FIRMS' PERCEPTIONS OF BARRIERS TO INNOVATION AND RESILIENCE: THE ITALIAN REGION OF FRIULI VENEZIA GIULIA DURING THE CRISIS*

OSTACOLI ALL'INNOVAZIONE E RESILIENZA REGIONALE: IL CASO DEL FRIULI VENEZIA GIULIA

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ABSTRACT

This paper connects the literature on obstacles to innovation to the concept of regional economic resilience by empirically assessing the relationship between the intensity of firms' engagement in innovative activities and self-reported obstacles to innovation during the unfolding of the latest economic and financial downturn. The analysis is grounded on a unique dataset on firm-level accounting data (CAD) and information from two waves (2008-10 and 2010-12) of the Community Innovation Survey (CIS) for a representative sample of firms in the Italian region of Friuli Venezia Giulia. The main results support the existence of severe deterring barriers in the region, and suggest that during the economic and financial crisis after 2008 firms' uncertainty about the market demand became dominant.

JEL Classification: O31, O32, O33.

Keywords: Obstacles to innovation, Engagement in innovative activities, Regional resilience, Economic and financial crisis.

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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 innovative investments and introduce incentives to support new ideas of firms willing to recover from the aftermath of the economic and financial crisis started in 2008. Firm innovation capabilities have been recognized as one of the main determinants of regional resilience, or "*the capacity of a regional or local economy to withstand or recover from market, competitive and environmental shocks to its developmental growth path* [...]" (Martin and Sunley, 2015, p. 13). Given that investing in innovation does not automatically imply that firms will come up with new products, processes or organizational structures, managers and policy makers have actively sought to identify and remove those factors that may hamper the innovation process.

In the extant literature, most of the contributions have focused either on the driving forces behind firm innovation or on the determinants of regional resilience, with little overlap between the two research lines. This paper investigates the relationship between the intensity of firms' engagement in innovation activity and their perception of obstacles in the Italian region of Friuli Venezia Giulia (FVG), and considers how such a relationship was affected by the financial and sovereign debt crisis that hit most European countries between 2008 and 2012.

Since the 1960s the region of FVG, a small and heavily industrialized region located in the North-East of Italy, has been characterized by high GDP growth rates. Unfortunately, the credit crunch that followed the 2011 economic and financial crisis severely hit the region's economy and the reduction in firms' investments was sharper than in the rest of Italy between 2012 and 2014 (Banca d'Italia, 2018).

The study adds a number of novel aspects to the still sparse literature on the regional dimension of obstacles to innovation and firms' behaviour in the aftermath of economic and financial shocks. First, the focus is on firms located in FVG, a region characterized by industrial clusters of SMEs operating mostly in traditional sectors. The focus on within-region firms' innovative behaviour provides interesting insights on the environmental components of firms' risk perceptions and their potential contribution to the resilience of the local system as a whole. The case of FVG is especially interesting for a reflection on the many middle-income regions in Europe, still competitive and wealthy relative to the mean of their country, but severely hit by the crisis that added up to an enduring decline brought about by technological change and globalization (Iammarino et al., 2019). Second, we introduce a new qualitative measure of innovation intensity that represents a proxy of firms' efforts: more complex operations 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 financial resources; the highest ranked activity is R&D that entails not only financial efforts, but also relational, human and knowledge capital. Third, the study is based on a unique dataset that comes from matching two different sources: the Community Innovation Survey (CIS), providing detailed information on firms' innovation activity in the region, and the Company Accounts Database (CAD),

containing accounting information in order to widen the range of firms' characteristics and ensure a better coverage of financial features. The combination of these data sources, and the timing of the panel structure (matching a subset of 317 potential innovators present in two CIS rounds, 2008-2010 and 2010-2012), allow us to grasp some implication of the consecutive waves of the economic and sovereign debt crisis. Fourth, regarding the empirical strategy, the 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 by focusing only on the firms that showed a real interest in innovation, that we define potential innovators (D'Este et al., 2012). Next, we limit endogeneity issues by working along two directions: enriching our model by exploiting firm-level accounting information, and relying on the most robust estimation techniques.

Our results grasp several aspects of the relationship between the intensity of engagement in innovative activities and reported obstacles of firms in the FVG region. Overall, the emerging picture points to the existence of strong deterrent barriers (i.e. those literally preventing firms from innovating), in particular related to financial and market factors, while obstacles related to human resources are instead pervasive, independent on the firm being innovation-active or not. In the second stage of the crisis (2010-12) firms' perception of the relevance of financial barriers is the highest at the extreme of the distribution, i.e. for non-innovators and for firms more intensely engaged in innovative investments, while that of market-related obstacles remains distinctively high for deterred firms. After the crisis hit, the relevance of demand risk and uncertain market competition is perceived even more acutely by all local firms, and particularly by the non-innovators, further curtailing investment in innovation and countercyclical strategies to cope with the crisis effects in the region.

The paper is organized as follows: Section 2 discusses the literature background; Section 3 describes the data and the rationale and construction of the variables used in the analysis; Section 4 provides a concise picture of the FVG region during the crisis period, presents some descriptive statistics, and offers a simple assessment of the resilience of the regional economic system; Section 5 explains the econometric approach and discusses the estimation results; Section 6 concludes and draws some implications.

2. Literature background

2.1 Firms, innovation obstacles and engagement

A large body of scholarly literature has addressed the relationship between firms' engagement in innovative activities and factors that may hamper firms' aspiration to innovate (see, for a review, D'Este et al., 2012). This eminently empirical literature, often based on data from innovation surveys such as the European Community Innovation Survey (CIS), has largely focused either on the factors that affect the firm's perception of the importance of obstacles to innovation (e.g. Mohnen and Rosa, 2001; Baldwin and Lin,

2002; Baldwin and Hanel, 2003; Galia and Legros, 2004; Iammarino et al., 2009), or on the impact of such obstacles on the propensity to innovate (e.g. Arundel, 1997; Tourigny and Le, 2004; Mohnen and Roller, 2005; Savignac, 2006 and 2008; Mohnen et al., 2007; Mancusi and Vezzulli, 2010).

