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The role of human capital in lowering the barriers to engaging in innovation: evidence from the Spanish innovation survey

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Abstract

This paper focuses on the role of human capital in reducing the barriers to firms' engagement in innovation activities. The paper distinguishes between firms facing barriers that stop them from engaging in any innovation activity, and firms that face impediments in the course of their innovation activity. We investigate whether human capital has a particularly strong impact in relation to lowering barriers among the former group of firms, since a strong skill base is likely to compensate for lack of experience in innovation-related activities or the complementary assets needed for innovation. We draw on four waves of the Spanish Innovation Survey and examine the impact of human capital on three types of obstacles to innovation: cost, knowledge, and market barriers. We find that human capital has a significant impact on reducing the barriers to innovation represented by knowledge shortages and market uncertainties.

Keywords: *Innovation; Innovation barriers; Logit panel data model*

JEL codes: *D21; C23; 031*

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1 Introduction

The innovation literature includes extensive studies of the drivers and sources of innovation, and the technological and organizational capabilities required for firms to become successful innovators (e.g. Schumpeter, 1950; von Hippel, 1988; Dosi et al., 2000). However, less attention has been paid to the factors that block firms' involvement in innovation activities.

The innovation survey-based literature focuses mainly on the effects of barriers to innovation on innovation propensity (Mohnen and Rosa, 2000; Mohnen and Roller, 2005; Savignac, 2008), and less on the role of barriers in discouraging firms' involvement in innovation-related activities, or on the factors that reduce the negative impacts of innovation barriers.

Redressing this imbalance is important for at least two reasons. First, from an innovation policy perspective and in order to foster innovation-based competition dynamics, it is important to identify the extent to which the population of potentially innovative firms is being deterred by entry barriers to innovation (Mytelka and Smith, 2002). Second, from both innovation management and policy perspectives, it is important to identify the factors that contribute to reducing the deterrent effects of certain barriers to innovation activity.

This paper aims at improving our understanding of firms that face *deterring* barriers to innovation and firms that are confronted by *revealed* barriers to innovation (D'Este et al., 2012). This distinction between *revealed* and *deterring* barriers is crucial to help disentangle two essentially different mechanisms related to the 'obstacles to innovation'. Deterring barriers refer to the barriers that prevent firms from engaging in innovation activities; revealed barriers refer to the obstacles that firms encounter in

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the course of their innovative activities.

The paper investigates the role played by human capital in lowering the barriers to innovation, paying particular attention to aspects such as: financial constraints, knowledge shortages and market uncertainties. We examine whether human capital helps to reduce these barriers by considering the two categories of firms: firms facing deterring barriers and firms facing revealed barriers. This research draws on four waves of the Spanish Innovation Survey to construct a longitudinal dataset of firms' innovation profiles.

The paper is structured as follows. Section 2 provides a discussion of the study context and sets out the research questions. Section 3 describes the data sources and Section 4 explains the method. Section 5 presents the results and Section 6 concludes.

2 Barriers to engagement in innovation activities

2.1 *Identifying firms that face deterring and revealed barriers to innovation*

Innovation has for long been recognized as a vital contributor to the economic performance and survival of firms (Cefis and Marsili, 2005; Coad and Rao, 2008; Demirel and Mazzucato, 2012). However, despite acknowledgement from industry practitioners and policy makers of the advantages of innovation, many potentially innovative firms persistently resist engagement in innovation activities. This is an issue that has attracted comparatively little research, despite its importance from a conceptual and an innovation policy perspective.

The claim that a significant proportion of potential innovators is not involved in innovation activities requires some clarification about what we mean by 'potential

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innovators'. In line with Savignac (2008) and D'Este et al. (2012) we define potential innovators as firms that invest in innovation-related activities (regardless of the success of these activities), as well as firms that do not invest in innovation but have experienced barriers to innovation. Drawing on the Spanish Innovation Survey, 31% of potentially innovative firms do not conduct any innovation-related activity (see Table 1). Savignac (2008), drawing on an innovation survey of manufacturing firms in France conducted in 2000, finds that 25% of the potentially innovative firms in her sample did not undertake any innovative activities.[1]

Although a considerable amount of research has been devoted to analysing the effects of different types of barriers and constraints to innovation, much of the survey-based literature focuses on the impact of barriers on the propensity to introduce a new product or process (Mohnen and Rosa, 2000; Mohnen and Roller, 2005; Savignac, 2008) or the impact of barriers on firms' research and development (R&D) intensity (Tiwari et al., 2007). Comparatively less is known about the role of barriers as factors deterring firms' involvement in innovation-related activities, or what factors might reduce the negative impact of innovation barriers (Radas and Bozic, 2012).

To improve our understanding of these issues, we distinguish two groups of firms. First, firms *deterred* from embarking on innovation activities. Potentially innovative firms can decide not to undertake innovation-related activities because of the barriers they would need to surmount. For example, firms that otherwise would be willing to undertake innovative projects, remain non-innovators due to lack of access to finance

[1] Our approach differs from Savignac's, thus these figures are not directly comparable. While we adopt an input-based definition of innovation activities (i.e. engagement in R&D and innovation-related activities), Savignac uses an output-based definition (i.e. market introduction of a new or improved product). Our approach is consistent with our objective of identifying those firms that experienced barriers and did not *invest* in any innovation-related activity. Section 3 explains in more detail how we define "potentially innovative" firms.

