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BARRIERS TO INNOVATION DURING THE CRISIS. THE CASE OF THE FRIULI VENEZIA GIULIA REGION[1]

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ABSTRACT

The purpose of this study is to empirically assess the relationship between the intensity of firms' engagement in innovative activities and self-reported obstacles to innovation during the unfolding of the recent economic and financial downturns. The analysis is grounded on a unique dataset that contains firm-level balance sheet data as well as information drawn from the Community Innovation Survey (CIS) for a representative sample of firms established in the Italian region of Friuli Venezia Giulia. Looking at the period 2008-2010, our results support the existence of a non-linear relationship among innovative activities and obstacles to innovation related to knowledge and market factors. We also find that financial barriers were perceived as highly important by most surveyed firms reflecting the credit crunch that followed the worsening of the macroeconomic conditions during the crisis. Relying on a subset of firms that were surveyed both in 2008-2010 and 2010-2012 we provide evidence that, in correspondence with the sovereign debt crisis, the perception of market-related obstacles rose dramatically while that of financial and knowledge-related obstacles decreased.

[1] The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Bank of Italy or of the Eurosystem.

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1. Introduction

The role of innovation in fostering economic growth has been at the core of the policy debate particularly in the most recent years, as policy makers have been trying to remove obstacles to innovation and introduce incentives to facilitate the engagement with new ideas of firms willing to recover from the aftermath of the economic and financial crisis. Given that investing in innovation does not automatically imply that a firm will come up with a new product, process or organizational form, also among enterprises that do try to innovate, managers have actively been seeking to remove those factors that may hamper the innovation process. In the extant literature, most of the contributions have explored the driving forces of innovation while, excluding few exceptions, too little effort has been devoted to better understand those factors that may either discourage firms from investing in innovative ventures or slow down the innovation process.

This paper aims to study the relationship between the intensity of firms' engagement in innovation activity and their perception of obstacles, and how it was affected by the financial and sovereign debt crisis that hit severely Italy and other European countries between 2008 and 2012. We consider three kinds of obstacles, respectively related to financial, knowledge and market factors, and try to assess their importance in preventing firms from engaging in innovation or in hampering those already involved in innovative projects.

The study presents a number of original contributions to the still scanty literature on the regional dimension of obstacles to innovation. First, the focus is on firms located in Friuli Venezia Giulia (FVG), a small and highly industrialized region in the North-East of Italy characterized by industrial clusters of small and medium size enterprises (SMEs) operating mostly in traditional sectors. The case of FVG, we believe, is especially interesting for a reflection on the vulnerability of a region still competitive and wealthy relative to the rest of the country, which however was severely hit by the crisis shock that added up to an enduring decline in the most recent years brought about by globalization pressures.

Second, we introduce a new qualitative measure of innovation intensity that represents a proxy of the intensity with which firms carry out innovative activities: more complex activities need a wider range of investment channels, thus a deeper intensity. The lowest ranking in innovation activity is the external acquisition of technology that mainly requires economic resources only; the highest ranked activity is R&D that entails not only economic investments, but also relational, human capital and knowledge resources. We then follow D'Este et al. (2012) in classifying the hampering factors into deterrent as opposed to revealed barriers, according to the particular timing when they affect the innovation process and the main consequences they produce. Deterrent barriers are defined as those obstacles that affect a priori firms decision to engage or not in an innovation project: they literally deter firms from innovating. When firms have already started to engage, instead, revealed barriers may arise as unexpected difficulties resulting in the project to be abandoned, slowed down or eventually succeed anyway: they reveal themselves through the process and force/challenge the firm either to give up or to learn more in order to overcome the constraints.

Third, the study is based on a unique data set that comes from matching two different sources: the first is the Community Innovation Survey (CIS) that provides detailed information on firms' innovation activity; the second is the Company Accounts Database (CAD) containing balance sheet information in order to widen the set of firms characteristics and have a better coverage of financial features. We carry out a first analysis on the basis of the CIS wave 2008-2010 that matches the unfolding of the severe financial and economic crisis; we then aim to grasp the impact of the crisis by exploiting a subset of firms that were surveyed both in 2008−2010 and 2010−2012 waves. This

allows us to assess how firms' perception of obstacles to innovation changed with the unfolding of the sovereign debt crisis.

Fourth, regarding the empirical strategy, our major concern is to control for the selection bias issue arising when firms display heterogeneity in their propensity to innovate. We therefore operate a careful choice of the relevant sample to analyze by focusing only on the firms that showed a real interest in innovation, that we define potential innovators. Potential innovators are selected from the full CIS wave 2008-2010 as the subsample of firms that either engaged in innovation or reported to have been hampered by at least one obstacle. Next, we address endogeneity issues by working along two directions: we enrich our model by exploiting a unique database containing several firm-level accounting information and we rely on the most robust estimation techniques.

We first run a recursive multivariate probit model (RMVP) on the 1,003 potential innovators of the CIS wave 2008-2010. In the analysis of cross-section data, the RMVP is considered as the more robust technique to control for endogeneity arising from the correlation between dependent variables and errors. Then, we exploit both CIS waves matching a subset of 445 potential innovators that were surveyed in 2008-2010 and in 2010-2012. A random-effect probit model is estimated on the resulting panel sample to implement robustness checks and control for the presence of firm-specific unobserved factors. Moreover, the timing of the panel structure allows us to assess how firms' perception of hampering factors changed when the sovereign debt crisis hit Italy.

Our estimation results grasp several aspect of the relationship between engagement in innovation activity and reported obstacles. Overall, the emerging picture points to the existence of a non-linear relationship: deterrent barriers are quite high and significant, in particular those related to market factors; when firms engage in innovation, the more intense the firm's involvement becomes, the more new unexpected obstacles, namely revealed barriers, seem to emerge.

Regarding the first CIS wave, we also find that economic barriers were pervasive, affecting both innovating and deterred firms alike. This may be an indication of the extreme difficulties in financing arising from the credit crunch that characterized the crisis starting in 2008. Moreover, relying on the panel subset of firms that were surveyed also in 2010-2012, we also provide evidence that in the second period firms' perception of financial and knowledge obstacles decreased while perception of market-related obstacles rose dramatically. This result suggests that market conditions were severely affected by the worsening of internal and external macroeconomic conditions in correspondence with the sovereign debt crisis.

The paper is organized as follows. Section 2 reviews the extant literature on the obstacles to innovation at firm level, and on the relevance of a regional (subnational) approach to the study of their relationship with the intensity of firm engagement in innovative activities. Section 3 describes the data and the variables used in the analysis, presenting some descriptive statistics. Section 4 explains the econometric approach, discusses the estimation results, and provides further robustness checks. Section 5 concludes and suggests promising directions for future research.

2. Literature Review- very preliminary and incomplete

2. 1. Obstacles to innovation and engagement in innovation activities

A large body of scholarly literature has addressed the relationship between firms' propensity to invest in innovative activities and driving factors that may foster or hamper firms' aspiration to innovate. The existence of financial constraints to innovation, both internal and external, has been traditionally studied by examining the sensitivity of firm R&D investment to a measure of its wealth (usually cash-flow). However, Kaplan and Zingales (1997, 2000) provide evidence that cash flow

sensitivity of investments do not necessarily identify liquidity constraints. Cash flow may also be indicative of high demand and expectations of future profits.