The first approach - which is closer to our empirical analysis here - focuses mainly on why firms perceive differently the obstacles to innovation, and the extent to which individual obstacles are complementary. Common results are that the greater the firm's engagement in innovation activities, the higher the importance attached to obstacles to innovation; and that the latter are perceived differently depending on firms' characteristics (e.g. size, sector). One explanation for the positive association between engagement in innovation and perception of barriers 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. Baldwin and Lin (2002), for example, 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 those obstacles that are positively correlated and that can be grouped in homogenous sets. In the same vein, D'Este et al. (2012) distinguish between two kinds of barriers to innovation: the first corresponds to *revealed* barriers and reflects the steepness of the innovation process and the firm's learning experience in investing in innovation; the second type, *deterring* barriers, encompasses the obstacles that prevent firms from committing to innovation investment tout court. To apply such a distinction, D'Este et al. (2012) identify potential innovators according to their aspiration to innovate, regardless of whether they were engaged or not in innovative activities: non-innovators, who self-report having faced barriers, fall in the group of potential innovators, and tend to assess the obstacles to innovation as relatively more important than many innovation-active firms (D'Este et al. 2012). This distinction allows mitigating the selection bias problem by ruling out from the analysis firms that are not interested in investing in innovation at the observed point in time, either because they had done it previously or because of market conditions in their industry.

One of the main merits of the second approach, which focusses on the opposite causal relationship - i.e. the role of obstacles perceptions in affecting the probability to engage in innovation - is the emphasis put on the possible endogeneity of the regressors (e.g. Mohnen and Roller, 2005; Savignac, 2006; Mohnen et al., 2007). More recent studies, particularly concerned with financial barriers, point out that the positive relationship between firms' perception of obstacles and engagement in innovation can be attributed to a combination of several sources of bias (e.g. Canepa and Stoneman, 2008; Savignac, 2008; Mancusi and Vezzulli, 2010; Silva and Carreira, 2012), such as the presence of heterogeneous unobserved firm-specific factors (e.g. entrepreneurial behaviour, risk propensity or market opportunities) that may impact on both aspects of the relationship, or the simultaneous determination of the obstacle perception and the decision to innovate.

The perception of obstacles to innovation is an inherently firm-specific dimension (Sitkin and Pablo, 1992; Ferriani et al., 2008). On the other hand, as the conceptualization of risk perception in the geography literature (e.g. Cutter et al., 2000) as pointed out, the extent to which a population (in this case, of firms) perceive external risks depends on both subjective evaluations, which are agent-specific, and objective environmental conditions, which apply to the probability of occurrence of a certain shock under specific temporal and spatial contexts. In recent studies following the Schumpeterian tradition, innovation strategies have been considered as cyclical, inasmuch as firms (in specific industries and regions) tend to reduce their innovative efforts in presence of uncertain and risky market conditions (e.g. Francois and Lloyd-Ellis, 2009); however, it has also been suggested that periods of economic instability or crisis generate a fertile environment for firms (in specific industries and places) to adopt counter-cyclical strategies and innovate (e.g. Aghion and Saint-Paul, 1998; Filippetti and Archibugi, 2011).

2.2 Firms' perceptions of obstacles and regional resilience

The relationship between innovative behaviour and perception of barriers cannot thus be properly understood without considering the set of opportunities and constraints firms face as a result of their external - industrial, technological and institutional - environment and its evolution (e.g. Nelson and Winter, 1982; Shane, 2001). The 2008 economic and financial crisis across Europe and the world uncovered a highly uneven geographical distribution of environmental factors, thereby drawing attention to differences between regions in their vulnerability to economic shocks and their ability to adapt to serious disruptions in the economic environment (e.g. Davies, 2011; Martin, 2011, 2012; Fingleton et al., 2012; Cellini and Torrisi, 2014; Sensier et al., 2016).

Despite the overriding attention paid to regional economic resilience in the last decade, the conceptual framing of the notion remains the subject of considerable academic debate (e.g. Bristow and Healy, 2014; Martin and Sunley, 2015; Boschma, 2015). Evolutionary theorists have emphasised the importance of selection environments, firm fitness, sectoral variety, innovation capacity and institutional arrangements, and asserted the need to grasp the "*capacities to withstand or resist the shock in the first place, the robustness of its firms and institutions in responding to it, and the extent and nature of the regional economy's recovery from it*" (Sensier et al., 2016, p. 131; see also Martin, 2012; Martin and Sunley, 2015). In this debate, limited attention has been devoted to consider the relevance of firms' innovation perceptions and strategies for regional vulnerability and resilience to shocks.

Long-standing research on innovation and regional development has emphasised that in dynamic regional innovation systems, often characterised by large urban agglomerations, firms tend to perceive barriers - of the revealed type - as a result of the steep learning curve behind their innovative efforts (e.g. Iammarino et al., 2009): agglomeration externalities and/or diversification of the local knowledge base support firms' exploration of emerging opportunities and new markets (e.g. Rodriguez-Pose, 1999; Gordon and McCann, 2005; Todtling and Trippl, 2005; Escribano et al., 2009), contributing to the resilience of the system as a whole. Conversely, in technologically less dynamic or inert regional systems, relatively more specialised,

oriented toward exploitation, refinement and efficiency improvements, firms experience more deterrent barriers and are discouraged from risky ventures (e.g. Gagliardi and Iammarino, 2018). In line with these insights, Cruz-Castro et al. (2017) find out that firm specific factors, such as larger size, export-orientation, high productivity, access to public grants, and share of R&D employees and engagement in cooperation agreements, lowered the probability to quit innovative projects during 2008-2012. Beside firm-specific characteristics, the study points out that the probability of continuing in house R&D also depends on the economic size of the region and on its innovation system.

Distinct geographical patterns in the perception of the obstacles to innovation characterise in particular single domestic firms and SMEs: the perception of barriers, in other words, does not significantly differ across regions if firms are multinationals or multiplants (see Iammarino et al., 2009 for Italy; and Gagliardi and Iammarino, 2018 for the UK). In addition, in the Italian case, domestic firms located in the macro-regions of Northern and Central Italy tend to perceive obstacles to innovation as relevant significantly less than their counterpart located in the South (Iammarino et al., 2009). While these studies have considered cross-regional differences within one national innovation system, the present work offers an additional perspective on firms' innovation investments and perception of obstacles, and their reactions during a global economic shock, within the context of a specific regional innovation system, FVG.