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for high-risk projects, lack of adequate channels of information about markets or technologies, or difficulties related to identifying suitable partners for innovation activities, among other reasons. In short, deterring barriers refer to obstacles that prevent firms from undertaking innovation activity. Baldwin and Lin (2002) examine these types of barriers in an investigation of the importance of the impediments faced by firms to the adoption of advanced technologies.

Second, there are firms that experience barriers that hamper their innovation performance in innovation-related projects. These are barriers that delay or slow down innovation projects, or are a major determinant of a decision to abandon an innovation project. While these firms indeed face barriers that constitute a substantial obstacle to the completion of their innovation activities, such barriers do not prevent firms from investing in an innovation project. We categorize these firms as facing *revealed* barriers, since these barriers emerge in the course of the innovation activity. Thus, revealed barriers refer to obstacles to innovation that are perceived as emerging in the course of their innovation-related activities. These types of barriers are addressed in the literature on the effect of financial constraints on success as an innovator or on the committed levels on R&D intensity (e.g. Baldwin and Hanel, 2003; Tiwari et al., 2007).

The distinction between these categories of firms and the nature of the barriers faced by them, is important for innovation policy. If policy is to foster innovation-based competition, it is necessary to identify the extent to which potentially innovative firms are excluded from engaging in innovation activities (i.e. to identify the proportion of potential innovators that are non-innovators), and to identify what characterizes those firms that are deterred from engaging in innovation activities. This would enable

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appropriate policies that might help to reduce the entry barriers to innovation (Chaminade and Edquist, 2006).

2.2 *The role of human capital in lowering barriers to engage in innovation*

The human resource management literature (Pfeffer, 1994; Youndt et al., 1996) and the knowledge-based theory (Grant, 1996) state that internal resources, particularly human resources, play a crucial role in developing and sustaining the firm's competitive advantage. Numerous empirical studies show that enhancing the employee skill-base is positively associated with the firm's economic (Arthur, 1994; MacDuffie, 1995) and innovation performance (Leiponen, 2005).

Highly skilled employees contribute to an adaptable, responsive and pro-active workforce. A strong skill base is not limited to the R&D function or to the engineering and scientific skills of employees, but involves every function within the firm from manufacturing and marketing to evaluation, planning and finance (Freel, 2005). Skills refer not only to scientific and engineering qualifications, but to a wider range of training backgrounds from law and management, to arts and design, all of which contribute to creative problem solving (Florida, 2002).

The breadth of the firm's skill base is important for innovation particularly in small and medium enterprises (SMEs) and newly-established companies, which may conduct very little formal R&D in house, and whose workforce may include very few (natural and physical) scientists and engineers. The rationale underlying policy initiatives to support innovation activities in SMEs and new firms is that these firms may not be best placed to obtain financial resources or have access to qualified personnel for undertaking highly risky and uncertain projects. This might result in

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potentially economically valuable innovative projects being rejected.[2] Support for firms' innovative activities prioritize SMEs and start-ups by establishing instruments oriented to providing financial support to compensate for the lack of complementary assets and, more specifically, the lack of highly skilled human resources. Such policy instruments include financial support for feasibility studies, obtaining property rights protection, consultancy and advice, and hiring highly skilled personnel.

Firms with a strong skills base are expected to be endowed with a particularly adaptable and responsive workforce, which reduces the challenges imposed by changes in market conditions or the emergence of disruptive technologies (Gibbons and Johnston, 1974; Cohen and Levinthal, 1990; Baldwin and Lin, 2002). Thus, we would expect that firms with higher proportions of highly skilled employees will be better able to overcome the obstacles to innovation.

This paper examines whether human capital plays a critical role in lowering the barriers faced by firms to involvement in innovation activities, by distinguishing between deterring and revealed barriers. We examine whether the effect of human capital in lowering the barriers to innovation is greater among those firms that are potential innovators, but have not yet invested resources in innovation-related activities. We would expect firms with a strong skills base to be more likely to overcome the barriers to innovation entry, compared to firms with lower levels of human capital. Firms with a high proportion of highly skilled employees are likely to be able to develop the capabilities to build wider professional and social networks and put in place learning processes and search strategies that allow identification of novel

[2] Community framework for state aid for research and development and innovation (2006). http://eur-lex.europa.eu/LexUriServ

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alternatives and ways to develop new products or processes (Cohen and Levinthal, 1990; Leiponen, 2005). In other words, firms with a strong skill base are likely to be better able to overcome or circumvent the deterring barriers imposed by financial constraints, knowledge shortages and market uncertainties. We expect that human capital should contribute to lowering the *deterring* barriers to innovation compared to the *revealed* barriers, since firms that have never engaged in innovation-related activities are particularly burdened by lack of experience and complementary assets. In other words, we would expect that firms with no prior engagement in innovation activities will benefit more from the availability of highly skilled employees compared to firms that have already developed R&D and innovation routines.

3 Data

The dataset for this paper includes information provided by the Spanish Technological Innovation Panel (PITEC). The data are collected by a joint effort of the Spanish National Statistics Institute (INE), the Spanish Foundation for Science and Technology (FECYT), and the Foundation for Technical Innovation (COTEC), based on a Community Innovation Survey type questionnaire. PITEC data are organized as a panel dataset; they are gathered using a consistent data collection methodology, and contain information from successive waves of the Spanish innovation survey. The unit of analysis is the single enterprise, whether independent or part of a larger group. The survey is modelled on OECD's Oslo Manual and provides information related to innovation activities that is comparable with micro-data on innovation for many other European Countries.

