No money, no honey? Financial versus knowledge and demand constraints on innovation

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Gabriele Pellegrino [a], Maria Savona[c, d]

Abstract

The paper adds to the literature on the barriers to innovation in two ways. First, we assess comparatively what mostly constrains firms' ability to translate investment in innovation activity into new products and processes, whether it is mainly finance, as most of the literature would suggest, or whether it is mostly knowledge and market-related aspects. Second, we suggest a method to correct for the sample selection bias that often affects empirical contributions to this scholarship. By filtering out firms that are not interested in innovation from those that struggle to engage in it, we obtain a relevant sample of potential innovators, which allows us to analyse the comparative effect of financial and non-financial barriers on innovation success. We find that demand-side factors, particularly concentrated market structure and lack of demand, are as important as financial constraints in determining firms' innovation failures. This evidence redirects attention from financial to non-financial barriers by considering traditional demand, market structure and regulation factors involved in reduced firm innovation performance. The empirical analysis is based on an unbalanced panel of firm-level data from four waves of the UK Community Innovation Survey (CIS) between 2002 and 2010 merged with data from the UK Business Structure Database.

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1. Introduction

Recent empirical innovation studies are devoting increasing attention to perception of the obstacles to innovation and their deterrent effect on firm propensity to engage in innovation activity, on the intensity of such engagement and the likelihood of innovating (for more detail see Section 2 and Baldwin and Lin, 2002; Galia and Legros, 2004; Canepa and Stoneman, 2007; Segarra Blasco et al, 2008; Tiwari et al., 2008; Savignac, 2008; Iammarino et al., 2009; Mancusi and Vezzulli, 2014, among others).

Assessing the actual impact of the obstacles to innovation on the rate of innovation failure/success has clear policy relevance, since removing or alleviating these barriers could enlarge the population of innovators and increase the innovation performance of current innovators (D'Este et al., 2008, 2012, 2014). A substantial number of works focus on the impact of financial obstacles. The emphasis on the financial conditions that enable innovation originates in the traditional cash-flow models (see Hall, 2002 for a review), which focus on the financial constraints to firms' R&D investments, and likely reflects the recent unfavourable financial downturn. Also, there is a rationale implied by an analytical focus on financial constraints. For instance, if it can be shown that firms do not innovate because they lack liquidity, struggle to access external financial sources or perceive innovation costs as excessive, it is relatively more straightforward for policy makers to alleviate these barriers by providing liquidity. This can take the form of additional subsidies, tax credits or channelling public funds to Venture Capital (VC) to increase (mainly R&D) innovation investments (Arqué-Castells, 2012; Bertoni and Tykvová, 2015).

In this paper, we argue that firms might encounter other types of obstacles and, despite access to or availability of financial liquidity to invest in innovation, might still perceive the conditions as not favouring innovation. These other constraints might include high barriers to market entry, lack of qualified personnel and lack of adequate information on technologies and

markets. All of these difficulties might produce persistent systemic failure to engage in innovation activities and/or to translate financial efforts into R&D and extend innovation activity into the introduction of new goods, services and processes.[1] Thus, it is more important for policy to extend analysis to non-financial obstacles. This will provide evidence on whether firms do not innovate due to the lack of appropriate information on technologies and market, lack of adequate skills or, and most likely during a financial downturn, because of sluggish destinations markets with low levels of demand, or markets dominated by established firms.[2]

This paper adds to the literature on barriers to innovation in two main respects. First, we build on and extend D'Este et al. (2008, 2012), who distinguish between 'deterring' and 'revealed' barriers,[3] by assessing the impact of revealed barriers on the translation of innovation activity into actual innovation output.[4,5] We take care to distinguish financial and non-financial obstacles and, unlike Tiwari et al. (2008) and Blanchard et al. (2013), we provide comparative evidence on whether access to knowledge, a concentrated market structure, uncertain demand or regulation have comparable or more substantial effects than finance on constraining firms' ability to translate innovation investments into new outputs.

Second, we build on other contributions (Savignac, 2008; Mancusi and Vezzulli, 2014; as well as D'Este et al., 2008, 2012), and suggest a method to correct for the sample selection bias that usually characterises empirical contributions to this scholarship, which has led to the

[1] In what follows, we use innovative products to refer to innovative goods and innovative services.
[2] Recent micro and macro level empirical evidence on the effects of the economic downturn on innovation investments by firms and countries, is provided in Archibugi and Filippetti, 2011; Archibugi et al., 2012).
[3] The distinction is based on the relation between the degree of engagement in innovation activity and the perceived importance of the constraints to innovation. Deterring barriers prevent firms from engaging at all in innovation activities, while revealed barriers are those barriers that are experienced "in the making" of innovation, which reflect the firm's awareness of them based on their engagement in innovation inputs.
[4] It is important here to highlight (see also Section 3) that in the innovation-survey literature the term 'innovation active' describes the degree to which firms devote financial effort to innovation (innovative inputs). It does not mean that the firm necessarily has introduced a new product or process as a consequence of its innovation investment. This distinction is central to our argument and often is blurred in the traditional literature on financing constraints (see Section 2.1).
[5] For the purpose of this paper, we do not focus on the degree of novelty of the product and therefore do not distinguish between goods or service new to the firm versus new to the market. Rather, we adopt a more conservative choice of focusing on the simple introduction of a product/process new to the firms *or* new to the market.

counterintuitive finding of a positive relation between intensity of innovation investments and perception of the obstacles to innovation (Mohnen and Rosa, 2000; Baldwin and Lin, 2002). We use a 'relevant sample of potential innovators', which we would suggest should represent the working sample of any CIS-based empirical contributions to the literature on barriers to innovation. Our sample is obtained by filtering out firms not willing to innovate and, therefore, which do not engage in any innovation activity for other reasons than the obstacles to this activity, from those that struggle to engage in innovation activity.

We draw on the UK CIS4, 5, 6 and 7 waves, which we merge with UK Business Structure data. Our longitudinal data provide descriptive evidence of whether there is a degree of persistence over time of "not innovation oriented", "failed innovator" or "innovator" status. This information, coupled with evidence on the type of barrier most likely to affect firms' innovation status, is of primary importance for policy making since it identifies the relevant population to which interventions should be targeted.[6]

Our findings show that traditional demand and market structure factors are as important as financial constraints for determining firms' innovation failure. While we find no significant evidence that firms attempting to innovate are constrained by lack of knowledge of technologies, we find that regulatory aspects can affect innovation performance, although to a lesser extent than financial constraints.

