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The Role Of Human Capital In Lowering Barriers To Engage In Innovation: Evidence From The Spanish Innovation Survey

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Abstract

This paper focuses on the role of human capital in attenuating the barriers that block firms from engaging in innovation activities. The paper distinguishes between firms facing deterring barriers to innovation (firms deterred from engaging in innovation activities) and firms confronting revealed barriers (firms that experience barriers alongside their engagement in innovation activities). We investigate whether human capital has a particularly strong impact in lowering barriers among the former group of firms, since a strong skill base is likely to compensate for the lack of previous experience in innovation-related activities or the necessary complementary assets associated to 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 obstacles. Results reveal that human capital has a significant impact in attenuating deterring barriers to innovation associated to knowledge shortages and market uncertainties.

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1 Introduction

Innovation studies have extensively examined the drivers and sources of innovation, paying particular attention to the technological and organizational capabilities that firms need to develop to become successful innovators (e.g. Schumpeter, 1950; Dosi, Nelson and Winter, 2002; von Hippel, 1994). This literature, however, has been comparatively less systematic in examining the factors that block firms' involvement in innovation activities.

While the innovation survey-based literature has largely focused on the impact of barriers on the propensity to innovate (Savignac, 2008; Mohnen and Rosa, 2000; Mohnen and Roller, 2003), much less attention has been devoted to examining the role of barriers as deterring factors on firms' involvement in innovation-related activities, or on the factors that reduce the negative impact of innovation barriers.

[Re]dressing this unbalance is crucial for at least two reasons. On the one hand, from an innovation policy perspective, it is important to identify the extent to which the population of potentially innovative firms is affected by deterring barriers to innovation activities, in order to foster innovation-based competition dynamics and attenuate systemic failures to innovation (Woolthuis, 2005; Chaminade et al., 2009). On the other hand, from both an innovation management and policy perspectives, it is important to identify the factors that are more likely to attenuate the negative impact of deterring barriers on innovation activities.

This paper aims at improving our understanding of the factors attenuating obstacles to innovation by distinguishing between firms that face *deterring* barriers to innovation and firms that confront *revealed* barriers to innovation (D'Este et al., 2011). As discussed throughout the paper, making this distinction between *revealed* and *deterring*

is crucial to help disentangling two essentially different mechanisms when referring to 'obstacles to innovation'. The paper also investigates the role of human capital in lowering barriers to innovation, paying particular attention to barriers such as: financial constraints, knowledge shortages and market uncertainties.

This research draws on four waves of the Spanish Innovation Survey to construct a longitudinal dataset on firms' innovation profiles. In order to avoid a sample selection bias problem, we consider only firms that are willing to participate in the innovation contest (i.e. we filter out firms that are not interested in undertaking innovation activities - see Savignac, 2008, for a similar method). We distinguish two groups of firms according to whether they engage in innovation-related activities or not. We finally examine whether human capital contributes to attenuate the barriers experienced by firms, for each of the two groups separately.

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

2 Barriers to engage in innovation activities

2.1 Identifying firms deterred from innovation activities

Innovation has long been recognised as a vital contributor to firm economic performance and survival. However, despite the ample support about the advantages of innovation among industry practitioners and policy makers, many potentially innovative firms remain persistently detached from deliberate effort towards innovation activities. This is an issue that has attracted comparatively little research, regardless of its importance from a conceptual and an innovation policy perspective.

The claim that a significant proportion of potential innovators are not involved in innovation activities requires, first, setting the scene and clarifying what is actually meant by potential innovators. In this we follow Savignac (2008)[3] and D'Este et al. (2011) in defining potential innovators as firms that invest in innovation-related activities (regardless of whether they are successful innovators or not), and firms that do not invest in innovation but experience barriers to innovation. Drawing on the Spanish Innovation Survey, 30% of potentially innovative firms do not conduct any innovation-related activity (see Table 1). Savignac (2008) also finds that, drawing on an innovation survey of manufacturing firms in France, conducted in 2000, 25% of the potentially innovative firms in her sample were firms without innovative activities.

Although a considerable amount of research has been devoted to analyze the effects of different types of barriers and constraints to innovation, much of the survey-based literature has focused on the impact of barriers on the propensity to introduce a new product or process (Savignac, 2008; Mohnen and Rosa, 2000; Mohnen and Roller, 2003) or the impact of barriers on firms' R&D intensity (Tiwari et al., 2007). However, comparatively less is known about the role of barriers as deterring factors on the firms' involvement in innovation-related activities, or about the factors that attenuate the negative impact of innovation barriers.

In order to improve our understanding on these issues, we propose to distinguish two groups of firms. On the one hand, firms *deterred* from innovation activities. Potentially innovative firms might be deterred from innovation-related activities as a consequence

[3] Our approach differs from hers, though, in that we have taken an input-based definition of innovation activities (i.e. efforts devoted to activities associated with innovation) rather than an output-based definition (i.e. market introduction of a new or improved product). We have taken this decision to be consistent with our purpose of distinguishing those firms that experienced barriers and did not *invest* in any innovation-related activity (as opposed to firms that did not introduce a new product or process). We explain in further detail how we define "potentially innovative" firms in Section 3.

of the barriers they face. This happens when firms that would be willing to undertake innovative projects, remain uninvolved in innovation-related activities as a result of factors such as: lacking access to finance for high-risk projects, lacking adequate channels to obtain information about markets or technologies, or having difficulties in meeting adequate partners for innovation activities, among other reasons. In short, deterring barriers refer to obstacles that prevent or block firms from undertaking innovative activities. Baldwin and Lin (2002), for instance, examine this type of barriers when investigating the importance of impediments faced by firms with regards to the adoption of advanced technologies.