In this paper we use 2006-2009 data. The advantage of the PITEC dataset is that its panel data structure allows us to control for unobserved heterogeneity. After

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excluding firms with no information on economic activity during the period 2006-2009, and firms belonging to the primary sector (agriculture and mining), we have a pooled sample of 40,786 firm-year observations.

In line with previous work (D'Este et al., 2012; Mohnen et al., 2008; Savignac, 2008), we filter out from the sample those firms with no stated intention of innovating. This corrects for sample selection bias that would result from asking all firms (irrespective of their willingness to engage in innovative activities) about the obstacles to innovation. In our study setting, we retain only those firms oriented to innovation during the period 2006-2009: we call these 'potentially innovative firms'.

In order to identify this group, we used the information contained in the PITEC for the four waves of the Spanish Innovation Survey (2006 to 2009), which asked two relevant questions. One about whether the firm has been engaged in innovation activities (considering 7 possible innovation-related activities shown in Table A1 in the Appendix), and one about whether the firm has experienced any barriers to innovation in the previous three years (see Table A2 in the Appendix). If a firm responds negatively to both questions in all four waves of the survey, we classify it as non-innovation oriented. The rationale is that firms that did not carry out innovation activities and did not experience any barriers to innovation are unlikely to have any aspirations to innovate. This left a sample of 36,607 firm-year observations (i.e. we excluded 4,179 firm-years, about 10.2% of our initial pooled sample).

Table 1 presents the total number of potentially innovative firms for each wave of the survey, broken down into degree of engagement in innovation-related activities. It can be seen that 26% to 36% of firms, depending on the survey wave, are not involved in any innovation activity; that about 50% of firms engage in just one or two innovation-

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related activities; and that *only* about 20% of the firms are involved in three or more innovative activities. This indicates that, systematically over time, a large proportion of firms take no part, or only have small involvement in innovation-related activities.

[Table 1]

As discussed in Section 2.2, one of the main aims of the present paper is to investigate whether human capital contributes to lowering deterring and revealed barriers to innovation. To do that, we need to identify those firms experiencing each type of barrier. While from a conceptual point of view the distinction between the two types of barriers might be clear-cut (see Section 2.1), its operationalization is more difficult empirically. Our approach to identifying the two groups of firms relies on the two Spanish innovation survey questions mentioned above (and see Appendix). The first question deals with engagement in innovation activities and asked: 'During the previous three-year period, did your enterprise engage in the following innovation activities?' (see Table A1); the second question deals with the factors hampering innovation and asked: 'During the previous three-year period, how important were the following factors as constraints to your innovation activities or influencing your decision not to innovate?' (see Table A2).

We categorized the two groups of firms as follows. Firms facing 'revealed' barriers include those firms that reported at least one barrier item and involvement in at least one innovation activity in the given period. We define firms facing 'deterring' barriers as those firms that report encountering at least one barrier item and no involvement in innovation activity in the given period.

Note that the two groups of firms have in common, experiencing at least one type of

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innovation barrier at some point between 2006 and 2009. In other words, regardless of how these firms assess the importance of the barriers to innovation, the firms in both groups have experienced innovation barriers. The difference between the two groups is whether or not they engaged in innovation-related activities in that period.[3]

Table 2 shows a similar pattern for the two groups of firms with respect to the ranking of obstacles according to their relative importance: cost related issues are ranked highest by a large proportion of firms in the two groups. However, there are some differences if we compare their assessments of the obstacles. For instance, the group of firms facing revealed barriers includes a higher proportion of cases reporting 'lack of external funds' as important, while the group of firms facing deterring barriers includes a higher proportion of companies reporting 'lack of qualified personnel', 'lack of technical information' and 'uncertainty regarding the demand of innovative products' as comparatively more important. Thus, *market* and *knowledge* related obstacles might be particularly important for firms facing deterring barriers compared to firms facing revealed barriers.

[Table 2]

4 Econometric model

4.1 *Dependent variables and methods*

As discussed in Section 2, we are interested in examining whether human capital contributes to lowering deterring and revealed barriers (i.e. cost, knowledge and market obstacles) to innovation.

[3] Note that, as pointed out by one reviewer, there is potentially a group of firms that remains unspecified. This is a group formed by those firms that engage in innovation activities but did not experience any type of barrier to innovation in the period 2006-2009. We do not include these firms in our analysis since the aim is to compare firms that experienced barriers. Also, firms engaging in innovation activities and reporting not experiencing any barriers represent no more than 2% of the total potentially innovative firms (777 firm-year observations out of 36,607), and their inclusion or exclusion does not affect our estimates.

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We measure firms' assessments of the barriers to innovation using data from the survey about the factors hindering innovation activity among the sampled firms. The questionnaire distinguishes between three different sets of factors: a) cost factors; b) knowledge factors; and c) market factors. Appendix Table A1 presents the barrier items included in the questionnaire.

