Essays on Determinants and Effects of Barriers to Innovation

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Chapter I
Introduction

1.1 The role of innovation at micro level

Innovation and technological change have traditionally been identified as key driving forces of firm-level productivity competitiveness and economic growth.

The empirical literature on the subject is large and consolidated. At the micro level, the seminal contribution of Griliches (1979) initiated a flourishing stream of literature aimed at investigating the relationship between innovation (mainly proxied by the level/intensity of R&D investment) and productivity. Following this, Crèpon, Duguet and Mairesse (1998), exploiting the increasing availability of detailed survey dataset, developed a more comprehensive model based on three distinct, but interrelated relationships: 1) the determinants of the firm's R&D decision; 2) the process leading from innovative inputs to innovative outputs (i.e. the creation and commercialisation of new product, process and services); 3) the conditions by which innovation increases firm's productivity.

A consolidated finding of this literature is that the overall impact of R&D on productivity is positive, generally statistically significant and with a magnitude that depends on the econometric methodology, the data and the level of analysis (country, sector, or firm). Griliches and Mairesse (1983), for example, using US and French data, find a productivity elasticity of R&D ranging from 0.10 for low-tech sectors to 0.20 for high-tech sectors. Hall and Mairesse (1995), focusing on a sample of 197 French companies obtain an estimated rate of return to R&D of 78% for the period 1980-1987. Griffith et al. (2006) study the R&D/productivity link for a sample of UK firms and find a positive impact (elasticity of 0.03), while Harhoff (1998), focusing on 443 Germany companies, find an elasticity of 0.14 for the period 1979-1989. More in general, this type of literature shows that a 10% increase in the R&D capital stock leads to an increase in output of between 0.5-2.5% (for a comprehensive survey, see Mairesse and Sassenou, 1991; Hall et al., 2010).

The robust empirical evidence pointing to the beneficial effect of R&D on firm's performance has certainly played a relevant role for developing a consolidated body of literature on the determinants and drivers of firm's innovation activity. In this respect, following the Schumpeterian tradition, the role played by factors like firm's size, market structure and industry specific characteristics in boosting firm's R&D activity has been extensively tested at the empirical level (see Kamien and Schwartz (1978) for an exhaustive discussion of the so-called "Schumpeterian hypothesis"). More recently, thanks also to the increasing availability of more detailed survey data, scholars have focused the attention on other firm and market characteristics. Among many, factors like propensity to export (Melitz, 2003), human capital (Leiponen, 2005), firm's age (Artés, 2009) and subsidies to innovation (González et al., 2005) have, generally, been identified as important drivers of firm's R&D activity (for a recent and exhaustive review of the determinants of R&D see Cohen, 2010).

The high interest shown by the innovation scholars on the determinants of the success of the firm's innovative activity have left little room for a systematic and comprehensive analysis of those factors that may instead cause firm's failure in engaging in innovation. This is quite surprising, considering the high policy relevance of identifying and removing factors hampering firm's decision to innovate and the realization of successful innovation projects. In this respect, identifying factors of success does not necessarily imply singling out the determinants of failure. It is therefore crucial to characterize the nature of the obstacles that firms face at different stages of their innovative process.

The relevance of these topics has been recently recognised by the new EU's long-term Strategy: "Horizon 2020" (European Commission, 2011). Indeed, along with the traditional target of reaching an R&D/GDP level of 3% at EU level, one of the main objectives that the Europe 2020 initiative clearly sets is to tackle a series of policy failures and to address some context-specific factors that may negatively influence the level of R&D intensity and the implementation of innovation projects. More in detail, the programme manifestly emphasises the urgency "…to identify the obstacles that need to be overcome in order to create a business environment in which innovative firms are more likely to grow"(European Commission, 2011).

Despite the unquestionable relevance of this topic, so far the scholarship providing empirical evidence about the nature and the effects of the obstacles a firm may encounter along the innovative process is still emerging. This doctoral thesis is primarily meant to add to this new stream of interest within the innovation literature and provide new insights on the topics of the perception of obstacles to innovation and their effects on firms' innovation activities. In what follows, we outline the main characteristics, methodological issues and conceptual limitations of the scattered evidence on the role of obstacles to innovation at firm level, in turn delineating the main contributions of the present work in this respect.

1.2 Barriers to innovation: an overview of the open issues analysed in the thesis

Within the recent stream of literature dealing with barriers to innovation two different but highly related empirical approaches can be identified.

A first group of contributions has analysed the effects of different barriers in deterring or slowing down the innovative effort of firms (see among the others, Mohnen and Rosa, 2001; Galia and Legros, 2004; Savignac, 2008). A second, relatively less consistent, group of contributions has instead explored the role played by some factors in affecting the firms perception of the importance of different type of barriers (see among the others, D'Este et al.; 2012, 2014; Hölzl and Janger, 2013, 2014).

Regardless of this distinction, most of these contributions have mainly focused the attention on just one category of obstacles to innovation a firm can face, namely cost and financial related ones. In particular, they look at the effect of financing constraints on the firm's level of investment in innovation (mainly proxied by investments in R&D). Indeed, as suggested by a well-established literature, innovative projects, due to their high level of complexity and uncertainty causing information asymmetries, could be severely affected by financial constraints (see Hall, 2002 for a review on the subject). All in all, empirical findings provide evidence in favour of a negative and significant impact of financial constraints on the firm's likelihood to engage in innovation.

The implicit rationale of confining attention to financial constraints might be related to the fact that it is more straightforward to draw policy implications when these boil down to increasing financial support to R&D spending. Indeed, once it is observed that firms are hindered in their innovative process by the lack of liquidity or because innovation is too expensive, financing constraints are confronted by providing money in the form of subsidies and tax credits to increase the level of investment in innovation.

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). Indeed, in addition to these cost factors, firms face a series of other important impediments to their innovation activity. These include regulations-related problems associated with tax regimes, government standards and red-tape; labour-related problems such as shortage of skills and training difficulties; knowledge-related problems such as lack of scientific and technical information, technological services; market and demand related obstacles such as the lack/uncertainty of demand about innovative goods and services. Providing evidence about the possible negative impact of the different types of obstacles is, for obvious reasons, very important for policy purposes, as eliminating or at least mitigating hindrances may represent an important mean to increase the numbers of active innovators and to render more effective the innovative processes of the existing base of innovators.

The paucity of contributions in this type of literature is even more surprising taking into account the increasing availability of firm level data over the last 10-15 years. Particularly relevant in this respect is the so called Community Innovation Survey (CIS) that represents the results of a common work at EU level aimed at providing regular surveys of innovation across Member States. Following the Oslo Manual's guidelines (OECD, 1997), this harmonized survey collects detailed information regarding both general characteristics and detailed peculiarities of the innovation activities of service and manufacturing firms with more than 10 employees. In particular, CIS offers exhaustive information about the barriers to innovation experienced by the firms. Indeed, it provides a direct indicator of the perception of obstacles to innovation, considering not only financial obstacles, but also knowledge/information-related barriers, market structure, demand and regulation obstacles. Moreover, the information included in CIS allows analysing whether this ample range of barriers affects the firm's innovative behaviour at different stage of the innovative process (decision to engage in innovation, intensity of investment in innovation, successful introduction of new processes/products).

In line with the previous discussion, most of the CIS-based literature has not fully exploited the whole set of information provided by this survey, mainly focusing the attention on financial and cost barriers to innovation (Tourigny and Le, 2004; Savignac, 2008; Tiwari et al., 2008; Mancusi and Vezzulli, 2010; Blanchard et al., 2013), with very few studies trying to extend the analysis to other obstacles factors (Iammarino et al., 2009; D'Este et al., 2012, 2014). More important, most of the CIS-based contributions have found a positive correlation between engagement in innovation and perception of barriers. Several explanations have been put forward in the attempt to explain this somehow counterintuitive result. Some scholars have for example interpreted this positive link as a signal of the ability of the firms to overcome the obstacles to innovation that they face (see Baldwin and Lin, 2002; Galia and Legros, 2004; Mohnen and Röller 2005). In other words, the more a firm innovates, the higher is its knowledge about the obstacles to innovation, the more is able to overcome them. Recently, a more convincing theory has been proposed by Savignac (2008) and D'Este et al. (2008). The authors point to a possible source of potential bias deriving from an inappropriate selection of the relevant sample for the analyses. More in detail, they propose to restrict the analysis to the cohort of the so called 'potential innovators', that is those firms that invest in innovation activities (regardless the success of this innovation activity), or that do not invest in innovation activity but have experienced barriers to innovations. In other words, in order to obtain consistent results, the empirical analyses have to be performed by excluding from the final sample those firms that are not willing to innovate (as they have declared to have not introduced any new product and/or process innovation) and that at the same time did not experience any barriers to innovation (see D' Este et al. 2012, Blanchard et al., 2012 for recent work applying this procedure of selection).

It is evident from the above discussion that the literature on obstacles to innovation presents a series of important conceptual and methodological limitations that do not allow to obtain a reliable and comprehensive picture of the nature and effects of the impediments that the firms face in their attempt to innovate. The main aim and contribution of the Second Chapter of this thesis, entitled "No money, no honey? Financial versus knowledge and demand constraints to innovation" is to try to overcome these important shortcomings. In particular, drawing on an unbalanced panel of almost 7,000 UK manufacturing and services firms observed for the period 2002-2010, the main aim and novelty of this work lies in the attempt to analyze the impact of obstacles to innovation on the translation of firms' engagement in innovative activities onto actual innovative outputs (both product and process innovation). In doing so, we add to the literature on the subject in three main respects. Firstly, we distinguish between financial and non-financial obstacles to innovation by providing evidence regarding other systemic types of barriers such as those related to access to knowledge, market structure and demand regulations. Secondly, in line with the methodological issue discussed above we correct for the potential sample selection bias by filtering out from the sample those firms with no stated intention of innovating. Thirdly, we perform our analysis within a panel context by using an econometric setting that allows us to control for possible additional bias caused by endogeneity and omitted variables problems.

The results of the econometric estimation show that demand and market related factors are as important as financing conditions in lowering the firm's probability to introduce new processes and/or products. Accordingly, we infer that the presence of competitors and the lack of demand are as crucial for firms to abandon an innovative project regardless an initial investment, as financial constraints are.

While in the second Chapter of this thesis we have provided a broad picture of the possible negative effects of the different obstacles on the firms' realization of innovative outputs, in the third Chapter entitled "Reviving demand-pull perspectives: the effect of demand uncertainty and stagnancy on R&D strategy" the focus is on a specific category of hindrance that could obstruct or slow down the firm's R&D activity, namely the lack and/or uncertainty of demand.

The role of demand as main driver of innovation activity is an old topic in innovation literature. Starting from the seminal contributions by Schmookler (1962; 1966) many authors have provided robust evidence both at micro and macro level to the so-called demand pull theory, according to which the introduction of new products and processes is strongly conditioned to the presence of demand and on positive expectations on profitability.

The relevance of this topic has been revived by the recent major economic global crisis and by the corresponding increasing policy interest. In this respect, the previously mentioned EU growth Strategy "Horizon 2020" identifies as one of the most relevant causes of policy failures that could generate a general loss of efficiency in the whole national innovation system the poor match between supply- and demand- side measures. Specific mention is made of the fact that if particular demand-side polices are not implemented, public efforts to fund research and to boost corporate R&D will fail to produce the expected socio-economic benefits.

In this work we try to look at the demand pull perspective in a novel way, that is to say from the viewpoint of barriers to innovation. More in detail, by making use of a long comprehensive panel of Spanish firms, we specifically look at the effects of demand uncertainty and stagnancy on firm's decisions to engage in R&D activities and the amount of financial effort devoted to it. Furthermore we conduct a careful sectoral analysis by looking at whether firms active in high or low-tech manufacturing or in knowledge intensive or low tech services are more or less dependent on demand conditions when deciding to perform R&D. Also in this case, in accordance with the previous discussion, we select the working sample by focusing on the 'potential innovator' group of firms.

The results of the econometric analyses show that uncertain demand and lack of demand are perceived as two completely different barriers. While uncertainty on demand does not seem to constrain R&D efforts, the perception of lack of demand does strongly reduce not only the amount of investment in R&D but also the likelihood of firms to engage in R&D activities. Moreover, sectoral affiliation does not seem to be particularly relevant when it relates to demand conditions, giving support to the speculation that positive expectations on market demand is a structural condition to be fulfilled for all firms prior to invest in R&D.

The second and third Chapter of this thesis look at the impact that different type of obstacles have in hampering the firm's propensity to invest in innovation activity and to realize/introduce innovative outputs (new products/process). However, as mentioned before, among the contributions in the innovation obstacles literature another different empirical approach can be identified. Specifically, some authors have provided evidence about those market and firm characteristics that may affect the firm's perception of the importance of the different innovation barriers (see D'Este et al.; 2012, Hölzl and Janger, 2013, 2014). An important characterization of this particular sub-stream of literature is the proposed differentiation between revealed and deterring barriers. As stressed by D'Este et al. (2012), this distinction is based on the relationship between the engagement in innovation activity and the perceived relevance of obstacles to innovation. Deterring barriers prevent firms from engaging at all in innovation activities; while revealed barriers connote those obstacles that firms face along the innovative process. In other words, it is possible that some potentially innovative firms can give up their attempt to innovate because they are obstructed by some barriers, whereas for others firms, the perception of obstacles to innovation could delay or slow down, but not prevent, their engagement in innovation activity. The empirical characterization of these two types of barriers is essential in terms of policy implications. Indeed, policy makers may be oriented towards the enlargement of the population of innovative-active firms by eliminating or mitigating obstacles that prevent firms from engaging in innovation activities; or may give support to the existing population of innovative-active firms by contrasting obstacles that impede successful completion of innovation projects.

In the fourth Chapter of this thesis, entitled "The perception of obstacles to innovation along the firm's life cycle", by applying this recently proposed conceptual frameworks that distinguish between revealed and deterring barriers to innovation, we assess whether an important firm's characteristics, namely firm's age, could affect the firm's perception of the different types of obstacles that can hinder or slow down the firm's innovative activity. In this respect, it is plausible to think that different types of innovation barriers could exercise a different deterring or hampering effect at different phases of the firm's life cycle. It could be the case that new born or young firms show, for different reasons, a higher level of sensitivity than more experienced firms to cost and financial factors or to the shortage of adequate skills in the implementation of innovative process. On the other hand, the lack/uncertainty on demand could be more relevant for firms in the mature stage of their life and that, most probably, operate in a highly saturated market.

We try to shed some light on these issues by exploring a comprehensive panel of Spanish manufacturing and services firms for the period 2004-2011. The empirical results show that different types of obstacles are perceived differently by firms of different ages. Firstly, a clear-cut negative relationship between firm's age and firm's assessment of both internal and external lack of funds is identified. Moreover, 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 stage of their life are significantly obstructed in their attempt to engage in innovation activity by the lack of qualified personnel. 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.

As emerged from the discussion above, the core of this work is organized in three different chapters. Although they are strictly linked and have to be considered as part of a common research project, each of them can be read independently of the rest. The organisation of each one is as follows.

Firstly, the subject, the motivation and the main contribution of the study with respect to the existing literature are presented. Secondly, a careful discussion of the theoretical approach to the topic is provided along with a comprehensive description of the dataset used for the empirical analysis. Thirdly, a detailed outline of the econometric methodologies used for the estimations is given and, finally, the main conclusions and some policy suggestions are provided.

Lastly, the fifth Chapter provides a general overview of the three previous chapters, outlines the main conclusions of the entire work and offers some policy implications and possible future lines of research.

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Chapter II
No money, no honey? Financial versus knowledge and demand constraints to innovation

2.1. Introduction

Recent empirical innovation literature has devoted an increasing attention to the perception of (mainly financial) obstacles to innovation and their deterring impact on firms' decisions to engage in innovation activity, the intensity of this engagement and the propensity to innovate (among others, and more in detail in Section 2.2, Baldwin and Lin, 2002; Galia and Legros, 2004; Canepa and Stoneman, 2007; Segarra Blasco et al, 2008; Tiwari et al., 2008; Savignac, 2008; Iammarino et al., 2009; Mancusi and Vezzulli, 2010).

Assessing the actual impact of obstacles on the innovation failure/success rate is of obvious policy relevance, as removing or alleviating hindrances might be an effective device to enlarge the population of innovators and increase the innovation performance of the existing base of innovators (D'Este et al., 2008, 2010 and 2012). However, an overwhelming majority of contributions have confined the analysis to the impact of financial obstacles. The marked emphasis on financial conditions to innovate originates from traditional cash-flow models (see Hall, 2002 for a review) – focusing on firms' financial constraints to carry out R&D investments – and most likely reflects the recent unfavorable financial downturn. Also, the implicit rationale of limiting the analysis on financial constraints is that – once ascertained that firms do not innovate because they lack liquidity or innovation costs are too high– it is relatively straightforward to draw policy implications: financing constraints are removed or at least alleviated by pouring liquidity in the form of additional subsidies/tax credits to increase levels of (mainly R&D) investments.

Here we argue that firms might encounter different types of obstacles and persist in their systemic failure in engaging in innovation activities and/or in translating financial effort into the actual introduction of successful new goods, services and processes[1]. It is therefore all the more important for policy purposes to extend the analysis to non-financial obstacles and be able to provide evidence on whether firms do not innovate due to the lack of appropriate information on technologies and market, or adequate skills, or, most likely in the midst of a financial crisis, because their destinations markets are sluggish in ensuring adequate levels of demand[2].

This paper aims to add to the evidence on the impact of obstacles to innovation and the implications in terms of innovation policy in four main respects.

First, in line with some of the most recent contributions (D'Este et al., 2008 and 2012; Savignac, 2008; Mancusi and Vezzulli, 2010) we are aware of and correct for the potential sample selection bias intrinsic to this type of analysis, by appropriately identifying the relevant sample and filtering out those firms which are not willing to innovate and therefore do not engage in any innovation activity for reasons others than obstacles. This allows overcoming the usual selection bias, which has led to the counterintuitive evidence of a positive relation between intensity of innovative investments and perception of obstacles to innovation (Mohnen and Rosa, 2000; Baldwin and Lin, 2002).

Second, this paper builds on the empirical evidence provided by D'Este et al. (2008, 2012), who distinguish between deterring and revealed barriers[3], and extends it by assessing the impact of 'revealed' barriers on the translation of innovative input into actual innovative output. In doing so, we are able to tell whether – even though firms choose to engage in innovative activities, that is they spend financial resources not only for intramural or extramural R&D

1 From now on we refer to innovative products to indicate both innovative goods and services.

2 Recent empirical evidence at micro and macro level on the effects of the economic downturn on innovation investments of firms and countries is provided in Archibugi and Filippetti, 2011; Archibugi, Filippetti and Frenz, 2012

3 The distinction is based on the relation between the degree of 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 are experienced "in the making" of innovation and reflect firms' awareness of their constraints as a result of their engagement in innovation inputs.

but also for capital equipment, training, acquisition of know-how and marketing - the presence of barriers represents a substantial hindrance to the completion of their innovation projects and the launch of new products or processes[4].

Third, we carefully distinguish between financial and non-financial obstacles and, unlike in Tiwari et al. (2008) or Blanchard et al. (2013), we provide evidence on whether other systemic types of obstacles such as those related to access to knowledge, market structure, demand or regulations, have a similar or more important deterring effect than finance in limiting firms' ability to translate innovation activities into new outputs[5].

Fourth, we do so within a panel econometric framework, drawing on the UK CIS4 to CIS7 panel, merged with the UK Business Structure data, in order to account for usual econometric issues such as endogeneity and firms' unobserved heterogeneity. The longitudinal evidence at our disposal also allows pinning down from a descriptive point of view whether a certain degree of persistence occurs in the status of "not innovation oriented", "failed innovator" or "innovator" over time[6]. This information, coupled with the evidence on what type of barrier is most likely to affect firms' innovation status, is of uttermost importance for policy purposes, as it allows identifying the relevant areas and target population for intervention.

Policy makers might prioritize the enlargement of the population of innovative-active firms (*innovation-widening)*, by removing or alleviating obstacles that prevent firms to engage in innovation activities; or strengthen the innovation capacity of 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. This paper aims to provide evidence to help this type of policy choice.

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4 For the purpose of this paper, we do not focus on the degree of novelty of the product and therefore do not distinguish between goods or service new to the firm versus new to the market. Rather, we adopt a less conservative choice of focusing on the simple introduction of a product/process new to the firms or new to the market.