The paper is structured as follows: Section 2 reviews the literature on the barriers to innovation and highlights the econometric issues. Section 3 describes the data, how our sample was identified, and the econometric strategy applied. Section 4 discusses the results and points

[6] For instance, policy makers might prioritize enlarging the population of innovation-active firms (*innovation-widening)* by removing or alleviating the obstacles to engagement in innovation activity, or strengthening the innovation capacity of the existing population of innovation-active firms (*innovation-deepening*) by removing or alleviating the obstacles to successful completion of innovation projects and adequate return from innovation investments. We will discuss this in the conclusion.

to the main contributions made by this analysis to the existing literature. Section 5 summarises the evidence and discusses some implications for innovation policy.

2. Financial and non-financial barriers to innovation

The literature on firms' innovation failure is relatively smaller than the core innovation literature, which focuses on the determinants of innovation success. This is somewhat puzzling, given the policy relevance of identifying and reducing the barriers to the firm's decision to spend on innovation activity and complete successful innovation projects. It would be short-sighted to suggest that identifying the success factors would also reveal what determines innovation failure. For instance, if large firms are more likely to introduce innovations, this does not mean that all small firms will find it difficult to be successful. Therefore, it is important to identify the types of hindrances firms encounter at different phases in the innovation cycle, that is, during the decision to innovate, engagement in innovation activity and introduction of a new product/process. We review a few of the contributions that deal with these issues, distinguishing between financial and non-financial obstacles.

2.1 Financing constraints and R&D investments

The majority of the work on the direct effect of the barriers to innovation, including innovation-related expenditure (inputs) and the introduction of innovation outputs, focus on (external) financing constraints on the firm's cash flow, which deter R&D investment (for a review, see Schiantarelli, 1996 and Hall, 2002; Bond et al., 1999 and Hottenrott and Peters, 2012). These contributions focus on the effect of financial constraints on the risk of sub-optimal and welfare-reducing investment. In particular, they are concerned with the high uncertainty, asymmetries and market complexity linked specifically to the financial returns on R&D investment and the ability to attract external funding. Most studies test the presence of

financing constraints indirectly, by looking at the sensitivity of R&D investments to changes in cash flow (e.g., Hall, 2008). However, some (Canepa and Stoneman, 2007; Savignac, 2008; Hottenrott and Peters, 2012) employ innovation surveys to access direct information on firms' perceptions of financing constraints. The empirical findings tend to confirm that encountering financial constraints significantly reduces the likelihood that firms will engage in innovation activity (Savignac, 2008) and that this pattern is more pronounced in small firms and in high-tech sectors (Canepa and Stoneman, 2007). Drawing on an ideal test to identify the role of financing constraints proposed by Hall (2008),[7] Hottenrott and Peters (2012) find that, in the context of equal internal availability of funds, firms with higher levels of innovation capabilities are more likely to face financial constraints to innovation.

However, the findings in the literature on finance and innovation and, particularly, the strand on Venture Capital (VC) are more consistent. For instance, Arqué-Castells (2012: 897) shows that in the case of Spain, 'VCs serve as a critical catalyst to moving inventions from the laboratory to the factory and on to consumers'. VCs usually prefer to invest in firms with higher innovation potential, although not in basic research or at the beginning of the innovation cycle, confirming that potentially highly innovative firms are more in need of external finance. Other studies show that VC certification, which signals to the market the goodness of the innovation investment, significantly affects recurrent resort to venture capital financing (Bertoni et al., 2015). Overall, this literature finds that external finance is a necessary, but not sufficient condition to ensure successful innovation (Casamatta, 2003). However, none of these contributions explicitly distinguish the role of finance in the context of innovation constraints, or attempt to account for the relative importance of financial and non-financial obstacles.

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

Some more recent work relies on data from innovation surveys to assess the relationship between the degree of engagement in innovation activity (input) and the perception of financial and non-financial constraints.

2.2 Experiencing barriers, engaging in innovation activity, and the propensity to innovate: CIS evidence

CIS data allow analysis of the role of obstacles to innovation to be extended in two main directions. First, they provide a *direct* indicator of the perception of the obstacles to innovation beyond only financial barriers. These obstacles include knowledge and information-related barriers, market structure, demand and regulation.[8] Second, it allows investigation of whether these barriers affect firm behaviour at different stages in the innovation cycle including making the decision to innovate, engaging in innovation activity and successful introduction of a new product/process.

The CIS-based literature in this field explores the complementarities between different innovation obstacles (Galia and Legros 2004; Mohnen and Röller, 2005), the association between the factors affecting perception of the importance of different barriers and innovation engagement (Baldwin and Lin, 2002; Iammarino et al., 2009; D'Este et al., 2012), and the impact of (mainly financial) obstacles to innovation (Tourigny and Le, 2004; Savignac, 2008; Tiwari et al., 2008; Mancusi and Vezzulli, 2014; Blanchard et al., 2013).

This highlights two important issues. First, most of the empirical findings show a positive relationship between engagement in innovation and perception of barriers. To try to make sense of this evidence, Savignac (2008) and D'Este et al., (2008) identify sources of potential bias that might explain the positive spurious correlation between innovation intensity and perception of obstacles, and the counter-intuitive results emerging from these analyses.

[8] A detailed description of the CIS questions on barriers is provided in Appendix Table A1.

These sources of bias include the presence of heterogeneous unobserved firm specific factors and the simultaneous spending for innovation projects and facing obstacles to innovation. There is also a particular source of bias, which is caused by the design of the CIS questionnaire and is linked to inappropriate selection of a relevant sample. No distinction is made between firms willing or not willing (or needing) to innovate (see Savignac, 2008 and D'Este et al., 2008, 2012).

