, 3) market factors. In detail, we focus the attention on 7 out of 9 barriers items, by excluding the cost barrier factor 'innovation cost too high', and by collapsing into one variable the two knowledge barriers items 'lack of technical information on technology' and 'lack of information on markets'[7]. Before discussing the results of the non-parametric analysis, it is useful to provide some general insights regarding the firms' evaluation of the barriers involved. Table 1 reports the proportion of firms assessing as highly important each of the 7 barriers items, considering both the total sample and the two groups of firms. Looking at the total sample, as expected, cost factors are the categories of obstacles showing the highest percentages (always above 30%), while, market related obstacles are in general considered more important than knowledge ones. Focusing on the two sub-sample of firms, with the exclusion of the item 'high innovation cost' the proportion of firms experiencing revealed barriers that assess as high important the obstacles to innovation is always higher than those facing deterring barriers. In line with the evidence provided

[7] We decide to exclude from the analysis the barrier item "innovation cost too high" because it looks redundant with respect to the other two cost barriers. The same rationale has been followed with respect to the choice of jointly considering the two obstacles variables related to lack of information on technology and market.

in D'Este (2012), these figures suggest that the firm's engagement in innovation activity can have a relevant effect in the firm's assessment of the related barriers and confirm the importance of taking into account the different nature of the barriers faced by the firms. As can be seen, this statement seems to be particularly true for the barrier item 'lack of internal funds', 'lack of qualified personnel' and 'uncertainty regarding the demand of innovative products'.

Figures A1 to A3 in the Appendix illustrate the graphic results of the lowess estimations obtained by considering the total sample of firms. As can be seen, the only factor that shows an overall clear linear trend is the cost factor, with the two related barrier items (lack of internal and external funds) showing a monotonic decreasing relationship with firm's age. A less clear and marked pattern is instead detected with respect to the knowledge factors. Indeed, among the three different barriers items the only one that shows a clear negative, albeit not so evident, negative relationship with age is the barrier item "difficulties in finding partners for innovation". Moving to the market factors, a clear U relationship is detected with reference to the market obstacle 'market dominated by established firms', with a decreasing relationship until around the sixtieth years and with firms in their mature stages of their life cycle appearing particular sensitive to this market related factors. This interesting trend is instead not observed with reference to the second market factor 'uncertainty regarding the demand of innovative products', the curve describing its relationship with age being practically flat.

4.2 Multivariate analysis

4.2.1 Variables and econometric methodology

In the following two subsections, we further investigate the preliminary evidence discussed before by applying multivariate analyses that allow determining the impact of firm's age on the firm's perception of obstacles to innovation after having controlled for observed and unobserved factors.

In line with the univariate analysis we consider as dependent variables 7 binary indicators, each of them identifying those firms that assess as high important the selected cost, knowledge and market barriers. Each of these factors will be regressed on a set of control variables and on a set of dummies variables identifying different age classes. The choice of the main control variables has been made both taking into account the information provided by the questionnaire and following the main insights provided by the literature.

Firstly, we control for firm's size by taking the natural logarithm of the firm's total numbers of employees. Previous evidence shows that larger firms are less sensitive to barriers to innovation activity than their smaller counterparts (see D'este et al. 2012; D'este et al., 2014). Indeed, big companies can rely more on internal founds, easy access to external founds, high level of appropriability and can exploit economies of scale; all factors that can be important in alleviating the negative impact of the obstacles to innovation (Schoonhoven et al. 1990, Katila and Shane, 2005). Since, the same favourable effects may regards firms that are part of an industrial group (see Mairesse and Mohnen, 2002), we also consider a variable that identifies this type of companies.

Secondly, we control for the degree of the internationalization of the firms by considering a variable which equals to 1 if the firm's most significant destination market is international and to 0 otherwise. In this respect, as suggested by D'Este et al. (2012), firms operating in foreign countries may suffer less from knowledge related obstacles to innovation as results of the so called learning by exporting process (see Clerides et al., 1998), but more from market related obstacles because they are exposed to a fiercer competition.