5 It is important to point out here (see also Section 2.3) that within the innovation-survey literature the term "innovation active" refers to the degree to which firms devote financial effort to innovation (innovative inputs). This does not entail that the firm has also managed to introduce a new product or process as a consequence of the innovation investments. This distinction is central to our argument and often undermined in the traditional literature on financing constraints (see Section 2.2.1).

6 We fully describe the status of innovator, failed innovator and not innovation-oriented in Section 2.4.3.

The paper is structured as follows: Section 2.2 reviews the literature on barriers to innovation, briefly reporting the econometric issues arising from this analysis. Section 2.3 describes in depth the relevant variables included in the merged UK CIS4-CIS7 and BSD panel data. Section 2.4 illustrates the econometric strategy and the decisions undertaken to identify the relevant sample[7]. Section 2.5 discusses the results, highlighting the main contributions of this analysis with respect to the existing literature. Section 2.6 builds upon this evidence to discuss the innovation policy implications of going beyond the hype on financing constraints.

2.2 Finance versus non-finance barriers to innovation

The literature analysing the factors affecting firms' failure in engaging in innovation is comparatively less extended than the core body of literature focusing on factors of success (briefly reviewed in Section 2.4.1). This is slightly puzzling, given the policy relevance of identifying (and releasing) factors obstructing firms' decisions to innovate, hampering financial effort devoted to it and completion of successful innovation projects. Identifying factors of success does not implicitly entail pinning down the determinants of failure: it would be a myopic policy assumption to infer this. For instance, if large firms are more likely to introduce an innovation, this does not mean that all small firms face problems in being successful. It is therefore of uttermost importance to identify what kinds of hindrances firms meet at different phases of the innovation cycle, i.e. in the decision to innovate, the engagement in innovation activities and the successful introduction of a new product/process. Here we systematize the few contributions that have dealt with these issues, distinguishing between financial and non-financial obstacles[8].

2.2.1 The origins: financing constraints and R&D investments

7 Comparison of the different estimations results shows that these are robust to the sample identified and to other selectivity issues. Other robustness checks are reverted to in the Appendix.

8 To some extent, this distinction overlaps with that between papers drawing or not on national and cross-country innovation surveys or with direct or indirect indicators on the experience of obstacles to innovation.

The large majority of contributions interested in the (direct) effect of hampering factors on innovation activity at large (including both innovation-related expenditures (inputs), and the introduction of innovation outputs) have focused on (external) financing constraints on firms' cash flow sensitivity to afford R&D investments (for a review, see Schiantarelli, 1996 and Hall, 2002; see also Bond et al., 1999 and Hottenrott and Peters, 2012). These contributions are concerned with the effect of financing constraints on the risk of a sub-optimal and welfare-reducing firms' level of investments. In particular, they all focus on the high uncertainty, asymmetries and market complexity specifically linked to the financial returns of R&D investments and the ability to attract external funds. Most studies test the presence of financing constraints indirectly, by looking at the sensitivity of R&D investments to changes in cash flows, as in Hall (2008). Other studies (Canepa and Stoneman, 2007; Savignac, 2008; Hottenrott and Peters, 2012) employ innovation surveys to access direct information on the perception of financing constraints by firms. Empirical findings tend to confirm that encountering financial constraints significantly lower the likelihood of firms to engage in innovative activities (Savignac, 2008) and this pattern is more pronounced in small firms and high-tech sectors (Canepa and Stoneman, 2007). Drawing on an ideal test for identifying the role of financing constraints put forward by Hall (2008)[9], Hottenrott and Peters (2012) find that firms with higher innovation capabilities are more likely to face financing constraints, holding equal internal availability of funds. More recently, an increasing number of contributions have relied on the use of innovation surveys to assess the relationship between the degree of engagement in innovation activities (input) and the perception of financial and non-financial constraints, which we briefly review below.

2.2.2 Facing barriers, engaging in innovation activities and propensity to innovate: CIS evidence

The data provided by CIS allow enlarging the analysis on the role of obstacles in two main directions. First, it provides a *direct* indicator on the perception of obstacles to innovation, which goes beyond the financial

9 Rather than using traditional innovation survey data on the perception of obstacles to innovation, Hall (2008) and later Hottenrott and Peters (2012) conduct an ideal experiment by providing firms with exogenous extra cash and observe whether they decide to spend it in innovation projects. The presence of (external) financing constraints is detected by decisions to devote extra cash to otherwise unfunded innovation projects.

obstacles only. This includes perception of knowledge and information-related barriers, market structure, demand and regulation obstacles. Second, it allows investigating whether this whole range of barriers affect firms' behaviour at different stages of the innovation cycle, whether on the decision to innovate, the engagement in innovation activities (which go beyond the traditional R&D expenditures) and the successful introduction of a new product/process.

CIS-based literature in this field has variously explored issues of complementarities between different innovation obstacles (Galia and Legros 2004; Mohnen and Röller, 2005); the links between factors affecting the perception of the importance of different barriers to innovation (Baldwin and Lin, 2002; Iammarino et al., 2009; D'Este et al., 2012); the impact of (mainly financial) obstacles to innovation (Tourigny and Le, 2004; Savignac, 2008; Tiwari et al., 2008; Mancusi and Vezzulli, 2010; Blanchard et al., 2013).

Two key issues are worth mentioning here. First of all, most of the empirical findings converge in pointing to a positive relationship between engagement in innovation and perception of barriers. In trying to make sense of this counterintuitive evidence, Savignac (2008) and D'Este et al., (2008) identify sources of potential bias, which explain the positive spurious correlation between innovation intensity and perception of obstacles and the counter-intuitive results emerging from these analyses. These sources of bias include the usual ones - such as the presence of heterogeneous unobserved firms' specific factors or the simultaneity of the status of spending for innovation projects and facing obstacles to innovation. Also, a specific source of bias is linked to an inappropriate selection of the relevant sample for the analysis, which does not distinguish between firms willing and not willing (or needing) to innovate, as suggested by Savignac (2008) and D'Este et al. (2008, 2012). Building on their work, subsequent contributions have therefore carefully selected the relevant sample (of firms willing to innovate and potentially failed by the presence of obstacles) and obtained expected signs (Mancusi and Vezzulli, 2010; Blanchard et al., 2013)[10].

Secondly, also within the CIS-based literature, an overwhelming number of contributions focus on financing constraints to innovation, treating the role of non-financial ones as a simple control factor (Tiwari et al., 2008; Mancusi and Vezzulli, 2010; Blanchard et al., 2013). Despite recognizing the fundamental – possibly exacerbating – role of other types of obstacles *indirectly* on the financing ones and *directly* on the innovation intensity of firms, none of

10 In line with these latest contributions, in this paper we carefully identify the relevant sample by filtering out firms not willing to innovate (see Section 2.4.3).

these contributions choose to provide a detail picture of other systemic sources of innovation failure[11].

The present work aims to contribute to provide such a picture, in the belief that the evidence-based identification of the characteristics of firms not willing to innovate on the one hand and those of firms willing to innovate, spending in innovation and failing introduction of new products on the other hand is crucial to target policy intervention.

Policy makers might prioritize the enlargement of the population of innovators, by removing or alleviating obstacles targeted to those firms that decide not to engage in innovation activities due to barriers (for an *innovation-widening* policy strategy); and/or strengthen the innovation capacity of the existing population of innovators, by removing or alleviating obstacles affecting firms who do not manage to translate financial effort devoted to innovation projects into the actual introduction of new product/process (for an *innovation-deepening* policy strategy).

11 The only exceptions are Iammarino et al., 2008 and D'Este et al., 2012. However, they both focus on the factors affecting the perception of obstacles, rather than their actual impact of these on innovation performance.

2.3. Data

The empirical analysis is based on firm-level data from four waves of the UK Community Innovation Survey (UKIS) for the period 2002 -2004 (UKIS 4); 2004-2006 (UKIS 5); 2006-2008 (UKIS 6) and 2008-2010 (UKIS 7). The UKIS is traditionally based on a stratified random sample (namely sector, region and size-band) drawn from the ONS (Office for National Statistics) Inter-Departmental Business Register (IDBR), and is representative at both the sector and the firm size level of the entire population of UK firms with more than 10 employees.

The dataset comprises a set of general information (main industry of affiliation, turnover, employment, founding year[12]) and a (much larger) set of innovation variables measuring the firms' engagement in innovation activity, economic and non-economic measures of the effects of innovation, subjective evaluations of factors hampering or fostering innovation[13], participation in cooperative innovation activities and some complementary innovation activities such as organisational change and marketing[14].

The survey sampled 28,000 UK enterprises in each wave with a relatively high response rate (58% for UKIS 4, 53% for UKIS 5, 51% for UKIS 6 and 50% for UKIS 7) that leads to a whole sample of 59,940 observations (40,709 firms observed for 1 up to 4 years[15]). Unfortunately, the high presence of missing values combined with the relatively short time series dimension of the panel leads to many variables being observed either never or just once for a considerable number of firms. Moreover, in line with what discussed in the previous section, filtering out the firms that are not willing to innovate and focusing on the "relevant sample" (i.e. the cohort of the so called 'potential innovators', see Section 2.4.3), leads to a further reduction of the sample size. Thus, the trade-off here is between applying panel econometric techniques that allow us to perform more precise estimations, though leading to a significant reduction of the sample size, or wiping out the time series

12 This additional information was drawn from the UK Business Structure Database.

13 The appendix reports the section of the UKIS questionnaire on barriers to innovation. These include cost, knowledge, market and regulation barriers.

14 The information on group belongings and on public financial support for innovation are not available due to slightly changes in the questionnaire designs through the four surveys.

15 Since CIS data are collected retrospectively (innovating over the past three years), the 9 years period pertaining to the four different surveys allows us to have data just for four time periods.

dimension in favour of a higher level of representativeness of the sample used for the analyses. We choose to opt for the first option, as we prefer to prioritise taking into account the unobservable firm heterogeneity[16]. Accordingly, after dropping those firms - pertaining to both the total sample and the relevant sample - that are observed for just one year (31,577); those operating in the primary and construction sectors (2,767 observations); those with missing values in all the variables used for our analysis (9,280 observations) we ended up with an unbalanced panel of 16,316 firms-year observations. Table 1 shows that about 60% of the 6,696 firms included in the final sample are observed for two periods; one third are observed for three periods while only a very negligible percentage of firms (less than 6%) are observed for the entire reference period of four years. No particular differences emerge between the two distinct panels (total and relevant sample) in terms of the percentage of firms observed each year.

Table 1. Structure of the panel (All sample - relevant sample)

	ALL SAMPLE			RELEVANT SAMPLE		
Time obs.	N° of firms	%	N° of obs.	N° of firms	%	N° of obs.
2	4,141	61.84	8,282	4,222	70.11	8,444
3	2,186	32.65	6,558	1,561	25.92	4,683
4	369	5.51	1,476	239	3.97	956
Total	6,696	100	16,316	6,022	100	14,083

16 As a robustness check we estimated a pooled probit model using a sample that includes also those firms observed just for one year. The results -available upon request - are consistent (both in terms of the sign and statistical significance of the estimated coefficients) with those discussed in Section 2.4.4.

2.4. Empirical analysis

2.4.1 Econometric strategy and specification

We analyse the impact of different types of obstacles to innovation on the firm's propensity to innovate[17]. In doing so we consider the following equation:

$$Y_{it} = I\ [\beta' X_{it} + \delta' Z_{it} + c_i + \varepsilon_{it} > 0] \qquad (1)$$

Where $I[\cdot]$ is an indicator function that takes on values 1 if the argument in brackets is true, and zero otherwise, Y_{it} is a binary variable that takes the value 1 if the firm i is innovative. X_{it} is a set of explanatory variables including the 'traditional' determinants of a firm's decision to innovate, Z_{it} is a vector of variables identifying different obstacles to innovation, c_i is the time invariant unobserved individual effect, and ε_{it} an idiosyncratic error term.

As for the set of traditional determinants of innovation (X_{it}), we first consider firm size measured as the logarithm of the firm's total number of employees (LSIZE). As initially pointed out by Schumpeter (1942), and subsequently emphasised by several authors, larger firms are more inclined to engage in innovation activity because they are less likely to be affected by liquidity constraints (easier access to external finance and larger internal funds) and can exploit the advantages deriving by economies of scale (see Cohen and Klepper, 1996; Mairesse and Mohnen, 2002).

Firms' propensity to innovate is also affected by market structure and conditions in terms of competitiveness. In this respect, a firm operating in an international context should be more prone to engage in innovation activity because of the high level of competition that characterises the global arena (e.g. Archibugi and Iammarino, 1999; Narula and Zanfei, 2003). Accordingly, we use a binary indicator of international competition (EXPORT_d), which equals to 1 if a firm's most significant destination market is international, and to 0 otherwise.

17 Since we are interested in innovation output rather than inputs (i.e. activities), we consider as being 'innovative' those firms that have introduced or developed a new product or process or that have been in the process of doing so during the surveyed period (answered positively at least one of the three questions listed in Table A1 in the Appendix).

As suggested by Piva and Vivarelli (2009), higher manpower skills can be related to a higher firm propensity to innovate. In fact, skilled workers in comparisons with their unskilled counterparts are more able to dealing with complexity, and more successful in exploiting innovative ideas (Song *et al.,* 2003). We therefore introduce a variable proxing the proportion of high skilled employees (engineers and graduates) within a firm (EDUHIGH).

The occurrence of other forms of innovation, with particular reference to those involving changes in the organisational structure of a firm has been shown to be complementary to more traditional sources of innovation (see Bresnahan *et al.*, 2002; Hitt and Brynjolfsson, 2002). Accordingly, we expect a positive impact of the binary variable 'IORG_d' - that identifies the implementation of major changes to organisational structure - on the firm' probability to engage in innovation.

We also use firm's age (AGE) to control for age related effects. We do not advance any hypothesis on the possible effect of firm's age on the probability to innovate because no univocal evidence has been provided by the literature. Keppler (1996) proposes a theoretical model according to which the number of innovations per firm at a given moment is higher, the younger the cohort of firm is. This should imply a negative relationship between the firm's age and its probability of innovating. However, as Galande and De la Fuente (2003) pointed out, the firm's age can also be seen as a proxy of the firm' knowledge and experience accumulated by the time and consequently it should be positively related to innovation.

Also, we introduce a dummy variable (INNEXP_d) that takes on value 1 if a firm has invested in innovation activity[18].

In addition, we control for the important role played by specific sector and technological factors in affecting the firm's propensity to introduce a new product/process, by including a complete set of industry dummies. Finally, in all the specifications we include time dummies to take into account possible business cycle effects, and regional dummies in order to control for unobserved heterogeneity across different UK regions.

The vector Z_{it} in equation (1), includes 4 different dummies variables[19] that take on value 1 if the firm has faced obstacle to innovation related to: 1)

18 In principle, it would have been better to consider a continuous variable measuring a firm's total investment in innovation activity; however to improve the readability of the results, we opted in favour of a dummy variable. Results based on the inclusion of the continuous variable indicating level of innovation expenditure are consistent with the binary variable and available on request by the authors.

costs factors (HIND_COST_d); 2) knowledge factors (HIND_KNOW_d); 3) market structure and demand factors (HIND_MARK_d); 4) regulation (HIND_REG_d).

As mentioned in Section 2.2, the contributions to the barriers literature are scattered and expected signs are not univocally determined. However, D'Este et al., (2010) have found that human capital has a significant role in attenuating those barriers linked to the shortage of skills and market uncertainties. In line with some empirical contributions (Cainelli et al., 2006; Piva and Vivarelli, 2007) we would also expect that a reasonable degree of certainty on the customer response and a dominant position within the market would lower the influence of barriers on the propensity to innovate. Also, based on the findings by Iammarino et al., (2009) and D'Este et al. (2008 and 2012) we also expect that the need to meet both national and European regulations lower firms' propensity to innovate.

Table A3 in the appendix summarises the list of variables employed in the empirical analyses and their definition. To estimate the coefficients in (1) we apply a probit random effect model. As it well known in literature, the implementation of this econometric method is conditional on the strong assumption that the time invariant error component c_i is uncorrelated with the covariates[20]. However, this could be an unrealistic assumption since it is very likely that unobservable factors in c_i are correlated with the variables included in X_{it} and Z_{it} (for example, managerial ability could be related to the occurrence of major changes in the firm' organisational structure).

To overcome this problem, Mundlak (1987) proposes to move the correlated component of the time invariant error term (c_i) by adding to the model (and estimating) the within mean of all the covariates[21]. However, if the

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19 As can be seen from table A2 in the appendix, the respondents to UKIS questionnaire are asked to report on their perception of the degree of importance (low, medium, high) of each barriers item. Although this additional information could be useful to perform more detailed analyses, the self-reported nature of the answers cast strong doubts on their reliability. Accordingly, we confine our attention to the 4 binary variables that identify those firms that have experienced obstacles to innovation. Nonetheless, as robustness checks, we estimate equation (1) considering two alternative definitions of the innovative obstacles variables (high, high-medium degree of importance). The results, available upon request, are mostly consistent with those discussed in Section 2.4.4.

20 The incidental parameter problem (Neyman and Scott, 1948) leads to inconsistent results if a fixed approach is used to estimate a probit model.

21 According to this method, equation (1) can be reformulated as $Y_{it} = I\ [\beta' X_{it} + \delta' Z_{it} + \theta'_1 \bar{Z}_i + \theta'_2 \bar{X}_i + a_i + \varepsilon_{it} > 0]$, where $\bar{X}_i$ and $\bar{Z}_i$ denote the mean of X_{it} and Z_{it} over time.

dataset used for the estimation shows a little within-variation, this method could lead to biased results (because of multicollinearity problems). Unfortunately, as shown in Table 2, this is what exactly happens with the data at our disposal.

Table 2. Correlation between the explanatory variables and their corresponding Mundlak means

AGE	0.99
EXPORT_d	0.92
EDU_HIGH	0.87
INNEXP_d	0.73
IORG_d	0.74
LSIZE	0.99
HIND_COST_d	0.79
HIND_KNOW_d	0.78
HIND_MARK_d	0.78
HIND_REG_d	0.75

All the explanatory variables show a correlation coefficient with their within means always above 70%. As a consequence, by using this estimation method, some of the variables become uninformative and turn out to be insignificant (see columns 3 and 6 of Table 3). Accordingly, the results obtained by considering the specification with the means have to be considered as a simple benchmark of the more reliable results of the RE specification (equation (1))[22].

2.4.2 Full sample results: counter-intuitive findings

Table 3 (columns 1-3) shows the marginal effects of the probit model. Specifically, columns 1 reports the results of a simple pooled probit, while columns 2 and 3 show the results of the random effects model in the two

22 Although the dataset at our disposal would allow us to perform some dynamic analysis by taking into account the lags of the dependent variables, due to the short time dimension of our panel we prefer to confine our analysis to static specifications (see Table 3). However, we performed some robustness checks controlling for the effect of the state dependence by applying a dynamic probit model method proposed by Wooldridge (2005). As expected, the results in Table A4 in the appendix mainly confirm the conclusions based on the discussed in section 2.4.2.

cases, i.e. with and without including the vectors of means as covariates. Since pooled probit estimations ignore the cross-correlation between the composite error terms in different periods for the same individuals, the correspondent results are used as a benchmark. However, the high level of significance of the likelihood ratio test for Rho equal to zero (lower part of columns 2) suggests that the unobserved heterogeneity appears to be important in explaining the innovative decision of a firm thus supporting the choice of a random effects specification.

Looking at the results in columns 2, we find the expected signs for all the traditional determinants of innovation activities. More in details, larger firms, firms that have introduced organisational changes, and that are more oriented towards international markets are also more likely to translate their innovative effort into innovative outputs. Moreover, as expected, those firms that invest in innovation activities, as well as those that hire high qualified workers seem to be more likely to introduce innovation output. As for the impact of the variable AGE, our results seem to support the evidence that younger firms are more likely than their mature counterparts to realise innovative products and/or processes.

Looking at the main variables of interest, the signs of the coefficients of the different obstacles to innovation are in line with the counterintuitive findings of most of the literature mentioned in Section 2.2. Three out of four of these variables, namely 'HIND_COST_d' (financial obstacles), 'HIND_KNOW_d' (knowledge obstacles) and 'HIND_MARK_d' (market structure/demand obstacles) turn out to have a positive and highly significant impact on the firm's propensity to innovate. The only variable that shows an expected negative sign is the variable 'HIND_REG_d' (5% of significance level).