Although the CIS focuses mainly on 'innovation-related' factors, it also gathers information on non-innovative firms. However, all of the firms responding to the survey are required to respond to the questions on the obstacles to innovation (see Appendix Tables A1 and A2). Firms might decide that they do not need to innovate due to lack of interest or because of recent innovation activity, thus, in principle, they will not experience obstacles to innovation. However, firms might also decide that they need or are willing to innovate and invest in innovation (potential innovators), but fail to introduce a new product/process (failed innovators). In other cases, the firm might decide to innovate and devote financial resources to innovation activity, and manage to introduce a new output (innovators).[9]

Some of the most recent contributions selected their samples (of firms willing to innovate and potentially failed by the presence of obstacles) more carefully, and obtain the expected signs (Mancusi and Vezzulli, 2014; Blanchard et al., 2013).

Most of this work focuses on the financial constraints to innovation and treat non-financial constraints as controls (Tiwari et al., 2008; Mancusi and Vezzulli, 2014; Blanchard et al., 2013). Despite acknowledging the fundamental – possibly exacerbating – effect of other types of obstacles, *indirectly* on financing difficulties and *directly* on the firm's innovation

[9] These alternative scenarios are depicted in Figure 1.

intensity, none of these contributions provides a detailed, comparative picture of other systemic sources of innovation failure.[10]

The present work provides a comparative assessment of the effect of the perception of different types of barriers on the propensity to innovate. It tries to rebalance the role of market structure, demand and knowledge vis à vis finance only, on limiting the ability of firms – including those with adequate finance – to complete innovation successfully. In our view, an evidence-based distinction between the characteristics of those firms not willing to innovate and those firms willing to innovate, and the effect on innovation and failure to introduce new products, are crucial for targeted policy interventions.

3. Data and methodology

3.1 Dataset and identification of the relevant sample

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

The dataset comprises a set of general information (main industry of affiliation, turnover, employment, founding year)[11] and a (much larger) set of innovation variables

[10] Exceptions are Iammarino et al., 2008 and D'Este et al., 2012, which, however, both focus on the factors affecting the *perception* of obstacles, rather than their impact on innovation performance.
[11] This additional information was drawn from the UK Business Structure Database.

measuring the firms' engagement in innovation activity, economic and non-economic measures of the effects of innovation, subjective evaluations of factors hampering or fostering innovation, participation in cooperative innovation activities and some complementary innovation activities such as organisational change and marketing.[12]

The survey sampled 28,000 UK enterprises in each wave with a relatively high response rate (58% for UKIS 4, 53% for UKIS 5, 51% for UKIS 6 and 50% for UKIS 7) that leads to a whole sample of 59,940 observations (40,709 firms observed for 1 up to 4 years).[13]

After excluding those firms operating in the primary and construction sectors (5,695 firm-year observations) and those with missing values in the variables used for our analysis (16,513 firm-year observations), we are left with a pooled sample of 37,732 firm-year observations.

In line with the discussion in the previous section and Figure 1, we filter out firms that are not willing to innovate, and focus on the relevant sample of potential innovators. That is, we exclude firms that, by inference, can be defined as *not innovation oriented* by filtering out 9,059 firm-year observations referring to firms that by deliberate choice had not introduced a product and/or process innovation and were not in process of doing so (see Appendix Table A3). These are also firms that that did not experience any barrier to innovation (i.e., had not experienced any of the 10 obstacles included in the question on barriers, see Appendix Table A1) regardless of whether they had invested or not in any innovation activities.[14] This resulted in a final sample of 28,673 firm-year observations (the "relevant sample") of so-called *potential*

[12] Information on group belonging and public financial support for innovation is not available due to slight changes to the questionnaire designs across the 4 surveys.
[13] Since CIS data are collected retrospectively (innovating over the past three years), the 9 years period pertaining to the four different surveys allows us to have data just for four time periods.
[14] A specific question in the CIS questionnaire refers to the willingness/not willingness to innovate (see table A2). Although this could have straightforwardly been used to select out the not-innovation oriented firms, the variables referred to this question are affected both by inconsistency in the response patterns (i.e. firms that have answered to the question but that have also reported to have introduced product or process innovations) and the presence of several missing values (no answer). We have therefore chose to select out the "not-innovation oriented" firms according to the (more consistent) strategy illustrated here.

innovators, that is, firms willing to innovate. The willingness to innovate is measured as having introduced a new product/process (i.e., positive response to at least one of the three questions in Appendix Table A3) or engaged in innovation activity (investment) while also experiencing at least one of the barriers to innovation.

Within the sample of potential innovators, we can distinguish firms (15,576 firm-year observations) that had embarked on or were engaged in an ongoing innovation project, or had introduced a new or significantly improved product or process, regardless of whether they had experienced (or not) any barriers to innovation (*innovators*) from those firms (13,097 firm-year observations) that had not managed to translate innovation inputs into a new marketable product/process (*failed innovators***)**.

Figure 1 depicts possible scenarios based on the firm's innovation decision process and the role played by the obstacles to innovation; it shows the sample size of each group of firms.

< INSERT FIGURE 1 >

Table 1 presents the composition of the panel, distinguishing between the total and the relevant sample. About 67% of the 25,997 firms included in the final sample are observed for just one period; around 22% are observed for two periods; and a negligible percentage of firms (1.5%) are observed for the entire four-year reference period. No particular differences are observed between the two panels (total and relevant samples) for the percentage of firms observed each year.

< INSERT TABLE 1 >

3.2 Econometric strategy and variables

We analyse the impact of different types of obstacles to innovation on the firm's propensity to innovate.[15] In doing so we consider the following equation:

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

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

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

The firm's propensity to innovate is affected also by the market structure and market competitiveness. Thus, a firm operating in an international context should be more likely to engage in innovation activity because of the high level of competition characterising the global arena (e.g., Archibugi and Iammarino, 1999; Narula and Zanfei, 2003). Accordingly, we use a binary indicator of international competition (Exporter), which equals 1 if the firm's most significant export market is international, and 0 otherwise.

[15] Recall that we are interested in innovation outputs (i.e. new introduced or developed product or process) rather than inputs (i.e. investment activities).

As suggested by Piva and Vivarelli (2009), higher skilled human resources can be related to a higher propensity to innovate. Skilled compared to unskilled workers are more able to deal with complexity and are more successful at exploiting innovative ideas (Song *et al.*, 2003). Therefore, we include a variable to proxy for the proportion of the firm's high skilled employees (engineers and graduates) (*higher education*).