On the other hand, potentially innovative firms may experience barriers that obstruct the performance achieved in their innovation activities, while being already engaged in innovation-related projects. These firms experience barriers that are likely to delay or slow down innovation projects, or may even represent a major determinant of the decision to abandon an innovation project. While these firms may face barriers that impose a substantial obstacle to the completion of their innovation activities, they are not prevented from investing in innovation-related activities. For this reason we categorize these firms as facing *revealed* barriers, since these barriers are observed by engaging in innovation activities. In other words, revealed barriers refer to obstacles to innovation that are realised by firms alongside their innovation-related activities. This is the type of barriers addressed in the literature when looking at the impact of financial constraints on the probability to become a successful innovator or on the intensity of innovation (e.g. Baldwin and Hanel, 2003; Tiwari et al., 2007).

The distinction between these two types of firms, and the nature of the barriers faced, is also important from the point of view of innovation policy. If policy makers aim at addressing systemic failures in the innovation system, it is crucial to identify the extent

of the problem (that is, the proportion of potential innovators that are detached from innovation activities) as well as to identify the main features of the actors deterred from engaging in innovation activities, in order to help design appropriate policies that confront systemic failures (Chaminade and Edquist, 2006). In other words, we need to gain a better understanding of the systemic factors that prevent firms from being innovation-active.

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

The resource-based theory has pointed out that internal resources, and particularly human resources, play a crucial role in developing and sustaining a firm's competitive advantage (Pfeffer, 1994; Youndt et al., 1996). A large number of empirical studies have shown that enhancing the skill-base of employees is positively associated with firms' economic (Arthur, 1994; MacDuffie, 1995) and innovation performance (Leiponen, 2005).

The availability of highly skilled employees is expected to equip firms with an adaptable, responsive and pro-active workforce. These attributes of a strong skill base are not limited to the R&D function or to engineering and scientific skills of employees. On the one hand, the skills of employees are a critical internal resource in every single function within a firm, from manufacturing and marketing to evaluation, planning and finance (Freel, 2005). On the other hand, it is not only about qualified scientists and engineers, but about educated individuals in a wide range of training backgrounds, from law and management to arts and design, who are capable to engage in creative problem solving (Florida, 2002).

It is important to bear this wider perspective in mind when referring to a firm's skill base, since human capital can be a particularly critical factor to favour innovation in small and medium enterprises (SMEs) and new-established companies, which often conduct very little formal R&D and may have a comparatively small proportion of (natural and physical) scientists and engineers among their employees. Indeed, much of the underlying rationale of policy initiatives to support innovation activities in SMEs and new-established firms is that such firms are particularly susceptible to suffer from an unfavourable position to get the appropriate levels of financial resources and/or access to qualified personnel to undertake highly risky and uncertain projects, causing potential valuable innovative projects for the economy not being carried out (see EC, 2006[4]). The supporting schemes aimed at favouring firms' innovative activities, which place SMEs and start ups high in the priorities for eligibility of state aids, draw upon instruments largely oriented to assist the beneficiary firms with financial support for compensating the lack of complementary assets, and more specifically, the lack of highly skilled human resources. These policy instruments include financial support for carrying out feasibility studies; assisting with the costs for industrial property rights; contracting advisory services; or hiring highly qualified personnel (among other activities associated with innovation).

In short, firms with a strong skill-base are expected to be endowed with a particularly adaptable and responsive workforce, which helps softening 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, 20). In consequence, we

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

would expect that firms with a higher proportion of highly skilled employees would be better positioned to overcome obstacles to innovation.

This paper aims to address whether human capital plays a critical role in lowering barriers to involvement in innovation activities faced by firms, by distinguishing between deterring and revealed barriers. We examine whether the impact of human capital to lowering barriers to innovation is particularly acute among firms that are potential innovators but have not yet invested resources in innovation-related activities. According to the literature reviewed in this section, we would expect that firms equipped with a strong skill-base are more likely to overcome systemic barriers to innovation, as firms with a high proportion of high-skilled employees are likely to develop capabilities to build wider professional and social networks and set up learning processes and search strategies that contribute to identify novel alternatives and pathways for developing new products or processes (Cohen and Levinthal, 1990; Leiponen, 2005). In other words, firms with a strong skill base should be more likely to overcome, or circumvent, the deterring barriers imposed by financial constraints, knowledge shortages and market uncertainties. In this sense, we would expect that human capital should particularly contribute to lowering *deterring* barriers to innovation, as opposed to *revealed* ones, since firms that have not engaged in innovation-related activities are distinctively burdened by the lack of prior expertise and complementary assets.

3 Data

The data set used in this paper contains firm level data from the Spanish Technological Innovation Panel (PITEC). The data is 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). PITEC is organized

as a panel data set, with a consistent data collection methodology over a number of time periods. The unit of analysis is the single enterprise, whether part of a larger group or independent. The data comes from a CIS-type survey, based on the OECD's Oslo Manual, and therefore includes information related to innovation activities comparable with the microdata on innovation of many other European Countries.