Since the fundamental contribution of Crèpon et al. (1998)[5], that developed an effective stylized model (known as CDM model) of three subsequent phases of the innovation process, many scholars attempted to analyze the innovation process relying on detailed firm-level survey data to obtain direct measures of financial and non-financial constraints based on firms self-assessment. In these studies different measures of innovation intensity, such as the incidence of new products on total sales, are regressed on several possible determinants of innovation including obstacles that may hamper the innovation process (REF). One counter intuitive result of most empirical analyses is that the degree of engagement in innovative activities is positively correlated with perceived obstacles. One possible explanation for this finding is that innovative firms are more likely to encounter obstacles (selection bias) and that the decision to innovate is influenced by some latent variable that is also correlated with obstacles.

The empirical evidence of survey based studies is unanimous about a positive relationship between the degree of engagement in innovative activities and the perception of barriers to innovation (e.g. Mohnen & Rosa, 2000; Mohnen & Roller, 2001; Baldwin and Lin, 2002; Galia and Legros, 2004; Tourigny & Le, 2004; Iammarino et al. 2009). Among these, for example, Baldwin and Lin (2002), using a representative sample of Canadian firms, point out that the perception of obstacles to innovation is higher for innovators than for non- innovators. In their view, innovators' awareness of obstacles is a signal of their ability to solve problems relating to the innovation process. Galia and Legros (2004), relying on a sample of innovation-active French firms, reach similar conclusions and provide an important contribution by identifying as complementary obstacles that are positively correlated and that can be grouped in homogenous sets.

Several contributions have also shown that once the endogeneity of hampering factors is corrected using suitable instruments, the impact of financial constraints on the propensity to innovate shows the expected negative sign. Furthermore, other studies have pointed out that the particular nature of the datasets used requires an appropriate selection of the sample to be analyzed, and the consideration of the likely endogeneity of regressors. Savignac (2008), for instance, correcting for endogeneity of innovation obstacles, reports evidence that French firms suffer from financial constraints. Mohnen et al. (2007) stated similar conclusions using Dutch CIS data. Silva and Carreira (2012) show analogous results relying on several waves of Portuguese CIS survey, while Canepa and Stoneman (2008) provide evidence for the UK. Savignac (2008) and Mancusi and Vezzulli (2010) are also concerned with heterogeneous unobserved firm-specific factors and selection bias that render inconsistent the estimates of the relationship between the intensity of innovative activities and the perception of the importance of financial constraints.

Following this literature, D'Este et al. (2012) distinguish between two kinds of barriers to innovation: the first corresponds to revealed barriers and reflects the degree of difficulty of the innovation process and the firm learning experience in engaging in innovation activity; the second, labeled deterring barriers, encompasses the obstacles that prevent firms from committing to innovation in the first place. The main idea is that obstacles are revealed to innovative firms' through a learning process that improve their awareness of the difficulties associated with the actual making of innovation. These barriers, that show up once the investment decision has already been taken, do not deter firms' engagement in innovative activities, albeit they may slow down or stop the

[5]According to the authors the innovation process starts with the firm's investment decision, then the actual innovation activity takes place and generates an output. The last step is the impact of the final output measured as a return on firm's productivity.

innovation process. To apply such a distinction, D'Este et al. (2012) identify potential innovators according to their aspiration to innovate, regardless of whether they are engaged or not in innovative activities. Thus non-innovators who self-report encountering deterrent barrier falls in the class of potential innovators. This framework allows mitigating the selection bias problem by ruling out from the analysis firms that are not interested in innovation - although they are not constrained by any type of barrier.

2.2 Regional vulnerability and perception of obstacles to innovation in times of crisis

The obstacles to innovation and their different nature, i.e. economic/financial, market-related, knowledge-related or institutional, are likely to be largely specific to the geographical location of firms, thus interacting with the characteristics of the external socio-economic and technological environment. The importance of contextual factors and systemic interactions in generating spillovers and affecting firms' propensity to innovate is a logical consequence of the interactive model, which puts emphasis on the relations with knowledge sources external to the firm. Such relations – at inter-firm level, between firms and the science infrastructure, between the business sector and the institutional environment, etc. – are strongly influenced by spatial proximity that favors cumulative processes (e.g. von Hippel, 1989; Cooke, 1997; Boschma and Lambooy, 1999; Simmie, 2003; Iammarino, 2005). The decision of firms to engage in innovative activities is clearly affected by their evaluation of the difficulties that will be encountered in the process of innovation in the region in which they operate. This is even more the case in a country such as Italy, which historically has been characterized by strong territorial imbalances, which have been exacerbated by the recent financial and economic crisis.

North-eastern Italy is a striking example of the Italian economic miracle of the 1960s that turned a land of poverty and migration into a highly industrialized and wealthy region. The industrial development has mainly been driven by industrial clusters of small and medium size enterprises operating in traditional industries. In particular, Friuli Venezia Giulia's leading specializations include furniture and electric appliances and heavy industry, such as machinery, metals and steel production (Annual Statistical Report, FVG, 2015). Many enterprises, especially the suppliers with low export capacity, have suffered increasingly from globalization processes. Recently, the financial and economic crisis strongly affected the regional economic performance: the GDP growth was negative in 2008 (-2.0%) and 2009 (-6.7%), and after a weak recovery in the following two years, it turned negative again in 2012 (-2.1%). Thus, the economic indicators point out that during the recent economic and financial downturns the difficulties of the regional productive sectors were deeper and longer than the country average.

3. Data, Variables and Descriptive Statistics

3.1 Variables and main indicators

3.1.1. Data Sources

Our analysis is grounded on a unique dataset that has been built by matching micro data from two different sources. The first source is the Community Innovation Survey (CIS), provided by the Regional Statistical Department for a sample of firms of the region Friuli Venezia Giulia[6]. CIS data,

[6]NUTS2 according to Eurostat classification.

collected according to EUROSTAT harmonized rules[7], represents an extremely rich source of qualitative and quantitative information on firms' characteristics and innovative behaviors, including their perception of the factors hampering the innovation process[8]. The survey covers all firms with 250 employees or more and a random sample of those with at least 10 employees, is representative of the regional productive sector by both industry and size (number of employees).

The 2008-2010 CIS wave collects answers from 1,134 respondent firms, while the 2010- 2012 wave consists of 1,139 units. Starting from the wave 2008-2010 we focus on 1,003 potential innovators, i.e. those firms that are truly interested in innovation. Since some of the respondents were surveyed in both waves, we could extract a panel of 445 that we use to carry out robustness checks and to study how firms' attitude toward innovation obstacles has been affected by the unfolding of the sovereign debt crisis.

The second source is represented by the Italian Company Accounts Database (CAD, Centrale dei Bilanci). This dataset, which is maintained by a consortium of banks, contains firms' balance sheet information, especially those related to the financial structure. One minor drawback of this source of information is that CADs data are available only for firms borrowing from banks belonging to the consortium. Another limitation is that balance sheet data, reflecting Italian accounting rules, are more detailed for larger firms than for smaller ones. We extracted firm-level financial data for the years 2006 to 2014 that match about 90 percent of the firms included in the 2008-2010 CIS wave.