For simplicity, we focus on the three sets of barriers mentioned above, rather than on the individual barrier items. To do this, we measure the extent to which firms assess barriers as important based on the construction of a dichotomous variable, indicating whether the firm assesses as important at least one barrier item (i.e. the variable takes the value 1 if the firm assesses at least one barrier within each set as highly important, and 0 otherwise). We distinguish between cost barriers ($CostBarriers_{it}$), knowledge barriers ($KnowBarriers_{it}$) and market barriers ($MarketBarriers_{it}$).[4]

To study the relationship between firms' characteristics and the barriers to innovation we investigate which factors influence their assessment of the barriers to innovation by estimating a logit panel data model:

$$P(DBarriers_{it} = 1 \mid X_{it}, Z_{it}, \mu_i) = \Lambda(\beta_1 HumanCapital_{it} + \beta_2 Size_{it} + \beta_3 Foreign + \beta_4 Startup_{it} + \\ + \beta_5 ApprConditions_{jt} + \beta_6 TechOpportunities_{jt} + \delta' Z_{it} + \mu_i)$$

where $\Lambda(z) = e^z/(1+e^z)$ is the logistic function. $DBarriers_{it}$ is a dummy variable that takes the value 1 if firm *i* assesses at least one obstacle to innovation as highly

[4] As a robustness check we adopted a more restrictive definition of knowledge barriers that did not incorporate the item "lack of qualified personnel". This was to avoid endogeneity issues arising from estimation of a dependent variable (i.e. knowledge barriers) that included an item about the importance of lack of qualified personnel and an explanatory variable (i.e. human capital) explicitly capturing the availability of employees with higher education degrees. The results are robust to this alternative specification and are available from the authors upon request.

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important in year *t*; X_{it} is a vector of the variables including measures of both firm-specific characteristics of *i*, and characteristics of the industry segment *j* in which *i* operates (see Section 4.2); Z_{it} indicates a series of firm-specific control variables; and μ_i denotes the unobserved firm-specific effects. The model is estimated relying on a random effects specification.[5]

4.2 *Independent and control variables*

Our main independent variable is the firm's human capital, measured as the proportion of the firm's total employees with a higher education degree ($HumanCapital_{it}$). This measure includes a university degree in any discipline, not just engineering and hard sciences. As explained in Section 2.2, we expect human capital to have a particularly strong impact on lowering barriers for firms that have not yet engaged in innovation - that is, firms facing deterring barriers. The other explanatory variables are described below.

First, a variable related to firm size measured as the natural logarithm of total number of employees (plus 1) ($Size_{it}$). Since large firms draw on internal pools of finance and knowledge-related resources, and benefit from scale advantages that allow them to spread the fixed costs of innovation over a larger volume of sales, we would expect larger firms to be better equipped to face barriers to innovation than smaller firms (Schoonhoven et al., 1990; Cohen and Klepper, 1996; Katila and Shane, 2005).

Second, a variable related to the firm's ownership structure ($Foreign_{it}$), measured as a

[5] We do not rely on a fixed effects specification because a large proportion of the firms in our sample are characterized by zeros for variations in the relevant dependent variables. This induces a loss in the number of firms available for the estimation. We preferred to have a larger (and more representative) sample and implement random effects only. More precisely, about 88% of firms characterized as facing "deterring barriers" in any year t, retain this status in t+1. Similarly, 83% of firms characterized as facing 'revealed barriers' at any time t, retain this status in t+1.

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dichotomous variable that takes the value 1 if the firm is foreign-owned (and zero otherwise). We expect that foreign-owned firms will be likely to face lower barriers to innovation compared to domestic firms, since parent companies are likely to provide their subsidiaries with capital at lower cost and provide easier access to export markets (Desai et al., 2008; Hanson et al., 2005).

Third, a variable stating whether the firm is a start-up is included ($Startup_{it}$), which takes the value 1 if the firm was established in the previous three years. The literature is rather vague about whether start-ups face stronger deterring barriers to innovation due to the liability of newness (Stinchcombe, 1965; Freeman et al., 1983; Schoonhaven et al., 1990; Tripsas, 1997) or whether their entrepreneurial dynamism and creativity makes them less sensitive to the barriers to innovation and more prone to introducing breakthrough innovations and challenging incumbent firms (Tushman and Anderson, 1986; Henderson, 1993; Christensen, 1997; Gans et al., 2002).

We also include as controls, three variables related to the extent of the firm's public financial support for innovation. These variables are dummies that equal 1 if the firm indicates having received public support for innovation, from one of the following organizations: European Union, Spanish national government, Spanish regional/local government ($FinanceEU_{it}$, $FinanceNational_{it}$ and $FinanceLocal_{it}$, respectively). We also include a variable for the firm's market orientation ($InternationalMkt_{it}$), defined as a binary variable that takes the value 1 if the firm sells its goods or services in other countries.

Regarding the industry and environmental conditions in which companies operate, we control for appropriability conditions and technological opportunities because both can influence the importance firms attach to different types of barriers.

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Appropriability conditions refer to the mechanisms available to the firms in a specific industry to appropriate the returns from innovation by controlling outward information flows that add to the pool of publicly available information (Cohen and Levinthal, 1989; Cassiman and Veugelers, 2002). We proxy for appropriability conditions using the average number of appropriability mechanisms adopted in year *t* within the industry segment *j* to which the firm belongs ($ApprConditions_{jt}$).[6] The appropriability mechanisms considered are: i) patents; ii) trademarks; iii) utility models; and iv) copyrights. Technological opportunities refer to the extent to which the firms in a particular industry consider that external sources of technological and scientific knowledge contribute significantly to their innovation activities (Rosenberg, 1976; Levin et al., 1985). We measure technological opportunities by the importance firms attach to different external sources of information for the innovation process. The questionnaire asked firms to rate the importance of the following information sources on a 4-point (1 - not important to 4 - very important) Likert scale: i) conferences, trade fairs and exhibitions; ii) scientific journals and trade/technical publications; iii) professional and industry associations. Based on the responses we proxy technological opportunities using an industry level variable based on the average score for these sources for firms operating in the same industry segment *j* in year *t* ($TechOpportunities_{jt}$).