The occurrence of other forms of innovation and, particularly those involving changes to the firm's organisational structure, have been shown to complement more traditional sources of innovation (see Bresnahan *et al.*, 2002; Hitt and Brynjolfsson, 2002). Thus, we expect a positive impact of the binary variable *organisation*, which measures the effect of the implementation of major changes to the firm's organisational structure on the firm's probability to engage in innovation.

We also use firm age (in natural logarithm) to control for age related effects. We do not hypothesise about the possible effect of firm age on the probability to innovate because there is no consensus on this in the literature. Keppler (1996) proposes a theoretical model which shows that the number of innovations per firm at a given moment is higher, the younger the firm. This should imply a negative relationship between firm age and its probability of innovating. However, Galande and De la Fuente (2003) point out that firm age can also proxy for the firm's knowledge and experience accumulated over time and, consequently, should be positively related to innovation. In order to check for possible nonlinearity effects, and in line with some recent contributions (Bertoni and Tykvovà, 2015), we also consider the squared values of this variable.

We consider the variable i*nnovative expenditure (turn)* to measure the firm's total innovation expenditure normalised by total turnover.

In addition, all the specifications include time dummies to take account of possible business cycle effects, and regional dummies in order to control for unobserved heterogeneity

across different UK regions. Finally, we control for the specific sector and the technological factors affecting the firm's propensity to introduce a new product/process, by including a complete set of industry dummies. Appendix Tables A4 and A5 present the sectoral composition and average employment for the total sample, and the sub-samples of potential innovators, failed innovators, innovators and non-innovation oriented firms. From a descriptive point of view, no particular differences emerge among the different groups of firms.

The vector Z_{it} in equation (1) includes four different dummies variables, for those firms facing at least one within the following groups of obstacle to innovation: 1) financial obstacles; 2) knowledge obstacles; 3) market obstacles; and 4) regulatory obstacles (see Appendix Table A6 for a detailed description of the variables employed in the empirical analyses and their definition) [16].

As mentioned in Section 2, in the contributions to the work on barriers the expected signs are not always confirmed. However, D'Este et al. (2014) find that human capital has a significant role in attenuating barriers related to skills shortages and market uncertainties. In line with some empirical contributions (Cainelli et al., 2006; Piva and Vivarelli, 2007; García-Quevedo et al., 2016) we would expect also that a perception of a reasonable degree of certainty on customers' responses to new products, and a dominant position in the market would reduce the market-related barriers to the propensity to innovate. Also, based on the findings in Iammarino et al., (2009) and D'Este et al. (2008, 2012) we expect that the need to meet both national and European regulation leads to a lower propensity to innovate.

[16] Appendix Table A1 shows that the respondents to the UKIS questionnaire are asked about their perception of the degree of importance (low, medium, high) of each barrier. Although this additional information would allow more detailed analysis, the self-reported nature of the responses casts doubt on their reliability. However, as a robustness check, we estimate equation (1) considering two alternative definitions of the innovation obstacles variables (perception of high, high-medium degree of importance). The results, which are available upon request, are consistent with those discussed in Section 4.4. Also, we have chosen to focus on the four binary variables that identify those firms that have experienced at least one within each of the four groups of obstacles to innovation in the form of financial, knowledge, market and regulation. The appropriateness of this choice is confirmed by the results (available upon request) of a polychoric factor analysis performed on the single barriers.

3.3 Descriptive evidence

Tables 2 and 3 present the descriptive statistics for the variables of interest computed according to the different categories of firms.

< INSERT TABLE 2 >

< INSERT TABLE 3 >

Table 2 shows that firm expenditures on innovation for the group of innovators is more than double the level of expenditure on innovation reported by the group of failed innovators.[17] There are also notable differences among the firm categories for the other variables of interest. Innovator firms are more oriented to export, more prone to implement organizational changes and hire more highly educated people than the categories failed and non-innovation oriented firms. The values of an ANOVA test (reported in Table 4) confirm the statistical significance of these differences among the three groups of firms.

< INSERT TABLE 4>

The lower part of Table 2 shows that the percentage of firms that have experienced obstacles to innovation is always high, with values ranging from 64% for regulatory obstacles, to 87% for financial obstacles. In addition, the percentage of firms experiencing different obstacles to innovation differs significantly between the groups of innovators and failed

[17] Due to the specific design of the UKIS questionnaire, non-innovative firms are also required to respond to the innovation inputs questions. Therefore, some of the non-innovation oriented firms in our sample show positive expenditure on innovation activity (see also fn. 3).

innovators, for all the obstacles items except market obstacles (see Table 5 which presents the results for the standard errors and level of significance of a mean comparison t-test).

< INSERT TABLE 5>

Table 2 shows also that, for knowledge and market obstacles, on average, the group of failed innovators experiences slightly lower barriers to innovation than the group of innovators. This initially puzzling result may be related to the relevant characterisation, originally proposed by D'Este et al. (2012), according to which obstacles to innovation can have two distinct types of effect on firms' innovation behaviour, namely a deterring or a revealed effect. More specifically, the different obstacles to innovation, apart from preventing the firm from engaging in innovation (deterring effect), might also significantly slow the firm's innovation process (revealed effect). Accordingly, there is no a priori reason to expect that the occurrence of obstacles to innovation is more frequent among failed innovators than innovators.

4. Econometric results

In this section we provide multivariate evidence of the effect of the different obstacles to innovation on the firm's propensity to introduce innovative products and/or processes. We estimate equation 1 by applying a pooled probit model with standard errors clustered at firm level.[18]

Table 6 reports the marginal effects of the explanatory variables on our dependent variable. We show the importance of appropriately defining the relevant sample, and correcting for potential selection bias caused by the specific design of the CIS questionnaire. We estimate

[18] Although our dataset would allow application of panel data estimation methods, the particular nature of these data led to our choice to use pooled data and to estimate a simple probit model with clustered standard errors. Table 1 shows that the longitudinal dimension of our data is limited, with almost 70% of our sample observed in only 1 year, and most of the other 30% in only 2 years. As a robustness check, we repeated the analysis by applying a random effects probit model. The results of the estimations, are available upon request and are largely in line with those reported in Table 6.

the model considering both the relevant sample (columns 1-3) and the whole sample (columns 4-6). We test the robustness of our results by considering three different specifications. First, we estimate a baseline model which includes the four obstacles variables and the main control variables (columns 1 and 4), and then consider two additional models (columns 2 and 3) with the variables ln(Age squared) and Innovation exp. (turn) added successively.