3.1.2. Defining barriers to innovation

The survey allows us to identify a direct measure of various hampering factors through each firm's own assessment. For the wave 2008-2010 a list of 9 potential obstacles[9] was provided and all participating firms (both engaged and not engaged in innovative activities) reported the importance of each obstacle according to a Likert scale ranging from 0 to 3 (not at all, low, medium or high). We collapsed answers into binary indicators by considering 'hampered' a firm that perceives the importance of an obstacle as either medium or high.

After checking for cross-correlations between individual items, we grouped them in three classes: financial, knowledge and market obstacles (Table A.1). The classification is coherent with that used by Galia and Legros (2004) and D'Este et al. (2012), and reflects the structure of the CIS questionnaire presented to firms as reported in Table A.1. In particular, financial barriers refer to difficulties in financing innovation investments deriving from their excessive cost or from the lack of appropriate financial resources, of either internal or external source. Knowledge obstacles are related to the scarcity of qualified personnel or the lack of information on available technologies, promising markets and suitable cooperation partners to innovate with. Finally, market barriers reflect the presence of incumbent firms with high market power or the instability of demand for innovative products or services.

[7]As pointed out by Mairesse and Mohnen (2010) "through a joint effort by the OECD and Eurostat these innovation surveys were formalized and standardized in the Oslo Manual, the first version of which appeared in 1992 and subsequent revisions in 1996 and 2005. The Oslo Manual (OECD, 1992, 1996, 2005) defines what is meant by an innovation, the different ways in which an enterprise can innovate, ways of quantitatively measuring innovation on the input and on the output side, various degrees of novelty of innovation, and various questions regarding the sources, the effects, the obstacles and the modalities of innovation".

[8]For more details see Appendix 1.

[9]Two more residual questions referring to the cases where innovation was not necessary to the firm because it was already introduced or not required to achieve customers' satisfaction have been disregarded. However, as described in Section 3.1.4, they have been helpful to exclude from the analysis those firms that, albeit not hampered by any factor, are not interested at all in engaging with innovative activities. id est laborum.

3.1.3. Measuring innovative activities

We model innovation intensity sorting firms' involvement with respect to the specific forms of investment required to implement the project. We argue that the wider is the range of channels necessary to undertake a particular innovation project, the more complex and risky is to implement it, and therefore the higher its intensity (i.e. the firm's engagement). In particular, we focus on three different channels: economic, relational/communication and technological ones.

The simplest way to innovate is through the external acquisition of technology, since it mostly requires financial resources only. Innovation intensity deepens when new available knowledge, whatever the source, has to be disseminated inside or outside the firm involving relational and communication investments. For instance, in the case of process innovations the new technologies become truly effective when employees feel confident in using them as a result of training programs; while in the case of new products or services to sell to customers, marketing schemes are crucial to promote goods' quality. Finally, we consider internal R&D as the most intense form of engagement, in that it requires significant amounts of economic, relational and technological resources that only a small number of firms can deploy.

The CIS questionnaire asked firms to report whether they engaged in any of eight listed activities in the period 2008-2010. After checking for the correlation between all these items, we grouped the closest ones into three indicators that grasp different qualitative aspects entailing economic, communication/relational and technological investments according to previous considerations. They are defined as dummy variables taking value 1 if the firm has engaged in that specific innovation effort in the reference period (see Table A.2).

The easiest level of involvement is represented by Technology acquisition that refers to the financial expenditure for external acquisition of R&D, machinery or other technology. Then it follows Training & Marketing that implies a higher degree of involvement in relational terms, regarding the implementation of training activities (to disseminate new knowledge inside the firm) or marketing activities (to promote innovation outside the firm). Lastly, the variable R&D embodies the most intense form of investment and captures the internal pursue of knowledge, technical or aesthetic design and other activities specifically related to the implementation of new products or processes[10].

Whereas previous literature has mainly relied on quantitative measures, such as the number of undertaken activities (D'Este et al., 2012) or the amount of expenses, our measure of innovation intensity is, to the best of our knowledge, a novelty. Ranking the intensity on the basis of qualitative variety of investments or innovative efforts allows us to attain a deeper and richer understanding of the relation under study.

3.1.4. Potential innovators

The existing literature has showed that the correlation between innovative activities and obstacles is severely affected by selection bias issues if the estimation is performed on the full available sample. In order to tackle this problem we need to identify firms that did not innovate because they were overcome by deterrent barriers, from those that were simply not interested in carrying out innovation projects. This latter category of firms represents an important source of upward selection bias and it should be left out from the analysis, as Hajivassiliou and Savignac (2008) explained in detail while studying the effect of financial constraints on firms' innovation propensity.

[10]For a detailed description of variables and their aggregation see Appendix 1.

As in Savignac (2008), Hajivassiliou and Savignac (2008), Mancusi and Vezzulli (2010) and D'Este et al. (2012), we focus our analysis on firms that show an aspiration to innovate, that we define potential innovators. Our selection rule is the following: either the firm has engaged in innovation activities (innovation-active), or it did not innovate but has been hampered by at least one obstacle (hampered or inactive). This criterion restricts our selected sample to 1,003 firms[11] 5. The remaining firms were excluded from the analysis. We consider them 'not in the innovation contest' since, albeit not constrained by any barrier, they did not engage in innovative activities, either for example because of the lack of demand of innovation from the market or because still relying on previous innovations.

3.2 Some stylized facts

Table 1 and 2 report the main characteristics of FVG firms in the period 2008-2010 that will be used to estimate our model in Section 4. Looking at Table 1 it emerges that if we restrict our analysis to potential innovators only, the sample reduces from 1,134 to 1,003 units; among them 85.1 percent reported financial barriers, while knowledge and market obstacles were each reported by about 60 percent of the sample.

Table 2 focuses on potential innovators to show the main differences between firms engaged in innovation activities and those that were deterred. As we expected innovation-active firms show on average a slightly lower incidence of barriers (they are not deterred), while they display an incidence of group membership and delivered innovations in organization and marketing that are about three times as high as that of hampered firms.

Descriptive statistics also allow us to get a first insight about the relationship we are studying. Table 3 shows the incidence of firms perceiving each obstacle as important according to their intensity of engagement in innovation: inactive, or using economic, relational/communication and technological channels – that is external acquisition, engagement in internal marketing and training activities and, finally, carrying out R&D projects.

The first remarkable finding is that obstacles to innovation were very relevant for inactive firms supporting the existence of deterrent barriers of economic, knowledge and market source. We also find evidence of a statistically significant non-linear relation between innovation intensity and both knowledge and market hampering factors. As in Baldwin and Lin (2002) and D'Este et al. (2012), a U-pattern emerges showing that as innovation intensity deepens, at first perceived obstacles decrease (deterrent barriers are no longer effective), then they rise again reflecting the occurrence of revealed barriers. A possible explanation to this counter-intuitive finding is that firms whose innovation activity is very intense are more aware of the obstacles to innovation while innovation-inactive firms' perception may reflect a high degree of uncertainty. On the contrary, financial obstacles show a flatter pattern pointing to a weaker correlation with innovation intensity. This means that these obstacles have been relevant for both innovating and deterred firms alike, possibly already reflecting the severity and pervasiveness of the financial crisis in the reference period (CIS 2008-10).