Finally, we include a set of five variables to control for the effect of sectoral characteristics. The sectoral dummies are defined distinguishing between low ($IndMLT_i$), medium ($IndMMT_i$) and high ($IndMHT_i$) technology sectors in manufacturing (according to the Eurostat/OECD classification) and the distinction between high-tech-knowledge intensive service sectors ($IndSHT_i$) and firms in other

[6] Industry segment is defined mainly at the NACE 2-digit sector level.

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service sectors ($IndSLT_i$).[7] Table 3 presents descriptive statistics of the variables used in this study; Table 4 reports the correlation matrix of the independent regressors. In general, correlation across the independent variables is low, suggesting the absence of any relevant multi-collinearity problems.

[Table 3 and Table 4]

Note that human capital shows a different distribution for the group of firms facing deterring barriers and the group facing revealed barriers (see Figure 1). Firms facing deterring barriers have lower levels of human capital, with a median of 8% of employees with higher education degrees compared to a median of 20% for firms facing revealed barriers. Moreover, the dispersion in the level of human capital is higher in the case of firms facing deterring barriers, with a coefficient of variation 47% higher compared to the group of firms facing revealed barriers. This reflects the comparatively smaller pool of highly qualified personnel accessible in firms facing deterring barriers, with a large proportion of firms exhibiting zero for number of university graduates among their employees.

[Figure 1]

5 Results

The empirical analysis exploring the factors attenuating the barriers to innovation is

[7] According to the Spanish classification, high-tech, knowledge-intensive services include the following economic activities: a) post and telecommunications; b) computing and related activities; and c) R&D.

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based on a logistic panel data model[8] where the dependent variables are a set of measures for whether the firm assesses as highly important at least one cost related (*CostBarriers*), knowledge related (*KnowBarriers*) and market related barrier (*MarketBarriers*).

The estimation is conducted on two sub-samples. One includes firms facing deterring barriers to innovation: that is, the group of potentially innovative firms that have not engaged in innovation activities. The second includes firms facing revealed barriers: that is, the group of potentially innovative firms that engage in innovation-related activities. We consider the firms' assessments of cost, knowledge and market barriers.

The results of the logistic panel data model are reported in Table 5. The first two columns in Table 5 report the results for cost barriers, comparing the groups of firms facing deterring and revealed barriers. Columns 3 and 4 report the results for knowledge barriers, and Columns 5 and 6 report the results for market barriers.[9]

[Table 5]

The results in Table 5 show that human capital (i.e. the proportion of employees with a higher education degree) has a mixed relationship with the assessments of the barriers to innovation. On the one hand, a higher level of human capital has a significant and negative association with deterring barriers – especially knowledge

[8] As a robustness check, we estimated an ordered probit panel data model where the dependent variable is a measure of the number of different barrier items (among cost, knowledge and market obstacles) ranked as highly important. The results were in line with those presented in the paper and are available from the authors on request.

[9] We checked whether our results were consistent if we controlled for correlation among the error terms of the regressions, for the three different types of barriers (cost, knowledge and market). We implemented multivariate probit regressions and controlled for clustering of within firm error terms. The results were not qualitatively different from those reported in Table 5 and are available from the authors on request. We are grateful to one of the reviewers for suggesting this robustness check.

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and market obstacles, but no significant correlation with obstacles associated with cost and finance. On the other hand, human capital does not reduce the obstacles to innovation for the group of firms facing revealed barriers. These results show that firms with a higher proportion of highly skilled employees are better equipped to overcome deterring obstacles to innovation related to knowledge and market obstacles, but that human capital does not play a significant role in helping firms to overcome revealed barriers to innovation.

Table 5 shows that the coefficient of firm size is negative and significant. In particular, other things being equal, larger firms assign lower importance to the barriers to innovation irrespective of whether these are revealed or deterring obstacles. We would stress that this result is consistent for all types of obstacles: cost, knowledge and market barriers. Being a foreign owned firm is significantly correlated with lower levels of obstacles to innovation. In particular, firms controlled by foreign companies assigned less importance to both deterring and revealed barriers to innovation, irrespective of the type of obstacle. However, being a new firm increases the importance of the barriers to innovation for firms facing revealed cost obstacles (though the effect is weakly significant).

In relation to the technological regimes characterizing the competitive environment in which the company operates, appropriability conditions seem to lower cost and market related barriers, while technological opportunities do not play a clear-cut role. Firms competing in industries where property rights are the dominant mechanism to appropriate the returns from innovation may be better placed to negotiate access to finance or strategic alliances with incumbent firms, which will lower the barriers associated with costs and market. Finally, the fact that access to public support for

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innovation is often positively associated with higher importance of the barriers to innovation, particularly in the revealed barriers group, may indicate that public funding schemes are more likely to be oriented to supporting firms already committed to innovation.