Table 3. Results from the panel probit estimates

	ALL SAMPLE			RELEVANT SAMPLE		
	(1) Pooled Probit	(2) RE Probit	(3) RE with means	(4) Pooled Probit	(5) RE Probit	(6) RE with means
AGE	-0.005***	-0.006***	-0.041**	-0.005***	-0.006***	-0.035*
	(0.001)	(0.002)	(0.020)	(0.001)	(0.002)	(0.019)
EXPORT_d	0.292***	0.336***	0.008	0.285***	0.324***	-0.008
	(0.026)	(0.034)	(0.064)	(0.027)	(0.036)	(0.068)
EDU_HIGH	0.002***	0.003***	0.001	0.002***	0.003***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
INNEXP_d	0.859***	0.993***	0.708***	0.817***	0.953***	0.695***
	(0.030)	(0.037)	(0.046)	(0.032)	(0.040)	(0.051)
IORG_d	0.533***	0.615***	0.438***	0.523***	0.606***	0.434***
	(0.026)	(0.033)	(0.043)	(0.027)	(0.034)	(0.045)
LSIZE	0.033***	0.048***	0.023*	0.036***	0.049***	0.035***
	(0.009)	(0.012)	(0.012)	(0.009)	(0.012)	(0.013)
HIND_COST_d	0.361***	0.417***	0.224***	-0.206***	-0.245***	-0.206***
	(0.040)	(0.049)	(0.064)	(0.043)	(0.053)	(0.069)
HIND_KNOW_d	0.174***	0.202***	0.082	0.038	0.036	-0.038
	(0.038)	(0.047)	(0.060)	(0.038)	(0.047)	(0.061)
HIND_MARK_d	0.131***	0.145***	0.058	-0.098***	-0.127***	-0.139**
	(0.038)	(0.046)	(0.059)	(0.038)	(0.046)	(0.061)
HIND_REG_d	-0.082***	-0.091**	-0.084*	-0.098***	-0.116***	-0.105**
	(0.029)	(0.036)	(0.047)	(0.029)	(0.036)	(0.048)
Intercept	-1.078***	-1.270***	-1.921***	-0.168*	-0.165	-0.543***
	(0.090)	(0.123)	(0.139)	(0.099)	(0.134)	(0.153)
N. of Obs.	16,316	16,316	16,316	14,083	14,083	14,083
lnL	-8,102.88	-7,919.81	-7,753.45	-7,392.13	-7,228.56	-7,151.22
ϱ		0.352	0.364		0.358	0.361
		(0.018)	(0.018)		(0.019)	(0.019)
LR test ϱ = 0		366.141	378.364		327.147	325.720
p-value		(0.000)	(0.000)		(0.000)	(0.000)
σ_u		0.738	0.756		0.747	0.752
		(0.029)	(0.030)		(0.031)	(0.032)

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets (calculated using the delta method). Time, industry and regional dummies are included. In all the specifications the dependent variable is a dummy that takes on value 1 if the firm can be defined as an innovator

As already mentioned in Section 2.2, these counter-intuitive results are a recurrent problem in the CIS-literature on barriers to innovation, due to several sources of bias (D'Este et al., 2008, 2012; Savignac, 2008; Mancusi and Vezzulli, 2010). We deal with this in the next two sections by appropriately selecting the relevant sample of firms.

2.4.3 Selecting the relevant sample

One of the possible causes of the counterintuitive positive impact of experiencing barriers and propensity to innovate emerging from our pooled sample results - and consistent with a good deal of contributions in the innovation literature reviewed in Section 2.3 - is related to the specific design of the CIS questionnaires. Although mainly focused on 'innovation-related' questions, CIS also gathers information on not innovative firms. All the surveyed firms are required to answer the section referred to the obstacles to innovation (see Table A2 and A5 in the Appendix). Firms might well decide that they do not need to innovate due to lack of interest, or because they have already innovated recently (and therefore in principle they do not experience obstacles); firms might also decide that they do need or are willing to innovate and indeed spend in innovation inputs (potential innovators) but they do not manage to introduce any new product/process (failed innovators); some firms do decide to innovate and indeed devote financial resources to innovation activities as well as manage to introduce a new output (innovators).

Figure 1 in the Appendix describes the dynamics and the possible scenarios resulting from the firm's innovative decision process according to the CIS questionnaire (see relevant sections in Tables A1, A2, A5 in the Appendix) and the role played by the obstacle to innovation. More specifically, we identify the following categories of firms and select out those that are not relevant to the present analysis, to target the relevant sample.

Not-innovation Oriented Firms: firms that are not willing to innovate, as they have declared to have not introduced any new product and/or process innovation as a result of a deliberate choice and were not in process of doing so. At the same time, they did not experience any barriers to innovation (i.e. had not experienced any of the 10 obstacles included in the question on barriers, see Table A2) regardless of whether they have invested or not in any innovation activities[23].

Potential Innovators: firms that are willing to innovate, either as they managed to introduce new products/processes (i.e. that has answered positively at least one of the three questions listed in Table A1) or they engaged in innovation activities (investments). At the same time, they have experienced at least one of the barriers to innovation.

Failed Innovators: firms that are willing to innovate (i.e. that are part of the sample of 'potential innovators'), i.e. they did engage in innovation activities but did not manage to translate innovation inputs into actual introduction of a new product/process.

Innovators: firms that are willing to innovate (i.e. that are part of the sample of 'potential innovators') and that have managed to introduce new or significantly improved product or process regardless of whether they have or not experienced any barriers to innovation.

The distribution of firms in the total sample as well as some descriptive statistics computed according these four categories are shown in Table 4 and 5.

Table 4 shows that only 2,233 observations (around 14% of the total sample) are included in the sub-sample of 'not-innovation oriented firms', while the remaining 14,085 observations (86% of the total sample) pertain to firms that can be defined as 'potential innovators'. Among this latter categories, 8,642 observations (61%) relate to the group of 'innovators' while the remaining 5,441 (39%) to the category of 'failed innovators'.

23 A specific question in the CIS questionnaire refers to the willingness/not willingness to innovate (see table A5). Although this could have straightforwardly been used to select out the not-innovation oriented firms, the variables referred to this question are affected both by inconsistency response patterns (i.e. firms that have answered to the question but that have also reported to have introduced product or process innovations) and the presence of several missing values (not answer). We have therefore chose to select out the "not-innovation oriented" firms according to the (more consistent) strategy indicated here.

Table 4. Descriptive statistics: mean and standard deviation (overall) of the variables: Total sample - Potential innovators - Failed Innovators - Innovators – Not innovation oriented firms

	Total Sample		***Pot. Innovators***		***Failed Innovators***		***Innovators***		***Not Inno. Or.***	
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*
Variables identifying the different sub-samples of firms according to our definitions										
POTEN_INN	0.86	0.34	1	0	1	0	1	0	0	0
INNOVATORS	0.53	0.5	0.61	0.49	0	0	1	0	0	0
DISCOURAGED	0.33	0.47	0.39	0.49	1	0	0	0	0	0
NOINN_OR	0.14	0.34	0	0	0	0	0	0	1	0
Explanatory variables										
AGE	22.12	10.11	22.15	10.13	22.11	10.09	22.18	10.15	21.89	9.98
EXPORT_d	0.45	0.50	0.49	0.50	0.37	0.48	0.56	0.50	0.24	0.43
EDU_HIGH	16.67	25.63	17.73	26.1	13.74	23.63	20.25	27.24	9.97	21.28
INNEXP_d	0.72	0.45	0.78	0.42	0.66	0.47	0.85	0.36	0.38	0.49
IORG_d	0.28	0.45	0.31	0.46	0.21	0.4	0.38	0.48	0.08	0.27
LSIZE	4.49	1.51	4.55	1.5	4.32	1.46	4.69	1.5	4.18	1.51
Obstacles to innovation										
HIND_COST_d	0.77	0.42	0.90	0.30	0.89	0.31	0.90	0.30	0	0
HIND_KNOW_d	0.72	0.45	0.83	0.37	0.80	0.4	0.85	0.35	0	0
HIND_MARK_d	0.73	0.45	0.84	0.36	0.83	0.38	0.85	0.35	0	0
HIND_REG_d	0.60	0.49	0.69	0.46	0.68	0.47	0.71	0.46	0	0
N. of Observations	16,316		14,083		5,441		8,642		2,233	

Table 5. Descriptive statistics: standard deviation (Between and Within) of the variables: Total sample - Potential innovators - Failed Innovators – Innovators – Not innovation-oriented firms

	Total Sample		***Pot. Innovators***		***Failed Innovators***		***Innovators***		***Not Inno. Or.***	
	St. Dev		*St. Dev*		*St. Dev*		*St. Dev*		*St. Dev*	
	Between	*Within*	*Between*	*Within*	*Between*	*Within*	*Between*	*Within*	*Between*	*Within*
Variables identifying the different sub-samples of firms according to our definitions										
POTEN_INN	0.31	0.18	0	0	0	0	0	0	0	0
INNOVATORS	0.40	0.31	0.38	0.32	0	0	0	0	0	0
FAIL_INN	0.36	0.31	0.38	0.32	0	0	0	0	0	0
NOINN_OR	0.31	0.18	0	0	0	0	0	0	0	0
Explanatory variables										
AGE	9.97	1.68	10.02	1.68	10.11	1.18	10.19	1.50	9.99	1.24
EXPORT_d	0.46	0.20	0.46	0.20	0.47	0.15	0.48	0.17	0.42	0.15
EDU_HIGH	22.55	12.68	23.06	12.59	22.92	9.27	25.26	10.80	20.62	9.41
INNEXP_d	0.34	0.30	0.31	0.28	0.42	0.25	0.33	0.20	0.43	0.28
IORG_d	0.34	0.30	0.35	0.31	0.38	0.20	0.41	0.29	0.27	0.14
LSIZE	1.49	0.21	1.49	0.20	1.48	0.13	1.50	0.19	1.55	0.16
Obstacles to innovation										
HIND_COST_d	0.34	0.26	0.22	0.22	0.28	0.17	0.25	0.18	0	0
HIND_KNOW_d	0.36	0.28	0.27	0.26	0.35	0.21	0.31	0.21	0	0
HIND_MARK_d	0.36	0.28	0.27	0.25	0.34	0.20	0.31	0.21	0	0
HIND_REG_d	0.38	0.32	0.34	0.32	0.43	0.24	0.39	0.27	0	0
N. of Observations	16,316		14,083		5,441		8,642		2,233	

Looking at the descriptive statistics related to our interest variables (mid-part of Table 4), not surprisingly, the large majority of 'innovators' (85%) have invested in at least one of the 7 categories of innovation activities included in the UKIS questionnaire, this percentage decreasing to 66% and 38% respectively for the categories of 'failed innovators' and 'not-innovation oriented firms'[24]. Moreover, notable differences among the different categories of firms can be detected with reference to the other variables of interest. In fact, the 'innovators' in comparison with the two other categories of firms (failed and not innovation oriented firms) turn out to be more oriented towards external market, more prone to implement organizational change and hire highly educated people.

As for the variables identifying the different obstacles to innovation, from the lower part of Table 4, surprisingly, no particular differences emerge between the category of 'failed innovators' and 'innovators'. The percentage of firms that have experienced obstacles to innovation is always very high ranging from 68% of 'failed firms' that have experienced regulations factors, to the 90% of 'innovators' that have experienced at least one of the 4 different cost factors obstacles.

Table 6 and 7 show the transition probabilities respectively from the 'not innovation-oriented' to the 'potential innovator' status and from the 'potential innovator' to the 'innovator' status.

Table 6. Transition probabilities of the Potential Innovators status

		Status in t		
		No Inn Or. Firms	Potential Innovators	Tot
Status in t-1	No Inn Or. Firms	56.92	43.08	100
	Potential Innovators	5.81	94.19	100

24 Due to the specific design of the UKIS questionnaire, also non-innovative firms are required to respond to the innovation inputs questions. Therefore, some of the "not-innovation oriented" firms in our sample show a positive expenditure in innovation activity (see also footnote 3).

More in detail Table 6 reports the frequency of a firm changing status over time from 'not-innovation oriented' to 'potential innovators' (and vice versa), while Table 7 shows the shifts from the status of 'failed innovators' to 'innovators' (in both directions).

Table 7. Transition probabilities of the Innovators status

		Status in t		
		Failed Innovators	Innovators	Tot
Status in t-1	Failed Innovators	52.78	47.22	100
	Innovators	26.03	73.97	100

Not surprisingly, the 'willingness' to innovate is the firm' characteristic that shows the highest level of persistence over time, with roughly 94% of 'potential innovators' in one period persisting in this status over the following time period[25]. On the other hand a substantial share (around 43%) of firms that are 'not-innovation oriented', become "willing to innovate" in the subsequent time period. This might be due to two different strategies. Either the firm has already innovated in the previous period (say t-1) so that it states to be not willing to innovate in t and eventually goes back to a "willing to innovate" status in t+1[26]. The second scenario is that these firms are dominated by market incumbents (See Table A5 "No need to market conditions") or any other market-related factor, such as the lack of a dynamic demand or some form of constraint on the consumer side. In this case, our conjecture is that the status of "not willingness" is likely to be assimilated to one in which the firm has actually encountered some form of market-related barrier[27].

By the same token, Table 7 shows that while the status of 'innovators' shows a relatively high persistence over time (almost 74% of firms remain in

25 Due to the particular construction of CIS questionnaires, here one time period refers to 2 years.

26 This is an interesting case to explore in our future research agenda, as such cyclical shifts in status would challenge much of the literature on innovation persistency.

27 We reserve to investigate these issues by disentangling the responses to the questions reported in Table A5 in our future work.

the same status over time), it appears that nearly 47% of firms that in t-1 belonged into the category of 'failed innovator' have changed their status becoming 'innovators' in t. This high share of firms, which have most likely managed to overcome barriers to innovation and introduce a new product or process, is also of great interest from a policy perspective. We suspect that much of the story here is due to the time-lag of returns to innovation or the timing of adjustment needed to meet regulations, ensure demand response to the diffusion of innovation or the acquisition of adequate skills or information on markets or technologies [28].

This evidence, although based on descriptive analyses, shows how important is identifying the relevant areas of intervention in order to implement targeted policy instruments.

2.4.4 Dealing with selection: relevant sample results

The estimation results (marginal effects) for the "relevant sample"[29] of firms are reported in columns 4 to 6 in Table 3. The first remarkable result is that the estimated coefficients associated to the relevant variables show the expected negative sign in three cases out of four, the only variable still showing a positive – albeit not significant - coefficients being 'HIND_KNOW_d'[30]. In particular, looking at the probit RE model (column 5), the presence of obstacles to innovation related to costs/market/regulations factors significantly reduce the firm's propensity to fall into the category of 'innovators' by respectively 24,5%, 12,7% and 11,6%. Accordingly, although the cost-related factors still appear to be the most relevant constraint to the firm' realisation of innovative outputs, our results clearly show a noticeable "hindrance effect" of other obstacles to innovation (namely market/demand and regulations related factors).

This evidence explicitly calls for a careful reflection on the opportunity to persist on the "hype" on financing-related barriers – and for what matters on the financing of innovation more in general. Other systemic failures hindering the firms' innovative performance emerge to be equally important in

28 Once again, this is certainly a topic for future investigation.

29 As a reminder, the relevant sample selects out those firms which are "not-innovation oriented".

30 Although still positive, the impact of this variable on the firm's propensity to innovate is negligible in terms of magnitude and not significant. Moreover, the marginal effects of this variable turn out to be (expectedly) negative in the 'RE with means' model (columns 6).

affecting firms' behaviour and innovation success, though these are much less straightforwardly addressable (see next section for a more detailed discussion of the policy implication of these results).

The relevance of these results is further corroborated by their robustness across the different models. In particular, comparing the results of the probit RE without means (columns 5) and with means (columns 6) we can see that the estimated marginal effects of the variables "HIND_COST_d", "HIND_MARK_d" and "HIND_REG_d" are extremely close in terms of magnitude.

Looking at the other regressors (the 'traditional' determinants of innovation) and in line with the results obtained using the total sample, larger, younger firms, firms implementing organizational change and more prone to trade in international market are also more likely to introduce innovative outputs. Moreover, it is worth noting that these results are very similar in terms of magnitude to the estimated marginal effects with those one in columns 2.

2.5. Concluding remarks

This paper aims to add to the scattered conceptual and empirical literature on barriers to innovation and allow innovation policy makers to gather a in-depth picture of what are the systemic failures hampering firms' engagement in innovation activities and innovation performance.

As in Savignac (2008) and D'Este et al. (2008 and 2012), we identify different policy target categories on the basis of firms' self-declarations in terms of willingness, need and not need to innovate. We then corroborate this a-priori classification by testing the actual impact of different obstacles to innovation on the propensity to innovate – given the engagement in at least one innovation investment.

Once selected the appropriate sample of firms 'willing to innovate', we then test whether, to what extent (and which) barriers affect the changing status of 'potential innovators' into 'failed innovators', i.e. which of the main systemic obstacles mostly affect the lack of returns of innovation investments in terms of new product/process.

We find that market structure and lack of demand are as important hindrances for firms as the financing constraints that the most traditional literature has emphasized on the basis of cash-flow models. We therefore infer that the presence of strong competitors and the lack of demand are as decisive for firms to give up innovation projects despite an initial investment, as are financial constraints.

It is therefore of uttermost importance for policy makers aiming at sustaining innovation to focus not just on the traditional increase of liquidity via, e.g. R&D tax credits, but also to be able to construct a concerted 'policy platform' embracing competition and macro-economic policy. Economic downturn, raising unemployment and lack of adequate final demand not only affect macro-economic recession directly but also indirectly via reducing incentives for firms to invest in innovation (for a discussion, see Archibugi and Filippetti, 2011).

Regulation constraints – which turn out to be significantly affecting the propensity to innovate, though more weakly – have to be considered as a potential area for intervention too, though more in depth investigation on the nature of these types of constraints must be carried out, possibly from a qualitative perspective.

Overall, policy makers might prioritize the enlargement of the population of innovators, by removing or alleviating obstacles targeted to those firms that decide not to engage in innovation activities due to barriers (for an *innovation-widening* policy strategy); and/or strengthen the innovation capacity of the existing population of innovators, by removing or alleviating obstacles affecting firms who do not manage to translate financial effort devoted to innovation projects into the actual introduction of new product/process (for an *innovation-deepening* policy strategy). In any of these cases, the evidence presented in this paper shed lights on the relevant issues and allows a better identification of the relevant policy targets.

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Appendix

Table A1. CIS questionnaire (innovation output related questions)

We qualified as innovative those firms that have positively answered to at least one of the following questions:		
	YES	NO
1. During the three-year period -----, did your enterprise introduce:		
• New or significantly improved goods. (Exclude the simple resale of new goods purchased from other enterprises and changes of a purely cosmetic nature)	☐	☐
• New or significantly improved services	☐	☐
2. During the three-year period -----, did your enterprise introduce any new or significantly improved processes for producing or supplying products (goods or services) which were new to your enterprise?	☐	☐
3. During the three-year period -----, did your enterprise introduce any new or significantly improved processes for producing or supplying products (goods or services) which were new to your industry?	☐	☐
4. During the three-year period -----, did your enterprise have any innovation activities to develop product or process innovations that you had to abandon or which were ongoing at the end of 2004?	☐	☐

Table A2. CIS 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	Excessive perceived economic risks	☐	☐	☐	☐
	Direct innovation costs too high	☐	☐	☐	☐
	Cost of finance	☐	☐	☐	☐
	Availability for finance	☐	☐	☐	☐
Knowledge factors	Lack of qualified personnel	☐	☐	☐	☐
	Lack of information on technology	☐	☐	☐	☐
	Lack of information on markets	☐	☐	☐	☐
Market factors	Market dominated by established enterprises	☐	☐	☐	☐
	Uncertain demand for innovative goods or services	☐	☐	☐	☐
Regulation factors	Need to meet UK Government regulations	☐	☐	☐	☐
	Need to meet EU regulations	☐	☐	☐	☐

Table A3. The variables: acronyms and definitions.