4. Empirical analysis

[11] Another "more restrictive" approach would require ruling out from the analysis those firms that, albeit hampered by at least one obstacle, reported that they are not interested in innovation because they had already concluded the desired projects and/or market conditions did not required it. The contradiction in the answer patterns may be a result of an error from the firm, reporting some obstacles encountered during general activity and not specifically during innovation activity. Applying this selection rule the sample would reduce to about 700 units.

4.1 Dealing with endogeneity

We are interested in estimating the relationship between the probability that an obstacle is perceived as important and the intensity of innovation engagement. Once the sample of potential innovators has been selected, we have to deal with the endogeneity of innovation intensity regressors.

The first source of endogeneity is associated to the existence of unknown heterogeneous factors that are correlated with both the probability to be hampered and the decision to innovate. We deal with the potential bias deriving from relevant variables left out from the regression by widening the set of our controls relying on the additional information provided by the CAD dataset.

The second endogeneity source derives from the fact that the choice to innovate and the assessment of obstacles could be simultaneously determined at firm level. In fact, firms are likely to examine the opportunity to innovate considering both potential benefits and costs as early as in the planning stage. Such preliminary assessment also includes estimates of risks and obstacles, even though further hampering factors might come into consideration during the implementation of the project. Moreover, the problem of simultaneity in obstacle assessment and innovation decision is enhanced by the particular nature of the dataset: CIS data come from a survey that covers a three-year period considering it as a unique time span. The fact that answers, potentially referring to different moments of the innovation process, are collapsed to the same time dimension would imply by itself a structure of simultaneity even for decisions that are temporally consecutive. Therefore, we consider the assessment of obstacles and the decision about the intensity of innovation investment as simultaneously determined.

In order to take into account endogeneity issues we proceed in two ways. First, focusing on the cross-sectional data of the survey's first wave (2008-2010), we implement a recursive multivariate probit model (RMVP) that is considered as the most robust cross-sectional estimation procedure by the recent econometric literature (Greene, 2012). For instance, Savignac (2008) and Mancusi and Vezzulli (2010) employed a recursive bivariate probit model to study the effects of endogenous financial constraints on firms' innovation propensity relying on survey data. Secondly, we try to overcome the limits imposed by cross-sectional methods and control for firm-specific unobservables by estimating a random-effect probit model relying on a panel subset of 445 firms that were surveyed in both CIS waves.

4.2 The recursive multivariate probit model

In this section we describe the recursive multivariate probit model (RMVP)[12] we rely on to estimate the relationship between the perception of obstacles to innovation and the intensity of firms' engagement. As shown by Greene (2012) the RMVP allows to control for potential endogeneity i.e. the correlation among the sets of obstacles and the error terms.

We start from the multivariate probit (MVP) model that represents a multiple-equation extension of the univariate probit model[13]. It allows the joint estimation of two or more probit equations through the interaction of their errors terms. The disturbances are jointly distributed as a standardized multivariate normal, with zero mean, unit variance and free cross-correlations. When

[12] The starting point would be the univariate probit model with three equations, one for each obstacle we consider. However, such model imposes two restrictions on the data: that the assessment of each obstacle is not correlated with that of the others, and that innovation intensity variables are exogenous. Both restrictions conflict with the hypothesis of simultaneous determination of obstacles and innovation investment, therefore we move to a more flexible model.

[13] In the case of the linear regression model the analogous extension is the seemingly unrelated regression.

the correlation coefficient between two equations' disturbances is significantly different from zero, this specification accounts for the existence of omitted or unobservable factors that affect both dependent variables simultaneously. Whereas, when the correlation is not different from zero, the two equations can be estimated separately as univariate probit models. In order to account for the interaction between different obstacles, D'Este et al. (2012) relied on a MVP to study the relation between firms' self-assessed obstacles and their innovation engagement.

In order to tackle the problem of endogeneity of some regressors, due to the simultaneous determination of such covariates and the dependent variable, it is necessary to generalize further the specification. Following Maddala (1983) and Greene (2012), we therefore rely on the RMVP model, which can account for endogenous binary regressors by adding equations that express each of these indicators as function of other exogenous controls[14].

We estimate a system of six equations encompassing three hampering factors (financial, knowledge and market barriers) and three variables measuring in ascending order the intensity of the engagement in innovative activities (technology acquisitions, training & marketing and R&D). Relying on the estimation procedure developed by Cappellari and Jenkins (2003), we estimate the following 6-variables RMVP for each set of obstacles y_{ij} and each measure of innovation intensity $x_{ij:}$

(1) $\text{Prob}(y_{ij} = 1) = \alpha_j + \beta'_j x_{ik} + \gamma'_j z_{ir} + \varepsilon_{ij}$

(2) $\text{Prob}(x_{ij} = 1) = \delta_j + \psi'_j z_{ir} + \upsilon_{ij}$

With

$$\eta_{ij} = \begin{pmatrix} \varepsilon_{ij} \\ \upsilon_{ij} \end{pmatrix} \sim N(0, \Omega)$$

and

$$\Omega = \begin{cases} 1 & if\ i = j \\ \rho_{ij} & if\ i \neq j \end{cases}$$

with j indicating the class of obstacle, j = {Financial, Knowledge, Market}; k indicating the intensity level of innovation activity, k = {external acquisition, training & marketing, internal R&D}; i = 1,...,N denotes firm i and z_{ir} is the set of control variables.

The RMVP allows the simultaneous choice on the six variables of interest. In the first three equations the probability of assessing each of the obstacles as important is modelled as a function of innovation intensity and other controls. The remaining three equations represent the recursive part of the model expressing the probabilities to invest in innovation at different levels of intensity, our endogenous variables, as function of several exogenous determinants of innovation. The standardized six error terms are jointly distributed as a six-variate normal density and their cross-correlations are allowed to be different from zero.

We tested several specifications of our model including the relevant CIS indicators and extending the set of regressors with balance sheet and income statement variables drawn from CAD. As discussed in section 3.1.1, when we merge the data we lose some observations and the resulting

[14] One particularly desirable feature of MVRP is that we do not need to worry about the endogenous nature of the variable in formulating the log likelihood function, therefore the estimation is straightforward.

sample CIS-CAD is made of 951 firms. Our final specification includes a set of control variables capturing firm-specific characteristics such as sector of activity, size, human capital endowment, and several dummies capturing whether the firm belongs to a group, degree of internationalization, granting of public funds, cooperation agreements with other firms, other measures of innovativeness and failures.. The set of explanatory variables has been further extended and refined thanks to the balance sheet data (from CAD). In particular, after many trials, the following variables have been selected and added: the return on assets (ROA) as a measure of profitability; the ratio of interest payments due to financial liabilities on turnover as a measure of tensions on the credit market; the share of financial loans on assets (leverage) that could signal the difficulty of getting credit for highly indebted firms; all the variables are ratios so to exclude any scale effect, that is already captured by the size dummy[15].