PITEC provides information from different successive waves of the Spanish innovation survey. In this paper we use specifically the data from the period 2006-2009. The advantage of using this dataset is that it allows us to control for unobserved heterogeneity by exploiting its panel data structure. After excluding those firms where no information was found about economic activity during the period 2006-2009 and those firms belonging to the primary sector (agriculture and mining), we are left with a pooled sample of 40786 firm-year observations.

Moreover, in line with previous work (D'Este et al., 2011; Monhen et al., 2008; Savignac, 2008), we filter out from our sample those firms that do not aim at innovating. This is done in order to correct for a sample selection bias problem, which emerges from asking all surveyed firms (irrespective of their willingness to engage in innovative activities) about obstacles to innovation. In the setting of this study, we keep only those firms that are oriented to innovation during the period 2006-2009: what we call '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). In particular, the survey includes two questions asking whether the firm has been engaged in innovation activities (see Table A1 in the Appendix) and whether it has experienced any barriers to innovation during the last three years (see Table A2 in the Appendix). If the firm responds negatively to these questions in each of the four waves of the survey, we

classified the firm as non-innovation oriented. The underlying rationale is that firms that did not carry out innovation activities and did not experience any barrier to innovation are unlikely to have any aspiration to innovate. After this procedure we are left with a sample containing 36607 firm-year observations (i.e. we exclude from our sample 4179 firm-years, about 10.2% of our initial pooled sample).

Table 1 displays the total number of potentially innovative firms for each wave of the survey, and its breakdown by degree of engagement in innovation-related activities. As the Table shows, between 26 and 36% of firms, depending on the specific wave of the survey, are not involved in any innovation activity. Moreover, about 50% of the firms engage in just 1 or 2 innovation-related activities, while *only* about 20% of the firms are involved in 3 or more innovative activities. This indicates that, systematically over time, a wide proportion of firms do not engage at all, or to a very little extent, 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 that are 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 operationalisation is more difficult from an empirical viewpoint. Our approach to identify the two groups of firms relies on the two questions from the Spanish innovation survey mentioned above (see Appendix). The first question deals with the engagement in innovation activities and asked "During the previous three year-period, did your enterprise engage in the following innovation activities?" (see Table A1); while 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).

Accordingly, we categorized the two groups of firms as follows. On the one hand, firms facing "revealed" barriers as those firms that report facing at least one barrier item and, at the same time, conducting at least one innovation activity in the given period. On the other hand, we define firms facing "deterring" barriers as those firms that report facing at least one barrier item and, at the same time, they do not conduct any innovation activity in the given period.

As we can see in Table 2, the two groups of firms display a similar pattern with respect to the ranking of obstacles in terms of their relative importance: cost related obstacles are considered as the most important ones for a larger proportion of firms in the two groups. However, there are some relevant differences when comparing the assessments of each type of obstacle separately. For instance, while the group of firms facing revealed barriers display a higher proportion of cases reporting 'lack of external funds' as important, the group of firms facing deterring barriers display a higher proportion of cases reporting 'lack of qualified personnel', 'lack of technical information' and 'uncertainty regarding the demand of innovative products' as comparatively more important. This indicates that *market* and *knowledge* related obstacles might be of particular importance for firms facing deterring barriers, as 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 to innovation for the different sets of obstacles (i.e. cost, knowledge and market obstacles).

We measure the firm assessment of barriers to innovation by using survey data on the assessment about factors hindering the innovation activity of the sampled firms. In particular, we have drawn on the responses to the question on the Spanish innovation survey on factors hampering innovation. The questionnaire distinguishes between different types of factors, grouped into three sets of obstacles: a) cost factors; b) knowledge factors; and c) market factors. Table A1 in the Appendix displays the barrier items included in the questionnaire.

For simplicity, we focus on the three sets of barriers mentioned above, rather than on the barrier items individually. In order to do this, we have measured the extent to which firms assess barriers as important is 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 has assessed as highly important at least one barrier within each set, and takes the value 0 otherwise). We distinguish between cost barriers ($DCostBarriers_{it}$), knowledge barriers ($DKnowBarriers_{it}$) and market barriers ($DMktBarriers_{it}$).

To study the relationship between firms' characteristics and barriers to innovation we investigate which factors influence the assessment of barriers to innovation through the estimation of the following logit panel data model:

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

where $\Lambda(z) = e^z/(1+e^z)$ is the logistic function. $DBarriers_{it}$ is a dummy variable taking value 1 if firm *i* assesses at least one obstacle to innovation as highly important in year *t*; X_{it} is a vector of variables including measures of both firm-specific characteristics of *i*, and characteristics of the industry segment *j* where *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 has been estimated relying on a random effect specification.[5]

4.2 Independent and control variables

Our main independent variable, as discussed in Section 2.1, is the firm's human capital, which we measure as the proportion of the total employees with higher education degree in the company ($HumanCapital_{it}$). This measure encompasses university degrees in any possible educational background, not only in engineering and hard sciences. The other explanatory variables are as follows.

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

[5] We did not rely on fixed effect specification cause most of firms contained in our sample were characterised by zero within variation of the relevant dependent variables. This induced a loss in the number of available firms for estimation. Thus, we preferred to stick to a much larger (and representative) sample and we implemented random effects only.