Variables identifying the different sub-samples of firms according our definitions	
POTEN_INN	Dummy =1 if firm is a potentially innovative firms (whether the firm has been engaged in innovation activities and/or has experienced any barrier to innovation activities during the three year period); 0 otherwise.
INNOVATORS	Dummy =1 if firm has introduced new or significantly improved products/processes or has any innovation activities that had abandon or which were ongoing at the end of the three year period ; 0 otherwise.
FAILED_INN	Dummy =1 if firm wanted to innovate but did not managed to do so because has experienced any barriers to innovation activity during the three year period; 0 otherwise.
NOINN_OR	Dummy =1 if firm has no innovative activities and did not experienced any barriers to innovation during the three year period; 0 otherwise.
Explanatory variables	
AGE	Years elapsed since founding.
EXPORT_d	Dummy =1 if the firm have traded in an international market during the three year period; 0 otherwise.
EDUHIGH	Ratio of highly educated personnel over total employment (these figures refer to the last year of each of the three years periods).
INNEXP_d	Dummy=1 if the firm has invested in at least one out of the 7 categories of innovation activity included in the questionnaire.
IORG_d	Dummy=1 if the firm have implemented major changes to its organisational structure (e.g. Introduction of cross-functional teams, outsourcing of major business function) during the three year period; 0 otherwise.
LSIZE	Log of the total number of firm's employees (these figures refer to the last year of each of the three years periods).
Obstacles to innovation	
HIND_COST_d	Dummy=1 if the firm has faced obstacle to innovation related to costs factors in the three years period; 0 otherwise.
HIND_KNOW_d	Dummy=1 if the firm has faced obstacle to innovation related to knowledge factors; 0 otherwise.
HIND_MARK_d	Dummy=1 if the firm has faced obstacle to innovation related to market factors; 0 otherwise.
HIND_REG_d	Dummy=1 if the firm has faced obstacle to innovation related to other factors during the three year period; 0 otherwise.

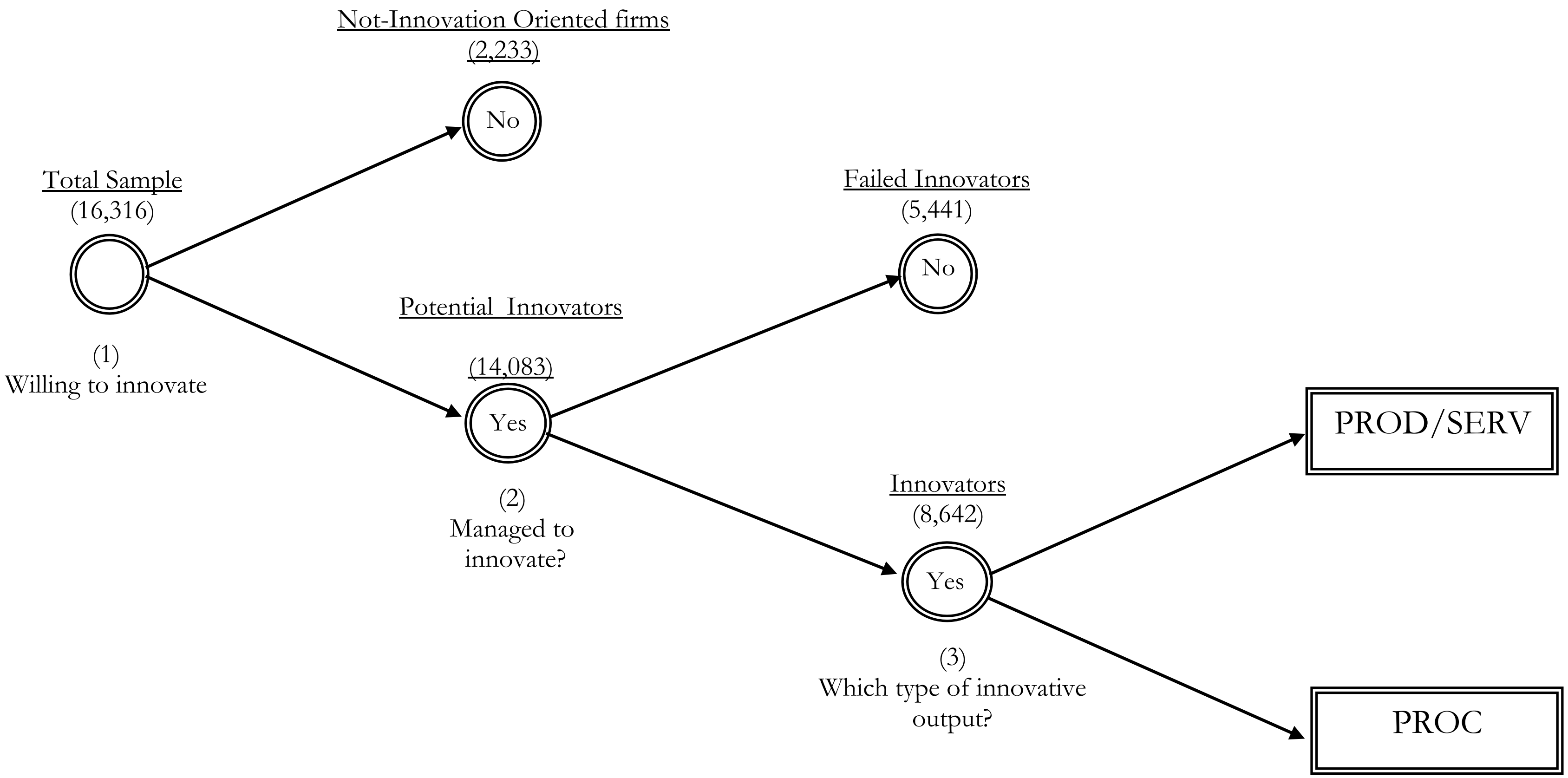
Table A4. Probit estimations (with lagged dependent variable)

	ALL SAMPLE		RELEVANT SAMPLE	
	(1) Wool. (no means)	(2) Wool. (with means)	(3) Wool. (no means)	(4) Wool. (with means)
INNOVATORS_1	0.495***	0.428***	0.493***	0.451***
	(0.071)	(0.075)	(0.068)	(0.071)
AGE	-0.002	-0.038	-0.002	-0.080***
	(0.002)	(0.028)	(0.002)	(0.027)
EXPORT_d	0.227***	0.031	0.214***	0.002
	(0.041)	(0.091)	(0.045)	(0.099)
EDU_HIGH	0.001*	0.001	0.002**	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
INNEXP_d	0.812***	0.699***	0.822***	0.753***
	(0.055)	(0.069)	(0.061)	(0.078)
IORG_d	0.542***	0.428***	0.538***	0.410***
	(0.043)	(0.059)	(0.046)	(0.063)
LSIZE	0.004	-0.009	0.018	-0.000
	(0.013)	(0.014)	(0.014)	(0.015)
HIND_COST_d	0.406***	0.362***	-0.265***	-0.274***
	(0.065)	(0.088)	(0.071)	(0.097)
HIND_KNOW_d	0.161***	0.102	0.044	-0.005
	(0.061)	(0.083)	(0.061)	(0.086)
HIND_MARK_d	-0.024	-0.050	-0.271***	-0.292***
	(0.059)	(0.081)	(0.061)	(0.085)
HIND_REG_d	0.012	-0.010	-0.006	-0.041
	(0.045)	(0.065)	(0.045)	(0.067)
INNOVATORS_0	0.363***	0.373***	0.343***	0.377***
	(0.083)	(0.086)	(0.079)	(0.082)
INTERCEPT	-1.611***	-1.769***	-0.653***	-0.718***
	(0.151)	(0.167)	(0.162)	(0.180)
Obs	7,427	7,427	6,240	6,240

Table A5. CIS questionnaire: Enterprise with no innovation activity.

If your enterprise had no innovation activities during the three-year period ----, please indicate why it has not been necessary or possible to innovate:	YES	NO
No need due to prior innovation	☐	☐
No need due to market condition	☐	☐
Factor constraining innovation	☐	☐

Figure1. The dynamics of the firm's innovative process and the role of the obstacles to innovation.



Chapter III
Reviving the demand-pull perspectives: the effect of demand uncertainty and stagnancy on R&D strategy

3.1. Introduction

The closely connected influences of demand and technological opportunities on the strategic decisions of firms to innovate and the aggregate outcomes of these decisions are well established subjects of research in innovation studies, since the seminal contribution of Schmookler (1966) and followed by a fierce debate among scholars in the field (Mowery and Rosenberg, 1979). A recent contribution (Di Stefano et al., 2012) reviews this debate by examining the evolution in this research, which has in turn come down in favour of either a technology-push or demand-pull source of innovation as it has sought to disentangle their relative importance in fostering innovation.

Interestingly, no previous study has analysed the demand-pull perspective from the viewpoint of barriers to innovation. As is common within the innovation literature, analyses of the factors of innovation success are proportionally more numerous than studies of patterns of failure and the effect of the lack of incentives. As such, scholars of demand-pull perspectives seem to have overlooked lack of demand or demand uncertainty as factors hampering decisions to invest in innovation.

The emerging literature on barriers to innovation has dealt primarily with the firms' characteristics that affect their perception of barriers to innovation or, when specifically examining the actual hindrances of perceived barriers, it has paid a disproportionate amount of interest to financial barriers and limitations to the financial capacity of firms to invest in R&D (see D'Este et al., 2012, and Pellegrino and Savona, 2013, for a review of this literature). This bias toward financial obstacles might well reflect the relative "dominance" of technology-push perspectives over interest in demand-related incentives to innovate.

Rather than contrasting the two perspectives empirically, here we seek to rebalance the overall picture by attempting to disentangle the effects of lack of demand, or perceived uncertainty about demand conditions, on firms' decisions to invest in R&D and the amount of resources they devote to the activity. The paper makes a number of contributions to the innovation literature: first, it adds to the recently renewed debate on demand-pull perspectives in innovation studies, by examining demand-related (i.e., lack of) incentives to invest in innovation. Second, it complements the emerging literature on barriers to innovation in two ways: on the one hand, by focusing on demand-related obstacles rather than on the more frequently explored financial barriers; and, on the other, by analyzing in detail whether experiencing demand-related obstacles is a sector-specific feature, that is, whether firms active in high- or low-tech manufacturing or in knowledge intensive or low-tech services are more or less dependent on demand conditions when deciding to perform R&D.

We find that demand uncertainty and stagnancy are two quite distinct barriers, having substantially different effects on firms' behaviour. We interpret this evidence in terms of the specific phase in the innovation cycle in which decisions to invest in R&D are formulated. While demand uncertainty has a weak, positive statistically significant effect on R&D plans, the perception of a lack of demand has a marked impact on not only the amount of investment in R&D but also the likelihood of firms engaging in R&D activities. Sectoral affiliation does not seem to be a factor in demand conditions, supporting the conjecture that positive expectations regarding market demand are a structural and necessary condition that has to be satisfied by all firms prior to deciding to invest in R&D. When considered from the perspective of barriers to innovation, demand-related incentives therefore seem to cut across sectoral specificities in technological opportunities.

In the section that follows we briefly review the two branches of literature mentioned above: that is, studies comparing demand-pull vs. technology-push sources of innovation and analyses of barriers to innovation. Section 3.3 describes the data employed in the empirical analysis; Section 3.4 illustrates the econometric strategy and the variables used in the estimations, while Section 3.5 discusses the results and provides a response to the main research question. Section 3.6 concludes.

3.2. Background literature

3.2.1 Demand-pull perspective revisited

The innovation literature has traditionally been somewhat ambivalent with regard to the role of demand as an incentive to innovation, besides that of technological opportunities. As suggested by Di Stefano et al., (2012) in a recent review, the debate between demand-pull and technology-push perspectives has evolved through different stages, from the rigid adoption of opposing stances by the supporters of demand-pull (Schmookler, 1962, 1966; Myers and Marquis, 1969; von Hippel, 1978, 1982) and its critics (Mowery and Rosenberg, 1979; Dosi, 1982; Kleinknecht and Verspagen, 1990) before settling, more recently, for a more balanced view which sees demand as a complementary (though not dominant) factor determining innovation. This body of literature includes both conceptual and empirical contributions (Cainelli et al., 2006; Piva and Vivarelli, 2007; Fontana and Guerzoni, 2008) as well as analyses conducted at both macro- and firm-levels.

For the purposes of our discussion here, it should suffice to recall the main arguments in the debate, relate them to the most recent literature on barriers to innovation (Section 3.2.2) and formulate the conjectures (Section 3.2.3) that we then test empirically in the remaining of the paper.

As Fontana and Guerzoni (2008) suggest, the intuition regarding the influence of demand on innovation was sparked by the seminal contributions of Schmookler (1962; 1966) and Myers and Marquis (1969), who claimed that the introduction of new products and processes is conditioned by the *presence of demand* or even possibly a *latent demand* and, in general, by *positive expectations of profitability* from returns to innovation. In the absence of these conditions, firms would simply not have any incentive to innovate. Moreover, the adoption and diffusion of (especially new) products are intrinsically subject to *uncertainty*, which would further reduce incentives to innovate. The arguments forwarded by the proponents of technology-push sources touched upon various issues, ranging from the reverse causality of the empirical relationships estimated by Schmookler (1966) and Meyers and Marquis (1969) to the difficulties of identifying the relevant demand affecting innovation incentives.

It is our contention, and one we come back to later, that market size – and therefore expectations regarding profitability – and demand uncertainty are very likely to refer to different *levels* of demand. First, positive expectations with regard to profitability and, hence, incentives to innovate, despite being intrinsically linked to the fate of the new product being launched, are affected primarily by the macro-conditions of aggregate demand and the market dynamism of the specific and related products. Even incremental product or process innovation would be hard to implement if forecasts of sales and returns to innovation were poor.

Second, while uncertainty might be linked to aggregate macro-conditions of demand, it is predominantly affected by the characteristics of the new products/services and the lack of information on users and their capabilities to adopt/benefit from the new product (see also von Tunzelmann and Wang, 2003 on user capabilities).

Of course, macro- and micro-demand conditions are likely to reinforce each other, though in the case of incremental product or process innovation, aggregate stagnancy of demand might be more influential, whereas in the case of radically new products or services it is the uncertainty that is likely to play a major role in terms of incentives to innovate (see also Fontana and Guerzoni, 2008).

3.2.2 Demand-pull as a barrier to innovation: stagnancy and uncertainty

Although the literature on barriers to innovation is relatively recent, scholars have found substantial evidence for the presence and effects of perceived hindrances on the propensity and intensity of engagement in innovation activities.

A large proportion of these studies have focused their attention on analyses of the effects of financial constraints on firms' cash flow sensitivity to afford R&D investments (for a review, see Schiantarelli, 1996; Hall, 2002; Bond et al., 1999; Hottenrott and Peters, 2012). Indeed, empirical evidence tends to confirm that encountering financial constraints significantly lowers the likelihood of firms engaging in innovative activities (Savignac, 2008), with this pattern being more pronounced in small firms and in high-tech sectors (Canepa and Stoneman, 2007; Hall, 2008; Hottenrott and Peters, 2012).

The implicit assumption behind this preferred focus of analysis is that it is essentially access to finance, financial uncertainty and information asymmetries that reduce the financial returns of R&D investments and the ability to attract external funds, thus reducing incentives to invest in R&D.

A few recent contributions have extended the analysis to non-financial obstacles to innovation, drawing primarily on evidence from innovation surveys, which allow the effects of knowledge-related obstacles (e.g., shortage of qualified employees, lack of information on technology and markets), market-related obstacles (e.g., lack of customer interest in innovative products, markets dominated by large incumbents), and barriers attributable to the need to fulfil national and international regulations) to be examined. Moreover, these innovation surveys allow researchers to look beyond the mere decision to invest in R&D and to take into account innovation outputs, such as the introduction of a new (to the market or to the firm) good or service or a new process.

Even within the CIS-based literature, an overwhelming number of contributions focus on the financial constraints to innovation, treating the role of non-financial constraints as a simple control factor (Tiwari et al., 2008; Mancusi and Vezzulli, 2010; Blanchard et al., 2013). Analyses of factors affecting the perception of all types of obstacles are provided, however, by Iammarino et al. (2009) and D'Este et al. (2008 and 2012). Pellegrino and Savona (2013) look at the effect of all types of barriers on the likelihood of being a successful innovator, recognizing the fundamental – possibly exacerbating – impact of other types of obstacles *indirectly* on the financial barriers and *directly* on the innovation intensity of firms. All these contributions point equally to the importance of the lack of access to finance and the lack of market responses to innovation.

3.2.3 Main conjectures

Overall, the implicit assumption behind the "bias" toward technology-push perspectives within the innovation literature is that firms plan their innovation investments in a context that is structurally and indefinitely capable of absorbing the outcomes of innovation, much in line with a blind trust in a sort of Say's Law[31] for innovative products. This would apply both at the general macro-economic level – that is, a general state of dynamism of aggregate consumption – and at the micro-level of analysis – that is, for the specific product/service/sector that has been introduced onto the market.

Without seeking to test the technology-push and demand-pull hypotheses empirically, here we contest this assumption and claim that if easy access to finance and the availability of funds are important conditions to *implement innovation investment plans*, trust and positive expectations regarding the state of demand are necessary conditions for firms to *enter the innovation contest* and *initiate innovation investment plans*.

Rather than focusing on market structure issues or "lack of customer interest", we turn our attention to firms' perception of the state of demand in terms of both the lack of demand *tout court* and market uncertainty. As far as the latter is concerned, we are aware that some scholars (see, for instance, Czarnitzki and Toole, 2011 and 2013) have analysed the effect of market uncertainty on R&D investment behaviour from a real option theory perspective, finding that uncertainty causes a fall in R&D investments, albeit mitigated by patent protection (Czarnitzki and Toole, 2011) and firms' size and market concentration (Czarnitzki and Toole, 2013).

Here we take a more heuristic approach to uncertainty and one that is more data driven, with the aim of testing whether firms' self-reported perception of market uncertainty[32] affects their investment behaviour. Specifically, we examine whether the decision to invest in R&D and the

31 Put simply, Jean Baptiste Say claimed that "supply always creates its own demand" – i.e., markets are able to infinitely absorb any quantity of production. The Keynesian framework overall rejected Say's Law. Here we might stretch the argument and argue that in the case of innovative products, the uncertainty of whether the launch of new products or services is going to be adopted by consumers and diffused in the markets is even higher than that affecting standard plans of production.

32 As explained in Section 3.3, information on market uncertainty is based on responses to a specific question formulated in terms of whether "uncertain demand for innovative goods or services" is perceived as a barrier to innovation. We believe that despite the qualitative, self-report nature of the information provided by this question (in common with all CIS-based evidence), it allows us to draw a plausible picture of firms' responses to increasing levels of (perceived) uncertainty.

amount of investment in R&D are affected by perceptions of these two demand-related obstacles over time and we empirically test this within a panel econometrics framework, as detailed in the next section.

Further, an important added value of this paper is the analysis it undertakes of possible sectoral differences in the way demand affects firms' propensity to invest in R&D[33]. Our conjecture is that service firms are substantially more sensitive to the state of demand when planning their innovative strategies. This is in line with much of the literature on innovation in services (for a review, see Gallouj and Savona, 2009), which claims that the importance of customers and user-producer interactions in services is substantially higher than in manufacturing sectors. Accordingly, we empirically test the conjectures above for both the whole sample of firms and for sub-samples of different macro-sectors, as explained in detail below.

3.3. Data

We draw on firm level data from the Spanish Technological Innovation Panel (PITEC), compiled jointly by 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 in line with the Oslo Manual guidelines (OECD, 1997) and, as such, they can be considered to constitute a Community Innovation Survey or CIS-type dataset. Thus, together with general information about the firm (main industry of affiliation, turnover, employment, founding year), PITEC also includes a (much larger) set of innovation variables that measure 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[34].

33 In the best tradition of innovation studies, this allows us to control for the role of different technological opportunities at the sectoral level and, therefore, to implicitly account for the "technology-push" argument.

34 Recent works based on the use of this dataset are López-García, et al. (2013), D'Este et al (2014) and Segarra and Teruel (2014)

An important feature that distinguishes PITEC from the majority of European CIS-type datasets is its longitudinal nature. Since 2003 systematic data collection has ensured the consistent representativeness of the population of Spanish manufacturing and service firms over a number of time periods.

In this study we use data for the period 2004-2011 and select our working database from the initial sample (100,016 firm-year observations). First, we discard all firms operating in the primary (1,628 observations), construction (3,914 observations), utilities (720 observations) and sewage/refuse disposal (318 observations) sectors and all firms involved in M&A transactions (8,543 observations)[35]. In line with our previous work (D'Este et al., 2008 and 2012; Pellegrino and Savona, 2013), we then select a relevant sample. To this end, we exclude 6,114 observations that refer to "non innovation-oriented firms", i.e., firms that did not introduce any type of innovation (goods, services or processes) and which at the same time did not encounter any barriers to innovation during the three-year period, and which we therefore infer are not interested in innovating. The resulting sample of 78,779 firm-year observations is further reduced by excluding all the missing values for the variables used in the empirical analysis (24,315 observations), as well as 354 firms that were observed for just one year.