4.2.1 Tetrachoric correlations

We first examine the structure of cross-correlations in the error terms emerging from the data. Since the six variables of interest are binary indicators, the traditional Pearson's correlation coefficient is inappropriate and, following Greene (2012), we compute tetrachoric correlations. This requires the estimation of a simple MVP model with six equations, one for each variable of interest (three obstacles and three innovation intensity indicators); each variable is regressed on a constant and its error term. Relying on the estimation procedure developed by Cappellari and Jenkins (2003), the equations are jointly estimated returning the mean value for each variable and the variance-covariance matrix.

We compute the correlations on two datasets: the first is the CIS sample (1,003 observations) and the second is the CIS-CAD sample (849 observations). The most interesting result is that, if we select a significance threshold of 10 per cent, financial obstacles never show a correlation with innovation intensity indicators. Moreover, the only significant cross-correlation involving financial barriers is with knowledge barriers (p-value 0.065) in the CIS sample; no correlation is significant in the CIS-CAD sample. This implies that when we estimate the relevant relations with the CIS-CAD sample, the probability of financial barriers can be estimated independently through a univariate probit model without any loss of generality. The absence of correlation can reflect the peculiar time span of our data: the years between 2008 and 2010 were deeply marked by the inversion of the economic cycle started in September 2008 with the collapse of Lehman Brothers, a leading American investment bank. The financial crisis spread from the United States larger banks to all over the world and from the financial sector to the real sector through a severe credit crunch. Banks heavily reduced their lending activity and interest rates on outstanding debts increased significantly. Therefore, firms' perception of financial obstacles may have reflected such pervasive credit restrictions in an exogenous way.

Regarding other variables, the errors between obstacles related to market conditions and knowledge accessibility show a strong and positive correlation. Furthermore, knowledge barriers show a significant and positive correlation with innovation investments in training and marketing and, only in the CIS-CAD sample, with those in research and development; finally, market barriers are strongly and negatively linked to innovation investments in external acquisition. When we compute again tetrachoric correlations on the five CIS-CAD variables remaining after removing financial constraints, the results are confirmed.

Therefore, when we investigate the relationship between barriers and innovation intensity using cross-sectional data, we follow two different strategies: a) with the CIS sample we estimate a RMVP

[15] For the complete variable list see Appendix 1.

model with all the 6 equations; b) with the CIS-CAD sample we estimate independently two models: a univariate probit model regarding financial constraints and a RMVP model with 5 equations referring to the remaining variables.

4.3 Estimation results

Our estimation results, reported in Table 4, grasp several aspect of the relationship between innovation activity and reported obstacles. Overall the emerging picture points to the existence of a non-linear relationship between the intensity of innovation involvement and barriers. Deterrent barriers are quite high and significant, in particular those related to market factors. When obstacles are not binding so severely firms can and do engage in innovation activity: the simplest way to achieve such improvements is through a technological transfer from external sources. However, as the engagement in innovation becomes more intense involving less standardized projects with higher complexity, new unexpected obstacles emerge that entail specifically relational, communication and knowledge aspects.

Training and marketing innovation shows a significant positive relation with both knowledge and market barriers, while it is not significant with financial ones. The R&D indicator deserves a more detailed discussion: it shows a positive correlation with financial constraints and a negative one with market obstacles (p-value=0.107). This behavior signals the existence of additional financial revealed barriers for firms that invest in R&D projects, which entail the highest degree of complexity. On the other hand, the negative relation between R&D and market barriers suggests that firms investing in R&D are also less exposed to competition: perhaps they take advantage of the increased productivity stemming from R&D investments, or they already enjoy a favorable market position before deciding to invest in R&D.

Regarding the effect of other controls, the presence of employees with a degree act so as to reduce the probability of perceiving financial barriers, while the presence of ongoing innovation, i.e. projects not concluded at the end of the reference period, has a positive impact, extended to market constraints. The lack of knowledge and qualified personnel was felt particularly by smaller enterprises, those with less than 50 employees. Finally, barriers related to unstable demand or markets dominated by incumbents were more severe for firms delivering organizational innovations, with smaller dimension, and operating in the sectors connected with the production of home furniture and metals and machinery that were deeply affected by the crisis.

When we focus on the CIS-CAD sample (Table 5), we trade off a wider set of exogenous regressors with a slightly lower number of observations. Since tetrachoric correlations show that financial obstacles' errors are not correlated with those of the other variables of interest, we estimate the probability that firms assess them as important through a univariate probit model; the relations between the remaining five variables are studied by the usual RMVP model.

The results broadly confirm CIS-only estimates. In particular, investments in external acquisition of technology are still associated to a lower probability to assess obstacles as important, even though the relation is significant only for the market ones. Expenditure in training and marketing is related to a higher probability that firms encounter significant knowledge or market barriers. Engagement in R&D projects significantly increases the likelihood of both financial and knowledge constraints.

The effects of other controls on barriers are coherent with what emerged in the analysis of the CIS-only sample. The main novelty regards the introduction of CAD variables in the set of regressors. The three covariates have no significant impact on knowledge barriers; therefore, the lack of knowledge and qualified personnel was neither exacerbated nor mitigated by CAD-based financial indicators. Restricting the analysis to financial obstacles only, the behavior of firm-level

financial indicators is coherent with our expectations on firms' management theory on the one hand, and with the difficult financial conditions prevailing in the reference period on the other.

As expected, the measure of profitability, ROA, shows a negative correlation (albeit not significant) with the barrier: higher returns on assets mean more internal resources that the entrepreneur can manage freely, and therefore lower financial constraints. In times when the functioning of ordinary credit flows was severely impaired, cash availability was likely to be essential in order to pursue the firm's strategic purposes, including investment in innovation. The share of turnover devoted to the repayment of loans (financing costs- turnover ratio) is positively related to the obstacle: a higher share of turnover committed to debt repayment means lower funds to finance current activity and investments, leading to increasing financial constraints. The particular strength of the relation may reflect the unexpected and generalized increase in interest rates, and therefore in the amount due to be repaid, that subtracted resources to other projects.

Finally, the index of firm financial structure (leverage), computed as the share of external debt on total resources (external and internal), does not show a significant impact. In standard conditions a financial structure imbalance, such as an excessive weight of external debt, signals the firm's weakness: it exposes the firm to the risk of a higher burden should interest rates raise and, therefore, it increases the likelihood of insolvency. However, the credit crunch that characterized the financial crisis was an exceptional situation that hit most firms independently of their intrinsic soundness. In the case of pervasive credit restrictions firms with a balanced financial structure would not have been much better off than the others, and our leverage variable would not be significant.

4.3.1 Controlling for firm-specific heterogeneous unobserved factors

As we aim to overcome the limits imposed by the cross-sectional nature of the CIS 2008-2010 dataset, we exploit also the wave 2010-2012. By matching firms' records we obtain a balanced panel of 890 observations (445 potential innovators that were surveyed in both waves). As far as questions about obstacles to innovation are concerned, the CIS questionnaire for the wave 2010-2012 differs with respect to the wave 2008-2010. We rely on three barriers indicators (financial, human resources and market) that are homogeneous throughout the whole 2008-2012 span (Table A.3 in Appendix 1). For the j-th obstacle y_{ijt} and the k-th measure of innovation intensity x_{ikt}, we estimate the following univariate equation:

$$(3) \qquad \text{Prob}\,(y_{it} = 1) = \alpha_j + \theta_i + \beta'_j x_{ikt} + \gamma'_j z_{irt} + \varepsilon_{ijt}$$

where each wave is denoted by t with t = 1,2, x_{ikt} is the vector of variables measuring innovation intensity and z_{irt} contains the same explanatory variables we used in the RMVP model. As in Greene (2012) to control for the incidental parameter problem and the presence of firm-specific unobserved factors θ_i, we run a random-effect probit model relying on the estimation procedure suggested by Mundlak (1978) and Chamberlain (1980). Both approaches fit data very well thus supporting the conclusion derived for the MVPM specification.