6 Discussion and conclusions

Despite the fact that innovation is often regarded as key to the firm's economic success, not all firms are willing to engage in innovation activities. About 30% of our sample of 'potential innovators' do not engage in *any* innovative activity, and another 50% engage only modestly (i.e. maximum of 2 innovation-related activities). This raises the question of why firms are deterred from innovation, and to what extent can human capital reduce the obstacles to firms' engagement in innovation activities. These are the questions addressed in this paper.

The paper contributes in three ways. First, it stresses the importance of distinguishing different groups of firms when examining barriers to innovation, between firms that face deterring barriers to innovation activities, and firms that already invest in innovation. Considering these two groups separately is important from both a conceptual and a policy perspective, because it helps to identify the barriers that systemically block engagement in innovation activities among potential innovating firms, and the barriers that are associated with managerial and organizational practices among firms that invest in innovation activities.

Second, financial obstacles are ranked highest by the survey respondents. Access to external funding for innovation (i.e. 'available finance from other organizations') emerged as a particularly strong barrier for firms already heavily engaged in

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innovation activities. Almost all the other barriers to innovation were perceived as more important by firms that do not engage in innovation activities, compared to firms already engaging in innovation activity. In particular, market and knowledge obstacles play a more important role for firms facing deterring barriers to innovation. In other words, firms that do not engage in innovative activities seem to assign more importance to obstacles such as market conditions (i.e. 'market dominated by established firms', 'uncertain demand for innovative products') and knowledge shortages (i.e. 'lack of qualified personnel', 'lack of information on technology'), compared to firms that are engaged in innovation-related activities.

To check the robustness of these findings this study should be replicated in different settings. However, they provide preliminary support for policy measures to promote innovation in addition to provision of finance and responses to imperfect financial markets. They suggest that policies are needed that would address systemic failures associated with weaknesses in the education, training and research infrastructure, lack of technological capabilities among firms, and entry barriers due to highly concentrated markets (among other things).

Third, this research examines the extent to which certain firm characteristics alleviate deterring and revealed obstacles to innovation. In particular, our results show that firms with higher levels of human capital are better equipped to face deterring barriers to innovation. This applies particularly to knowledge and market obstacles. These results highlight the importance of a science and technology infrastructure (and universities in particular) to supply a talented workforce and avoid shortages of skills in the market. It also highlights the importance of raising awareness among firms

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about the need to introduce the organizational changes in order continuously to upgrade their skills base, particularly for firms not yet involved in innovation-related activities.

It should be noted that our finding that human capital does not play a significant role in lowering the barriers for firms already engaged in innovation activities, does not mean that the availability of highly qualified personnel is irrelevant for these firms. It may reflect that, among firms engaged in innovation activities, the impact of human capital might be mediated by complementary investments oriented to innovation. As Leiponen (2005) shows, investments in innovation and the employee skills base are complementary, and improve firms' innovation performance. However, our results show that human capital is likely to be a critical factor per se in reducing the barriers to innovation for firms not engaged in innovation-related activities.

Our results also highlight the relevance of other firm characteristics to the importance of the barriers to innovation. Small firms seem to be clearly disadvantaged in relation to both deterring and revealed barriers to innovation. As expected, large firms seem to benefit from economies of scale and scope which reduce the importance of the obstacles to innovation. Locally-owned firms seem particularly affected by all types of obstacles to innovation, compared to foreign firms. This points to the importance of policy initiatives to support risky projects conducted by small, locally-owned firms. With regard to recently established firms, our results show that being a start-up does not seem to imply either advantage or disadvantage in overcoming deterring or revealed barriers.

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This study has several limitations. First, our sample of non-innovators is likely to be underrepresented (this type of survey tends to have an overrepresentation of firms that carry out innovative activities), which would suggest some caution when making inferences about the whole population of firms, and particularly 'potential innovators' which do not engage in innovation activities. Second, our measure of human capital is very broadly defined and it might be better to qualify the level of skills for different types of occupations. Thirdly, we do not introduce explicitly (apart from industry controls) the role of environmental factors (such as location and regional policies) in shaping firms' assessments of barriers. Finally, although the analysis in this paper tries to control for some effects that might hide omitted variable bias driven by unobserved heterogeneity, the absence of a pure experimental setting to allow a conclusive analysis suggests caution when interpreting the results in a causal way. We plan to address these issues more explicitly in future work.

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Tables

Table 1: Proportion of potentially innovative firms involved in innovation-related activities, for the 4 waves of the survey (%)

Degree of involvement in innovation-related activities*	Waves of the survey				
	2006	2007	2008	2009	Total (for the pooled sample)
Not involved	25.7	29.2	33.3	35.5	30.8
Involved in 1-2	53.6	50.3	47.7	45.6	49.4
Involved in 3-4	17.3	17.2	16.1	16.1	16.7
Involved in 5-7	3.4	3.4	2.9	2.8	3.1
Number of firms	9609	9214	9054	8730	36607

*The seven innovation-related activities considered in the survey are: *Intramural (in-house) R&D*; *Acquisition of R&D (extramural R&D)*; *Acquisition of machinery, equipment or software*; *Acquisition of external knowledge*; *Training*; *Market introduction of innovations*; and *All forms of design.*

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Table 2: Proportion of firms assessing obstacles to innovation as highly important (%)