In the estimation results obtained considering the relevant sample (columns 1-3), we notice that, in three out of four cases, the estimated coefficients of the obstacles variables show a highly significant hindering effect on the firm's propensity to be an innovator. Knowledge obstacles is the only category that does not show a significant relationship with the dependent variable. However, the results in column 1 suggest that the presence of financial obstacles significantly reduces the firm's probability to translate innovative efforts into innovation output by 7%. Similarly, firms experiencing market-related obstacles are 4.7% less likely to introduce any kind of innovative product or process, than those firms that do not experience this impediment. Finally, regulatory barriers significantly reduce the firm's propensity to introduce an innovative product and/or process, by 2.6%; these results are robust across different specifications (see Table 6 columns 2 and 3).

To ascertain whether or not the observed differences in the magnitude of the marginal effects of these three obstacles variables are statistically significant, we perform a series of Wald tests, which consider the marginal effects reported in Table 6 column 1. The results of the tests do not suggest any statistically significant differences between financial and market related factors (p-value of the Wald test: 0.125) or between market related obstacles and regulatory obstacles (Wald test p-value is 0.14). However, the impact of financial obstacles on firms' propensity to introduce an innovative product and/or process appears to be significantly higher than the impact of regulation (Wald test p-value: 0.001).

Overall, this evidence calls for a more extended empirical analysis of the role of non-financial barriers since lack of finance does not seem to be the only problem suffered by failed innovators. Other systemic barriers to innovative performance emerge as being equally important for affecting firm behaviour and innovation success, although they are more difficult to analyse.

The other regressors show the expected signs for all the traditional determinants of innovation activities. Specifically, larger firms, firms that introduced organisational changes and are more oriented to international markets, are more likely to translate their innovative efforts into innovative outputs. Also, as expected, those firms with more highly qualified staff, and firms reporting more intensive innovative efforts, seem more likely to introduce innovations to the market (see column 3). Although not all of the literature agrees, our results seem to support those studies that find that younger firms are more likely than their mature counterparts to develop innovative products and/or processes, although the variable age turns out to be insignificant when we consider its squared value (see Table 6 column 2).

Finally, the p-values of the Wald tests reported in the lower part of Table 6 confirm the importance of controlling for sectoral, geographic and time fixed effects. Indeed, the null hypothesis that the regional, sectoral and time dummies are jointly equal to zero is always rejected.

It is worth a brief comment on the results reported in Table 6 columns 4-6, for the total sample, which includes the 9,059 firm-year observations referring to the sample of non-innovation oriented firms. It can be seen that the signs and the coefficients of the different obstacles to innovation are in line with the counterintuitive findings in most of the studies mentioned in Section 2.2. Indeed, all the obstacles variables have a positive and highly significant impact on the firm's propensity to innovate. This evidence demonstrates the

importance of correcting for the selection bias in CIS-based studies of the barriers to innovation.

< INSERT TABLE 6 >

6. Conclusions and policy implications

This paper adds to the conceptual and empirical literature on the barriers to innovation and provides information for policy makers by presenting an in-depth, unbiased picture of the main financial and non-financial barriers to firms' abilities to translate innovation efforts (inputs) into successful innovations (outputs).

We add to the work of Savignac (2008) and D'Este et al. (2008, 2012) and identify a 'relevant sample' of potential innovators vis à vis non-innovation oriented firms, on the basis of their self-declarations about their willingness to innovate. We claim and demonstrate empirically that, in the context of assessing the effect of the barriers to innovation, it is important to filter out those firms that are not willing or do not need to innovate (non-innovation oriented) from those that choose to devote financial resources to innovation, but do not manage to produce an innovation (failed innovators) due to the barriers to innovation.

We confirmed our a-priori classification by testing the effect of potential (which engage in at least one innovative activity) innovators' perception of the relevance of different obstacles to innovation on their propensity to innovate. Specifically, we predicted and test the conjecture that non-financial (market structure, demand, knowledge) obstacles to innovation are at least as important as financial barriers for affecting innovation propensity.

We found that market related barriers, such as a concentrated market structure and lack of or sluggish demand from consumers, are as important hindrances for firms as financial constraints, which are emphasised in most of the traditional literature using cash-flow models.

We found also that regulation significantly and negatively constrains firms' innovation propensity. In comparative terms, we found support for our initial conjecture that financial constraints are as important as market obstacles for affecting innovation (performance) success, and are more important than regulatory factors.

This evidence is consistent with most of the literature on finance and innovation, for instance, studies of venture capital and innovation, which find that venture capital investments and the frequency with which firms use this type of selective and competitive external financial resource, are generally associated to high innovation potential (Casamatta, 2003; Arqué-Castells, 2012; Bertoni et al., 2015). However, the presence of adequate demand for innovative product is not necessarily guaranteed.

Although we focus on a specific country and use self-reported responses from firms, our results allow us to conclude that it is important for policy aimed at supporting innovation, to focus on both increasing liquidity via R&D tax credits and similar tools, and a policy platform that includes competition and demand-related instruments. The current economic downturn, which has increased unemployment and resulted in poor demand dynamics, has reduced the incentives for firms to invest in innovation (for a discussion, see Archibugi and Filippetti, 2011).

The type of analysis conducted here and the data at our disposal do not allow more than these general comments on the economic downturn. Further corroboration of our findings will require a more in depth analysis of targeted demand-side innovation policy and a rebalancing of the supply-bias in innovation policy, with a greater focus on the demand-side (Edler and Georghiou, 2007). There has been some interest in demand-side innovation policy (OECD, 2011; see also Uyarra, 2013; Uyarra et al., 2014). However, most of this literature is interested in the role and efficacy of public procurement, beyond traditional supply-side policies such as R&D tax credits and standards. Some scholars have suggested user-led innovation initiatives,

lead-market policies and the role of intermediates to ensure the success of public procurement (Uyarra et al., 2014; Edler and Yeow, 2016). There seems to be a consensus on the positive role of public procurement for overcoming systemic failures and creating a critical mass of selective demand for innovation, which, in some contexts, stimulates firms' efforts (Uyarra et al., 2014). Our findings support the need for carefully articulated use of public procurement of innovation.