Second, a variable related to the firm's ownership structure, measured as a dichotomous variable that takes the value 1 if the firm is foreign-owned (and zero otherwise). We expect that foreign-owned firms are likely to face lower deterring barriers to innovation, compared to domestic firms, as parent companies are likely to provide lower costs of capital and easier access to export markets to their subsidiaries (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 has been established in the previous 3-year period. The existing literature is rather inconclusive with respect to whether startups 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 barriers to innovation and prone to introduce breakthrough innovations and challenge incumbent firms (Tushman and Anderson, 1986; Henderson, 1993; Christensen, 1997; Gans et al., 2002).

We have also included, as controls, three variables related to the extent to which the firm has been recipient of public financial support to innovation. These variables are dummies equating 1 if the firm indicates that it received public support for its innovative activities from one of the following organizations: European Union, Spanish national government and Spanish regional/local governments ($FinanceEU_{it}$, $FinanceNational_{it}$, $FinanceLocal_{it}$ respectively). We also included a variable representing the market orientation of the firm ($InternationalMkt_{it}$), which is defined as a binary variable and 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. We proxy for appropriability conditions by using the average number of appropriability mechanisms adopted within the industry segment *j* the firm belongs to in year *t* ($ApprConditions_{jt}$)[6]. The appropriability mechanisms considered are: i) patents, ii) trademarks, iii) utility models and iv) copyrights. On the other hand, technological opportunities are measured by the importance of different information sources for the innovation process of the firm. In the questionnaire, firms were asked to rate the importance of the following sources on a 4 point Likert scale (from 1 - not important; to 4 - very important): i) conferences, trade fairs and exhibitions, ii) scientific journal and trade/technical publications and iii) professional and industry associations. Based on the responses on this question we proxy technological opportunities through an industry level variable using the average score of the above sources for firms operating in the same industry segment *j* in year *t* ($TechOpportunities_{jt}$).

Finally, we have included a set of five variables to control for the effect of sectoral characteristics. The sectoral dummies have been defined taking into account the distinction between low ($IndMLT_i$), medium-high ($IndMMT_i$) and high ($IndMHT_i$) technology sectors in manufacturing (as defined by Eurostat/OECD classification) and the distinction between High-tech-knowledge intensive service sectors ($IndSHT_i$) and firms in other service sectors ($IndSLT_i$).[7] In Table 3 we provide descriptive statistics of the variables used in this study while Table 4 reports the correlation matrix for the independent regressors. In general, the correlation across the independent variables is low, thus suggesting the absence of any relevant problems of multicollinearity.

[6] The industry segment is mainly defined at the NACE two-digit sector level.

[7] According to the Spanish classification the group of High-tech knowledge-intensive service sector comprised the following economic activities: a) post and telecommunications, b) computer and related activities, and c) research and development.

[Table 3 and Table 4]

It is worth noting that human capital displays a different distribution for the group of firms facing deterring barriers and the group facing revealed barriers (see Figure 1). While the former group of firms has lower levels of human capital, the dispersion of human capital levels across firms is larger, compared to the latter group. More specifically, the mean and median figures for the proportion of employees with a higher education degree is about 18% and 8%, respectively, for the former group of firms, representing less than half the levels characterising the latter group (31% and 20%, respectively). Whereas the dispersion in the level of human capital is higher in the case of firms facing deterring barriers, with a coefficient of variation being about 40% larger compared to the group of firms facing revealed barriers.

[Figure 1]

5 Results

The empirical analysis exploring the factors attenuating barriers to innovation is based on a logistic panel data model[8] that takes, as dependent variable, a measure indicating whether the firm assesses as highly important at least one barrier item (regarding cost, knowledge and market obstacles). The estimation is conducted on two sub-samples.

On the one hand, firms facing deterring barriers to innovation: that is, the group of potentially innovative firms that have not been engaged in innovation activities. Since non-innovators report their assessment on how important cost, knowledge and market obstacles are, we define the following dependent variables: one related to cost barriers

[8] As a robustness check of the results, we also estimated an ordered probit panel data model that takes, as dependent variable, a measure indicating the number of different barrier items assessed as highly important (regarding to cost, knowledge and market obstacles). Results are in line with those presented in the paper and are available from the authors upon request.

(*DCostBarriers*), one related to knowledge barriers (*DKnowBarriers*) and another one related to market barriers (*DMarketBarriers*).

On the other hand, we consider firms facing revealed barriers: that is, the group of potentially innovative firms that engage in innovation-related activities. As in the previous case, these firms report their assessments on cost, knowledge and market barriers, so we consider the following dependent variables: one related to cost barriers (*DCostBarriers*), one related to knowledge barriers (*DKnowBarriers*) and another one related to market barriers (*DMarketBarriers*).

The results for the logistic panel data model are reported in Table 5. The first two columns of Table 5 report the results for cost barriers, comparing the group of firms facing deterring barriers (*Cost_Det*) and the group facing revealed barriers (*Cost_Rev*). The next two columns follow the same logic, reporting the results for the case of knowledge barriers (*Know_Det* and *Know_Rev*). The last two columns report the results for the case of market barriers (*Market_Det* and *Market_Rev*).