We also control for appropriability conditions by identifying those firms that make use of patents and informal methods to protect the innovation and for the possible beneficial effects of public policy instrument 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 2 shows the descriptive statistics (mean and standard deviation) for the above mentioned variables for the overall sample and for the two sub-samples of firms facing deterring *vs* revealed barriers.

As expected, the two groups of firms present some notables differences. In particular, those firms that have experienced revealed obstacles to innovation are much more oriented to foreign markets, to use formal and informal methods of protection and have an higher probability to receive public subsidies than the group of firms that have experienced deterred barriers.

< INSERT TABLE 2 >

In order to provide a more comprehensive and articulated picture of the role played by firm's age in affecting the firm's perception of the different obstacles to

innovation and to control for possible nonlinear effects, we consider a set of dummy variables each of them identifying a different phase of the firm's life cycle. In choosing the different age thresholds, we have tried to guarantee a good representation of the different phases of the firm's life course and at the same time to avoid big disparities (in terms of number of firms) among the different age categories. As a result, we select the following 5 age classes: from 1 to 8 years, from 9 to 20 years, from 21 to 30 years, from 31 to 50 years, more than 51 years.

Table 3 depicts the composition of the different samples by age categories, while Figure A4 in the appendix shows the proportion of firms that assess as high important the seven obstacles barriers by age categories and by considering the two groups of firms. As can be seen, in line with the results from the non-parametric estimations, it appears a clear negative relationship between firm's age and firm's perception of cost barriers to innovation with a notable difference between the reported percentage of the first and last age category. On the contrary, much less marked differences among the 5 age classes are detected with respect to the other two obstacle factors. Interesting enough, looking at the "deterring" sample the market factor 'uncertain demand for innovative goods' appears to be more important for more experienced firms than those in the early stages of their life.

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

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

Where $I[\cdot]$ is an indicator function that takes on values 1 if the argument in brackets is true, and zero otherwise, Y_{jit} (j = 1,…7) denotes the 7 binary obstacles variables, X_{it} is the vector of control variables described before, Age_{kit} (k = 1,…5) represents the set of dummies identifying the 5 age categories, c_i is the time invariant unobserved individual effect, and ε_{it} an idiosyncratic error term.

Equation (1) is estimated by applying standard random effect probit model[8]. As usual, in order to avoid the dummy trap problem with respect to the inclusion of the set of age dummies a reference age 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[9], 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's age is central in our analysis, in order to deal with these problems we use a well-known method proposed by Suits (1984). More in detail, according to this simple methodology, once the equation has been estimated, one can choose a value *k* and add it to each of the coefficients of the age dummies and subtract it from the constant term (including of course the zero coefficient of the dropped–out industry)[10]. The effect of each age categories will be thus interpreted as deviations from the average age effects.

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[8] Alternatively we could have considered a fixed effect specification. However, due to a small degree of variation in the dependent variables, the use of this econometric model would cause a notable reduction of the sample of firms considered for the analysis. We prefer to preserve the representativeness of the sample therefor implementing a random effect model.

[9] The econometric specification includes a set of 8 time and 34 industry dummies.

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

4.2.2 Results

Tables 4, 5 and 6 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[11].

Looking at Table 4 (total sample), the most evident result is the clear inverted U relationship between firm's age and firm's assessment of cost barriers. Indeed, in accordance with the discussion put forward in section 2.2, young firms (up to 20 years) seem to be significantly obstructed in their innovative activity by both internal and external lack of financial resources, whereas firms pertaining to the last three age categories appear to be considerably less affected by these barriers items. While the estimations in Table 6 (sample of firms coping with revealed barriers) fully corroborate these results (see columns 1 and 2), some interesting insights can be found when we focus on the sample of firms facing deterring barriers to innovation. In particular, as can be seen from Table 5, the deterring effects of both cost factors appear to be relevant just for the youngest category of firms (1-8 years) with the coefficients of the age class '9-20' no longer significant and with the only negative and highly significant parameter for the variable identifying those firms with an age ranging from 31 to 50 years. Besides demonstrating the relevance of distinguishing different groups of firms when analysing barriers to innovation, these results confirm our hypothesis according to which newly create firms are particularly hindered by the lack of internal and external founds when they want to start an innovative project.