Table 1 shows the composition of the final dataset following data cleaning. As can be seen, half of the 9,132 firms (54,110 observations) included in the final sample are observed for all eight periods (2004-2011); about 23% are observed for seven periods while only a negligible percentage of firms (around 10%) are observed for less than five years. These figures allow us to confirm with confidence the suitability of this dataset for the subsequent dynamic analysis.

35 It is common practice in the innovation literature to focus on private manufacturing and services companies and to exclude public utilities and primary activities owing to differences in the regulatory framework in which they operate. In the case of M&A transactions, firms were eliminated from the sample in the years following the merger or acquisition.

Table 1. Composition of the panel

Time obs.	N° of firms	%	% Cum	N° of obs.
2	384	4.26	4.26	768
3	511	5.55	9.81	1,533
4	647	7.08	16.89	2,588
5	893	9.85	26.74	4,465
6	2,123	23.25	49.99	12,738
7	4,574	50.01	100.00	32,018
Total	9,132	100		54,110

Note: the final sample only comprises firms for which a lag of the dependent variable is available. This implies that t=2 refers to firms that are observed for at least three periods, t=3 corresponds to firms that are observed for four periods and so on.

3.4. Econometric strategy and variables

As discussed above, the main aim of this paper is to assess empirically whether and, if so, how demand-related obstacles to innovation affect two important innovative decisions taken by firms: their propensity to engage in R&D and, conditional on that, the level of investment in R&D. As stressed by a largely consolidated stream of literature, innovation and, in particular, R&D activities are processes that present high degrees of cumulativeness and irreversibility and, as a result, are characterised by a high level of persistence (see Atkinson and Stiglitz, 1960; David, 1985; Dosi, 1988; Cefis and Orsenigo, 2001). This evidence is fully supported by our data. Indeed, if we examine the transition probabilities of engaging in R&D activities (see Table 2) it emerges that almost 86% of R&D performers in one year retained this same status during the subsequent year. This percentage rises to 91% in the case of non R&D performers that did not change their status into the next period.

This evidence suggests that the use of an autoregressive specification for the two decisions taken by a firm in relation to its R&D activities is the most suitable. Accordingly, our empirical strategy is based on the estimation of the following two equations:

$$y_{1it}^{*} = \varphi_1 y_{1i,t-1} + \beta_1^{'} x_{it} + c_{1i} + v_{1it} \quad (1)$$

$$y_{2it}^{*} = \varphi_2 y_{2i,t-1} + \beta_2^{'} x_{it} + c_{2i} + v_{2it} \quad (2)$$

where y_{1it}^{*} and y_{2it}^{*} denote the two latent dependent variables representing respectively firm *i*'s propensity at period *t* (*i* = 1,…N; *t* = 1,….T) to engage in R&D (expressed as a binary variable), and firm *i*'s decision regarding the level of investment to make in R&D activity (the natural logarithm of R&D expenditure). For each firm *i*, $y_{1i,t-1}$ and $y_{2i,t-1}$ represent the one-period lag of the y_{1it}^{*} and y_{2it}^{*} dependent variables, while x is a vector of explanatory variables that has been chosen taking into account both the characteristics of the dataset at our disposal and the main insights provided by the literature on the subject.

Table 2. Transition probabilities: R&D performers

		Performer in t	
		R&D	
		0	1
Performer in t-1	0	90.95	9.05
	1	14.15	85.85
	Total	43.98	56.02

More specifically, we first consider a binary indicator of *international competition*, which is equal to 1 if a firm's most significant market of destination is international and equal to 0 otherwise. On the grounds that international markets tend to be characterized by a higher level of competition, this variable should exert a positive effect on the firm's propensity to innovate (e.g., Archibugi and Iammarino, 1999; Narula and Zanfei, 2003; Cassiman *et al.*, 2010). However, some authors (see, for example, Clerides *et al.*, 1998) warn of the possible existence of a reverse causation: most innovative firms are more likely to penetrate foreign markets and self-select themselves so as to engage in tougher foreign competition. In order to deal with this endogeneity issue we consider the one-period lagged value of this variable.

Reverse causation has also been observed in the relationship between *public subsidies* and innovation activity. Most of the literature on the subject provides empirical support for the positive impact of incentive schemes on a firm's propensity to both engage in and undertake R&D (see, for example, Callejon and García-Quevedo, 2005; González *et al.,* 2005 for the Spanish case). However, other contributions cast some doubt on the reliability of such a relationship because of the potential endogeneity of public funding (see, for example, Wallsten, 2000). Accordingly, the t-1 value of an indicator of whether the firm has received public support for innovation is included.

A one-period lagged value has also been considered for two indicators of whether the firm makes use respectively of *patents* and *informal methods* (registration of design, trademarks, copyrights) to protect its innovations[36]. In this case, the rationale is that the positive impact of the mechanisms of appropriability used by a firm take time to make themselves manifest.

We also use a variable recording a firm's *age* to control for age related effects. The theoretical and empirical literatures provide mixed evidence regarding the possible effect of age on engagement in/realization of innovation activities. Klepper (1996) provides a theoretical model that points to a negative relationship between a firm's age and its probability of innovating. However, as Galande and De la Fuente (2003) point out, a firm's age can also be seen as a proxy of the firm's knowledge and experience accumulated over time and, consequently, it should be positively related to innovation.

36 Previous studies generally show a clear-cut, positive link between these factors and a firm's innovative activity (see Levin et al., 1987; Salomon and Shaver, 2005; Liu and Buck, 2007).

Moreover, in line with various studies that stress the expected innovative benefits for a firm that is a *member of an industrial group* (see Mairesse and Mohnen, 2002), such as easier access to finance and positive intra-group knowledge spillovers, we include a dummy variable identifying this characteristic.

A further important factor that might influence a firm's R&D decision is the business cycle. In order to control for this aspect, in line with some recent contributions (see Aghion et al., 2012; Lopez Garcia et al., 2013), we use a micro-level perspective to identify idiosyncratic shocks to firms by considering *firm's sales growth*.

Finally, following the Schumpeterian tradition, we consider a variable reporting the log of the total number of employees as a measure of *firm size* and a set of *industry dummies* variables (based on the 2-digit CNAE codes[37]).

In the case of the demand-related obstacles, in line with the discussion in Section 3.2 and the rationale underpinning this, we single out two binary variables that identify an increase (over a yearly base) in the degree of importance (irrelevant, low, medium, high) that the firms assign to the following two barriers specified as "uncertain demand for innovative goods and services" and "lack of demand for innovation"[38]. Finally, we control for possible additional negative effects of *other obstacles* to innovation, including a dichotomous variable recording an annual increase in the importance of the firm's level of perception of the remaining obstacle categories (cost and knowledge related obstacles, market dominated by established firms). Table A1 in the Appendix shows the list of variables, their acronyms and a detailed description.

As for the econometric methodology, in order to estimate equations (1) and (2), we apply the method proposed by Wooldridge (2005) based on a conditional maximum likelihood estimator. The author proposes a simple solution in order to address the two well-known problems that might bias the results in a dynamic random effects probit/tobit context: the initial condition

37 The Spanish industrial classification codes (CNAE) correspond to the European NACE taxonomy.

38 We opted to use these constructed variables in light of the high within-variation of the obstacle variables. However, by construction, the variables take the value 0 in the case of firms persistently assessing the two barriers as highly relevant. We therefore perform robustness checks by considering instead two dichotomous variables taking the value 1 when a firm evaluates as highly relevant the lack/uncertainty of demand and 0 otherwise. The results shown in tables A3-A4 and A5 in the Appendix are remarkably consistent with those discussed in Section 3.5.2.

problem and the correlation between the individual error term and the explanatory variables. Specifically, Wooldridge suggests modelling the firm-specific error term as follows:

$$c_{ji} = \alpha_{j0} + \alpha_{j1} y_{ji0} + \alpha_{j2} \bar{x}_i + a_{ji} \qquad (3)$$

where $\bar{x}_i$ refers to the within mean of the x_{it} vector of explanatory variables and embodies the elements that are correlated with x_{it}, while y_{ji0} (with j = 1,2) are the initial conditions of the dependent variables that are supposed to be correlated with the individual error term.

The new equations (1) and (2), obtained by replacing the individual error terms c_{ji} (with j= 1,2) in the right-hand side of equation 3, are estimated using standard random effects probit (equation (1)) and tobit (equation (2), due to the censored nature of R&D expenditure) software.

3.5. Empirical evidence

3.5.1. Descriptive statistics

One of the conjectures forwarded in this paper is that a firm's sectoral affiliation is a major determinant of the nature and dimension of the effects of demand obstacles on its innovative behaviour. Following the classification proposed by Eurostat and based on an aggregation of NACE manufacturing and service sectors, we identify four macro-categories: high/medium-high tech manufacturing industries (HMHt), low/medium-low tech manufacturing industries (LMLt), knowledge-intensive services sectors (KIS) and less knowledge-intensive services sectors (LKIS). Table 3 depicts the sectoral (2 digit) composition and the distribution of these four macro-categories and reports the mean of the two demand obstacle variables *Lack of demand* and *Uncertainty* for each sector.

Table 3. Sectoral composition for macro categories (relative frequencies) and percentage of firms that experienced an increase in the degree of importance of the demand (uncertainty and lack) related obstacles

	Freq. For category	% over category	% over total	Incr. in lack of demand	Incr. in uncertainty demand
Low/Med-Low	18,730	100.00	34.61	16.27	19.87
Petroleum	39	0.21	0.07	10.26	20.51
Food products beverages, tobacco	4,109	21.94	7.59	16.50	19.96
Textiles	1,180	6.30	2.18	13.90	16.86
Wearing apparel	370	1.98	0.68	14.32	24.32
Leather -products, footwear	359	1.91	0.66	19.50	18.38
Wood-products, cork	599	3.20	1.11	20.03	24.71
Pulp/paper-products	546	2.92	1.01	13.00	16.12
Rubber and plastics	1,981	10.57	3.66	14.89	19.59
Mineral products (no metallic)	1,736	9.27	3.21	17.40	20.68
Basic metals	955	5.10	1.76	16.65	20.52
Fabricated metal products	3,464	18.49	6.40	17.26	20.84
Furniture	1,119	5.98	2.07	18.77	21.00
Other manufacturing n.e.c.	1,835	9.80	3.39	14.39	18.37
Repair of fabricated metal products	438	2.34	0.81	13.47	19.86

In terms of sectoral composition, there is a slight prevalence of LMLt firms, constituting 35% of the total observations, while the remaining 65% of the observations are roughly equally distributed among the three other sectoral categories (HMHt, KIS and LKIS). If we consider the sectoral frequencies in terms of the macro-categories, around 22% of the LMLt firms operate in the food, beverage and tobacco sectors; around 29% of HMHt companies are active in the chemical sectors; 35% of KIS firms carry out computer programming activities and, finally, 36% of the LKIS firms are active in the trade sector. Across these four macro-sectors, almost 20% of firms have experienced an increase in the degree of importance assigned to demand uncertainty, while a lower percentage (around 16%) experienced an increase in the degree of importance of the lack of demand as a perceived obstacle. In the case of the sectoral categories, no striking differences can be found, with a percentage range running from 13.54 (HMHt) to 17.90 (LKIS) for the *Uncertainty* variable and from 17.39 (HMHt) to 22.26 (LKIS) for the *Lack of demand* variable. Overall, these figures reveal a quite high responsiveness on the part of firms to changes in the demand condition that can hamper their innovation activities. This evidence is further corroborated by the figures in Table 4, which report the mean values (in percentages) of the two demand-related obstacles by year and sectoral categories. As is apparent, though, these variables show considerable within variation. Our examination of possible sectoral specificities in terms of a firm's characteristics (see Table 5 for the summary statistics – mean and standard deviation – of the variables presented above) reveals that some of the differences are in line with expectations.

Table 3 (Continuation). Sectoral composition for macro categories (relative frequencies) and percentage of firms that experienced an increase in the degree of importance of the demand (uncertainty and lack) related obstacles

	Freq. For category	% over category	% over total	Incr. in lack of demand	Incr. in uncertainty demand
High/Med-High	11,736	100.00	21.69	13.54	17.39
Chemicals	3,364	28.67	6.22	12.90	16.59
Pharmaceutical	909	7.75	1.68	10.34	16.50
Electronic, optical, computer products	1,049	8.94	1.94	12.96	17.35
Electrical equipment	1,265	10.77	2.34	13.20	18.02
Other machinery	3,540	30.17	6.54	15.31	17.91
Motor vehicles	1,274	10.86	2.35	13.19	18.29
Aerospace	143	1.21	0.26	13.29	15.38
Other transport equipment	192	1.64	0.35	15.10	17.71
KIS	11,942	100.00	22.07	15.26	19.58
Telecommunications	312	2.61	0.58	13.46	22.12
Computer programming activities	4,207	35.24	7.77	15.43	20.25
Other inform. and communication serv.	951	7.96	1.76	18.30	22.08
Financial intermediation, insurance	1,086	9.09	2.01	15.29	17.03
Research and development services	1,678	14.05	3.10	11.98	17.10
Other activities*	3,505	29.34	6.48	19.60	19.80
Education	203	1.70	0.38	15.76	20.20
LKIS	11,702	100.00	21.63	17.90	22.26
Trade	4,236	36.20	7.83	16.34	20.87
Passenger transport, warehousing	1,153	9.86	2.13	20.29	23.42
Hotels and Restaurants	708	6.04	1.31	17.37	23.73
Real Estate	317	2.71	0.59	19.87	22.71
Public administration and auxiliary serv.	3,186	27.22	5.89	17.92	23.07
Other service activities**	2,102	17.97	3.88	8.52	22.65
TOTAL	54,110		100.00	15.81	19.78

* Legal activities; Activities of head offices; Architectural activities; Advertising agencies; Specialised design activities; Veterinary activities.

** Washing and (dry-)cleaning of textile and fur products; Repair of computers and peripheral equipment.

Specifically: 1) HMHt and KIS firms appear to be more likely to engage in R&D, to invest more in R&D and to have a higher probability of receiving subsidies for their innovation activity (in line with the previous discussion) than do the other two categories; 2) firms in the manufacturing sectors show a much higher propensity to export than those active in the services sectors; 3) while no striking sectoral differences emerge with respect to the firm's propensity to use informal methods of protection (the lowest percentage being associated, as expected, with LKIS firms), HMHt firms are much more likely to protect the results of their innovation activity by means of patents than are the firms operating in the other sectors (with only 5% of LKIS firms resorting to appropriability methods of this type).

Table 4. Percentage of firms that report an increase in the degree of importance of the demand (uncertainty and lack) related obstacles. (by year and sectoral categories)

	2005		2006		2007		2008		2009		2010		2011	
	Un. Dem	Lack Dem	Un. Dem	Lack Dem	Un. Dem	Lack Dem	Un. Dem	Lack Dem	Un. Dem	Lack Dem	Un. Dem	Lack Dem	Un. Dem	Lack Dem
Low/Med-Low	24.1	18.8	19.9	16.8	19.1	13.9	20.5	17.2	19.1	15.3	18.6	16.7	18.0	15.4
High/Med-High	20.0	16.9	17.7	13.3	17.0	12.0	18.1	14.2	16.9	11.5	16.8	13.9	15.2	13.4
KIS	24.4	17.8	20.9	15.5	19.1	14.6	20.0	16.3	17.7	15.4	17.4	14.2	18.4	13.3
LKIS	26.6	20.3	23.5	20.6	20.4	15.3	25.1	18.2	20.4	17.9	19.8	16.5	20.4	16.9
Total	23.7	18.5	20.4	16.5	18.9	13.9	20.9	16.6	18.6	15.1	18.2	15.5	18.0	14.8
Observations	6,616		8,524		8,439		8,229		7,931		7,459		6,912	

If we examine the remaining variables, on average 37% of the observations refer to firms that are part of an industrial group: this percentage ranges from 34% for firms in the LMLt category to 42% for those in the MHMt group. Finally, turning to the variable ln(Size) and ln(Age), on average, firms acting in the KIS sectors appear to be younger and smaller than their counterparts in the other sectoral categories[39].

39 It is worth nothing that, since we use panel data, the revealed negative relationship between R&D and age might be due to a survivorship bias. Indeed, as the subsequent surveys can only account for firms that have survived until the date of data collection, the probability that the resulting sample may be biased towards the more successful companies is not negligible. This could be particularly true for new born and young firms which are more likely to be affected by early failure.

Table 5. Descriptive statistics: mean and standard deviation of the variables; all firms and 4 sectoral categories

	All firms		*Low/Med-low*		*High/Med-high*		*Kis*		*Lkis*	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
ln(R&D)	7.20	6.21	6.92	6.05	9.62	5.52	8.43	6.17	3.95	5.67
R&D dummy	0.58	0.49	0.58	0.49	0.77	0.42	0.66	0.47	0.33	0.47
R&D dummy t-1	0.63	0.48	0.63	0.48	0.80	0.40	0.70	0.46	0.37	0.48
Lack of demand	0.16	0.36	0.16	0.37	0.14	0.34	0.15	0.36	0.18	0.38
Uncertainty	0.20	0.40	0.20	0.40	0.17	0.38	0.20	0.40	0.22	0.42
ln(Age)	3.06	0.65	3.19	0.62	3.20	0.63	2.77	0.66	3.02	0.61
Exporter dummy t-1	0.63	0.48	0.77	0.42	0.85	0.36	0.43	0.50	0.37	0.48
Industrial group	0.37	0.48	0.34	0.47	0.42	0.49	0.35	0.48	0.39	0.49
Patent dummy t-1	0.13	0.33	0.13	0.33	0.20	0.40	0.13	0.33	0.05	0.22
Informal protection dummy t-1	0.24	0.43	0.25	0.44	0.27	0.44	0.26	0.44	0.18	0.38
ln(Size)	4.10	1.56	4.05	1.29	4.08	1.34	3.66	1.67	4.65	1.87
Subsidy dummy t-1	0.37	0.48	0.35	0.48	0.42	0.49	0.48	0.50	0.22	0.42
Sales growth	0.00	0.59	-0.01	0.42	0.00	0.51	0.02	0.78	0.00	0.66
Other obstacles	0.47	0.50	0.48	0.50	0.45	0.50	0.47	0.50	0.46	0.50
Observation	54,110		18,730		11,736		11,942		11,702	

Table 6 reports the mean values of the variables for the four different firm types identified by taking into account their "demand obstacle status". More specifically we distinguish those firms that did not experience an increase in the degree of relevance assigned to either of the two obstacles, from those that report an increase in the degree of importance of only the *lack of demand* obstacle; only the *uncertainty* demand obstacle; or both types of demand obstacle. We find that firms belonging to the first category appear to present quite distinct characteristics from those presented by firms in any of the remaining groups. Specifically, firms that did not report any increase in the degree of relevance assigned to either of the two obstacles present higher values for all the variables considered, with the exception of the variables of *other obstacles* and *sales growth*. In contrast, and as expected, firms presenting positive values for the demand obstacle variables appear to be less R&D oriented (both in terms of the probability of conducting the activity and the level of investment) than their counterparts, and this is particularly true in the case of firms that report an increase in the level of importance of the *lack of demand* obstacle. This evidence is largely robust across the four sectoral categories. Albeit solely at the descriptive level, this evidence seems to suggest that, regardless of the sector, demand conditions play an important role in affecting innovative firms' decisions. We test this in an econometric framework in the next section.

3.5.2. Econometric results

The estimation results for the propensity to engage in R&D (probit estimations) and for the amount of expenditure dedicated to R&D (tobit estimations) for the whole sample are reported in Table 7. The table shows the estimated parameters of the main variables of interest, the demand obstacles, and the control variables.

The results for the control variables present the expected signs and significance. First, both R&D decisions (whether or not to invest and how much to invest) appear to be highly persistent over time as the parameters for the initial value and the lagged dependent variables are positive and highly significant. Second, in both estimations, the traditional firm characteristics affecting decisions related to R&D expenditure present the expected sign. Larger firms that conduct business internationally are more likely to carry out R&D activities and to devote more resources to them. Moreover, although the literature is not unanimous on this point, our results suggest that there is a negative and significant relationship between age and R&D, so that younger firms are more likely to carry out R&D activities. Third, other variables that characterise the innovation behaviour of firms, including the use of intellectual property rights and being recipients of public subsidies, also have a positive effect on R&D investments. Finally, while firms with higher levels of sales growth are more likely to engage in R&D and to invest more in R&D, the increase in the perception of other obstacles to innovation exerts, as expected, a negative and highly significant effect on both decisions taken by the firm.