	List of obstacles to innovation	***Firms facing deterring barriers (NT=11271)***	***Firms facing revealed barriers (NT=24559)***	χ^2 difference test (d.f.)
Cost Factors	Lack of internal funds	35.32	34.45	2.57(1)
	Lack of external funds	30.01	33.29	38.15(1)***
	High innovation costs	37.77	35.11	23.71(1)***
Knowledge Factors	Lack of qualified personnel	15.56	11.91	90.97(1)***
	Lack of technical information	10.1	7.5	68.06(1)***
	Lack of market information	9.36	8.66	4.72(1)*
	Difficulty in finding partners for innovation	14.93	12.08	55.6(1)***
Market Factors	Market dominated by established firms	22.16	20.68	10.24(1)***
	Uncertainty regarding the demand of innovative products	26.17	23.34	33.69(1)***

[a] *The number of firm-year observations do not sum to the total 36607, because there are 777 firm-year observations that are facing neither deterring nor revealed barriers to innovation. These are those firms that, despite carrying out innovative activities, have not experienced any barrier to innovation See footnote 3 for a more detailed explanation.*

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Figure 1: Kernel density distribution of human capital by type of barrier

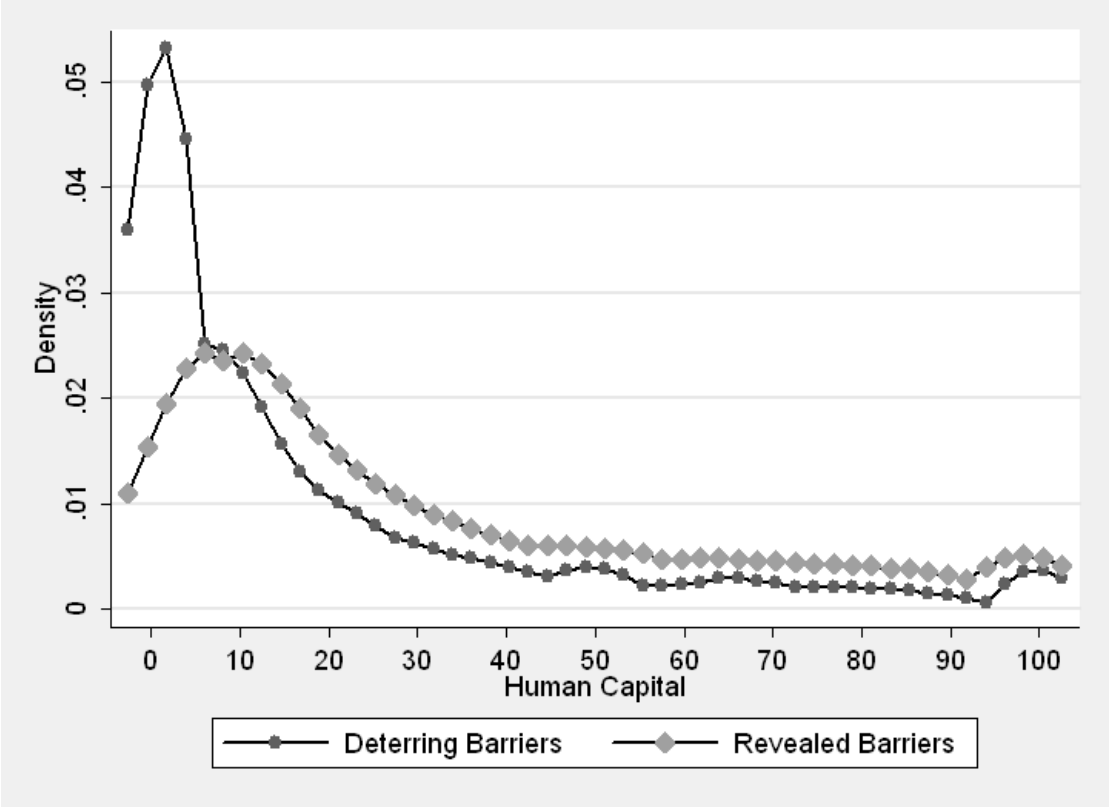

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Table 3: Descriptive statistics for the pooled sample (NT=35830)

	Mean	Std.Dev.	Min	Max
Outcome variables				
CostBarriers	0.53	0.50	0	1
KnowBarriers	0.27	0.44	0	1
MarketBarriers	0.34	0.47	0	1
Explanatory variables				
HumanCapital	27.20	28.81	0	100
Size	4.04	1.56	0.69	10.63
Foreign	0.10	0.30	0	1
Startup	0.04	0.19	0	1
InternationalMkt	0.64	0.48	0	1
ApprConditions	0.10	0.04	0.02	0.21
TechOpportunities	0.87	0.23	0.12	1.67
FinanceLocal	0.24	0.43	0	1
FinanceNational	0.21	0.41	0	1
FinanceEU	0.05	0.21	0	1
IndMHT	0.05	0.22	0	1
IndMMT	0.20	0.40	0	1
IndSHT	0.13	0.34	0	1
IndMLT	0.33	0.47	0	1
IndSLT	0.29	0.45	0	1

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Table 4: Correlation matrix of explanatory variables