[11] As a robustness check, in order to control for correlation among the errors terms of the repressors for the different obstacles variables we implement a multivariate probit regression. The results, available upon request, are in line with those reported in Table 4 - 5 - 6.

Turning the attention to the other types of obstacles, an interesting evidence can be found with respect to the association between firm's age and the barrier item 'lack of qualified personnel'. Indeed, the estimated parameters in column 3 of Table 5 show that this knowledge related obstacle is significantly less important in deterring the engagement in innovation activity of those firms at the early stages of their life (1-8 years) than the group of firms with the sample's average age. On the contrary, the only category of firms for which the lack of qualified personnel appear to be a relevant deterring factor in their innovative attempt are those belonging the last age category (more than 51 years). This result seems to suggest that firms in the mature stages of their life cycle, being characterised by a well-established organization and production practices, are in a position of disadvantage at reorganizing and adopting competencies and expertise in order to start a new innovative project. On the other hand, new born and young companies that enter the market with an innovative idea appear to be well-equipped in terms of skilled workers and human capital. Different results are instead detected with respect to the sample of firms encountering revealed barriers to innovation. In this case, in fact, while the parameter of the age class '>51' is no longer significant, a positive, albeit barely significant, association with the first age class (1 to 8 years) and the barriers item 'lack of qualified personnel' is detected.

Moving the attention to the two market factors, the only notable result is represented by the highly significant association, in the group of firms facing revealed barriers, between the last age category and the barrier item 'uncertain demand for innovative goods/services'.

Regarding the other firm characteristics, as expected, larger firms and firms belonging to an industrial group appear to perceive as less relevant the different obstacles to innovation with respect to their counterparts. Furthermore, as can be seen,

the variable ‘subsidies’ is frequently positive and significantly correlated with higher importance of the barriers to innovation. As suggested by D’Este et al., (2014) this evidence may be related to the fact that this type of public policy are usually more oriented towards innovative firms.

In relation to the two variables identifying appropriability means, while no effect are detected in the deterring barriers group, both patent and informal protection appear to be positively associated with higher level of relevance of the different obstacles items as far as the sample of revealed barriers is concerned.

Finally, firms more oriented towards foreign markets seem to suffer less from the obstacle to innovation activity ‘lack of qualified personnel’, calling for a possible beneficial effect of the learning by exporting mechanism. Interesting enough, this type of firms seem to be more affected than their counterparts by the lack of external founds.

< INSERT TABLES 4, 5 AND 6 >

5. Conclusions

In this paper we have tried to add to the scant literature on barriers to innovation by empirically investigating the role played by firm’s age in affecting the perception of the different types of barriers to innovation. Furthermore, building on a theoretical framework firstly proposed by D’Este et al. (2012), this particular relationship has been investigated by considering the distinction between firms facing revealed *vs* deterring barriers. In pursuing this aim, we have performed both univariate and multivariate

analyses by focusing on a large representative sample of Spanish manufacturing and services firms observed for the period 2004-2011.

Our results, besides confirming the importance of distinguishing deterring *vs* revealed barriers, show that different types of obstacles are perceived differently by firms of different ages.

Firstly, a clear-cut inverted U relationship between firm's age and firm's assessment of both internal and external lack of funds is identified, in particular with reference to the group of firms facing revealed barriers to innovation. This result, if on the one hand confirms the importance of policy intervention aiming at financing the innovative project promoted by newly created firms, on the other hand, suggests the implementation of policy schemes with the objective to financially sustain those firms already engaged in innovation activity and that have entered the market recently (less than 20 years).

Furthermore, firms at the early stages of their life seem to be less sensitive to the effect of lack of qualified personnel when they have to start an innovative project, but more affected by this type of obstacle when they are already engaged in innovation activities. On the other hand, firms in their mature stages of their life are significantly obstructed in their attempt to engage in innovation activity by the lack of qualified personnel. According to our interpretation, this result may be linked to the organisational rigidity and structured routines that characterised the incumbents firms and that could cause resistances and difficulties to adjust competencies and expertise.