[Table 5]

Results from Table 5 show that human capital (i.e. the proportion of employees with a higher education degree) has a mixed effect on the assessment of barriers to innovation. On the one hand, human capital is found to have a significant and negative effect on deterring barriers associated to knowledge and market obstacles, but it has no impact on obstacles associated to costs and finance. On the other hand, human capital has no significant impact in attenuating 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 particularly better equipped to overcome deterring obstacles to innovation rather than revealed ones (at least for knowledge and market related obstacles).

Table 5 also shows a negative and significant coefficient for firm size. In particular, other things being equal, being a larger firm lowers the assessment of barriers to innovation irrespective of facing revealed or deterring obstacles. It is worth stressing that this result is consistent for all types of obstacles, being them cost, knowledge or market barriers. On the same token, being foreign owned has a clear-cut effect on the reduction of obstacles to innovation. In particular, firms controlled by foreign companies assess as less important both deterring and revealed barriers to innovation irrespective of the type of obstacle. However, being a new firm seems to increase the assessment of barriers to innovation for firms facing cost revealed obstacles.

As for the technological regimes that characterize 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 a prevalent mechanism to appropriate the returns form innovation may be better placed to negotiate access to finance or strategic alliances with incumbent firms, thus lowering the barriers associated with costs and markets. Finally, the fact that access to public support for innovation is often positively associated with the assessment of the importance of barriers, particularly in the case of the group facing revealed barriers to innovation, may be signalling that public schemes are likely to be particularly oriented to support firms that are already heavily committed to innovation.

6 Discussion and conclusions

Despite the fact that innovation is often seen to be the key to a firm's economic success, not all firms willing to innovate engage in innovation activities. As this paper shows, about 30% of our sample of "potential innovators" do not engage in *any* innovative

activity, and another 50% engage only modestly (i.e. in two innovation-related activities at most). This raises the issue about why firms are deterred from innovation and to what extent human capital attenuates the obstacles faced by firms to engage in innovation activities. These are the main questions addressed in this paper.

The paper contribution is threefold. First, the paper stresses the importance to distinguish between two different groups of firms when examining barriers to innovation: those firms that face deterring barriers to innovation activities, and those firms that already invest in innovation. Considering these two groups separately is important from both a conceptual and a policy perspective, because it helps disentangle barriers that operate systemically in blocking innovation activities among potential innovating firms, from barriers that are associated with managerial and organisational factors within firms that invest in innovation activities.

Second, the paper shows that, while financial obstacles are the most prevalent among survey respondents, cost-related barriers are particularly strong among firms heavily engaged in innovation activities. In contrast, market and knowledge obstacles play a more important role among firms facing deterring barriers to innovation activities. In other words, firms seem to be strongly deterred from innovation by factors such as market conditions (i.e. 'market dominated by established firms' or 'uncertain demand for innovative products') and knowledge shortages (i.e. 'lack of qualified personnel' or 'lack of information on technology'), besides financial constraints.

It would be important to replicate this study in different settings in order to check for the robustness of these findings. Nevertheless, these findings provide preliminary evidence that points towards policy measures to promote innovation that expand well-beyond the availability of finance and the response to imperfect financial markets. These results point towards policies addressing systemic failures on innovation

associated with the weaknesses of the research infrastructure, the lack of technological capabilities among firms, and the deterring barriers emerging from highly concentrated markets (among others).

Third, this research has also addressed 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 with regards to knowledge and market obstacles. These results highlight the importance of a science and technology infrastructure (and of universities in particular) as suppliers of a talented workforce in order to avoid a shortage of skills available on the market; but also highlights the importance of raising awareness among firms about the need to introduce the organisational changes required to continuously upgrading their skill-base, particularly regarding firms not yet involved in innovation-related activities.

It is worth noting that our finding that human capital does not play a significant role in lowering barriers among firms already engaged in innovation activities, does not mean that human capital is irrelevant in such setting. It may simply reflect that, among firms engaged in innovation activities, human capital plays a more complementary role when combined with specific investments oriented to innovation. As Leiponen (2005) has shown, investments in innovation and the skill base of employees complement each other to improve firm's innovation performance. What our results point out is that human capital is likely to be a critical factor per se in driving down barriers to innovation among firms not engaged in innovation-related investments.

Our results also point out the relevance of some other firm characteristics in shaping the assessment on barriers to innovation. Small firms seem to be clearly disadvantaged to face both deterring and revealed barriers on innovation. As expected, large firms seem

to benefit from economies of scale and scope that attenuate the importance of obstacles to innovation. Similarly, local-owned firms seem to be particularly sensitive to all type of obstacles to innovation, as compared to foreign firms. In this sense, policy initiatives oriented to support risky projects by small and local-owned firms should be welcomed. With regards to the role of recently created firms, our results show that being a startup does not seem to imply either an advantage or a disadvantage to face deterring or revealed barriers.

This study has a number of limitations. First, our sample of non-innovators is likely to be underrepresented (this type of surveys tend to have an overrepresentation of firms that carry out innovative activities), and therefore we need to be cautious about making inferences to the whole population of firms, and particularly to "potential innovators" that do not carry out innovation activities. Second, our measure of human capital is probably too broadly defined, and it would be better to qualify the level of skills for different type of occupations. Finally, we have not introduced explicitly (besides industry controls) the role of environmental factors (such as the characteristics of location and regional policies) in shaping the assessment of firms about barriers. We plan to address these latter issues more explicitly in future work.