Results reported in Table 6[16] show that engagement in innovative activities does not affect the perception of financial barriers. Indeed, firms that did not engage in innovative projects perceive financial obstacles equally to those that were engaged, regardless the level of engagement. The perception of financial obstacles depends on firm's financial indicators. ROA, which can be an

[16] Estimates are based on 588 observations due to the presence of missing values in the CAD variables. Estimates obtained using the CIS sample alone do not display significant differences.

indicator of the firms' potential for self-financing, negatively affects the probability that financial barriers are perceived as highly important. The cost of external financing, which here is summarized by the financing costs on sales, has a significant positive effect on financial barriers, while leverage has a slight, but significant, positive effect. Finally, being part of a group negatively affects the perception of financial barriers probably because of intra-group financing.

Barriers due to lack of adequate human resources are less likely to be perceived as highly important by firms that engage in external acquisitions, while firms that engage in marketing and training activities display a higher probability with respect to firms that are interested but not engaged in innovation. Being involved in R&D activities does not impact on the probability of perceiving the lack of adequate human capital as important with respect to innovation-inactive firms. The presence of abandoned innovation projects positively affects the probability of firms perceiving as highly important the lack of adequate human capital. Looking at industrial sectors, our estimates shows that firms that operate in miscellaneous services are less likely to perceive lack of adequate human capital as an important barrier to innovation.

Market barriers are perceived as less important by firms that engage in external innovation, while firms that engage in marketing and training activity and firms that introduced organizational innovation are more likely to perceive these barriers as highly important with respect to firms that are interested but not engaged in innovation. Public funding lowers the probability to perceive as important this sort of barrier, whilst belonging to a group enhance it, as well as having an innovation process ongoing. A factor that negatively influences the perception of market constraints is firm size: indeed small firms are more likely to regard them as highly important; conversely, operating in sectors such as miscellaneous manufacturing, miscellaneous services and commercial services decreases firms sensitiveness to obstacles to innovation.

4.3.2 The propensity to innovate during the crisis

We use our 445 firms' panel dataset also to grasp some insight on how the relationship between the probabilities of perceiving self-reported barriers as highly important were affected by the deteriorating macroeconomic conditions following the sovereign debt crisis. Results are presented in Table 7[17], showing that during the second span 2010-2012 the probabilities that firms perceive financial and knowledge obstacles as highly important decreased while it rose dramatically for market-related obstacles, reflecting the rise in uncertainty that followed the worsening of the internal and external macroeconomic conditions. This outcome may be triggered by the high incidence of SME on the FVG productive structure, as well as its relative specialization in traditional sectors that were already facing tougher competition from emerging economies in the years before the crisis.

5. Conclusions

In this study we investigated the intensity of the relationship between innovation activity and related obstacles for a representative sample of firms based in the Italian region Friuli Venezia Giulia in the years of the big recession (2008-2010) and the sovereign debt crisis (2010-2012). Descriptive statistics support the existence of severe financial, knowledge and market obstacles that hampered most of potential innovators. We also find that financial barriers were pervasive, affecting both innovating and deterred firms alike. This may be an indication of the extreme difficulties in financing arising from the credit crunch that characterized the crisis starting in 2008.

[17] Estimates are based on 588 observations due to the presence of missing values in the CAD variables. Estimates obtained using the CIS sample alone do not display significant differences.

Looking at the period 2008-2010, our results from MVRP model show a non-linear relationship among innovative activities and obstacles to innovation related to knowledge and market factors. Deterrent barriers are quite high and significant, in particular those related to market factors. When firms engage in innovation, the more intense their involvement, the more new unexpected obstacles, namely revealed barriers, emerge. We find that the probability of perceiving knowledge-related barriers as highly important is positively affected by the engagement in the most intense and complex forms of innovative activities, namely R&D and within-firm training and marketing tasks. These results support the emergence of learning barriers due to the difficulty to finance riskier projects and to disseminate information both internally, by training employees, and externally, by promoting products or services on the market. For financial barriers the probability is positively affected by R&D activity. The perception of market barriers is negatively related with the outsourcing of the innovative process and positively affected by internal training and marketing activities.

Relying on a subset of firms that were surveyed both in 2008-2010 and 2010-2012 we provide evidence that, in correspondence with the sovereign debt crisis, the perception of market related obstacles rose dramatically while perception of financial and knowledge- related obstacles decreased. This result suggests that market conditions were severely affected by the worsening of internal and external macroeconomic conditions.

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6. Appendix

Variables	Type	Definitions
Any inn. Output introduced	0/1	1 if firm *i* introduces a process innovation or a product innovation into the market in years 2008-10 or 2010-12, 0 otherwise. A process innovation is the implementation of a new or significantly improved production process, distribution method, or support activity for goods or services, such as maintenance systems or operations for purchasing, accounting, or computing (exclude purely organizational innovation). A product innovation is the market introduction of a new or significantly improved good or service with respect to its capabilities, user friendliness, components or sub-systems. Process or product innovations (new or improved) must be new to the enterprise, but they do not need to be new to the market.
Organization inn.	0/1	1 if firm *i* introduces an organizational innovation in year *t*, 0 otherwise. An organizational innovation is a new organizational method in the enterprise's business practices (including knowledge management), workplace organization and decision making, or external relations that has not been previously used by the enterprise. It must be the result of strategic decisions taken by management. It exclude mergers or acquisitions, even if for the first time.
Marketing inn.	0/1	1 if firm *i* introduces a marketing innovation in year *t*, 0 otherwise. A marketing innovation is the implementation of a new marketing concept or strategy that differs significantly from the enterprise's existing marketing methods and which has not been used before. It requires significant changes in product design or packaging, product placement, product promotion or pricing. It exclude seasonal, regular and other routine changes in marketing methods.
Any inn. input	0/1	The firm is involved in at least 1 of the following innovation activities: engagement in intramural R&D, engagement in extramural R&D, engagement in acquisition of machinery, engagement in other external knowledge, engagement in training of employees, and engagement in market introduction of innovation
Part of a group	0/1	1 if firm *i* belongs to a group, 0 otherwise
More than 20 employees	0/1	1 if firm *i* has more than 20 employees at the end of 2010 or 2012, 0 otherwise
Degree	0/1	At least 1 employe has a university degree in firm *i*
Abandoned inn. projects	0/1	1 if firm *i* abandoned innovation activities in the years 2008-10 or 2010-12, 0 otherwise.
Ongoing inn. projects	0/1	1 if firm *i* had innovation activities still ongoing at the end of 2010 or 2012, 0 otherwise.
Sector Dummies	0/1	Sector-specific component captured by forty two sector dummies
Time Dummy	0/1	Time-specific component captured by time dummy
Cooperation	0/1	1 if firm *i* had any cooperation with other customers, suppliers, competitors, 0 otherwise
Funding	0/1	1 if firm *i* received public financial support for innovation activities, 0 otherwise
Exporter	0/1	1 if firm *i* sells on foreign markets, 0 otherwise.
	0/1	1 if firm *i* belongs to a group, 0 otherwise (Non-affiliated as based)