Regulation constraints, which we found significantly affecting the propensity to innovate although less so than financial constraints, should be considered as a potential area for intervention. However, more in depth investigation of the nature of these types of constraints is required and, possibly, from a qualitative perspective. The effect of regulation barriers might be sector-specific, with firms operating in highly regulated markets (i.e. pharmaceuticals, biotechnology) perceiving regulation as a constraint, but in some cases also an incentive to innovate and catch up to the technological frontier. Research on the effects of regulation would be an interesting area for future research, although CIS data on this area are usually not comparable across countries.

For knowledge related barriers, the evidence varies. Lack of adequate human capital and knowledge about technologies are consistently not significant. This result can be interpreted from a comparative perspective. In the context of the recession, it seems that asymmetric information on technological opportunities or lack of adequate human capital have no significant constraining effect on firms' innovation propensity, whereas lack or uncertainty of demand, and lack of finance do. It might be that the UK context is less prone to suffer from a shortage of skilled human capital and skills mismatches than stagnant demand and, especially in the context of the propensity to introduce incremental (new to the firm) and process innovations alongside radical (new to the market) products.

Another interesting area for future study would be to examine the differential effect that different obstacles have on the introduction of incremental and radical innovation. Policymakers should build on this evidence when prioritizing interventions aimed at strengthening the innovation capacity of the population of potential innovators, by removing or alleviating the obstacles affecting firms who do not manage to translate financial efforts devoted to innovation projects, into marketable new products/processes.

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Figure 1. Selection of the relevant sample: the role of obstacles along the innovation process

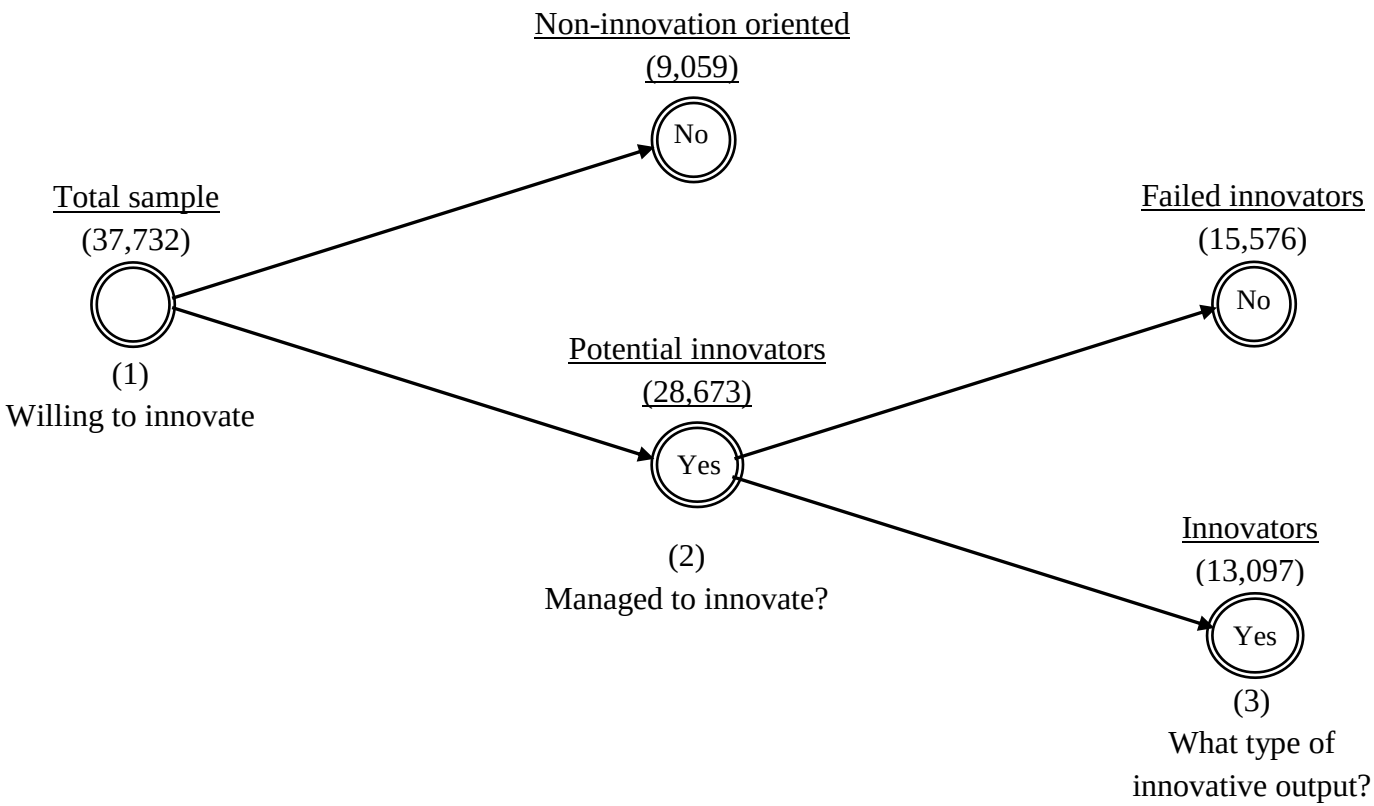

Table 1. Structure of the panel: Full sample and relevant sample (potential innovators)

	FULL SAMPLE			RELEVANT SAMPLE		
Time Obs.	N. of firms	%	N. of obs.	N. of firms	%	N. of obs.
1	17,511	67.36	17,511	14,884	71.58	14,884
2	5,627	21.64	11,254	4,153	19.97	8,306
3	2,469	9.50	7,407	1,541	7.41	4,623
4	390	1.50	1,560	215	1.03	860
Total	25,997	100	37,732	20,793	100	28,673

Table 2. Descriptive statistics: mean and standard deviation (overall) in total sample, potential innovators, failed innovators, innovators and non-innovation oriented firms