Finally, mature firms appear to assign more importance to obstacles factors related to market and demand conditions than firms characterized by a lower degree of experience.

Although is behind the scope of this paper to provide a guideline for policy makers, our results could have relevant policy implication. Indeed, providing evidence on the distinction between deterring and revealed barriers in relation to firms' age and by considering a wide range of factors obstructing the innovation activity is fundamental in order to identify the nature and best timing of policy actions and strategic decisions in relation to the firm's life cycle.

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Table 1. Proportion of firms assessing obstacles to innovation as highly important

	Tot	Deterred	Revealed	Men 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 2. 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 3. Composition of the different samples by age categories

	Total sample		Deterring		Revealed	
Firm's age	Freq.	Percent.	Freq.	Percent.	Freq.	Percent.
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 4. 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***	0.216***	0.031	0.042	0.049	0.051	-0.026
	(0.031)	(0.030)	(0.039)	(0.038)	(0.035)	(0.034)	(0.031)
9-20	0.065***	0.054***	-0.007	0.043	-0.015	-0.009	-0.038
	(0.021)	(0.020)	(0.026)	(0.026)	(0.024)	(0.023)	(0.020)
21-30	-0.084***	-0.069***	0.016	0.042	-0.013	-0.017	-0.020
	(0.023)	(0.022)	(0.029)	(0.028)	(0.027)	(0.025)	(0.022)
31-50	-0.132***	-0.088***	-0.040	-0.059*	-0.005	-0.047	-0.012
	(0.029)	(0.028)	(0.035)	(0.035)	(0.033)	(0.031)	(0.027)
>51	-0.106***	-0.114***	-0.000	-0.068	-0.017	0.022	0.097**
	(0.047)	(0.045)	(0.057)	(0.056)	(0.052)	(0.050)	(0.044)
Foreign markets	0.039	0.100***	-0.105***	-0.014	-0.034	0.025	0.046*
	(0.025)	(0.025)	(0.032)	(0.031)	(0.029)	(0.028)	(0.025)
Industrial group	-0.232***	-0.218***	-0.268***	-0.187***	-0.259***	-0.171***	-0.140***
	(0.029)	(0.028)	(0.036)	(0.035)	(0.033)	(0.031)	(0.028)
Informal protection	0.074***	0.107***	0.078***	0.076***	0.064**	0.077***	0.087***
	(0.022)	(0.022)	(0.028)	(0.028)	(0.027)	(0.024)	(0.022)
Patent	-0.001	0.066**	-0.012	0.052	0.133***	0.018	0.009
	(0.030)	(0.029)	(0.039)	(0.037)	(0.036)	(0.033)	(0.030)
ln(Size)	-0.247***	-0.184***	-0.085***	-0.107***	-0.138***	-0.107***	-0.133***
	(0.012)	(0.011)	(0.014)	(0.014)	(0.013)	(0.012)	(0.011)
Subsidy	0.042**	-0.052***	-0.032	0.103***	0.018	-0.006	0.021
	(0.020)	(0.019)	(0.026)	(0.025)	(0.024)	(0.022)	(0.020)
Constant	0.161	-0.113	-1.779***	-1.743***	-1.193***	-1.293***	-1.278***
	(0.101)	(0.095)	(0.122)	(0.120)	(0.106)	(0.110)	(0.099)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sectoral Dummies	Yes	Yes	Yes	Yes	Yes	Yes	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***	1.288***	1.396***	1.374***	1.222***	1.373***	1.214***
	(0.019)	(0.017)	(0.025)	(0.024)	(0.022)	(0.021)	(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 5. 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***	0.263***	-0.160**	-0.049	-0.011	0.067	-0.061
	(0.059)	(0.058)	(0.072)	(0.073)	(0.069)	(0.063)	(0.059)
9-20	0.030	0.037	-0.020	0.014	0.025	-0.072**	-0.061*
	(0.036)	(0.036)	(0.044)	(0.045)	(0.042)	(0.040)	(0.036)
21-30	-0.088**	-0.059	0.011	-0.007	0.016	-0.067	-0.002