Table 6. Descriptive statistics: mean of the variables by sectoral categories and by obstacles variables status (whole sample, LMLt, HMHt)

	All the sample				*Low/Med-low*				*High/Med-high*			
	No-obst.	*Uncer. Dem.*	*Lack of Dem.*	*Both Obst*	*No-obst.*	*Uncer. Dem.*	*Lack of Dem.*	*Both Obst*	*No-obst.*	*Uncer. Dem.*	*Lack of Dem.*	*Both Obst*
ln(R&D)	7.65	6.87	5.34	5.57	7.36	6.70	5.11	5.37	10.01	9.35	7.43	8.15
R&D dummy	0.62	0.56	0.44	0.46	0.61	0.55	0.43	0.46	0.79	0.74	0.61	0.67
R&D dummy t-1	0.65	0.58	0.56	0.54	0.65	0.58	0.57	0.55	0.82	0.77	0.73	0.73
ln(Age)	3.08	3.01	3.01	3.04	3.20	3.14	3.14	3.18	3.22	3.16	3.16	3.14
Lack of demand	0	0	1	1	0	0	1	1	0	0	1	1
Uncertainty	0	1	0	1	0	1	0	1	0	1	0	1
Exporter dummy t-1	0.65	0.59	0.58	0.56	0.78	0.74	0.73	0.70	0.86	0.83	0.82	0.78
Industrial group	0.38	0.35	0.33	0.35	0.35	0.33	0.28	0.31	0.43	0.41	0.36	0.39
Patent dummy t-1	0.13	0.11	0.11	0.10	0.13	0.12	0.11	0.10	0.20	0.17	0.17	0.17
Informal prot. dummy t-1	0.25	0.22	0.22	0.20	0.26	0.24	0.23	0.22	0.28	0.25	0.23	0.24
ln(Size)	4.14	4.05	3.94	4.06	4.10	3.99	3.81	3.96	4.12	4.07	3.87	3.91
Subsidy dummy t-1	0.38	0.35	0.33	0.32	0.36	0.33	0.32	0.33	0.42	0.42	0.37	0.37
Sales growth	0.00	0.01	-0.03	-0.01	-0.01	-0.01	-0.05	0.00	0.01	0.01	-0.02	-0.03
Other obstacles	0.40	0.60	0.74	0.54	0.41	0.61	0.74	0.54	0.39	0.64	0.73	0.51
Observation	38,244	7,313	5,161	3,392	13,198	2,485	1,811	1,236	8,733	1,414	962	627
%	70.68	13.52	9.54	6.27	70.46	13.27	9.67	6.60	74.41	12.05	8.20	5.34

Table 6 (continued) - Descriptive statistics: mean of the variables by sectoral categories and by obstacles variables status (Kis and LKIS)

	Kis				*Lkis*			
	No-obst.	*Uncer. Dem.*	*Lack of Dem.*	*Both Obst*	*No-obst.*	*Uncer. Dem.*	*Lack of Dem.*	*Both Obst*
ln(R&D)	8.77	8.40	6.84	6.94	4.31	3.75	2.80	2.73
R&D dummy	0.69	0.67	0.55	0.55	0.36	0.31	0.24	0.24
R&D dummy t-1	0.72	0.70	0.65	0.62	0.39	0.32	0.35	0.33
ln(Age)	2.80	2.70	2.70	2.78	3.04	2.99	2.99	2.97
Lack of demand	0	0	1	1	0	0	1	1
Uncertainty	0	1	0	1	0	1	0	1
Exporter dummy t-1	0.45	0.41	0.39	0.38	0.39	0.34	0.34	0.34
Industrial group	0.35	0.33	0.33	0.36	0.39	0.37	0.38	0.38
Patent dummy t-1	0.13	0.13	0.11	0.10	0.06	0.05	0.05	0.03
Informal protect. dummy t-1	0.26	0.25	0.24	0.20	0.19	0.15	0.17	0.15
ln(Size)	3.71	3.53	3.50	3.67	4.67	4.62	4.56	4.65
Subsidy dummy t-1	0.49	0.48	0.43	0.39	0.23	0.21	0.20	0.19
Sales growth	0.02	0.04	-0.01	-0.05	0.00	0.01	-0.05	0.02
Other obstacles	0.40	0.64	0.74	0.59	0.40	0.50	0.75	0.52
Observation	8,491	1,629	1,113	709	7,822	1,785	1,275	820
%	71.1	13.64	9.32	5.94	66.84	15.25	10.9	7.01

The results of the estimations (Tables 8 and 9) are consistent with most of the previous results regarding the effect and significance of the control variables across the four groups of sectors. The parameters for the initial conditions and the lagged dependent variables are positive and significant showing that the likelihood of carrying out R&D and R&D investment are highly persistent across different sectors. In addition, as in the estimation for the full sample, size and participation in foreign markets present a positive relationship with the decision to engage in R&D and the level of investment. Public subsidies also show positive and significant parameters across the four groups of sectors. On the other hand, age is only significant in the less knowledge-intensive services, showing a negative link as in the full-sample estimation. Finally, the negative effect of the variable controlling for other obstacles is particularly important in high and medium-high technology manufacturing sectors and in knowledge-intensive sectors.

3.5.2.1. Uncertainty, lack of demand and R&D strategies

Turning to our main variables of interest, we find that an increase in the level of demand uncertainty for innovative goods or services as perceived by firms does not affect their R&D decisions and presents a weak positive relation to the amount of R&D invested. In particular, in the sectoral estimations the parameter is not significant and, therefore, an increase in uncertainty neither affects the likelihood of engaging in R&D nor the amount invested in these activities.

As discussed in Section 3.2, the theoretical literature examining the relationship between uncertainty and R&D does not offer a conclusive answer. The few empirical studies in this field seem to support a negative relationship (Czarnitzki and Toole, 2011 & 2013), while in some recent research work (Stein and Stone, 2013) a positive relationship between uncertainty and R&D investment has been found, which seems to be (weakly) supported by our full-sample estimations. Our results suggest that there might be a defensive strategy in response to an increase in perceived demand uncertainty in terms of firms' opting to invest or opting to devote more of their budget to R&D.

The weakly positive relation between uncertainty and R&D behaviour might be explained by a "caution effect" that leads to a reduction in the responsiveness of R&D to changes in business conditions when uncertainty is higher (Bloom, 2007; Bloom et al., 2007). Overall, our findings support the (robust) evidence on the persistence over time of R&D activities (see also

Cefis and Orsenigo, 2001): decisions to invest in R&D therefore seem to belong to firms' structural, long-term strategies. After all, particularly when investing in basic research and in the first phases of applied research, returns to R&D are themselves almost by definition highly uncertain and in most cases highly risky. Part of the demand uncertainty might therefore be already "incorporated" in the strategic horizon of firms' decisions and may even be considered an incentive to face uncertainty by competing in terms of product quality.

In contrast with this result, and interestingly for the purpose of our analysis, the firms' perception of deterioration in demand conditions has a strong and significantly negative effect on R&D strategy. Falling or the lack of demand for goods and services not only has a negative effect on the amount invested in R&D but also reduces the likelihood of engaging in R&D altogether[40]. Although a general stagnation of demand may affect prices and therefore lead to a net increase in demand for cheaper innovative products (OECD, 2012), our results show that the negative effect is clearly dominant, suggesting that rather than uncertainty with regard to the demand for a single product or for a specific portfolio of products, it is the general macro-economic condition and, therefore, expectations regarding the aggregate state of the economy that affect firms' R&D strategies. This confirms our conjecture that, especially in time of crisis, demand-pull perspectives on innovation should be revisited and made better use of for (macro) policy purposes. We will return to these considerations in the concluding section.

3.5.2.2. Uncertainty, lack of demand and R&D strategies – sectoral specificities

The estimations carried out for the four groups of sectors (Tables 8 and 9), distinguishing between manufacturing and service sectors as well as their respective technological content, show that the effect of demand obstacles on R&D investments are homogenous across sectors. Our results are therefore robust, confirming that demand conditions affect the R&D behaviour in all types of firm, regardless of their sectoral affiliation. High demand uncertainty neither affects the likelihood of performing R&D nor the amount invested in it, in any of the four sectors. In contrast, deterioration in general demand conditions has a negative effect across all four sectors.

40 Even when considering the joint effect of the increase in lack and uncertainty of demand, as shown in Table 2A in the appendix, it clearly emerges that the negative effect of the perceived lack of demand dominates over uncertainty, as the net effect is still negative.

However, the magnitude of these effects is not homogeneous across all sectors. In particular, the reduction in demand has a more intense effect on expenditure in R&D in the less knowledge-intensive services.

3.6. Concluding remarks

This paper has revived demand-pull perspectives from the point of view of barriers to innovation and investigated whether perceptions of a lack of demand and of demand uncertainty negatively affect the propensity to invest in R&D and the intensity of the financial effort devoted to this activity.

Our main conjecture is that the size of the destination market and expectations regarding profitability (that is, the perceived lack of demand and of market dynamism) are likely to have impacts other than the mere uncertainty regarding the propensity to engage in R&D and the intensity of that engagement. While the former reflects a general trust in the state of the economy and is, hence, more of a macro-condition that firms need to verify, the latter is a micro-condition concerning the specific characteristics of the product and, hence, the actual user needs that the product is supposed to satisfy. Our claim, for which we provide empirical support, is that a lack of trust in the macro-condition of demand's dynamism represents more of a deterrent for firms to even engage in innovative activities, whereas uncertainty regarding the specific demand and user needs, while still being a deterrent, are likely to be incorporated in the firms' specific R&D plans.

We have found support for this conjecture. From our analysis it emerges that while the perception of an increasing lack of demand has a significant, strong and negative effect on both the decision to invest and the amount of investment in R&D, increasing demand uncertainty does not seem to have any significant effect or to have a weakly significant positive effect (Stein and Stone, 2013). Part of the demand uncertainty might therefore be already "incorporated" in the strategic horizon of firms' decisions when they engage in an intrinsically risky and uncertain activity such as R&D.

These findings contribute to the debate on demand-pull and technology-push approaches in innovation studies from a radically novel perspective, namely, that of barriers to innovation.

The literature on barriers is increasingly important due to its obvious policy relevance. However, much of the scholarship produced to date, with few exceptions, has focused on financial barriers, overlooking other important hindrances that firms might face when deciding to innovate. Overlooking demand-related obstacles – we argue – reflects the dominance of technology-push perspectives and the way the debate between demand-pull and technology-push has been shaped over time (see Di Stefano et al., 2012 for a recent review).

An exhaustive consideration of the policy implications of these findings goes beyond the scope of this paper. However, our results confirm the importance of demand as a strong incentive to innovate. We support the need to foster demand-side innovation policies in the innovation policy agenda (Archibugi and Filippetti, 2011). Although the role of demand is still incipient in innovation policies (Edler and Georghiu, 2007), recent trends show an increase in, and a growing emphasis on, the use of demand-side innovation measures (OECD, 2011; Edler, 2013). These measures may help guarantee markets for new goods and services and complement supply-side innovation policy tools to promote innovation efforts and performance.

Finally, our results show that the lack of demand affects negatively the decision to invest in R&D for the four groups of sectors considered. Although the sectors differ in terms of their innovation dynamics, these results suggest that demand-oriented innovation policies may stimulate R&D in all types of industry. Nevertheless, further research is needed to analyse in greater detail the reaction of individual industries to the lack of demand and the convenience of targeting different sectors with different policy tools.

Table 7. Dynamic RE probit and tobit estimations for the whole sample

	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)
R&D Dummy t-1	0.263***		0.268***	
	(0.005)		(0.005)	
R&D Dummy t_0	0.229***		0.219***	
	(0.008)		(0.008)	
Ln (R&D) t-1		0.023***		0.023***
		(0.000)		(0.000)
Ln (R&D) t_0		0.016***		0.015***
		(0.000)		(0.000)
Uncertainty	0.002	0.005**		
	(0.004)	(0.002)		
Lack of demand			-0.070***	-0.042***
			(0.004)	(0.002)
ln(Age)	-0.003	-0.006**	-0.003	-0.006**
	(0.004)	(0.003)	(0.004)	(0.002)
Exporter dummy t-1	0.061***	0.033***	0.060***	0.032***
	(0.005)	(0.003)	(0.005)	(0.003)
Industrial group	0.013***	0.004	0.013***	0.004
	(0.005)	(0.003)	(0.005)	(0.003)
Patent dummy t-1	0.039***	0.007**	0.039***	0.007**
	(0.007)	(0.003)	(0.007)	(0.003)
Informal protection dummy t-1	0.033***	0.016***	0.031***	0.015***
	(0.005)	(0.002)	(0.005)	(0.002)
ln(Size)	0.036***	0.019***	0.034***	0.018***
	(0.002)	(0.001)	(0.002)	(0.001)
Subsidy dummy t-1	0.053***	0.019***	0.052***	0.019***
	(0.004)	(0.002)	(0.004)	(0.002)
Sales growth	0.019***	0.010***	0.018***	0.010***
	(0.003)	(0.001)	(0.003)	(0.001)
Other obstacles	-0.024***	-0.009***	-0.017***	-0.005***
	(0.003)	(0.002)	(0.003)	(0.002)
N° of observations	54,110	31,558	54,110	31,558
Log likelihood	-18,349.36	-110,152.19	-18,230.76	-115,420.97
σ_u	0.829***	3.286***	0.804***	3.286***
	(0.025)	(0.063)	(0.025)	(0.062)
Rho	0.407***	0.311***	0.393***	0.311***
LR test for Rho	741.549	2,759.567	676.358	8,805.801
p-value	0.000	0.000	0.000	0.000

Table 8. Dynamic RE probit and tobit estimations for Manufacturing sectors (Low/medium and High/medium tech sectors)

	Low/medium-low tech Sectors				High/medium-high tech Sectors			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
R&D Dummy t-1	0.299***		0.303***		0.215***		0.220***	
	(0.009)		(0.009)		(0.012)		(0.012)	
R&D Dummy t_0	0.236***		0.225***		0.183***		0.174***	
	(0.015)		(0.015)		(0.017)		(0.017)	
Ln (R&D) t-1		0.026***		0.026***		0.015***		0.015***
		(0.000)		(0.000)		(0.000)		(0.000)
Ln (R&D) t_0		0.015***		0.015***		0.007***		0.007***
		(0.000)		(0.000)		(0.000)		(0.000)
Uncertainty	0.001	0.007			0.001	0.002		
	(0.007)	(0.004)			(0.007)	(0.002)		
Lack of demand			-0.082***	-0.050***			-0.060***	-0.024***
			(0.008)	(0.005)			(0.008)	(0.003)
ln(Age)	0.000	-0.002	0.001	-0.002	0.001	-0.002	0.001	-0.002
	(0.008)	(0.004)	(0.007)	(0.005)	(0.008)	(0.003)	(0.008)	(0.003)
Exporter dummy t-1	0.083***	0.055***	0.080***	0.054***	0.058***	0.023***	0.056***	0.023***
	(0.009)	(0.006)	(0.009)	(0.006)	(0.010)	(0.004)	(0.010)	(0.004)
Industrial group	0.032***	0.014**	0.031***	0.015**	-0.014	-0.060*	-0.014	-0.006*
	(0.010)	(0.006)	(0.010)	(0.006)	(0.010)	(0.003)	(0.010)	(0.003)
Patent dummy t-1	0.051***	0.015**	0.049***	0.015**	0.025**	0.003	0.026**	0.003
	(0.012)	(0.006)	(0.012)	(0.006)	(0.011)	(0.003)	(0.011)	(0.003)

Table 8 (continuation). Dynamic RE probit and tobit estimations for Manufacturing sectors (Low/medium and High/medium tech sectors)

	Low/medium-low tech Sectors				High/medium-high tech Sectors			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
Informal protection d. t-1	0.035***	0.018***	0.033***	0.017***	0.037***	0.010***	0.036***	0.010***
	(0.009)	(0.005)	(0.009)	(0.005)	(0.009)	(0.003)	(0.009)	(0.003)
ln(Size)	0.064***	0.036***	0.062***	0.035***	0.049***	0.016***	0.047***	0.015***
	(0.005)	(0.003)	(0.004)	(0.003)	(0.005)	(0.001)	(0.005)	(0.002)
Subsidy d. t-1	0.043***	0.016***	0.043***	0.016***	0.034***	0.006***	0.034***	0.006***
	(0.007)	(0.004)	(0.007)	(0.003)	(0.008)	(0.002)	(0.007)	(0.002)
Sales growth	0.020***	0.013***	0.019***	0.013***	0.013**	0.006***	0.012**	0.006***
	(0.007)	(0.004)	(0.007)	(0.004)	(0.005)	(0.002)	(0.005)	(0.002)
Other obstacles	-0.013**	-0.003	-0.006	0.002	-0.042***	-0.010***	-0.037***	-0.008***
	(0.006)	(0.003)	(0.006)	(0.004)	(0.006)	(0.002)	(0.006)	(0.002)
N° of observ.	18,730	10,774	18,730	10,774	11,736	8,985	11,736	8,985
Log likelihood	-6,962.8	-38,630.8	-6,906.7	-38,575.7	-3,444.0	-27,914.7	-3,414.47	-27,877.3
σ_u	0.813***	3.398***	0.783***	3.318***	0.896***	2.375***	0.857***	2.318***
	(0.039)	(0.111)	(0.039)	(0.112)	(0.061)	(0.097)	(0.061)	(0.097)
Rho	0.398***	0.297***	0.380***	0.288***	0.446***	0.278***	0.423***	0.268***
LR test for Rho	279.950	935.581	250.348	885.615	148.184	604.328	129.396	566.990
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets (calculated using the delta method). Time and industry dummies are included. Marginal effects reported.

Table 9. Dynamic RE probit and tobit estimations for services sectors (KIS and LKIS)

	KIS				LKIS			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
R&D Dummy $t-1$	0.275***		0.278***		0.233***		0.237***	
	(0.011)		(0.011)		(0.010)		(0.010)	
R&D Dummy t_0	0.175***		0.168***		0.244***		0.234***	
	(0.017)		(0.017)		(0.016)		(0.016)	
Ln (R&D) $t-1$		0.021***		0.021***		0.021***		0.021***
		(0.000)		(0.000)		(0.001)		(0.001)
Ln (R&D) t_0		0.010***		0.010***		0.022***		0.021***
		(0.000)		(0.000)		(0.001)		(0.001)
Uncertainty	0.002	0.002			0.006	0.009		
	(0.008)	(0.004)			(0.008)	(0.006)		
Lack of demand			-0.050***	-0.024***			-0.074***	-0.060***
			(0.009)	(0.004)			(0.009)	(0.007)
ln(Age)	-0.008	-0.006	-0.009	-0.007	-0.026***	-0.026***	-0.027***	-0.026***
	(0.009)	(0.005)	(0.009)	(0.005)	(0.009)	(0.007)	(0.008)	(0.007)
Exporter dummy t-1	0.032***	0.009**	0.031***	0.009**	0.049***	0.031***	0.048***	0.031***
	(0.009)	(0.004)	(0.009)	(0.004)	(0.009)	(0.008)	(0.009)	(0.007)
Industrial group	-0.023**	-0.012**	-0.022**	-0.011**	0.018*	0.015*	0.018*	0.015*
	(0.011)	(0.005)	(0.011)	(0.005)	(0.010)	(0.008)	(0.010)	(0.008)
Patent dummy t-1	0.011	-0.003	0.012	-0.003	0.065***	0.028**	0.063***	0.028**
	(0.014)	(0.006)	(0.014)	(0.006)	(0.017)	(0.011)	(0.017)	(0.011)

Table 9 (continuation). Dynamic RE probit and tobit estimations for services sectors (KIS and LKIS)

	KIS				LKIS			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
Informal protect. Dum. t-1	0.028***	0.011***	0.027***	0.010**	0.024**	0.015**	0.023**	0.014*
	(0.009)	(0.004)	(0.009)	(0.004)	(0.010)	(0.007)	(0.010)	(0.007)
ln(Size)	0.034***	0.017***	0.033***	0.016***	0.019***	0.015***	0.018***	0.014***
	(0.004)	(0.002)	(0.004)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)
Subsidy dummy t-1	0.066***	0.022***	0.065***	0.022***	0.068***	0.037***	0.067***	0.037***
	(0.008)	(0.004)	(0.008)	(0.004)	(0.009)	(0.007)	(0.009)	(0.007)
Sales growth	0.022***	0.010***	0.021***	0.010***	0.013**	0.009**	0.012**	0.008**
	(0.004)	(0.002)	(0.004)	(0.002)	(0.005)	(0.003)	(0.005)	(0.003)
Other obstacles	-0.031***	-0.010***	-0.025***	-0.008**	-0.014**	-0.005	-0.006	0.001
	(0.007)	(0.003)	(0.007)	(0.003)	(0.007)	(0.005)	(0.007)	(0.005)
N° of observ.	11,942	7,919	11,942	7,919	11,702	3,880	11,702	3,880
Log likelihood	-3,990.23	-26,751.9	-3,973.86	-26,736.8	-3,806.35	-15,858.8	-3,770.68	-15,823.3
σ_u	0.758***	2.808***	0.734***	2.769***	0.806***	5.131***	0.778***	5.005***
	(0.052)	(0.120)	(0.052)	(0.121)	(0.053)	(0.235)	(0.053)	(0.234)
Rho	0.365***	0.267***	0.350***	0.262***	0.394***	0.365***	0.377***	0.355***
LR test for Rho	126.762	546.201	114.697	525.103	152.728	478.487	137.003	457.777
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets (calculated using the delta method). Time and industry dummies are included. Marginal effects reported.