3. Data and Main Variables

3.1 Data sources and sample definition

Our analysis is grounded on an original dataset that was built by matching micro-data from two different sources. The first is the Community Innovation Survey (CIS), provided by the Regional Statistical Department for a representative sample of firms of the (NUTS2) FVG region. CIS data, collected according to EUROSTAT harmonized rules (see, for all, Mairesse and Mohnen, 2010), represent an extremely rich source of qualitative and quantitative information on firms' characteristics and innovative behaviours, including their perception of the obstacles obstructing the innovation process. The survey, that covers all firms with 250 employees or more and a random sample of those with at least 10 employees, is representative of the regional industrial structure by both industry and firm size (i.e. number of employees).

The 2008-2010 CIS wave collected answers from 1,134 respondent firms in the region, while the 2010-2012 wave consisted of 1,139 units. Starting from the 2008-10 wave, 835 potential innovators, i.e. those firms that were truly interested in innovation in the period observed, were selected.[1] As some of the respondents were surveyed in both waves, a panel of 317 potential innovators (634 observations) was extracted across 2008-10 and 2010-12.

[1] Potential innovators were selected from the CIS as the subsample of firms that either engaged in innovation activities or reported to have been hampered by at least one obstacle.

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' accounting information especially related to the enterprise's financial structure. One minor drawback of this source is that CAD data are available only for firms borrowing from banks belonging to the consortium. A further limitation is that accounting 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 80 percent of the firms included in the 2008-10 CIS wave: the resulting CIS-CAD sample consists of 925 firms, of which 691 potential innovators including the 317 firms of our panel. Our empirical analysis in Section 4 uses first the CIS-CAD cross-section sample to run a multivariate probit model to grasp insights on the relationship between the perception of obstacles and firms' innovation behaviour, and then performs a random-effect panel probit on the 317 firms' subsample to study how firms' attitudes toward innovation obstacles were affected by the unfolding of the sovereign debt crisis.

3.2 Variables and main indicators

Defining barriers to innovation

The CIS questionnaire has a dedicated section reporting various categories of obstacles: all respondent firms (both engaged and not engaged in innovation activities) reported the importance of each obstacle type according to a Likert scale ranging from 0 to 3 (not at all, low, medium or high importance). We collapsed answers into binary indicators taking value 1 if the firm perceived the importance of an obstacle as high, and 0 in all other cases.

After checking for cross-correlations between individual obstacles in each survey wave, we harmonised the 2008-10 and 2010-12 CIS questionnaires and we grouped them in three categories: financial, human resources and market obstacles (Table A.1 in the Appendix).[2] 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 administered to firms. Financial barriers refer to difficulties in financing innovation investments deriving from lack of appropriate funding; human resources obstacles are related to the scarcity of qualified personnel; market barriers reflect the presence of incumbent firms with high market power, and/or the uncertainty of demand for innovative products or services.

Measuring engagement in innovation

We model innovation intensity by sorting firms' involvement with respect to the specific forms of investment required to implement the project (Koschatzky, 1999). 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 the intensity of the firm's engagement/effort.

[2] To ensure coherence between the slightly different questionnaires adopted in the two CIS waves in relation to the obstacles section, the analysis here is based on the shorter obstacles list reported in the 2010-12 wave, thus on the cross-wave harmonised information included in our dataset.

The simplest way to innovate is through the external acquisition of technology, since it mostly requires financial resources. Innovation intensity deepens when new available knowledge, whatever the source, has to be disseminated inside or outside the firm involving relational and communication investments (e.g. Rogers, 2004): 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, marketing schemes are crucial to promote goods' quality to potential customers. Internal R&D is generally considered the most demanding form of firm's innovation efforts, as it requires significant amounts of financial, relational and technological resources that only a relatively small number of firms can deploy.

Both 2008-10 and 2010-12 CIS questionnaires asked firms to report whether they engaged in any of eight listed innovative activities. We grouped them into three indicators that grasp different qualitative aspects of innovation investments according to the above considerations. They were defined as dummy variables taking value 1 if the firm has engaged in that particular innovation activity in the reference period (Table A.2 in the Appendix): such dummies are mutually exclusive since for each firm only the dummy representing its highest degree of innovation effort takes value 1. Starting from the highest, the ranking is: Internal R&D, Training & marketing, Technology acquisition. Whereas previous literature has mainly relied on quantitative measures (e.g. the number of undertaken innovative activities or the amount of expenses), our measure of innovation intensity, that ranks the intensity of the firm's innovative engagement on the basis of the qualitative variety of investments, offers a deeper understanding of the relation under study.

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. As mentioned in section 2.1 above, 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 in the reference period. This latter category of firms represents an important source of upward selection bias and it should be left out from the analysis (Hajivassiliou and Savignac, 2008).

As in Savignac (2008), Hajivassiliou and Savignac (2008), Mancusi and Vezzulli (2010) and D'Este et al. (2012), we focussed our analysis on firms that showed an aspiration to innovate, i.e. the potential innovators. Our selection rule was the following: either the firm engaged in some form of innovation investment as described above (innovation-active), or it did not and was deterred by at least one obstacle (deterred). This criterion restricted our selected sample to 835 firms from the 1,134 respondents of the 2008-10 CIS wave: the remaining firms were excluded from the analysis, as considered 'not in the innovation contest' (D'Este et al., 2012) since, albeit not constrained by any barrier, they declared not to have engaged in innovative activities either because of the lack of demand for innovation from the relevant market's competitive conditions, or because still relying on previously (to the surveyed period) introduced innovations.

4. The region: Friuli Venezia Giulia in the post-2008 period

4.1 FGV, firms and obstacles to innovation

North-Eastern Italy - the macro-region of FVG - 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 SMEs operating in traditional industries, such as furniture and electric appliances, and heavy industry, such as machinery, metals and steel (FVG, 2015). Even if FVG shows shares of workers both with higher education in sciences and technology and employed in high technology sectors below the Italian average, the region has a high incidence of innovative firms with a relevant presence of SMEs. According to the Italian National Institute for Statistics (Istat), during the 2010s FVG has been a leading innovation-oriented region in Italy in terms of percentage of innovators, rate of patents per million of inhabitants and expenses in R&D activities as a ratio to regional GDP (Istat-Cnel, 2013; Istat, 2015, 2016 and 2017).