	(0.041)	(0.040)	(0.049)	(0.050)	(0.047)	(0.044)	(0.040)
31-50	-0.156***	-0.156***	-0.062	-0.032	-0.011	-0.055	0.059
	(0.050)	(0.049)	(0.060)	(0.062)	(0.058)	(0.055)	(0.049)
>51	-0.136*	-0.085	0.231***	0.074	-0.019	0.128	0.065
	(0.081)	(0.079)	(0.093)	(0.099)	(0.094)	(0.086)	(0.078)
Foreign markets	0.035	0.096**	-0.133**	-0.085	-0.020	-0.035	0.097**
	(0.044)	(0.044)	(0.054)	(0.056)	(0.051)	(0.049)	(0.044)
Industrial group	-0.463***	-0.436***	-0.433***	-0.415***	-0.486***	-0.375***	-0.385***
	(0.052)	(0.051)	(0.065)	(0.067)	(0.062)	(0.058)	(0.052)
Informal protection	0.007	0.056	-0.004	0.002	0.001	-0.056	0.087
	(0.056)	(0.055)	(0.069)	(0.071)	(0.068)	(0.062)	(0.056)
Patent	-0.009	0.117	-0.299*	-0.197	-0.058	-0.053	-0.216*
	(0.111)	(0.108)	(0.153)	(0.151)	(0.139)	(0.129)	(0.115)
ln(Size)	-0.211***	-0.159***	-0.067***	-0.089***	-0.119***	-0.058***	-0.134***
	(0.018)	(0.017)	(0.021)	(0.022)	(0.020)	(0.019)	(0.018)
Subsidy	0.040	-0.117*	0.008	0.195**	0.051	0.068	0.082
	(0.068)	(0.068)	(0.086)	(0.086)	(0.082)	(0.077)	(0.068)
Constant	0.304**	-0.119***	-1.509***	-1.470***	-1.299***	-1.349***	-1.046***
	(0.148)	(0.145)	(0.182)	(0.185)	(0.170)	(0.169)	(0.151)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sectoral Dummies	Yes	Yes	Yes	Yes	Yes	Yes	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***	1.329***	1.441***	1.454***	1.309***	1.435***	1.288***
	(0.035)	(0.034)	(0.044)	(0.047)	(0.042)	(0.040)	(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 6. 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***	0.200***	0.088*	0.046	0.059	0.041	-0.031
	(0.039)	(0.037)	(0.047)	(0.046)	(0.043)	(0.041)	(0.038)
9-20	0.106***	0.075***	-0.000	0.048	-0.028	-0.002	-0.029
	(0.027)	(0.025)	(0.033)	(0.032)	(0.030)	(0.029)	(0.025)
21-30	-0.099***	-0.087***	0.037	0.080**	-0.039	-0.043	-0.049*
	(0.030)	(0.028)	(0.037)	(0.035)	(0.034)	(0.032)	(0.028)
31-50	-0.144***	-0.071**	-0.025	-0.082**	0.000	-0.051	-0.028
	(0.037)	(0.034)	(0.044)	(0.043)	(0.040)	(0.039)	(0.034)
>51	-0.090	-0.117**	-0.099	-0.092	0.008	0.054	0.138***
	(0.059)	(0.055)	(0.070)	(0.068)	(0.063)	(0.060)	(0.053)
Foreign markets	0.047	0.119***	-0.083**	0.009	-0.013	0.061*	0.027
	(0.033)	(0.031)	(0.041)	(0.040)	(0.037)	(0.036)	(0.032)
Industrial group	-0.172***	-0.165***	-0.196***	-0.109**	-0.192***	-0.102***	-0.064*
	(0.036)	(0.034)	(0.045)	(0.043)	(0.041)	(0.039)	(0.035)
Informal protection	0.082***	0.102***	0.116***	0.104***	0.085***	0.100***	0.091***
	(0.026)	(0.025)	(0.034)	(0.032)	(0.031)	(0.028)	(0.026)
Patent	-0.009	0.068**	0.011	0.089**	0.156***	0.038	0.030
	(0.033)	(0.032)	(0.043)	(0.040)	(0.039)	(0.036)	(0.033)
ln(Size)	-0.277***	-0.213***	-0.088***	-0.136***	-0.139***	-0.148***	-0.143***
	(0.016)	(0.015)	(0.019)	(0.018)	(0.017)	(0.016)	(0.015)
Subsidy	0.065***	-0.062***	0.024	0.119***	0.075***	0.036	0.058**
	(0.024)	(0.023)	(0.031)	(0.030)	(0.028)	(0.026)	(0.024)
Constant	0.285**	0.145	-2.000***	-1.882***	-1.215***	-1.222***	-1.400***
	(0.132)	(0.123)	(0.160)	(0.158)	(0.136)	(0.143)	(0.130)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sectoral Dummies	Yes	Yes	Yes	Yes	Yes	Yes	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***	1.420***	1.515***	1.476***	1.321***	1.503***	1.320***
	(0.026)	(0.023)	(0.033)	(0.031)	(0.028)	(0.028)	(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