	Total Sample		***Pot. Innovators***		***Failed Innov.***		***Innovators***		***Not Inno. Or.***	
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*
Explanatory variables										
ln(Age)	2.88	0.67	2.89	0.66	2.90	0.66	2.88	0.65	2.87	0.70
Ln(Age sq.)	8.75	3.41	8.76	3.38	8.83	3.39	8.71	3.37	8.70	3.50
Exporter	0.38	0.49	0.43	0.49	0.31	0.46	0.53	0.50	0.23	0.42
Higher Education	15.81	25.89	17.57	26.72	13.42	24.01	21.07	28.34	10.21	22.12
Innovation expenditure (turn)	0.75	1.06	0.91	1.12	0.53	0.85	1.24	1.21	0.24	0.61
Organization	0.25	0.43	0.30	0.46	0.18	0.39	0.39	0.49	0.08	0.27
ln (Size)	4.15	1.49	4.21	1.49	4.08	1.45	4.31	1.52	3.99	1.46
Obstacles to innovation										
Financial obstacles	0.66	0.47	0.87	0.34	0.87	0.33	0.86	0.34	0	0
Knowledge obstacles	0.60	0.49	0.79	0.41	0.78	0.42	0.81	0.40	0	0
Market obstacles	0.61	0.49	0.81	0.40	0.80	0.40	0.81	0.40	0	0
Regulation barriers	0.49	0.50	0.64	0.48	0.65	0.48	0.64	0.48	0	0
N. of Observation	37,732		28,673		13,097		15,576		9,059	

Table 3. Descriptive statistics: standard deviation (between and within) total sample, potential innovators, failed innovators, innovators and non-innovation oriented firms

	Total Sample		***Pot. Innovators***		***Failed Innov.***		***Innovators***		***Not Inno. Or.***	
	St. Dev		*St. Dev*		*St. Dev*		*St. Dev*		*St. Dev*	
	Between	*Within*	*Between*	*Within*	*Between*	*Within*	*Between*	*Within*	*Between*	*Within*
Explanatory variables										
ln(Age)	0.70	0.08	0.68	0.08	0.67	0.06	0.68	0.07	0.71	0.05
Ln(Age sq)	3.50	0.39	3.45	0.36	3.44	0.28	3.43	0.32	3.55	0.25
Exporter	0.47	0.15	0.48	0.14	0.46	0.10	0.49	0.12	0.41	0.09
High Education	25.22	9.32	26.04	8.71	24.06	6.37	27.90	7.67	21.98	6.05
Innovation expenditure (turn)	1.03	0.44	1.09	0.43	0.85	0.29	1.19	0.39	0.60	0.19
Organization	0.40	0.21	0.42	0.21	0.39	0.14	0.46	0.20	0.27	0.08
ln (Size)	1.45	0.15	1.47	0.14	1.45	0.09	1.50	0.13	1.45	0.10
Obstacles to innovation										
Financial obstacles	0.44	0.22	0.32	0.16	0.32	0.12	0.33	0.13	0	0
Knowledge obstacles	0.45	0.23	0.39	0.19	0.40	0.15	0.39	0.15	0	0
Market obstacles	0.45	0.23	0.38	0.18	0.38	0.14	0.46	0.19	0	0
Regulation barriers	0.46	0.24	0.45	0.22	0.46	0.16	0.46	0.19	0	0
N. of Observation	37,732		28,673		13,097		15,576		9,059	

Table 4. Analysis of Variance (ANOVA) test of the main explanatory variables among innovators, failed innovators and non-innovation oriented firms

	Innovators *vs* failed innovators	Innovators *vs* non-innov. oriented	Failed inn. *vs* non-inn. oriented
Explanatory variables			
ln(Age)	-0.02*	0.01	0.03*
ln(Age sq.)	-0.12*	0.01	0.12*
Exporter	0.22*	0.30*	0.09*
High Education	7.65*	10.85*	3.20*
Innovat. exp (turn)	0.71*	0.99*	0.29*
Organisation	0.21*	0.31*	0.10*
ln (Size)	0.23*	0.32*	0.09*

Notes: Because of the unequal group sample sizes, the significance of the difference in the average level of the explanatory variables among the three different groups was evaluated by applying the post hoc pair comparison of mean differences (Tukey/Kramer method) (Hinkle et al., 1994). The pairwise comparisons is based upon the studentised range distribution (* indicates significance at 5%)

Table 5. T-test of the obstacles to innovation variables between innovators and failed innovators

	Innovators *vs* failed innovators	
Financial obstacles	-0.01**	(0.004)
Knowledge obstacles	0.03***	(0.005)
Market obstacles	0.01	(0.005)
Regulation obstacles	-0.01**	(0.006)

Notes: *****, **** and * indicate significance at the 1%, 5% and 10% levels, respectively. T statistics in brackets

Table 6. Probit estimations (marginal effects) of the likelihood of being an innovator (relevant sample and full sample)

	Relevant Sample			Full sample		
	(1)	(2)	(3)	(4)	(5)	(6)
Financial Obstacles	-0.070***	-0.070***	-0.091***	0.211***	0.211***	0.180***
	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)	(0.010)
Knowledge Obstacles	0.015	0.015	0.006	0.091***	0.091***	0.081***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Market Obstacles	-0.047***	-0.047***	-0.049***	0.071***	0.071***	0.066***
	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)	(0.010)
Regulation obstacles	-0.026***	-0.026***	-0.031***	-0.013*	-0.013*	-0.019**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Exporter	0.137***	0.137***	0.121***	0.132***	0.132***	0.117***
	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)
High Education	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Organisation	0.234***	0.234***	0.206***	0.235***	0.235***	0.207***
	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)
ln (Size)	0.018***	0.018***	0.030***	0.013***	0.014***	0.025***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
ln(Age)	-0.029***	-0.020	-0.004	-0.027***	0.002	0.010
	(0.005)	(0.031)	(0.032)	(0.005)	(0.027)	(0.028)
ln(Age squared)		-0.002	-0.002		-0.006	-0.005
		(0.006)	(0.006)		(0.005)	(0.005)
Innovation exp. (turn.)			0.147***			0.147***
			(0.005)			(0.004)
Wald test Year	0.000	0.000	0.000	0.000	0.000	0.000
Wald test Reg.	0.005	0.005	0.015	0.000	0.000	0.000
Wald test Sect.	0.000	0.000	0.000	0.000	0.000	0.000
Obs.	28,673	28,673	28, 673	37,732	37,732	37,732
Log likelihood	-17,576.030	-17,575.984	-16,625.383	-20,210.155	-20,209.553	-19,050.354

Notes: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. Robust standard errors in brackets clustered at firm level (calculated using the delta method). In all the specifications, the dependent variable is a dummy that takes the value 1 if the firm can be defined as an innovator.