References

1. Arthur, J.B. 1994. Effects of human resource systems on manufacturing performance and turnover. *Academy of Management Journal* 37: 670-687.
2. Baldwin, J. and Lin, Z. 2002. Impediments to advanced technology adoption for Canadian manufacturers. *Research Policy* 31: 1-18.
3. Baldwin, J. and Gellatly, G. 2003. *Innovation strategies and performance in small firms*. Cheltenham: Edward Elgar.
4. Baldwin, J. and Hanel, P. 2003. *Innovation and knowledge creation in an open economy. Canadian industry and international implications.* Cambridge, Cambridge University Press.
5. Breschi, S., Malerba, F. and Orsenigo, L. 2000. Technological regimes and Schumpeterian patterns of innovation. *The Economic Journal* 110 (463): 388-410.
6. Chaminade, C., Intarakumnerd, P. and Sapprasert, K. 2008. Measuring systematic failures in innovation systems in developing countries using innovation survey data: the case of Thailand. Presented at the Globelics Conference, September 2008, Mexico.
7. Chaminade, C. and Edquist, C. 2006. From theory to practice. The use of the systems of innovation approach in innovation policy. In Hage, J., De Meeus, M. (eds.) *Innovation, learning and institutions*. Oxford, Oxford University Press.
8. Christensen, C.M. 1997. *The innovator's dilemma: when new technologies cause great firms to fail*. Boston: Harvard Business School Press.
9. Christensen, C.M., Bower, J.L. 1996. Customer power, strategic investment and the failure of leading firms. *Strategic Management Journal* 17, 197-218.
10. Cohen, W.M. and Klepper, S. 1996. A reprise of size and R&D. *The Economic Journal*, 106 (437): 925-951.

11. Cohen. W.M. and Levinthal. D. 1989. Innovation and learning: The two faces of R & D. *The Economic Journal*, 99(397):569–596.

12. Cohen,W.M. and Levinthal, D. 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly* 35: 128-152.

13. Criscuolo, P., Nicolau, N., and Salter, A. 2006. The elixir or burden of youth? Exploring differences among start-ups and established firms in innovation behaviour in the UK. Report for the UK Department of Trade and Industry.

14. D'Este, P., Iammarino, S., Savona, M., von Tunzelmann, N. 2011. What hampers innovation? Revealed versus deterring barriers (forthcoming in *Research Policy*)

15. Desai, M., Fritz, F., Forbes., K. 2008. Financial constraints and growth: multinational and local firm responses to currency depreciations". *Review of Financial Studies* 21 (6): 2857-2888.

16. Dougherty, D. 1992. Interpretive barriers to successful product innovation in large firms. *Organization Science* 3 (2), 179-202.

17. Dosi, G., Nelson, R.R. and Winter, S.G. 2000. *The nature and dynamics of organizational capabilities*. Oxford: Oxford University Press.

18. Ferriani, S., Garnsey, E. and Probert, D. 2008. Sustaining breakthrough innovation in large established firms: learning traps and counteracting strategies, in Bessant, J. and Venables, T. (eds.) *Creating wealth from knowledge*. Cheltenham: Edward Elgar.

19. Freel, M.S. 2005. Patterns of innovation and skills in small firms. *Technovation* 25: 123-134.

20. Freeman, J., Caroll, G.R. and Hannan, M.T. 1983. The liability of newness: age dependence in organizational death rates. *American Sociological Review* 48: 692-710.

21. Galia, F., Legros, D. 2004. Complementarities between obstacles to innovation: evidence from France. *Research Policy* 33, 1185-99.

22. Gans, J.S., Hsu, D.H. and Stern, S. 2002. When does start-up innovation spur the gale of creative destruction? *Rand Journal of Economics* 33 (4): 571-586.

23. Gibbons, M., Johnston, R., 1974. The roles of science in technological innovation. *Research Policy* 3, 220-242.

24. Hall. B. and Mairesse. J. 2006. Empirical studies of innovation in the knowledge-driven economy. *Economics of Innovation and New Technology*, 15(4-5):289–299.

25. Hanson, G., Mataloni, R., Slaughter, M. 2005. Vertical production networks in multinational firms". Review of Economics and Statistics 87 (4): 664-678.

26. Henderson, R. 1993. Underinvestment and incompetence as responses to radical innovation: evidence from the photolithographic alignment equipment industry. *Rand Journal of Economics* 24: 248-70.

27. Iammarino, S., Sanna-Randaccio, F. and Savona, M. 2009. The perception of obstacles to innovation. Foreign multinationals and domestic firms in Italy. *Revue d'Economie Industrielle* 125: 75-104.

28. Katila, R., Shane, S. 2005. When does lack of resources make new firms innovative? *Academy of Management Journal* 48 (5), 814-29.

29. Klevorick, A.K., Levin, R.C., Nelson, R.R. and Winter, S.G. 1995. On the sources and significance of interindustry differences in technological opportunities. *Research Policy* 24: 185-205.