Many enterprises, especially the suppliers with low export capacity, have suffered increasingly from globalization processes; despite in the years preceding the crisis the export of the region raised more than the national average, it suffered a sharper reduction than the rest of Italy between 2007 and 2013, recovering only between 2014 and 2016 (FGB, 2014, 2017). The economic crisis severely hit the propensity of FVG's firms to innovate as, on the basis of the CIS surveys for the waves 2010-12 and 2012-14, the percentage of firms that innovated went down from 58.8% in 2012 from to 42.2% in 2014.

The region is also very weakly internationally integrated, with a share of only 1.6% of all foreign-owned enterprises located in Italy at the end of 2015 - the lowest of the Italian North - and very limited active internationalization of local firms abroad (ITA, 2018). The crisis has severely affected FVG's economic performance: 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%), following the national trend (Faggian et al., 2018). Despite being above the national average in terms of level of economic wealth measured by GDP per capita, indicators point out that during the economic and financial downturns the difficulties of the regional productive sectors were deeper than the country average.

Tables 1 and 2 report the main characteristics of FVG firms included in the CIS 2008-2010. Table 1 shows that, restricting our analysis to potential innovators only, firms in the region perceive, as the most pervasive obstacles, those related to the lack of financing opportunities (both internal and external) and market factors such as demand uncertainty and presence of incumbent firms.

[Table 1 about here]

Table 2 focuses on potential innovators to show the main differences between the firms engaged in innovation activities and those that were deterred by the obstacles. Innovation-active firms show on average a lower incidence of obstacles' perception, while they display much higher firm size (in terms of both

workforce and revenues), incidence of graduated employees, participation in corporate groups, export capacity; the introduction of organizational and marketing innovations is about three times higher as that of deterred firms.

[Table 2 about here]

Descriptive statistics also provide a first insight about the relationship under study. Table 3 shows the incidence of firms perceiving each obstacle as highly important according to the intensity of their engagement in innovation: null (innovation deterred), or investing in innovation through different, increasingly demanding, channels - i.e. external acquisition of technology, marketing and training activities, and R&D projects. The first observation is that obstacles to innovation are very relevant for hampered firms, supporting the existence of deterrent barriers of financial, market and, to a lesser extent, personnel-related nature preventing firms' innovation efforts.

[Table 3 about here]

Table 4 shows the same relationship but referring to the subset of 317 firms included in the panel. Interestingly, during the second CIS wave 2010-12 a lower percentage of potential innovators appear to be deterred by financial and human skill barriers with respect to the previous wave, while the perception of market obstacles sharply rises for any level of innovation intensity. Innovation active firms, as expected, becoming more aware of the credit crunch and of the unfolding of the sovereign debts crisis, perceive a higher relevance of financial constraints, but the main concern for most firms is uncertainty in market and demand.

[Table 4 about here]

4.2 Innovation capabilities and vulnerability of FVG during the crisis

In this section we assess the performance of FVG's innovation capabilities during the crisis and its aftermath and we explore the role of different firms and sectors with respect to the vulnerability of the regional economic system to the 2011 sovereign debt crisis following the procedure proposed by Bristow and Healy (2018). First, we use macro level data on employment to detect turning points in the regional economy business cycle. Second, we move to a micro level analysis to grasp some indication on which kind of firms played a major role in the vulnerability of the economic system. Finally, we connect descriptive results to the previous section's evidence of the sharp rise in market obstacles perception.

According to the Regional Innovation Scoreboard (RIS, European Commission, 2017), FVG is a "moderate+ Innovator"[3] and, since 2011, its innovation performance has marginally improved. Data reported in the RIS 2017 (Table 5) highlight that the region is a strong innovator within the national context, - with

[3] "Moderate Innovators are all regions with a relative performance between 50% and 90% of the EU average in 2017." (see European Commission, 2017, Methodology Report, p. 31).

most indicators in the table above the Italian average (= 100), while it is only a moderate innovator compared to the EU average.

[Table 5 about here]

According to the RIS 2016, the innovation capability of the region increased after the sovereign debt crisis hitting its peak in 2014, and then it went down during the period 2015-16. To assess the resilience capability of the region and to grasp its interplay with the performance of its innovative and non-innovative firms we follow a two-step analysis. First, we assess the regional resilience according to the procedure suggested by Bristow and Healy (2018), i.e., we evaluate the output and the employment loss of the region during the sovereign debt crisis. Second, we observe ex-post if there has been a recovery.

As in Martin (2012), resilience is measured in absolute terms, and not in a comparative way with respect to other territories. Thus, to decide if FVG looks like a resistant region, a recovered region, a still recovering region or a still downturn economy, we adopt the following criterion: "Resilient regions then are those that either did not experience a downturn in employment following the global economic shock (Resistant) or those that experienced a downturn in employment but recovered to pre-shock peak levels by 2011 (Recovered). Regions that were not resilient to the crisis are those that have not recovered to pre-shock peak levels by 2011, and this category is subdivided into two further categories: those that have registered an upturn in employment but had not recovered to their pre-shock peak by 2011 (Not Recovered: Upturn) and those that were still to record an upturn in employment by 2011 (Not Recovered: Downturn)." (see Bristow and Healy, 2018, p. 273).

Looking at the dynamics of employment in FVG (Figure 1), we can see that it took 6 years to the region to go back to its 2011 level (2011=100) and that in 2015 it was still far away from the 2007-08 peak. We also observe that the region's economic system has shown vulnerability to the severe 2011 economic shock more than other North Eastern regions and the Italian average.

[Figure 1 about here]

A micro level comparison of employment dynamics helps us to understand which firms (innovative vs. non-innovative) are "more responsible" for the region economic system's lack of resilience. Our CIS data do not fully match Istat aggregate data, but being the CIS sample representative of the regional economy we believe that it could be a good proxy of regional dynamics. Table 6 shows that, on average, innovation- active firms, besides being larger, were also able to increase their employment even after the 2011 economic shock, while for non-innovative firms we observe a reduction in the number of employees. This is obviously indicative evidence, but it suggests that innovation-inactive firms were not able to respond to the downturn following the sovereign debt crisis.