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

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

Table A2. PITEC questionnaire: engagement in innovation activity

During the three-year period ----,----. did your enterprise engage in the following innovation activities?	YES	NO
Intramural (in-house) R&D 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	☐	☐
Acquisition of R&D (extramural R&D) 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 organizations	☐	☐
Acquisition of machinery, equipment and software Acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved goods, services, production processes, or delivery methods	☐	☐
Acquisition of external knowledge Purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other enterprises or organizations	☐	☐
Training Internal or external training for your personnel specifically for the development and/or introduction of innovations	☐	☐
All forms of Design 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.	☐	☐
Market introduction of innovations Activities for the market preparation and introduction of new or significantly improved goods and services, including market research and launch advertising.	☐	☐

Figure 1. Local linear smooth (lowess): relationship between firm'age and cost obstacles

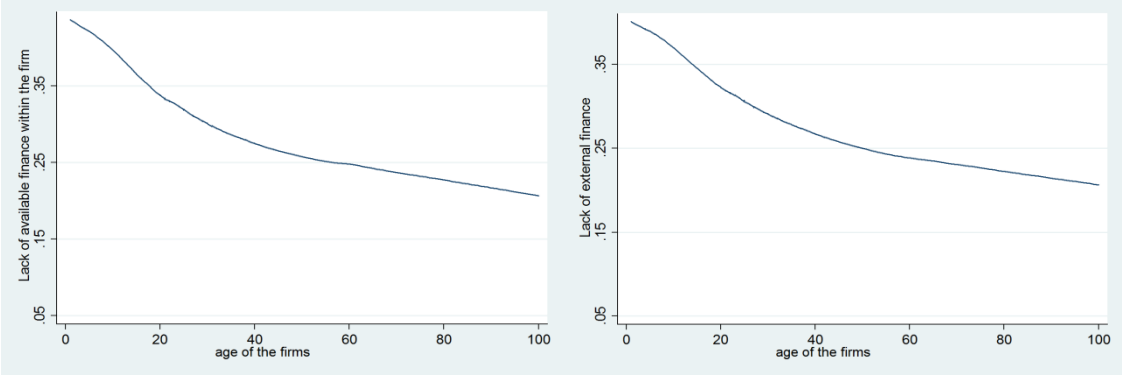

Figure 2. Local linear smooth (lowess): relationship between firm'age and knowledge obstacles