30. Leiponen, A. 2005. Skills and innovation. *International Journal of Industrial Organisation* 23: 303-323.

31. Leonard-Barton, D. 1995. *Wellsprings of knowledge*. Boston, M.A.: Harvard Business School Press

32. Levin, R.C. and Reiss, P.C. 1988.Cost-reducing and demand creating R&D with spillovers. *Rand Journal of Economics* 19 (4): 538-556.

33. MacDuffie, J.P. 1995. Human resource bundles and manufacturing performance: organizational logic and flexible production systems in the world auto industry. *Industrial and Labor Relations Review* 48: 197-221.

34. Mancusi, M. L., Vezzulli, A. 2010. R&D, Innovation and Liquidity Constraints. KITeS Working Papers n. 30, KITeS, Centre for Knowledge, Internationalization and Technology Studies, Università Bocconi, Milano, Italy.

35. Mohnen, P., Roller, L. 2005. Complementarities in innovation policy. *European Economic Review*, 49 (6): 1431-1450.

36. Mohnen, P., Rosa, J., 2000. Les obstacles à l'innovation dans les industries de services au Canada. CIRANO Scientific Series, 2000s-14. http://www.cirano.umontreal.ca/publication/documents.html.

37. Mohnen, P.; Palm, F.; Van Der Loeff, S. & Tiwari, A. (2008), 'Financial constraints and other obstacles: are they a threat to innovation activity?', *De Economist* 156(2), 201-214.

38. Nelson, R.R. and Winter, S.G. 1982. *An evolutionary theory of economic change*. Cambridge, Mass.: The Belknap Press of Harvard University Press.

39. Pfeffer, J. 1994. *Competitive advantage through people*. Boston: Harvard Business School Press.

40. Rothwell, R. and Dodgson, M. 1994. Innovation and size of firm, in Dodgson, M. and Rothwell, R. (eds.), *The Handbook of Industrial Innovation*. Cheltenham: Edward Elgar.

41. Savignac, F. (2008), 'Impact of financial constraints on innovation: What can be learned from a direct measure?', *Economics of Innovation and New Technology* 17(6), 553-569.

42. Schneider, C. and Veugelers, R. 2008. On young innovative companies: why they matter and how (not) to policy surrport them. Cophenagen Business School, Working Paper 4-2008.

43. Schoonhoven, C., Eisenhardt, K., Lyman, K. 1990. Speeding products to market: waiting time to first product introduction in new firms. *Administrative Science Quarterly* 35, 177-207.

44. Schumpeter, J.A. 1950. *Capitalism, Socialism and Democracy*. 3rd Ed. NewYork: Harper & Row.

45. Schumpeter, J.A. 1934. *The theory of economic development*. Cambridge, Mass.: Harvard Economic Studies.

46. Stinchcombe, A. L. 1965. Social structure and organizations, in March, J.G. (ed.), *Handbook of Organizations*. Chicago: Rand McNally.

47. Tiwari, A.K., Mohnen, P., Palm, F.C., van der Loeff, S.S. 2007. Financial Constraints and R&D Investment: Evidence from CIS. UNU-MERIT Working Paper 2007-011, United Nations University.

48. Tourigny, D., Le, C.D. 2004. Impediments to innovation faced by Canadian manufacturing firms. *Economics of Innovation and New Technology* 13(3): 217-50.

49. Tripsas, M. 1997. Unravelling the process of creative destruction: complementary assets and incumbent survival in the typesetter industry. *Strategic Management Journal*, Summer Special Issue 18, 119-42.

50. Tushman, M.L., Anderson, P. 1986. Technological discontinuities and organizational environments. *Administrative Science Quarterly* 31, 439-65.

51. Von Hippel, E. 1988. *The sources of innovation*. Oxford: Oxford University Press.

52. Woolthuis, R.K. 2005. A system failure framework for innovation policy design. *Technovation* 25: 609-619.

53. Youndt, M.A., Snell, S.A., Dean, J.W. and Lepak, D.P. 1996. Human resource management, manufacturing strategy, and firm performance. *Academy of Management Journal* 39 (4): 836-866.

Figures & 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

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

	List of obstacles to innovation	Group of firms **not** involved in innovation activities (*firms facing deterring barriers*)	Group of firms involved in innovation activities (*firms facing revealed barriers*)	χ^2 difference test (degrees of freedom are in parenthesis)
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)*
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)***
N[a]		11271	24559	

[a]*The number of revealed and deterring barriers do not sum to the total cause there are 777 firms 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.*