[Table 6 about here]

5. Econometric analysis

5.1 Limiting endogeneity

We are interested in estimating the relationship between the probability that an obstacle is perceived as important and the intensity of innovation engagement. After selecting the sample of potential innovators, we tackled 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 perceive obstacles as important 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. In particular, we add two important exogenous variables from the accounting data: 1. the return on assets (ROA), i.e. the ratio of earnings before interest and taxes on total assets, calculated as a 4-year average; 2. the ratio of financial debts to the sum of firm's own resources and financial debts (leverage). The first index is an indicator of the ability to generate returns, and is therefore correlated with productivity. The second, computed as the share of external debt on total resources (external and internal) captures the general stability of the firm financial structure, its sustainability over time and its resilience to external shocks. Firms able to generate positive and sustainable returns are better equipped to cope with the risks entailed by innovation investments and therefore they should perceive obstacles as less threatening.

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 by considering both potential benefits and costs as early as in the planning stage of their innovation strategies. Such preliminary assessment also includes estimates of risks and obstacles, even though further barriers might come into consideration during the project implementation phases. Moreover, the problem of simultaneity in obstacle assessment and innovation decision is intrinsic to the particular nature of the dataset: CIS data comes from survey waves each covering a three-year period considering it as a single 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. We start our analysis by first focusing on the cross-sectional data CIS-CAD 2008-10: the resulting sample CIS-CAD is made of 691 potential innovators.[4]

[4] Merging the data implies losing some observations and selection bias may affect the distribution firms' propensity to innovate. As a robustness check, we therefore estimated our equations relying on the full set of CIS potential innovators: the signs of the estimates obtained using CIS data match those obtained using CIS-CAD data although they exhibit a smaller magnitude.

A multivariate probit model (MVP) takes into account the fact that the obstacles are simultaneously determined.[5] We then 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 the CIS-CAD panel subset of 317 potential innovators that were surveyed in both CIS waves.

5.2 Cross-sectional analysis: the multivariate probit model

On the cross section 2008-10 CIS-CAD we run a multivariate probit (MVP)[6] model that represents the multiple-equation extension of the univariate probit model.[7] 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 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. Relying on the estimation procedure developed by Cappellari and Jenkins (2003), we estimate a system of three equations, one for each obstacle group (financial, human resources, and market). For each firm i=1….N and each set of obstacles y_{ij}:

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

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

We tested several specifications of our model including the relevant CIS indicators and extending the set of regressors with accounting variables drawn from CAD. Our final specification includes a set of control variables capturing firm-specific characteristics such as macro-sector of activity, size, human capital endowment, and several dummies capturing whether the firm belongs to a group, and measures of innovativeness and failures. Size is expected to be negatively related with high perception of financial obstacles (Savignac, 2008), being an indicator of lower financial constraints. Following Savignac (2008), from the CAD data we included the two variables that have been found to affect the probability to suffer financial constraints: 1. the ROA, which accounts for productivity and it is hypothesized to be negatively related with the perception of financial obstacles; 2. the share of financial debt on total asset (leverage) which accounts for firms' financial structure and it is hypothesized to be positively related with the perception of

[5] For instance, D'Este et al. (2012) employed a multivariate probit model to study the effects of several classes of endogenous constraints on firms' innovation propensity relying on survey data.

[6] The starting point would be the univariate probit model with three equations, one for each obstacle group considered. 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 opted for a more flexible model.

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

financial obstacles as it signals the difficulty of getting credit for highly indebted firms. All variables are ratios so to exclude any scale effect that is already captured by the size dummy. The complete list of variables is reported in Table A.3 in the Appendix.

Table 7 shows several aspects of the relationship between innovation activity and reported obstacles. Overall the emerging picture points to the existence of high and significant deterrent barriers in relation to financial and market factors. When obstacles are not binding so severely to prevent innovation *tout court*, firms can and do engage in innovation activity: external acquisition of technology, training and marketing, and R&D activities significantly reduce firms' perception of financial and market obstacles. On the other hand, firms' perceptions of human resources-related obstacles do not show any strongly significant relation with our innovation intensity variables. This means that these obstacles have been relevant for both innovation-active and deterred firms alike.

[Table 7 about here]

The strong correlation between innovation intensity and lower perception of the relevance of financial and market constraints reflects 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, the 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 and market obstacles is likely to markedly differ between those firms already 'on the innovation ladder' and those non-innovators that did not innovate because discouraged by such barriers.

Regarding the effect of other controls, in with the literature financial constraints are felt significantly less by the largest firms in terms of both number of employees and revenue (more than 50 million euros highly significant). Firms' worries related to demand and market entry barriers are associated with the regional sectoral structure, being less relevant for firms operating in non-manufacturing sectors.[8] Lack of human resources and demand uncertainty are neither exacerbated nor mitigated by CAD-based financial indicators. Considering financial obstacles instead, the behaviour of firm-level financial indicators is coherent with both management theory and the financial conditions prevailing in the reference period. The measure of profitability, ROA, shows a significant negative correlation with financial barriers: higher returns on assets mean more internal resources that the firm can manage freely, therefore lowering perception of 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 risky investments in innovation. The index of firm financial structure, leverage, shows a small, albeit highly significant, impact.

[8] Looking at the FVG economy value added, firms operating in the service sector account for roughly 70% of the total, while manufacturing and construction firms for respectively 23 and 4% (Bank of Italy, 2018).

We conducted a robustness analysis of the results obtained for equation 1 over two dimensions. First, we collapsed the three obstacles in one single obstacle: our estimates are sharper than those obtained considering the three obstacles separately. However, this new obstacle measure is not very informative as it implies that almost every potential innovator in our dataset is constrained. Thus, we conclude that our approach allows us to shed some light on the role of each individual obstacles. Second, we used a different measure of obstacle perception, obtained by collapsing low, medium and high levels of importance. We estimate again equation 1 and we did not notice any qualitative difference in the results except that the variable that identifies the innovation status gives sharper a coefficient especially for market obstacles.

5.3 The random-effect panel probit model

In order to control for firm specific heterogeneous unobserved factors, we exploited the balanced panel of 317 potential innovators surveyed in both waves. For the j-th obstacle y_{ijt} and the k-th measure of innovation intensity x_{ikt}, we estimate the following univariate equation:

$$(2) \qquad \text{Prob}\,(y_{it} = 1) = \alpha_j + \theta_i + \beta'_j x_{ikt} + \gamma'_j z_{irt} + \varepsilon_{ijt}$$

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 set of control variables as for equation 1. 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).