		(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*
(1)	*Size*														
(2)	*HumanCapital*	-0.31													
(3)	*Foreign*	0.27	-0.04												
(4)	*Startup*	-0.06	0.22	-0.04											
(5)	*InternatiomalMkt*	0.14	-0.09	0.15	-0.02										
(6)	*ApprConditions*	-0.18	0.15	0.02	0.10	0.21									
(7)	*TechOpportunities*	-0.21	0.34	0.01	0.17	0.12	0.73								
(8)	*FinanceLocal*	-0.06	0.20	-0.06	0.15	0.08	0.16	0.20							
(9)	*FinanceNational*	0.06	0.22	-0.01	0.16	0.12	0.16	0.24	0.32						
(10)	*FinanceEU*	0.04	0.18	-0.02	0.16	0.06	0.13	0.20	0.21	0.27					
(11)	*IndMHT*	-0.01	0.06	0.04	0.04	0.08	0.31	0.30	0.03	0.09	0.02				
(12)	*IndMMT*	-0.02	-0.13	0.08	-0.05	0.22	0.18	0.22	0.02	0.02	-0.04	-0.11			
(13)	*IndSHT*	-0.16	0.43	-0.04	0.18	-0.14	0.28	0.37	0.13	0.15	0.16	-0.09	-0.19		
(14)	*IndMLT*	0.00	-0.34	-0.03	-0.11	0.19	0.04	-0.18	-0.04	-0.07	-0.08	-0.16	-0.35	-0.27	
(15)	*IndSLT*	0.13	0.12	-0.03	0.01	-0.32	-0.56	-0.43	-0.09	-0.09	-0.01	-0.15	-0.31	-0.25	-0.45

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Table 5: Results of the logit panel data model reporting factors lowering barriers to engage in innovation

	Dependent variable: whether the firm assesses at least 1 barrier item as highly important					
	CostBarriers		**KnowBarriers**		**MarketBarriers**	
	Deterring	**Revealed**	**Deterring**	**Revealed**	**Deterring**	**Revealed**
HumanCapital	0.001	-0.003	-0.007***	-0.000	-0.005**	-0.002
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Size	-0.707***	-0.751***	-0.362***	-0.412***	-0.363***	-0.376***
	(0.042)	(0.036)	(0.039)	(0.032)	(0.038)	(0.032)
Foreign	-0.718***	-0.399***	-1.146***	-0.649***	-0.419**	-0.519***
	(0.188)	(0.130)	(0.214)	(0.135)	(0.191)	(0.126)
Startup	0.630	0.273*	0.685*	0.061	0.540	0.090
	(0.397)	(0.143)	(0.387)	(0.135)	(0.379)	(0.133)
InternationalMkt	0.187*	0.114	0.040	-0.086	0.197*	0.110
	(0.106)	(0.088)	(0.107)	(0.083)	(0.104)	(0.082)
ApprConditions	-9.457***	-9.710***	-2.589	3.726**	-4.675**	-5.919***
	(2.190)	(1.631)	(2.212)	(1.551)	(2.140)	(1.511)
TechOpportunities	0.304	0.124	-0.089	-0.980***	0.405	0.234
	(0.365)	(0.305)	(0.369)	(0.289)	(0.359)	(0.283)
FinanceLocal	-0.175	0.111	0.285	0.104	-0.256	0.023
	(0.205)	(0.068)	(0.209)	(0.066)	(0.206)	(0.064)
FinanceNational	-0.167	0.218***	-0.425	0.200***	-0.008	0.291***
	(0.284)	(0.070)	(0.295)	(0.070)	(0.277)	(0.067)
FinanceEU	0.457	0.191	0.239	0.100	0.793	0.222*
	(0.581)	(0.134)	(0.598)	(0.132)	(0.575)	(0.128)
Industry dummies	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
Constant	4.300***	5.155***	0.439	0.013	0.073	0.899**
	(0.593)	(0.396)	(0.576)	(0.361)	(0.566)	(0.356)
Log-likelihood	-6158.363	-12600	-5596.690	-11237.081	-6085.684	-12400
Wald χ^2(d.f.)	463.302(14)***	639.770(14)***	164.158(14)***	276.678(14)***	168.352(14)***	276.407(14)***
Firm-year observations	11271	24559	11271	24559	11271	24559
Firm observations	5049	8181	5049	8181	5049	8181

Legend: * p<0.10, ** p<0.05, *** p<0.01. Robust standard errors and degrees of freedom are in round brackets. Robust standard errors have been computed via 500 bootstrap replications.

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APPENDIX.

Table A1. Engagement in innovation-related activities: *During the previous three years, did your enterprise engage in the following innovation activities?*

Innovation-related activities	No	Yes
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 or processes	☐	☐
Acquisition of R&D (extramural R&D) Same activities as above, bur purchased by your enterprise and performed by other companies (including other enterprises within your group) or by public or private research organisations	☐	☐
Acquisition of machinery, equipment or 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 organisations	☐	☐
Training Internal or external training for your personnel specifically for the development and/or introduction of innovations	☐	☐
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.	☐	☐
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.	☐	☐

Table A2. Barriers to innovation: ***During the previous three-years, how important were the following factors as constraints to your innovation activities or influencing a decision not to innovate?***

Factors	Items	Factor not experienced	Degree of importance Low	Medium	High
Cost Factors	Lack of available finance within the firm	☐	☐	☐	☐
	Lack of available finance from other organisations	☐	☐	☐	☐
	Direct innovation costs too high	☐	☐	☐	☐
Knowledge Factors	Lack of qualified personnel	☐	☐	☐	☐
	Lack of information on technology	☐	☐	☐	☐
	Lack of information on markets	☐	☐	☐	☐
	Difficulty in finding partners for innovation	☐	☐	☐	☐
Market Factors	Market dominated by established enterprises	☐	☐	☐	☐
	Uncertain demand for innovative goods / services	☐	☐	☐	☐