Table A.1

CIS 2008-2010 questionnaire: obstacles to innovation

Classes	Items	Degree of importance:			
		Not experienced	low	medium	high
		0		**1**	
Financial factors	Lack of funds within your enterprise or group				
	Lack of finance from sources outside your enterprise				
	Innovation costs too high				
Knowledge factors	Lack of qualified personnel				
	Lack of information on technology				
	Lack of information on markets				
	Difficulty in finding cooperation partners for innovation				
Market factors	Market dominated by established enterprises				
	Uncertain demand for innovative goods or services				

Table A.2

CIS 2008-2010 questionnaire: innovative activities

Classes	Items	0	1
Tecnology acquisition	Acquisition of extramural R&D		
	Acquisition of machinery		
	Acquisition of other technologies		
Training & marketing	Training for innovative activities		
	Marketing for new product/processes		
Broad internal R&D	In-house R&D		
	Design		
	Other activities supporting innovation		

Table A.3

CIS 2010-2012 questionnaire: obstacles to innovation

Classes	Items	Degree of importance:			
		Not experienced	low	medium	high
		0		1	
Financial factors	Lack of adequate finance				
Knowledge factors	Lack of qualified personnel				
Market factors	Lack of demand				
	Dominant market share held by competitors				

Table 1

Data descriptive statistics – CIS Wave: 2008-2010

(Percentage of firms)

	Full sample		Potential innovators		p-value
	Mean	Std. Dev.	Mean	Std. Dev.	
Type of obstacles to innovation[*]					
Financial obstacles	75.3	43.1	85.1	35.5	0.000
Knowledge obstacles	53.9	49.9	60.9	48.8	0.001
Market obstacles	55.7	49.7	63.0	48.3	0.000
Firms' characteristics					
External acquisitions	31.9	46.7	36.1	48.0	0.043
Training & Marketing	18.3	38.7	20.7	40.6	0.164
R&D	21.1	40.8	23.8	42.6	0.129
Organizational innovation	34.9	47.7	37.9	48.5	0.155
Marketing innovation	26.5	44.2	28.7	45.3	0.263
Exporter	36.4	48.1	36.7	48.2	0.897
Public grants	15.0	35.7	16.9	37.5	0.218
Part of a group	17.2	37.8	17.3	37.9	0.926
Cooperation agreements	8.6	28.0	9.7	29.6	0.372
Degree	52.6	49.9	54.1	49.9	0.490
Abandoned innovation projects	3.6	18.7	4.1	19.8	0.572
Ongoing innovation activities	18.7	39.0	21.1	40.8	0.159
Small	81.6	38.8	81.6	38.8	0.993
Number of observations	1,134		1,003		

[*] Percentage of firms assessing items as important (medium/high importance).

Table 2

Potential innovators – CIS Wave: 2008-2010

(Percentage of firms)

	Mean	Std. Dev.	Mean	Std. Dev.	
	Engaged in innovative activities				
	No		**Yes**		p-value
Financial obstacles	85.9	34.9	84.1	36.6	0.438
Knowledge obstacles	61.4	48.7	60.2	49.0	0.703
Market obstacles	66.9	47.1	57.2	49.5	0.002
Firms' characteristics					
External acquisitions	–	–	59.5	49.2	–
Training & Marketing	–	–	15.7	36.4	–
R&D	–	–	24.9	43.3	–
Organizational innovation	19.8	39.9	64.9	47.8	0.000
Marketing innovation	15.1	35.9	49.0	50.1	0.000
Exporter	26.3	44.1	52.2	50.0	0.000
Public grants	–	–	42.3	49.5	–
Part of a group	10.1	30.2	28.1	45.0	0.000
Cooperation agreements	–	–	24.1	42.8	–
Degree	43.3	49.6	70.4	45.7	0.000
Abandoned innovation projects	–	–	10.2	30.3	–
Ongoing innovation activities	–	–	52.7	49.9	–
Small	90.0	30.0	68.9	46.3	0.000
Number of observations	601		402		

*Percentage of firms assessing items as important (medium/high importance).

Table 3

Innovation intensity and perception of obstacles – CIS Wave: 2008-2010

(Percentage of potential innovators assessing the obstacle as important by innovation intensity)

	Degree of engagement				
Type of obstacles	**Inactive**	**External acquisitions**	**Training & Marketing**	**R&D**	**Chi-square (χ^2)**
Financial obstacles	85.9	81.0	79.4	86.6	3.67
Knowledge obstacles	61.4	46.0	61.9	65.7	11.72[a]
Market obstacles	66.9	46.0	55.6	62.3	17.84[a]

***Statistically significant at 1%. **stat. Sig. at 5%. H0: row and columns variables are independent.

Table 4

Recursive multivariate probit results (RMVP) - CIS wave: 2008-2010

	Dependent variables[a]					
	Financial Obstacles		Knowledge Obstacles		Market Obstacles	
Explanatory variables	**Coefficient**	**s.e.**	**Coefficient**	**s.e.**	**Coefficient**	**s.e.**
External acquisition	-0.584*	0.350	-0.584**	0.296	-1.141***	0.289
Training & Marketing	-0.174	0.278	1.527***	0.162	1.088***	0.215
R&D	0.961**	0.449	-0.235	0.324	-0.479	0.297
Organizational innovation	-0.205	0.126	0.052	0.108	0.189*	0.109
Marketing innovation	0.228*	0.135	-0.109	0.107	-0.064	0.110
Exporter	0.137	0.124	-0.057	0.099	0.066	0.101
Public grants	-0.055	0.186	0.066	0.159	0.161	0.162
Part of a group	-0.176	0.142	0.099	0.120	0.182	0.123
Cooperation agreements	0.048	0.209	-0.157	0.172	-0.100	0.170
Degree	-0.309***	0.116	-0.047	0.095	0.038	0.096
Abandoned innovation projects	-0.119	0.265	0.238	0.232	0.260	0.229
Ongoing innovation activities	0.347*	0.196	-0.043	0.165	0.304*	0.167
Small	0.145	0.147	0.285**	0.125	0.289**	0.129
Other manufacturing	0.058	0.205	0.052	0.161	-0.040	0.163
Metal mechanics	-0.267	0.216	0.316*	0.176	0.474***	0.183
Furniture	0.005	0.197	0.015	0.149	0.280*	0.156
Commercial services	0.043	0.151	0.010	0.118	-0.212*	0.118
Transportations	-0.105	0.192	-0.056	0.158	0.013	0.162
Other services	-0.260	0.185	0.029	0.163	-0.233	0.164
Constant	1.100***	0.187	0.010	0.155	0.171	0.158
Number of observations	1,003					

a Whether the firm assesses at least 1 barrier-item as important, for each set of barriers.
b Averages over the periods 2006-2010 for the first wave and 2010-14 for the second wave.
* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Table 5