Results reported in Table 8 show, first of all, that innovation-deterred firms continue to perceive financial obstacles rather more acutely than firms active in the simplest form of innovative investment: in other words, financial obstacles preoccupations are equally relevant at the extreme of the distribution (either non-innovators or highly innovators) also during the unfolding of the crisis. This is consistent with all the controls for financial obstacles: firm size in terms of revenue negatively affect financial barriers' perception; the latter are significantly associated to the financial indicators: the ROA index negatively affects the probability that financial barriers are perceived as important, while leverage has a positive effect. Thus, an imbalanced financial structure, 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.

[Table 8 about here]

On the other hand, the engagement in any of the three levels of innovation intensity still significantly reduces the perception of market barriers as important: innovativeness is intrinsically linked to control of market conditions. The second phase of the crisis sees an increase in market and competitiveness risks for firms, particularly SMEs with no previous innovation investment. Consistently, a high and sustainable ability

to generate income, measured by the ROA, becomes strongly significant in reducing perceptions of market and demand constraints.

Furthermore, we use our CIS-CAD 317 firms' panel dataset to grasp additional insights on how the relationship between the probability of perceiving barriers to innovation as important is affected by the deteriorating macroeconomic conditions following the sovereign debt crisis. Results are presented in Table 9 showing that for the second CIS wave 2010-2012 the probabilities that all firms perceive financial and human resources obstacles as important are considerably reduced - both coefficients of the dummy 2010-12 are negative and significant at the 1% level: this might indicate that in the second stage of the crisis such barriers become more pervasive, affecting innovators and non-innovators alike. The perception of market-related obstacles instead rises substantially, and particularly for non-innovators, suggesting that the worsening of the demand further discourage them from innovative (and counter-cyclical) strategies, undermining the overall capacity of the system to react to the crisis. In line with the findings of Gagliardi and Iammarino (2018), this outcome is likely to be triggered by the high incidence of SMEs in 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.

[Table 9 about here]

6. Conclusions

In this study we investigated the relationship between the intensity of firms' engagement in innovative activities and self-reported obstacles to innovation for a representative sample of firms in the Italian region of Friuli Venezia Giulia during the big recession (2008 − 2010) and the sovereign debt crisis (2010 − 2012). Results support the existence of severe financial and market obstacles hampering mostly non-innovator firms in the region, while barriers related to human resources are more pervasive, affecting both innovation-active and deterred firms alike.

Relying on a subset of firms that were surveyed both in 2008-2010 and 2010-2012 we provide evidence that innovativeness is intrinsically linked to a stronger control of the market and demand conditions. The CAD-based indicators of firms' financial health increase their overall influence on the perception of obstacles for our panel, and their sign is in line with expectations: profitability (ROA index) mitigated financial and market obstacles; leverage points to much higher perception of financial barriers for firms with an imbalanced financial structure. In correspondence with the sovereign debt crisis, the perception of market-related obstacles rose for all firms generally, and particularly for non-innovators.

Estimation results and our analysis on the FVG's economic system vulnerability point out that the sharp rise in firms' perception of market risk and uncertainty reflects the relatively low resilience of FVG to

sizeable exogenous shocks such as the latest crisis. This interpretation is coherent with the dynamics observed, especially in the regional labour market, as the rise in market-related obstacles is closely linked to the sharp reduction in the propensity to invest and innovate of FVG's firms. Moreover, during the credit crunch the downfall in FVG investments and exports, two main characteristics of innovative firms, was sharper than in the rest of Italy.

Undoubtedly, it is not an easy task for policy makers to design the intervention that can help firms to mitigate the consequences of a rise in demand risk perceptions in a region such as FVG. Showing both strong features – such as relatively high per capita income and quality of local government and institutions – and less positive characteristics – e.g. a general skill -mismatch and a comparably slow-growing specialisation model – FVG belongs to the European middle-income regional group which faces some of the hardest developmental challenges (Iammarino et al., 2019). The policy debate on the link between regional economic resilience and innovation suggests that the requisites for tackling regional vulnerability and lack of economic vitality are place-sensitive, multilevel and integrated policy actions. Innovation activities should be supported at all scales of intensity, away from the R&D-only focus, through a system of financial incentives to stimulate firms' propensity to generate new ideas, along with significant investments in (all levels of) education and re-skilling (Lenzi, 2019); capabilities advancement also demands more investment in hardware and orgware to sustain a higher-quality, more cost-sensitive growth process. Second, it is important to strengthen the regional system of innovation by promoting intra-regional networks facilitating the upgrading of traditional industrial clustering through both horizontal (i.e. general purpose) and complementary technologies and fostering diversification towards higher value added productions (Calignano, 2019). Third, and related to the previous point, it is crucial to overcome traditional internationalisation promotion based solely on export, by supporting both passive (inward) and active (outward) internationalisation of firms, especially SMEs, to help them become more integrated in transnational production networks and global value chains which can provide new markets and demand sources, as well as valuable exchanges of both labour and capital.

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TABLES & FIGURES

Table 1 – Information on the CIS Wave 2008-2010 sample in the region of Friuli Venezia Giulia

Data descriptive statistics
(percentage of firms)

	Full sample		Potential innovators		p-value
	Mean	Std. Dev.	Mean	Std. Dev.	
Types of obstacles[*]					
Financial obstacles	35.1	47.7	35.1	47.7	0.000
Human resources obstacles	8.1	27.3	11.0	31.3	0.032
Market obstacles	26.3	26.3	35.7	47.9	0.000
Firms' characteristics[**]					
Technology acquisition	31.9	46.7	43.4	49.6	0.000
Training & Marketing	18.3	38.7	24.9	43.3	0.000
R&D	21.1	40.8	28.6	45.2	0.000
Organizational innovation	34.9	47.7	40.8	49.2	0.008
Marketing innovation	26.5	44.2	31.0	46.3	0.031
Exporter	36.4	48.1	39.3	48.9	0.196
Public grants	15.0	35.7	20.4	40.3	0.002
Part of a group	17.2	37.8	18.9	39.2	0.327
Cooperation agreements	8.6	28.0	11.6	32.1	0.027
Graduate workers	52.6	50.0	55.4	49.7	0.217
Abandoned innovation projects	3.6	18.7	4.9	21.6	0.165
Ongoing innovation activities	18.7	39.0	25.4	43.5	0.000
More than 20 employees	41.7	49.3	41.4	49.3	0.903
Revenues above 50 million euros	5.6	23.1	6.5	24.6	0.452
Number of observations	1,134		835		

[*]Percentage of firms assessing items as highly important. [**]Percentage of firms presenting a specific characteristic.