Figure 1: Distribution of human capital by type of barrier

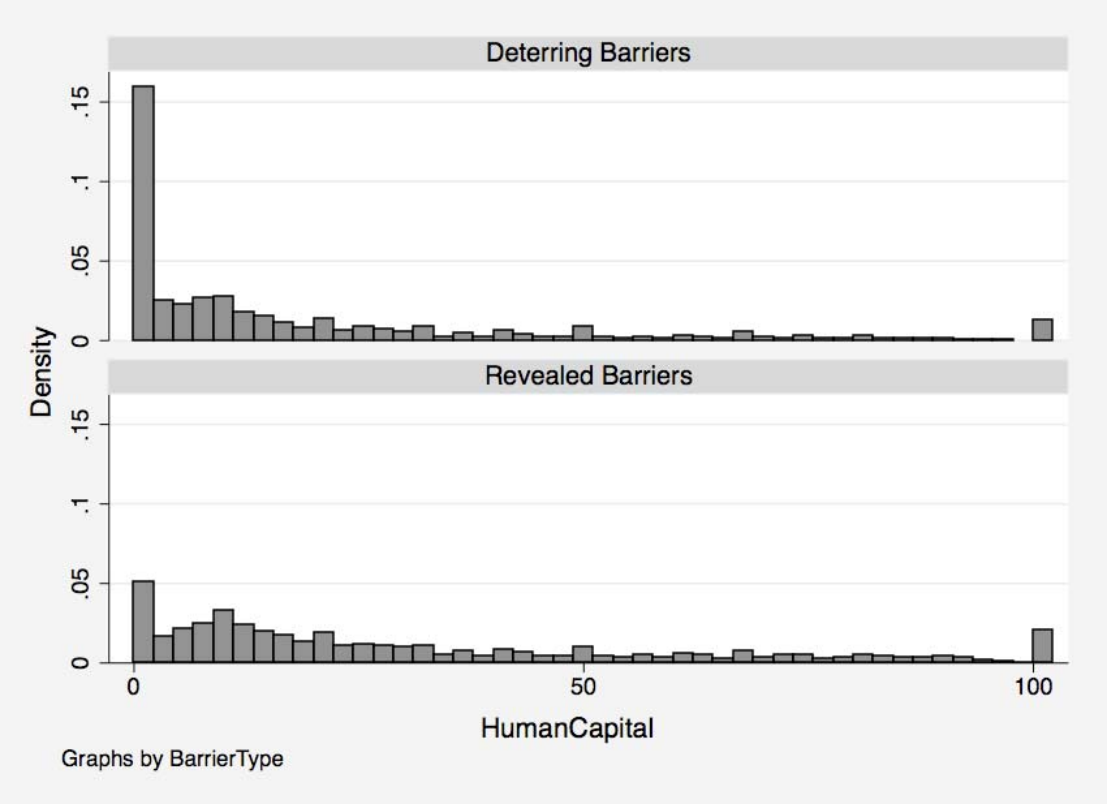

Table 3: Descriptive statistics for the pooled sample (NT=36607)

	Mean	Std.Dev	Min	Max
Outcome variables				
DInnovation	0.69	0.46	0	1
DCostBarriers	0.52	0.50	0	1
DKnowBarriers	0.20	0.40	0	1
DMarketBarriers	0.33	0.47	0	1
Explanatory variables				
HumanCapital	27.21	28.85	0	100
Size	4.05	1.56	0.69	10.63
Foreign	0.10	0.30	0	1
Startup	0.04	0.19	0	1
InternationalMkt	0.63	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	0.42	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

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)	*InternationalMkt*	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

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					
	Cost_Det	**Cost_Rev**	**Know_Det**	**Know_Rev**	**Mkt_Det**	**Mkt_Rev**
HumanCapital	0.001	-0.003	-0.012***	-0.000	-0.005**	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Size	-0.707***	-0.751***	-0.315***	-0.368***	-0.363***	-0.376***
	(0.042)	(0.036)	(0.043)	(0.036)	(0.038)	(0.032)
Foreign	-0.718***	-0.399***	-0.861***	-0.737***	-0.419**	-0.519***
	(0.188)	(0.130)	(0.234)	(0.152)	(0.191)	(0.126)
Startup	0.630	0.273*	0.240	0.038	0.540	0.090
	(0.397)	(0.143)	(0.433)	(0.150)	(0.379)	(0.133)
InternationalMkt	0.187*	0.114	-0.168	-0.037	0.197*	0.110
	(0.106)	(0.088)	(0.117)	(0.092)	(0.104)	(0.082)
ApprConditions	-9.457***	-9.710***	-0.583	5.927***	-4.675**	-5.919***
	(2.190)	(1.631)	(2.394)	(1.706)	(2.140)	(1.511)
TechOpportunities	0.304	0.124	-0.347	-1.756***	0.405	0.234
	(0.365)	(0.305)	(0.401)	(0.318)	(0.359)	(0.283)
FinanceLocal	-0.175	0.111	0.386*	0.149**	-0.256	0.023
	(0.205)	(0.068)	(0.226)	(0.073)	(0.206)	(0.064)
FinanceNational	-0.167	0.218***	-0.313	0.187**	-0.008	0.291***
	(0.284)	(0.070)	(0.326)	(0.077)	(0.277)	(0.067)
FinanceEU	0.457	0.191	-0.259	0.292**	0.793	0.222*
	(0.581)	(0.134)	(0.681)	(0.143)	(0.575)	(0.128)
Industry dummies	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
Constant	4.300***	5.155***	-0.599	-0.828**	0.073	0.899**
	(0.593)	(0.396)	(0.624)	(0.397)	(0.566)	(0.356)
Log-likelihood	-6158.36	-12600	-4810.16	-9481.88	-6085.68	-12400
Wald χ^2	463.302(14)***	639.770(14)***	121.963(14)***	214.933(14)***	168.352(14)***	276.407(14)***
Observations	11271	24559	11271	24559	11271	24559
Groups	5049	8181	5049	8181	5049	8181

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

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	☐	☐	☐	☐
Market Factors	Market dominated by established enterprises	☐	☐	☐	☐
	Uncertain demand for innovative goods / services	☐	☐	☐	☐