Univariate probit and RMVP results - CIS-CAD Wave: 2008-2010

	Dependent variables[a]					
	Financial Obstacles [b]		Knowledge Obstacles [c]		Market Obstacles [c]	
Explanatory variables	**Coefficient**	**s.e.**	**Coefficient**	**s.e.**	**Coefficient**	**s.e.**
External acquisition	-0.228	0.174	-0.334	0.359	-1.038***	0.353
Training &Marketing	0.016	0.188	0.959**	0.403	1.361***	0.373
R&D	0.372*	0.200	0.812**	0.392	-0.024	0.365
Organizational innovation	-0.220	0.137	-0.052	0.131	0.109	0.139
Marketing innovation	0.232	0.152	0.006	0.137	-0.137	0.135
Exporter	0.203	0.136	-0.098	0.111	-0.069	0.114
Public grants	-0.117	0.190	-0.238	0.190	0.017	0.201
Part of a group	-0.148	0.160	0.024	0.130	0.185	0.134
Cooperation agreements	0.009	0.229	-0.344*	0.198	-0.330	0.203
Degree	-0.267**	0.128	-0.099	0.110	-0.049	0.116
Abandoned innovation projects	-0.148	0.307	0.232	0.278	0.226	0.273
Ongoing innovation activities	0.432**	0.192	-0.277	0.212	0.144	0.226
Small	0.054	0.166	0.238*	0.136	0.268*	0.140
Other manufactures	0.009	0.224	0.034	0.171	-0.056	0.175
Metal mechanics	-0.326	0.235	0.200	0.194	0.509**	0.202
Furniture	0.095	0.241	-0.158	0.171	0.314*	0.182
Commercial services	0.013	0.163	-0.004	0.134	-0.147	0.134
Transportations	-0.103	0.207	0.036	0.172	0.117	0.177
Other services	-0.210	0.236	0.112	0.202	-0.153	0.209
Return on assets (ROA)	-0.010	0.006	0.001	0.004	0.007*	0.004
Financing costs/turnover ratio	0.266***	0.060	0.005	0.024	-0.028	0.024
Leverage	0.000	0.000	0.000	0.000	0.000	0.000
Constant	0.851***	0.215	0.023	0.171	0.227	0.177
Number of observations	841					

a Whether the firm assesses at least 1 barrier-item as important, for each set of barriers.
* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Table 6

Univariate Random-effects Probit - Waves: 2008-2010 and 2010-2012

	Dependent variables[a]					
	Financial Obstacles		Human Resources Obstacles		Market Obstacles	
Explanatory variables	**Coefficient**	**s.e.**	**Coefficient**	**s.e.**	**Coefficient**	**s.e.**
External acquisition	0.221	0.180	-0.385**	0.183	-0.351**	0.162
Training & Marketing	0.197	0.182	0.350**	0.176	0.363**	0.162
R&D	0.152	0.192	-0.192	0.184	0.116	0.173
Organizational innovation	-0.095	0.151	0.085	0.147	0.371***	0.133
Marketing innovation	0.130	0.168	0.387**	0.161	0.052	0.151
Exporter	-0.112	0.156	-0.368**	0.151	0.087	0.136
Public grants	-0.093	0.191	0.086	0.181	-0.288*	0.169
Part of a group	-0.357**	0.169	-0.210	0.164	0.576***	0.153
Cooperation agreements	0.112	0.215	-0.028	0.202	-0.107	0.192
Degree	-0.156	0.154	-0.008	0.147	0.218	0.135
Abandoned innovation projects	0.163	0.311	0.582**	0.290	0.425	0.298
Ongoing innovation activities	0.186	0.186	0.291	0.180	0.391**	0.164
Small	0.231	0.182	0.052	0.176	0.527***	0.161
Other manufactures	-0.293	0.228	-0.129	0.217	-0.624***	0.197
Metal mechanics	-0.180	0.319	0.165	0.298	-0.050	0.286
Furniture	0.453	0.382	-0.160	0.334	0.023	0.311
Commercial services	-0.222	0.196	-0.232	0.191	-0.466***	0.173
Transportations	0.278	0.230	-0.339	0.228	-0.313	0.195
Other services	0.032	0.281	-0.514*	0.278	-0.601**	0.237
Return on assets (ROA)	-0.021**	0.010	0.011	0.009	-0.008	0.008
Financing costs/turnover	0.093**	0.041	0.003	0.032	0.03	0.033
Leverage	0.006***	0.002	0.001	0.002	-0.001	0.002
Constant	-0.094	0.247	-0.437*	0.238	-0.264	0.215
Number of observations	588					

a Whether the firm assesses at least 1 barrier-item as important, for each set of barriers.

* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

Table 7

Univariate Random-effects Probit - Perceived Obstacles during the Crisis

	Dependent variables[a]					
	Financial Obstacles		Human Resources Obstacles		Market Obstacles	
Explanatory variables	**Coefficient**	**s.e.**	**Coefficient**	**s.e.**	**Coefficient**	**s.e.**
Dummy (2010-2012)	-0.419**	0.179	-0.665***	0.184	0.974***	0.198
External acquisition	0.344*	0.197	-0.272	0.197	-0.683***	0.202
Training & Marketing	0.278	0.194	0.468**	0.195	0.300	0.188
R&D	0.162	0.201	-0.230	0.198	0.135	0.195
Organization innovation	-0.121	0.159	0.059	0.157	0.494***	0.160
Marketing innovation	0.161	0.177	0.451***	0.175	-0.012	0.170
Exporter	-0.107	0.165	-0.399**	0.163	0.073	0.149
Public grants	-0.072	0.201	0.122	0.194	-0.402**	0.198
Part of a group	-0.280	0.180	-0.060	0.180	0.452***	0.174
Cooperation agreements	0.112	0.227	-0.032	0.217	-0.119	0.215
Degree	-0.182	0.163	-0.017	0.156	0.278*	0.152
Abandoned innovation projects	0.141	0.331	0.573*	0.315	0.632	0.343
Ongoing innovation activities	0.186	0.196	0.315	0.194	0.493**	0.194
Small	0.283	0.196	0.052	0.117	0.522***	0.184
Other manufactures	-0.298	0.242	-0.115	0.233	-0.755***	0.229
Metal mechanics	-0.181	0.340	0.221	0.322	-0.035	0.320
Furniture	0.530	0.410	-0.054	0.363	-0.083	0.352
Commercial services	-0.218	0.208	-0.248	0.205	-0.539***	0.198
Transportations	0.299	0.244	-0.338	0.242	-0.367***	0.217
Other services	0.052	0.299	-0.503*	0.300	-0.753***	0.275
Return on assets (ROA)	-0.023**	0.011	0.012	0.010	-0.008	0.009
Financing costs/turnover	0.106**	0.045	0.006	0.035	0.000	0.037
Leverage	0.005**	0.002	0.001	0.002	-0.001	0.002
Constant	0.311	0.311	0.178	0.298	-1.254***	0.317
Number of observations	588					

a Whether the firm assesses at least 1 barrier-item as important, for each set of barriers.
* $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$