Table 2 – Potential innovators of the CIS Wave 2008-2010 sample in the region of Friuli Venezia Giulia

Innovation-active and Deterred firms
(percentage of firms)

	Engaged in innovative activities?				
	No (Deterred firms)		**Yes (Innovation-active firms)**		p-value
	Mean	Std. Dev.	Mean	Std. Dev.	
Types of obstacles[*]					
Financial obstacles	58.2	49.4	36.3	48.2	0.000
Human resources obstacles	12.9	33.6	9.0	28.6	0.065
Market obstacles	46.9	50.0	23.6	42.5	0.000
Firms' characteristics[**]					
Technology acquisition	–	–	90.0	30.0	–
Training & Marketing	–	–	51.7	50.0	–
R&D	–	–	59.5	49.2	–
Organizational innovation	18.5	38.9	64.9	47.8	0.000
Marketing innovation	14.3	35.1	49.0	50.1	0.000
Exporter	27.3	44.6	52.2	50.0	0.000
Public grants	–	–	42.3	49.5	–
Part of a group	10.4	30.6	28.1	45.0	0.000
Cooperation agreements	–	–	24.1	42.8	–
Graduate workers	41.6	49.3	70.4	45.7	0.000
Abandoned innovation projects	–	–	10.2	30.3	–
Ongoing innovation activities	–	–	52.7	50.0	–
More than 20 employees	30.0	45.9	53.7	49.9	0.000
Revenues above 50 million euros	1.6	12.6	11.7	32.2	0.000
Number of observations	433		402		

[*]Percentage of firms assessing items as highly important. [**]Percentage of firms presenting a specific characteristic.

Table 3 – Firm innovation intensity and perception of obstacles in CIS 2008-2010

Innovation-active and Deterred firms: CIS Wave 2008-2010
(Percentage of potential innovators assessing the obstacle as highly important by innovation intensity)

Type of obstacles	Degree of engagement in innovation				
	Deterred firms	Innovation-active firms			
		Technology acquisition	Training & Marketing	R&D	Chi-square (χ^2)
Financial	58.2	31.0	38.1	38.1	41.52***
Human resources	12.9	10.0	6.4	9.2	3.93
Market	46.9	18.0	25.4	25.5	*50.94***

***statistically significant at 1%. **statistically significant at 5%.
H0: row and column variables are independent.

Table 4 – Firm innovation intensity and perception of obstacles in CIS panel subsample 2008-2012

Innovation-active and Deterred firms: CIS panel subsample

(Percentage of potential innovators assessing the obstacle as highly important by innovation intensity in each CIS wave)

Type of obstacles	Degree of engagement in innovation				
	Deterred firms	Innovation-active firms			
		Technology acquisition	Training & Marketing	R&D	Chi-square (χ^2)
2008-2010 Wave					
Financial	50.0	16.7	32.0	31.5	18.21***
Human resources	13.5	5.6	8.0	8.3	3.09
Market	47.3	16.7	16.0	19.4	30.64***
2010-2012 Wave					
Financial	28.5	35.0	28.6	35.0	0.85
Human resources	2.1	0.0	3.6	1.3	0.98
Market	60.6	50.0	32.1	56.6	8.44**

***statistically significant at 1%. **statistically significant at 5%.

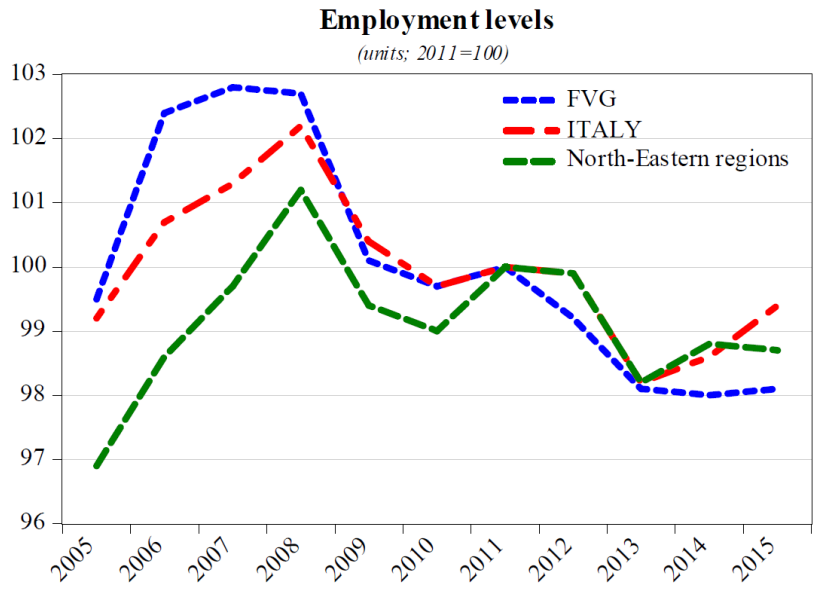
H0: row and column variables are independent.

Table 5 - Composition of the FGV Regional Innovation Scoreboard 2017

Category	Description	Score *(Normalised for outliers)*	Standardized Score *(as a % of the benchmark area)*	
		FVG	**FGV in Italy (=100)**	**FGV in E28 (=100)**
Enablers of innovation	Percentage of population (age 25-64) with a university degree	0.348	109	63
	Public R&D expenditures (% of GDP)	0.554	111	101
	Employment in knowledge-intensive services and medium-high/high-tech manufacturing (% of total workforce)	0.545	98	102
Innovation activity	Business R&D expenditures (% of GDP)	0.367	109	81
	Public-private co-publications	0.316	129	106
	EPO patent applications per billion GDP (in PPP)	0.492	162	126
Innovation capacity	Regional Innovation Index 2017	0.399	119.2	87.8
	Regional Innovation Index 2011	0.383	114.9	86.6

Source: European Commission (2017). See Bristow and Healy (2018) for more details.