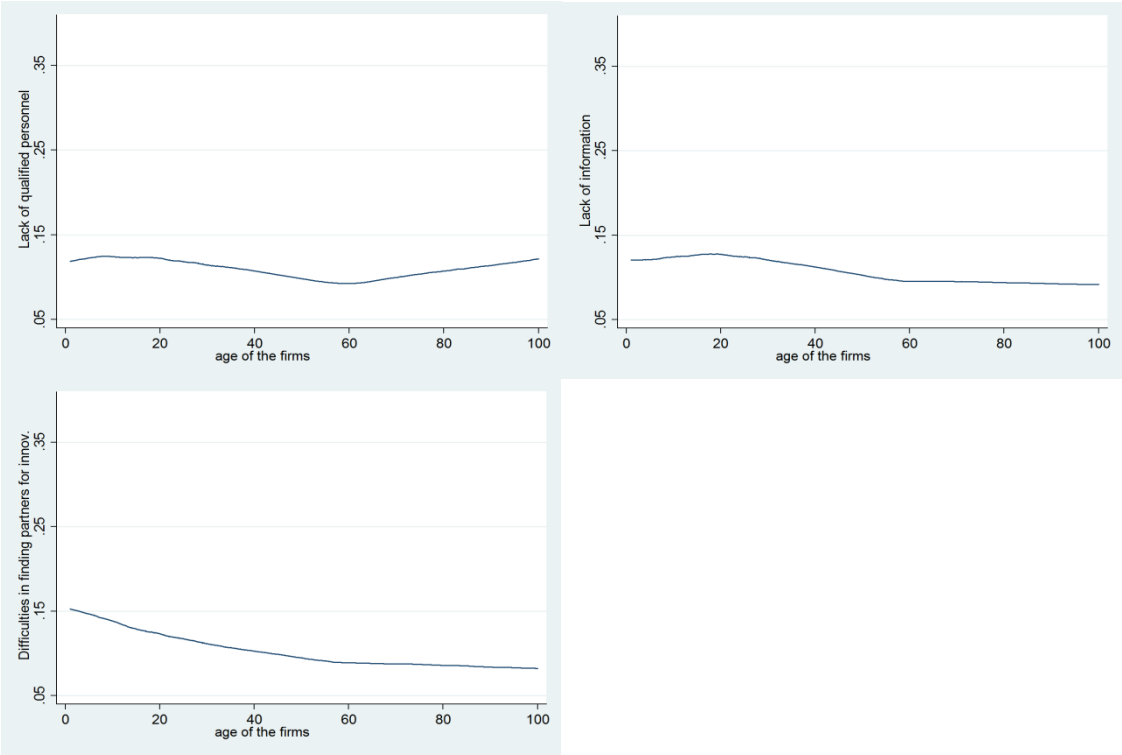

Figure 3. Local linear smooth (lowess): relationship between firm'age and market obstacles

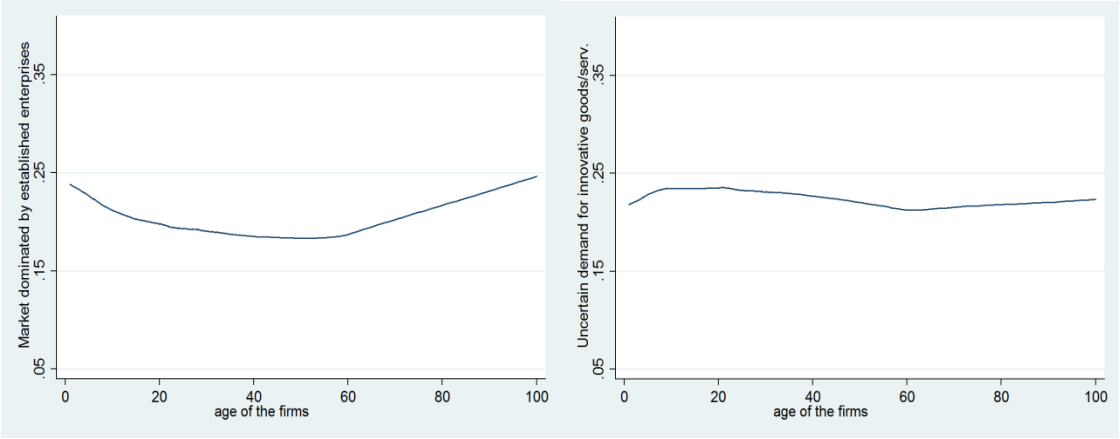

Figure A4. Average firm's perception of obstacles to innovation by age categories (revealed and deterred samples)