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Appendix

Table A1. The variables: acronyms and definitions.

Dependent variables (Innovative Inputs)	
R&D dummy	Dummy =1 if firm's R&D (both internal and external) expenditures are positive
ln(R&D)	Natural log of the total firm's expenditures in R&D (both internal and external)
Independent variables (control variables)	
ln(Age)	Natural log of the firm's age (calculated as years elapsed since founding)
Exporter dummy	Dummy =1 if the firm have traded in an international market during the three year period; 0 otherwise
Industrial group	Dummy =1 if the firm is part of an industrial group, 0 otherwise
Patent dummy	Dummy=1 if the firm uses patents; 0 otherwise
Informal prot. dummy	Dummy=1 if the firm adopts others instruments of protection than patents; 0 otherwise
ln(Size)	Log of the total number of firm's employees
Subsidy dummy	Dummy = 1 if the firm has received public support for innovation; 0 otherwise
Sales growth	Growth rates of sales (calculated by taking logarithmic differences of sales levels)
Other obstacles	Dummy=1 if the firm reports an higher degree of importance (from period t to period t+1) for at least one of the remaining obstacles variables; 0 otherwise
Independent variables (Obstacle demand variables)	
Lack of demand	Dummy=1 if the firm reports an higher degree of importance (from period t to period t+1) for the obstacles variables "it was not necessary to innovate due to the Lack of demand for innovation"; 0 otherwise
Uncertainty	Dummy=1 if the firm reports an higher degree of importance (from period t to period t+1) for the obstacles variables "Uncertain demand for innovative goods or services"; 0 otherwise

Table A2. Robustness check: Dynamic RE probit and tobit estimations with both the demand obstacles variable

	Whole Sample			LMLt		HMHt		KIS		LKIS
	(1) R&D dummy	(2) Ln (R&D)	(3) R&D dummy	(4) Ln (R&D)	(5) R&D dummy	(6) Ln (R&D)	(7) R&D dummy	(8) Ln (R&D)	(9) R&D dummy	(10) Ln (R&D)
R&D Dummy t-1	0.264***		0.300***		0.216***		0.275***		0.234***	
	(0.005)		(0.009)		(0.012)		(0.011)		(0.010)	
R&D Dummy t_0	0.227***		0.233***		0.181***		0.173***		0.240***	
	(0.008)		(0.015)		(0.017)		(0.017)		(0.016)	
Ln (R&D) t-1		0.023***		0.026***		0.015***		0.022***		0.021***
		(0.000)		(0.001)		(0.000)		(0.001)		(0.001)
Ln (R&D) t_0		0.015***		0.015***		0.007***		0.010***		0.022***
		(0.000)		(0.001)		(0.001)		(0.001)		(0.001)
ln(Age)	-0.003	-0.006**	0.000	-0.002	0.001	-0.002	-0.008	-0.006	-0.027***	-0.027***
	(0.004)	(0.003)	(0.008)	(0.005)	(0.008)	(0.003)	(0.009)	(0.005)	(0.009)	(0.008)
Exporter dummy t-1	0.061***	0.032***	0.082***	0.055***	0.057***	0.023***	0.031***	0.009**	0.049***	0.031***
	(0.005)	(0.003)	(0.009)	(0.006)	(0.010)	(0.004)	(0.009)	(0.004)	(0.009)	(0.008)
Industrial group	0.013***	0.004	0.032***	0.014**	-0.014	-0.006*	-0.023**	-0.012**	0.018*	0.014*
	(0.005)	(0.003)	(0.010)	(0.006)	(0.010)	(0.003)	(0.011)	(0.005)	(0.010)	(0.008)
Patent dummy t-1	0.039***	0.007**	0.050***	0.015**	0.025**	0.003	0.011	-0.003	0.064***	0.028**
	(0.007)	(0.003)	(0.012)	(0.006)	(0.011)	(0.003)	(0.014)	(0.006)	(0.017)	(0.011)
Infor. protect. dum. t-1	0.032***	0.016***	0.034***	0.018***	0.037***	0.010***	0.028***	0.010***	0.023**	0.014*
	(0.005)	(0.002)	(0.009)	(0.005)	(0.009)	(0.003)	(0.009)	(0.004)	(0.010)	(0.007)
ln(Size)	0.036***	0.019***	0.064***	0.036***	0.049***	0.016***	0.034***	0.017***	0.019***	0.014***
	(0.002)	(0.001)	(0.005)	(0.003)	(0.005)	(0.002)	(0.004)	(0.002)	(0.003)	(0.003)

Table A2 (continuation). Robustness check: Dynamic RE probit and tobit estimations with both the demand obstacles variable

	Whole Sample		LMLt		HMHt		KIS		LKIS	
	(1) R&D dummy	(2) Ln (R&D)	(3) R&D dummy	(4) Ln (R&D)	(5) R&D dummy	(6) Ln (R&D)	(7) R&D dummy	(8) Ln (R&D)	(9) R&D dummy	(10) Ln (R&D)
Subsidy dum. t-1	0.053***	0.019***	0.043***	0.016***	0.034***	0.006***	0.066***	0.022***	0.068***	0.037***
	(0.004)	(0.002)	(0.007)	(0.004)	(0.008)	(0.002)	(0.008)	(0.004)	(0.009)	(0.007)
Sales growth	0.018***	0.010***	0.021***	0.013***	0.013**	0.006***	0.022***	0.010***	0.013***	0.009**
	(0.003)	(0.001)	(0.007)	(0.004)	(0.005)	(0.002)	(0.004)	(0.002)	(0.005)	(0.004)
Demand obstacles	-0.040***	-0.021***	-0.046***	-0.026***	-0.024**	-0.008*	-0.025*	-0.009	-0.056***	-0.045***
	(0.006)	(0.004)	(0.011)	(0.007)	(0.012)	(0.004)	(0.013)	(0.007)	(0.013)	(0.011)
Other obstacles	-0.024***	-0.008***	-0.014**	-0.002	-0.042***	-0.010***	-0.030***	-0.010***	-0.015**	-0.005
	(0.003)	(0.002)	(0.006)	(0.003)	(0.006)	(0.002)	(0.007)	(0.003)	(0.007)	(0.005)
N° of obs.	54,110	31,558	18,730	10,774	11,736	8,985	11,942	7,919	11,702	3,880
Log likelihood	-18,329.66	-110,278.7	-6,954.99	-38,625.1	-3,442.05	-27,913.2	-3,988.48	-26,751.2	-3,797.46	-15,850.9
σ_u	0.821***	3.339***	0.805***	3.378***	0.890***	2.367***	0.753***	2.802***	0.797***	5.093***
	(0.025)	(0.062)	(0.039)	(0.111)	(0.061)	(0.097)	(0.052)	(0.120)	(0.053)	(0.235)
ϱ	0.403***	0.317***	0.393***	0.295***	0.442***	0.276***	0.362***	0.266***	0.388***	0.361***
LR test for Rho	719.478	2,853.464	271.269	920.858	144.563	597.539	123.517	541.750	147.587	471.681
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets (calculated using the delta method). Time and industry dummies are included. Marginal effects reported

Table A3. Robustness check: Dynamic RE probit and tobit estimations with the obstacles variables identifying those firms assessing as highly important the lack/uncertainty of demand (whole sample).

	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)
R&D Dummy t-1	0.263*** (0.005)		0.263*** (0.005)	
R&D Dummy t_0	0.229*** (0.008)		0.214*** (0.008)	
Ln (R&D) t-1		0.023*** (0.000)		0.022*** (0.000)
Ln (R&D) t_0		0.016*** (0.000)		0.015*** (0.000)
Uncertainty (high)	-0.003 (0.004)	-0.002 (0.002)		
Lack of demand (high)			-0.155*** (0.008)	-0.12*** (0.005)
ln(Age)	-0.003 (0.004)	-0.006** (0.003)	-0.001 (0.004)	-0.005* (0.002)
Exporter dummy t-1	0.061*** (0.005)	0.032*** (0.003)	0.058*** (0.005)	0.030*** (0.003)
Industrial group	0.013** (0.005)	0.004 (0.003)	0.012** (0.005)	0.003 (0.003)
Patent dummy t-1	0.039*** (0.007)	0.007** (0.003)	0.038*** (0.006)	0.007** (0.00)
Informal protection dummy t-1	0.033*** (0.005)	0.016*** (0.002)	0.031*** (0.005)	0.015*** (0.002)
ln(Size)	0.036*** (0.002)	0.019*** (0.001)	0.034*** (0.002)	0.018*** (0.001)
Subsidy dummy t-1	0.053*** (0.004)	0.019*** (0.003)	0.050*** (0.004)	0.017*** (0.002)
Sales growth	0.019*** (0.003)	0.010*** (0.01)	0.017*** (0.003)	0.010*** (0.001)
Other obstacles	-0.024*** (0.003)	-0.008*** (0.002)	-0.024*** (0.003)	-0.008*** (0.002)
N° of observations	54,110	31,558	54,110	31,558
Log likelihood	-18,349.30	-110,295.05	-18,135.34	-109,984.6
σ_u	0.829*** (0.025)	3.353*** (0.062)	0.800*** (0.024)	3.244*** (0.062)
ϱ	0.407***	0.319***	0.390***	0.306***
LR test for Rho	741.687	2,886.465	690.512	2,734.302
p-value	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets (calculated using the delta method). Time and industry dummies are included. Marginal effects reported.

Table A4. Robustness check: Dynamic RE probit and tobit estimations with the obstacles variables identifying those firms assessing as highly important the lack/uncertainty of demand (manufacturing sectors).

	Low/medium-low tech Sectors				High/medium-high tech Sectors			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
R&D Dummy t-1	0.299***		0.297***		0.215***		0.219***	
	(0.009)		(0.009)		(0.012)		(0.012)	
R&D Dummy t_0	0.236***		0.219***		0.183***		0.171***	
	(0.015)		(0.015)		(0.017)		(0.017)	
Ln (R&D) t-1		0.026***		0.025***		0.015***		0.015***
		(0.000)		(0.001)		(0.000)		(0.000)
Ln (R&D) t_0		0.015***		0.014***		0.007***		0.007***
		(0.000)		(0.001)		(0.001)		(0.001)
Uncertainty (high)	0.000	-0.000			-0.003	-0.002		
	(0.008)	(0.005)			(0.008)	(0.002)		
Lack of dem. (high)			-0.186***	-0.146***			-0.110***	-0.058***
			(0.014)	(0.009)			(0.015)	(0.006)
ln(Age)	0.000	-0.002	0.002	-0.000	0.001	-0.021	0.001	-0.002
	(0.008)	(0.005)	(0.007)	(0.004)	(0.008)	(0.003)	(0.008)	(0.003)
Exporter dum. t-1	0.083***	0.055***	0.077***	0.051***	0.058***	0.023***	0.057***	0.028***
	(0.009)	(0.006)	(0.009)	(0.006)	(0.010)	(0.003)	(0.010)	(0.003)
Industrial group	0.032***	0.014**	0.032***	0.015***	-0.014	-0.006*	-0.016	-0.007**
	(0.010)	(0.005)	(0.010)	(0.006)	(0.010)	(0.003)	(0.010)	(0.003)
Patent dummy t-1	0.051***	0.015**	0.047***	0.014**	0.025**	0.002	0.025**	0.002
	(0.012)	(0.006)	(0.012)	(0.006)	(0.011)	(0.003)	(0.011)	(0.003)

Table A4 (continuation). Robustness check: Dynamic RE probit and tobit estimations with the obstacles variables identifying those firms assessing as highly important the lack/uncertainty of demand (manufacturing sectors).

	Low/medium-low tech Sectors				High/medium-high tech Sectors			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
Inf. prot. Dum. t-1	0.035***	0.018***	0.033***	0.017***	0.037***	0.010***	0.035***	0.010***
	(0.009)	(0.005)	(0.008)	(0.005)	(0.009)	(0.003)	(0.009)	(0.002)
ln(Size)	0.064***	0.036***	0.060***	0.034***	0.049***	0.016***	0.047***	0.015***
	(0.005)	(0.003)	(0.004)	(0.003)	(0.005)	(0.002)	(0.005)	(0.002)
Subsidy dummy t-1	0.043***	0.016***	0.039***	0.014***	0.034***	0.006***	0.032***	0.006**
	(0.007)	(0.004)	(0.007)	(0.004)	(0.008)	(0.002)	(0.007)	(0.002)
Sales growth	0.020***	0.013***	0.018**	0.012***	0.013**	0.006***	0.013**	0.006***
	(0.007)	(0.004)	(0.007)	(0.004)	(0.005)	(0.002)	(0.005)	(0.002)
Other obstacles	-0.013**	-0.002	-0.014**	-0.003	-0.042***	-0.010***	-0.042***	-0.001***
	(0.006)	(0.003)	(0.006)	(0.004)	(0.006)	(0.002)	(0.006)	(0.002)
N° of obs.	18,730	10,774	18,730	10,774	11,736	8,985	11,736	8,985
Log likelihood	-6,962.8	-38,632.1	-6,874.5	-38,506.8	-3,444.0	-27,914.7	-3,417.2	-27,867.8
σ_u	0.813***	3.398***	0.783***	3.280***	0.898***	2.377***	0.854***	2.294***
	(0.039)	(0.111)	(0.038)	(0.110)	(0.061)	(0.097)	(0.060)	(0.097)
P	0.398***	0.297***	0.380***	0.284***	0.446***	0.278***	0.422***	0.264***
LR test Rho	279.635	934.860	262.300	891.461	148.547	604.306	132.658	556.862
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets (calculated using the delta method). Time and industry dummies are included. Marginal effects reported.

Table A5. Robustness check: Dynamic RE probit and tobit estimations with the obstacles variables identifying those firms assessing as highly important the lack/uncertainty of demand (services sectors).

	KIS				LKIS			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
R&D Dummy t-1	0.275*** (0.011)		0.272*** (0.011)		0.232*** (0.010)		0.230*** (0.010)	
R&D Dummy t_0	0.175*** (0.017)		0.167*** (0.016)		0.244*** (0.016)		0.229*** (0.016)	
Ln (R&D) t-1		0.021*** (0.000)		0.021*** (0.000)		0.021*** (0.001)		0.021*** (0.001)
Ln (R&D) t_0		0.010*** (0.001)		0.009*** (0.001)		0.021*** (0.001)		0.021*** (0.001)
Uncertainty (high)	-0.004 (0.009)	-0.004 (0.004)			-0.002 (0.010)	-0.001 (0.008)		
Lack of demand (high)			-0.133*** (0.016)	-0.085*** (0.009)			-0.162*** (0.016)	-0.153*** (0.013)
ln(Age)	-0.008 (0.009)	-0.006 (0.004)	-0.007 (0.009)	-0.005 (0.005)	-0.026*** (0.009)	-0.026*** (0.008)	-0.025*** (0.008)	-0.025*** (0.007)
Exporter dummy t-1	0.031*** (0.009)	0.009** (0.004)	0.029*** (0.009)	0.008** (0.004)	0.049*** (0.009)	0.031*** (0.008)	0.045*** (0.009)	0.028*** (0.007)
Industrial group	-0.023** (0.011)	-0.012** (0.005)	-0.022** (0.011)	-0.012** (0.005)	0.018* (0.010)	0.014* (0.008)	0.016* (0.010)	0.013 (0.008)
Patent dummy t-1	0.011 (0.014)	-0.003 (0.005)	0.009 (0.014)	-0.003 (0.005)	0.065*** (0.017)	0.028** (0.011)	0.067*** (0.016)	0.030*** (0.011)

Table A5 (continuation). Robustness check: Dynamic RE probit and tobit estimations with the obstacles variables identifying those firms assessing as highly important the lack/uncertainty of demand (services sectors).

	KIS				LKIS			
	(1) R&D Dummy	(2) Ln (R&D)	(3) R&D Dummy	(4) Ln (R&D)	(5) R&D Dummy	(6) Ln (R&D)	(7) R&D Dummy	(8) Ln (R&D)
Informal protect. Dum. t-1	0.028***	0.010***	0.027***	0.010**	0.024**	0.014*	0.021**	0.013*
	(0.009)	(0.004)	(0.009)	(0.004)	(0.010)	(0.007)	(0.010)	(0.011)
ln(Size)	0.034***	0.017***	0.033***	0.016***	0.019***	0.014***	0.018***	0.014***
	(0.004)	(0.002)	(0.004)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)
Subsidy dummy t-1	0.066***	0.022***	0.065***	0.021***	0.068***	0.037***	0.065***	0.035***
	(0.008)	(0.004)	(0.008)	(0.004)	(0.009)	(0.007)	(0.009)	(0.007)
Sales growth	0.022***	0.010***	0.021***	0.010***	0.013**	0.008**	0.011**	0.007**
	(0.004)	(0.002)	(0.004)	(0.002)	(0.005)	(0.004)	(0.005)	(0.003)
Other obstacles	-0.031***	-0.010***	-0.030***	-0.011***	-0.014**	-0.005	-0.013*	-0.003
	(0.007)	(0.003)	(0.007)	(0.003)	(0.007)	(0.005)	(0.007)	(0.005)
N° of obs.	11,942	7,919	11,942	7,919	11,702	3,880	11,702	3,880
Log likelihood	-3,990.17	-26,751.8	-3,955.99	-26,704.3	-3,806.61	-15,859.8	-3,744.65	-15,784.3
σ_u	0.759***	2.808***	0.741***	2.752***	0.806***	5.130***	0.786***	4.961***
	(0.052)	(0.120)	(0.051)	(0.120)	(0.053)	(0.235)	(0.052)	(0.232)
ϱ	0.365***	0.267***	0.354***	0.260***	0.394***	0.364***	0.382***	0.352***
LR test for Rho	126.781	545.907	122.008	529.891	152.299	477.609	144.365	457.093
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets (calculated using the delta method). Time and industry dummies are included. Marginal effects reported.

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

4.1. 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[41]). 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

41 Klepper propose a theoretical model in order to study the evolution of firm's innovation along the industry life cycle. Huergo and Jamandreu empirically look at how the probability of introducing innovations by manufacturing firms change at different stages of their lives

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 to 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). Most of these contributions have mainly focused on the effects of financial constraints on the firm's innovative behavior (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[42]. In doing so, we will perform both univariate and multivariate analyses by drawing on a large longitudinal dataset of Spanish

42 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 4.2 for a more detailed discussion about revealed and deterring barriers).

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 negative relationship between both internal and external lack of financial resources and firm's 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 4.2 reviews the theoretical and empirical literature about barriers to innovation and puts forward some hypotheses related to the main research questions. Section 4.3 provides a detailed description of the dataset and some descriptive evidence. Section 4.4 presents the empirical strategy and discusses the main results. Section 4.5 concludes.

4.2. The literature

4.2.1 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, has 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 has 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., 2012, Pellegrino and Savona, 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.* deterring 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.