Figure 1 – Employment trends in FVG relative to Italy and macro-region, 2005-2015



Source: ISTAT.

Table 6 - Employment dynamics in Friuli Venezia Giulia

Firm's type	Average number of employees		
	2008	**2010**	**2012**
Total	71.8	71.5	71.1
Innovation-active	132.2	132.8	137.3
Innovation-inactive	38.6	37.9	33.1

Source: Authors' elaborations on CIS waves 2008-2010 and 2010-12

Table 7 – Cross section regression CIS-CAD 2008-10

Results of multivariate probit - CIS-CAD: 2008-2010						
Explanatory variables	**Dependent variables[a]**					
	Financial Obstacles		**Human Resources Obstacles**		**Market Obstacles**	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Technology acquisition	-0.762***	0.174	-0.247	0.221	-0.905***	0.179
Training & Marketing	-0.573***	0.213	-0.593*	0.327	-0.596***	0.211
R&D	-0.460***	0.165	-0.427*	0.229	-0.864***	0.170
Part of a group	-0.098	0.157	0.157	0.201	0.061	0.159
Less than 10yrs in business	0.150	0.127	0.026	0.165	0.077	0.129
More than 20 employees	-0.227*	0.122	0.086	0.158	-0.050	0.123
Revenues between 10 and 50 million of euros	-0.130	0.171	-0.028	0.228	0.013	0.173
Revenues above 50 million of euros	-0.741***	0.294	0.014	0.333	-0.130	0.265
Graduate workers	-0.157	0.116	-0.250*	0.152	0.066	0.117
Construction sector	0.137	0.138	-0.100	0.173	-0.253*	0.139
Service sector	0.069	0.129	-0.248	0.167	-0.241*	0.130
Return on Assets (RoA)[b]	-0.016*	0.008	0.013	0.009	0.006	0.008
Leverage[b]	0.008***	0.002	0.000	0.000	-0.001	0.002
Abandoned innovation projects	0.202	0.254	0.329	0.306	0.403*	0.251
Ongoing innovation activities	0.285*	0.154	0.234	0.210	0.048	0.158
Constant	-0.153	0.166	-0.979***	0.171	0.208	0.166
Number of observations/firms	691					

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

Table 8 – Panel regression

Results of the random-effect probit

(subsample panel for the CIS-CAD Waves 2008-2010 and 2010-2012)

Explanatory variables	Dependent variables[a]					
	Financial Obstacles		Human Resources Obstacles		Market Obstacles	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Technology acquisition	-0.542**	0.252	-0.194	0.379	-0.799***	0.224
Training & Marketing	-0.148	0.241	-0.109	0.361	-0.854***	0.236
R&D	-0.230	0.201	0.127	0.282	-0.626***	0.184
Part of a group	-0.236	0.158	-0.131	0.244	0.282**	0.141
Less than 10yrs in business	0.051	0.161	0.051	0.237	-0.112	0.149
More than 20 employees	-0.115	0.149	0.062	0.222	-0.129	0.138
Revenues between 10 and 50 million of euros	-0.416**	0.223	-0.075	0.345	0.144	0.197
Revenues above 50 million of euros	-0.706***	0.285	0.252	0.389	0.122	0.236
Graduate workers	-0.117	0.143	-0.428**	0.220	-0.150	0.132
Construction sector	0.074	0.191	-0.075	0.266	0.423**	0.176
Service sector	-0.137	0.180	-0.296	0.262	0.039	0.161
Return on Assets (RoA)[b]	-2.941***	1.027	0.397	1.479	-3.026***	0.993
Leverage[b]	1.182***	0.227	-0.112	0.308	-0.213	0.199
Abandoned innovation projects	0.480*	0.305	0.599	0.418	0.609**	0.283
Ongoing innovation activities	0.309*	0.191	-0.399	0.298	0.207	0.172
Constant	-0.662***	0.226	-1.250***	0.343	0.096	0.204
Number of observations	631					
Number of firms	317					

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

b Averages over the periods 2006-2010 for the 2008-2010 CIS wave and 2010-2014 for the 2010-2012 CIS wave.

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

Table 9 – Panel regression - Perceived obstacles during the crisis

Results of the random-effect probit

(subsample panel for the CIS-CAD Waves 2008-2010 and 2010-2012)

Explanatory variables	Dependent variables[a]					
	Financial Obstacles		Human Resources Obstacles		Market Obstacles	
	Coefficient	s.e.	Coefficient	s.e.	Coefficient	s.e.
Dummy 2010-12	-0.494***	0.132	-1.304***	0.399	0.640***	0.123
Technology acquisition	-0.637**	0.263	-0.470	0.514	-0.737***	0.241
Training & Marketing	-0.137	0.252	0.193	0.486	-0.914***	0.251
R&D	-0.307	0.212	0.024	0.378	-0.575***	0.196
Part of a group	-0.061	0.172	0.311	0.349	0.049***	0.157
Less than 10yrs in business	0.069	0.170	0.077	0.330	-0.130	0.161
More than 20 employees	-0.144	0.158	0.022	0.309	-0.116	0.149
Revenues between 10 and 50 million of euros	-0.464**	0.236	-0.259	0.483	0.218	0.214
Revenues above 50 million of euros	-0.811***	0.303	0.105	0.530	0.242	0.258
Graduate workers	-0.138	0.150	-0.500*	0.391	-0.141	0.142
Construction sector	0.071	0.202	-0.101	0.371	0.466***	0.191
Service sector	-0.153	0.191	-0.410	0.375	0.042	0.174
Return on Assets (RoA)[b]	-3.822***	1.121	-1.063	2.171	-2.514**	1.046
Leverage[b]	1.236***	0.242	-0.187	0.438	-0.184	0.215
Abandoned innovation projects	0.444	0.322	0.772	0.599	0.702**	0.304
Ongoing innovation activities	0.286	0.198	-0.752	0.476	0.238	0.185
Constant	-0.426*	0.245	-1.067**	0.491	-0.265	0.230
Number of observations	634					
Number of firms	317					

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

b Averages over the periods 2006-2010 for the 2008-2010 CIS wave and 2010-2014 for the 2010-2012 CIS wave.

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