4.2.2 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 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. However, 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, knowledge related obstacles may be important for mature firms as well. Indeed, companies with a high level of experience in the market, 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. This organizational and production rigidity could also limit the capacity of mature firms to react promptly to changes in demand conditions. As result, these firms may appear to be more sensitive to barriers to innovation related to uncertainty demand of innovative goods. 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 4.4, the results of our empirical analyses give important support to these propositions.

4.3. 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[43].

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)[44]. Furthermore, due to the high presence of missing values for the variables employed in the empirical specification (see Section 4.4.2.1) 15,289 observations have been ruled out.

In addition, according to the discussion presented in Section 4.2, we retain just the sample of 'Potential Innovators'. In other words, we exclude

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

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

from the final sample those firms that, by inference, can be defined as 'Not innovation oriented firms'. As already pointed out (see Section 4.2), 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 the Appendix)[45], 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[46]. 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[47].

45 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.
46 Note that the only difference between the two groups regards the degree of engagement in innovation activity.
47 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.

4.4. Empirical analysis

4.4.1 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'[48].

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 facing revealed and deterring barriers to innovation. 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, 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 in D'Este et al., (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'.

48 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.

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 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 particularly marked, 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 obstacle 'market dominated by established firms', with a decreasing relationship until around the sixtieth year 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.

Table 1. 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		

4.4.2 Multivariate analysis

4.4.2.1 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 notable 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 deterring barriers. These descriptive evidence further corroborate the importance of taking into account the different nature of the barriers faced by the firms.

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	

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[49].

49 In choosing the first age class we refer to some recent contributions that, in order to identify and explore the innovative peculiarities of young companies, use a cut-off point of 8 years (see Pellegrino et al., 2012 and García-Quevedo et al., 2014; see also Van Praag and

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.

Table 3. Composition of the different samples by age categories

	Total sample		Deterring		Revealed	
Firm's age	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

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

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

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

Versloot, 2007). Robustness checks were performed assuming alternative thresholds or the 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 4.4.2.2.

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[50]. As usual, in order to avoid the dummy trap problem with respect to 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[51], 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)[52]. The effect of each age category will be thus interpreted as deviations from the average age effects.

4.4.2.2 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[53].

Looking at Table 4 (total sample), the most evident result is the clear negative relationship between firm's age and firm's assessment of cost barriers. Indeed, in accordance with the discussion put forward in section 4.2.2, young

50 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 therefore implementing a random effect model.

51 The econometric specification includes a set of 8 time and 34 industry dummies.

52 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).

53 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.

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.

Turning the attention to the other types of obstacles, 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 to 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.

In relation to the two variables identifying appropriability means, while no effects 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.

4.5. 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 negative 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.

In terms of future research, it could be certainly worthwhile going beyond the simple distinction among different age groups and to explore deeply the relationship between firm's age and firm's perception of obstacles to innovation. One possibility to accomplish this aim would be to use proper non-parametric techniques that allow considering the entire age distribution, without assigning any particular functional form to the relationship of interest. Moreover, in order to complement the findings of the present work, it could be also interesting to look at the impact that the different obstacles to innovation have in hindering and slowing down the innovation activity (both at input and output side) of firms of different ages.

Table 4. Probit Random Effect estimations for the whole sample

	(1) Cost.(int.)	(2) Cost.(ext.)	(3) Know.(skill)	(4) Know.(info)	(5) Know.(coop)	(6) Mkt.(incum.)	(7) 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) Cost.(int.)	(2) Cost.(ext.)	(3) Know.(skill)	(4) Know.(info)	(5) Know.(co.)	(6) Mkt.(inc.)	(7) 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	-20,045.6	-20,699.5	-11,526.9	-12,275.3	-12,412.6	-16,362.0	-18,426.7
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	11,728.10	10,727.91	6,294.18	6,699.46	5,376.08	9,419.94	8,321.63
p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

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

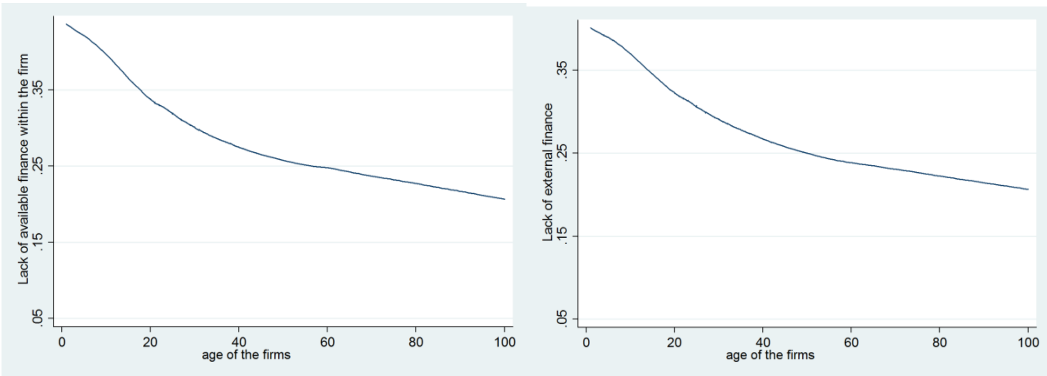


Figure 2. Local linear smooth (lowess): relationship between firm'age and knowledge obstacles

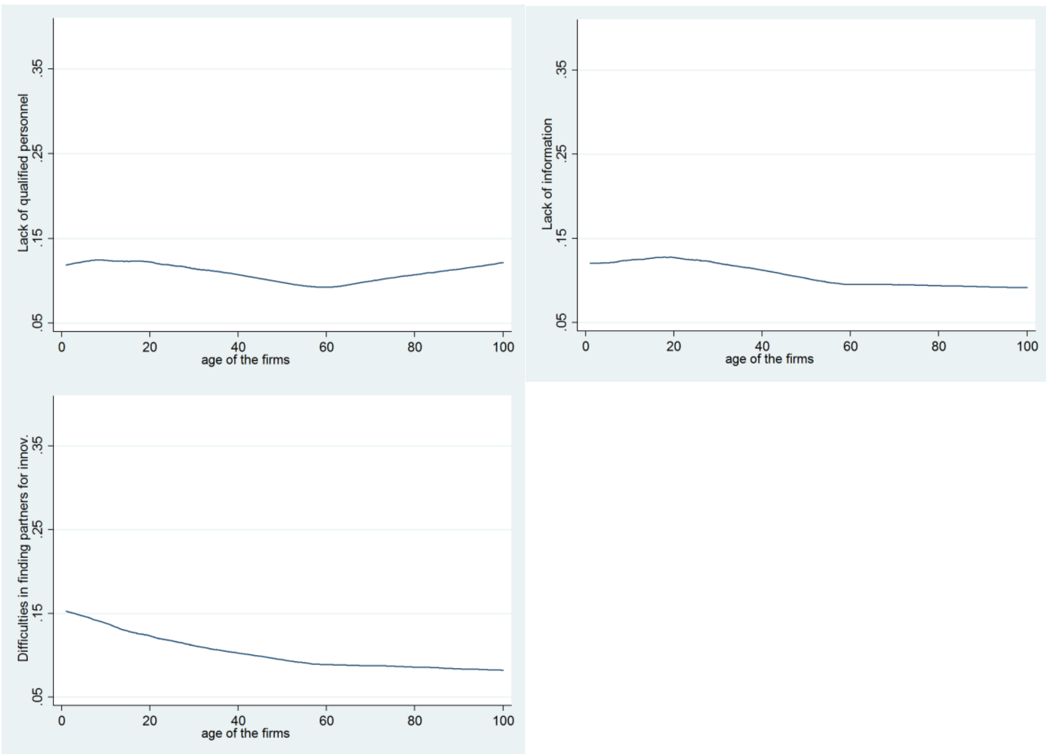


Figure 3. Local linear smooth (lowess): relationship between firm'age and market obstacles

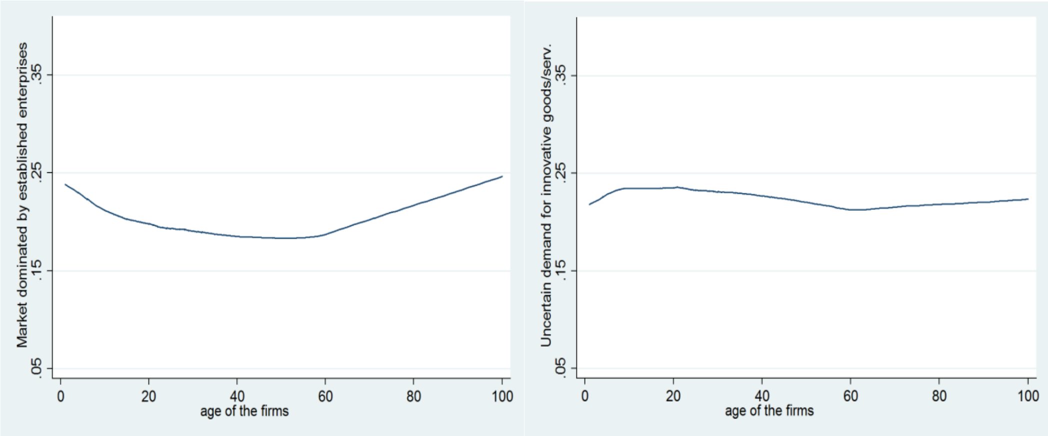
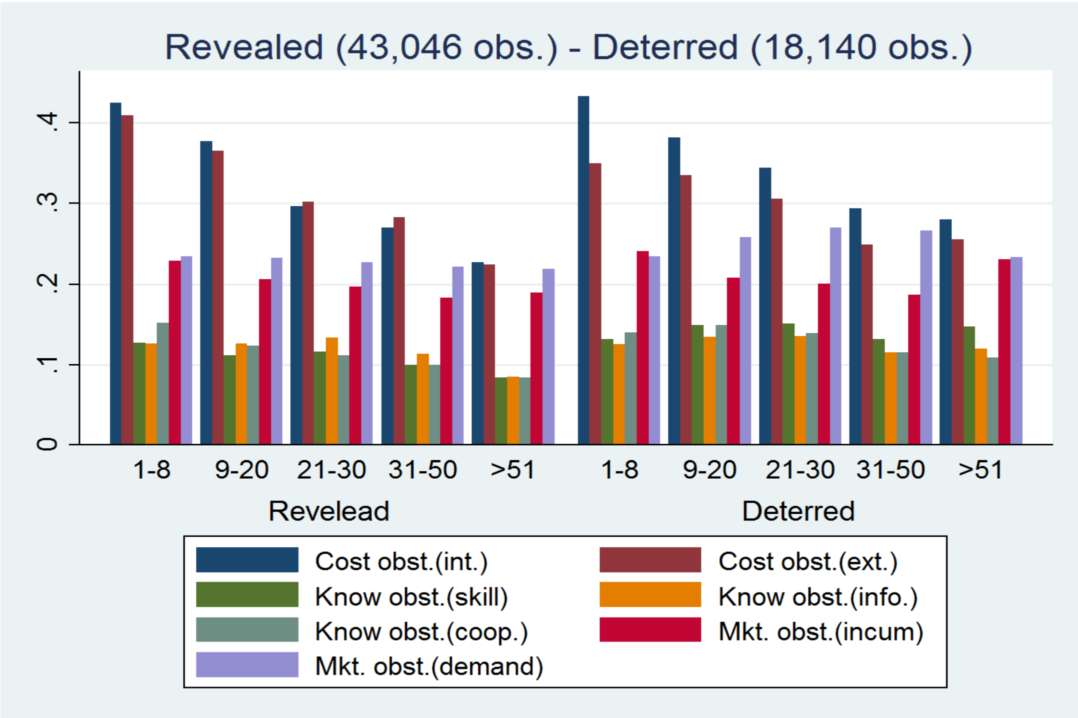


Figure A4. Average firm's perception of obstacles to innovation by age categories (revealed and deterred samples)



Chapter V
Concluding remarks and policy implications

This thesis consists of three essays on the determinants and effects of barriers to innovation faced by firms. In this concluding chapter I briefly discuss the main findings, derive the policy implications that emerge from them, and suggest further directions for future research.

Within the innovation literature, analyses of the determinants of innovation success are comparatively more extended than studies looking at factors affecting firm's failure in engaging in innovation activity and the effects of the lack of incentives. Nevertheless, the vast majority of the few recent studies that has looked at the nature and the consequences of the obstacles to innovation have focused the attention on just one category of obstacles, namely cost and financial related ones. No systematic evidence has been provided about the possible hindrance effect exerted by other types of barriers. Chapters 2 and 3 of this thesis go in this direction.

By drawing on the UK CIS panel for the period 2004-2011, Chapter 2 empirically tests the actual impact of different types of obstacles to innovation in hampering the firms' realization of innovative products and or processes. Based on the distinction between 'potential innovators' and 'not innovation oriented firms' the econometric results show that demand- and market-related factors are as important as financing conditions in determining firms' innovation failures.

This evidence demonstrate how relevant is the identification of the different causes of the systemic failures that prevent firms from engaging in innovation activities in order to design appropriate and effective policy instruments. In detail, our findings clearly suggest the need to take into account other obstacles to innovation apart from the financing constraints that the most traditional literature has emphasised on the basis of cash flow models. It is therefore essential for policy makers aiming at boosting innovation to focus not just on the increase of firm's liquidity by means of the traditional instruments (e.g. grants, R&D tax incentives, measures to facilitate access to private funding), but also to enlarge the spectrum of policy interventions by including competition, regulations and macro-economic policies. For example, more emphasis should be put on structural measures to contrast weaknesses of national innovation systems, embracing concrete actions to reduce red tape for business and to sustain the demand of innovative goods in a long term perspective. Moreover, since the analysis conducted in this Chapter looks at the innovative output side of the firm's innovative activity, this evidence may be also relevant from the perspective of innovation management. Indeed, showing robust insights about the barriers faced by firms that impede or complicate the introduction of new products and/or processes in the market could surely be important in helping managers at implementing proper corporate strategies oriented to overcoming the obstacles to innovation. For instance, according to our evidence, managers should promote the creation of specific area inside the organizations aimed at properly identifying and address the most relevant regulations related-problems that can be associated with government standards.

Chapter 2 provides a general overview regarding the possible negative effects of an ample range of obstacles on the firm's realizations of innovative outputs. However, it says nothing about the impact of the barriers in obstructing or slowing down the firm's engagement in innovative inputs. Chapter 3 partially address this issue by looking at whether the perception of lack of demand and demand uncertainty negatively affects decisions to invest and amount of financial effort devoted to R&D.

The results of the econometric analysis, obtained by using a panel of Spanish manufacturing and services firms observed for the period 2004-2011, show that while perception of increasing lack of demand has a significant, strong and negative effect on both decisions to invest and amount of investments in R&D, increasing demand uncertainty does not appear to have any significant effect or have a weakly significant positive effect. Moreover, additional analyses indicate that these results are robust across different macro sectoral categories, namely high and low tech manufacturing and knowledge intensive or low tech services.

These findings strongly confirm the relevance of demand as a crucial incentive to innovate by implicitly supporting the need to foster demand-side innovation policies in the innovation agenda. This appears of particular interest in the light of the current global financial crisis, a context that surely exacerbates the negative effects of demand related obstacles on the firm's propensity to innovate. The new Europe 2020 strategy further remarks the importance of this issue by explicitly identifying as a systemic cause of policy failure the poor match between supply- and demand- side measures. Indeed, the traditional measures aimed at funding basic research, higher education institutions and private R&D will lose effectiveness if they are not combined with proper policies that stimulate the demand for innovative products and processes. In this respect, macro-level policies should 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 subsides and specific policies aimed ad 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 and to complement other policies tools (like supply-side polices) to boost innovation and growth.

After having empirically assessed the hindering effects of different type of obstacles on the distinct phases of the firm's innovative process, in the fourth Chapter we shift the focus to the analysis of those factors that can somehow influence the firm's assessment of the obstacles to innovation. In particular, we provide evidence about the role played by firm's age in affecting the firm's perception of the different barriers to innovation activity. In doing so we make a distinction between those firms that experience deterring barriers to innovation *vs* revealed barriers to innovation. This characterization refers to the different role played by the barriers to innovation during the diverse phases of the firm's innovative process and allows distinguishing between those firms that give up their attempt to innovate because they are deterred by some obstacles, from those firms whose innovative process has been hampered/slowed-down by the same obstacles.

The results of the empirical analysis, obtained by using a panel of Spanish manufacturing and services firms observed for the period 2004-2011, clearly show that distinct types of obstacles are perceived differently by firms of different ages. Firstly, a negative relationship between firm's assessment of both internal and external lack of funds and firm's age is detected.

This evidence suggests that newly established firms, usually characterised by scarce internal funds and low reputation on the financial market, are more sensitive than their mature counterparts to cost and financial factors that have a role in hindering their innovative activity. It is therefore evident the need to design specific policy measures aimed at financing start-ups, young companies and more in general firms in the early stages of their life, in order to help them implementing and developing innovative processes. Furthermore, specific attention should be devoted to programmes geared towards the promotion of remarkably risky projects conducted by young innovative companies. In this respect 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 innervations could be desirable in order to render the policy instrument more effective and to avoid usual deadweight and substitution effects.

Another result stemming from the econometric analysis of this chapter points to some interesting dissimilarities in the level of perception of the knowledge obstacle 'lack of qualified personnel' of firms of different ages. In this respect, this obstacle factor appears to be remarkably important for firms in their mature stages of their life cycle that want to start a new innovative project (deterred effect), but irrelevant for well experienced firms already active in innovation. 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, but in a position of disadvantage with respect to this obstacles factor if they are already engaged in innovation activity.

These findings evidently 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.

Overall, the findings offered by the fourth Chapter 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 cycle. Indeed, the design of proper and effective policy instruments can be pursued only by identifying why and to what extent different types of companies are excluded from the "innovation arena". More in detail, policy makers might give more relevance to the enlargement of the population of innovative-active firms (*innovation-widening)*, by removing or attenuating barriers that prevent firms from engaging in innovation activities; or strengthen the innovation capacity of the existing population of innovative-active firms (*innovation-deepening*), by removing or attenuating obstacles that obstruct successful completion of innovation projects and adequate returns to innovation investments.

While the second chapter of this thesis draws on UK data, the remaining two make use of Spanish data. Although we do not perform any cross-country comparison analysis, the empirical evidence provided by this thesis can give some preliminary insights about the nature, the determinants and the effects of barriers to innovation faced by firms located in countries characterised by marked differences in terms of their economic and technological development. In this respect, the findings obtained in Chapter 3 and 4 could serve as important reference for countries with similar characteristics to Spain. This could be the case for Southern European countries, that are quite distant from the technological frontier, and whose core industrial structure is characterized by the massive presence of traditional and low-mid-tech sectors. On the other hand the evidence proposed in Chapter 2 could be generalized to more advanced European countries that are closer to the technological frontier.

Gathering evidence about the nature of barriers experienced by firms operating in countries with distinct peculiarities is certainly relevant in the light of the interest on this topic demonstrated by European policy makers. In particular, the Europe 2020 flagship initiative Innovation Union clearly calls for the implementation of policy measures aimed at identifying and contrasting the specific barriers that impede or slow down the firm's innovative process.

Finally, each of the three empirical works of this thesis presents a number of possible directions for future research.

Starting form the second Chapter, it would be interesting to look at different degrees of novelty of the firm's innovative output. In this respect, it could be the case that different types of obstacles have a diverse hindering effect on innovative products and/or processes that are new only to the firm or new also for the market in which the firm operate. It would be also relevant to extend the econometric analyses by looking at possible complementarity effects among the different barriers to innovation. Indeed, many findings in the literature point into the direction that firms experiencing barriers to innovation usually experience many simultaneously.

Turning the attention to the third Chapter, since its main research aim is to look at the effects of demand uncertainty and stagnancy on firms' decisions to innovate, it would be interesting to assess properly the possible exacerbating effects of the current financial crisis. Another possible extension might entail replicating the empirical analysis focusing on alternative innovative inputs other than formal R&D, such as extramural R&D expenditures and investments in technological change embodied in the acquisition of innovative machineries. Furthermore, in line with the interesting results obtained at the sectoral level, future research is needed to analyse in greater detail the reaction of individual industries to the lack/uncertainty of demand.

As for the fourth Chapter, it would be worthwhile trying to apply more advanced statistical techniques (such as non-parametric methods) in order to explore more in depth the relationship between firm's age and firm's perception of obstacles to innovation. In addition to that, another possible future research avenue might entail the investigation of the hindering effect of the different barriers to innovation on the innovation activity (both at input and output level) of firms of different ages.

Overall, the growing interest among policy makers and the paucity of contributions on the subject 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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