Appendix

Table A1. CIS questionnaire: barriers to innovation

During the three year period ---- how important were the following factors as constraints on your innovation activities or as an influence on the decision to innovate?

Barrier factors	Barrier items	Factors not experienced	Degree of importance		
			Low	Med.	High
Financial obstacles	Excessive perceived economic risks	☐	☐	☐	☐
	Direct innovation costs too high	☐	☐	☐	☐
	Cost of finance	☐	☐	☐	☐
	Availability of finance	☐	☐	☐	☐
Knowledge obstacles	Lack of qualified personnel	☐	☐	☐	☐
	Lack of information on technology	☐	☐	☐	☐
	Lack of information on markets	☐	☐	☐	☐
Market obstacles	Market dominated by established enterprises	☐	☐	☐	☐
	Uncertain demand for innovative goods or services	☐	☐	☐	☐
Regulation obstacles	Need to meet EU/UK Government regulations	☐	☐	☐	☐

Table A2. CIS questionnaire: Enterprise with no innovation activity.

If your enterprise had no innovation activities during the three-year period ----, please indicate why it was not necessary or possible to innovate:

	YES	NO
No need due to prior innovation	☐	☐
No need due to market condition	☐	☐
Factor constraining innovation	☐	☐

Table A3. CIS questionnaire (innovation output questions)

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

Table A4 Sectoral composition and average employment - full sample and potential innovators

	Full Sample		*Pot. Innovators*	
	N	Av. Em.	N	Av. Em.
Manufac. of food products	1,210	348	1,053	377
Manufac. of textiles	333	117	273	127
Manufac. of wearing apparel	173	66	139	68
Manufac. of leather and leather products	41	96	38	92
Manufac. of wood and cork (exc. furniture)	455	77	368	87
Manufac. of paper and paper products	346	146	288	159
Manufac. of print materials and reproduction of recorded media	1,011	171	841	184
Manufac. of coke, refined petroleum	20	349	17	388
Manufac. of chemicals and chemical products	470	311	430	311
Manufac. of rubber and plastic products/refined petroleum	860	147	741	154
Manufac. of other metallic mineral products	432	200	348	213
Manufac. of basic metals	229	264	184	297
Manufac. of fabricated metal products	1,728	68	1,354	75
Manufac. of machinery and equipment n.e.c.	1,090	158	953	163
Manufac. of computer electronic and optical products	86	229	73	224
Manufac. of electrical equipment	626	157	538	170
Manufac. of radio, TV and communications equipment	312	196	292	203
Manufac. of medical and optical instruments	588	134	536	140
Manufac. of motor vehicles, trailers	647	258	560	264
Manufac. of other transport equipment	342	486	269	524
Manufac. of furniture	1,013	99	869	107
Recycling	183	74	142	84
Wholesale retail and repair of motor vehicles	1,209	286	764	287
Wholesale trade except motor vehicle	2,517	232	1,910	221
Retail trade except motor vehicles	3,127	584	2,028	694
Hotels and similar accommodation	2,535	515	1,648	643
Transport, storage, communications	1,669	219	1,178	248
Water transport	69	148	46	160
Air transport	51	555	36	685
Transport support activities	942	282	678	278
Post and telecommunications	693	298	546	353
Financial services activities except insurance	329	605	254	730
Insurance reinsurance and pension funds	162	559	135	531
Activities auxiliary to financial services	943	188	721	202
Real estate activities	1,451	184	935	212
Renting of machinery and equipment	795	133	555	149
Computer programming and consultancy	1,313	226	1,176	236
Scientific research and development	573	142	501	147
Other business activities	6,912	375	5,083	375
Sewage and refuse disposal	34	64	30	48
Recreational, cultural and sporting activities	213	40	143	45
	37,732	289	28,673	304

Table A5 Sectoral composition and average employment: Failed innovators, innovators and non-innovation oriented firms

	Innovators		*Failed Innov*		*Not Inno. Or.*	
	N	Av. Em.	N	Av. Em.	N	Av. Em.
Manufac. of food products	692	446	361	245	157	151
Manufac. of textiles	162	151	111	92	60	73
Manufac. of wearing apparel/leather	115	82	70	93	37	85
Manufac. of wood and cork (ecx. furniture)	195	108	173	65	87	35
Manufac. of paper and paper products	167	174	121	138	58	82
Manufac. of print. Mater. and reproduction of rec. media	491	195	350	170	170	103
Manufac. of chemicals and chemical prod	341	334	89	223	40	320
Manufac. of rubber and plastic products/refined petrol.	512	202	246	390	122	112
Manufac. of other metallic mineral products	217	247	131	156	84	148
Manufac. of basic metals	102	375	82	199	45	133
Manufac. of fabricated metal products	714	86	640	62	374	45
Manufac. of machinery and equipment n.e.c.	626	196	327	98	137	125
Manufac. of computer electronic and optical products	60	258	13	65	13	257
Manufac. of electrical equipment	371	201	167	102	88	75
Manufac. of radio, TV and communications equipment	229	221	63	139	20	95
Manufac. of medical and optical instruments	423	159	113	69	52	70
Manufac. of motor vehicles, trailers	355	312	205	181	87	221
Manufac. of other transport equipment	165	750	104	165	73	345
Manufac. of furniture	532	117	337	91	144	55
Recycling	70	94	72	74	41	41
Wholesale retail and repair of motor vehicles	282	319	482	268	445	284
Wholesale trade except motor vehicle	982	263	928	176	607	268
Retail trade except motor vehicles	770	1194	1,258	388	1,099	380
Hotels and similar accommodation	655	876	993	489	887	276
Transport, storage, communications	395	332	783	206	491	148
Water transport	26	146	20	179	23	125
Air transport	17	1111	19	303	15	243
Transport support activities	328	283	350	273	264	291
Post and telecommunications	317	375	229	321	147	94
Financial services activities except insurance	174	948	80	256	75	179
Insurance reinsurance and pension funds	88	712	47	192	27	702
Activities auxiliary to financial services	407	274	314	109	222	141
Real estate activities	400	278	535	163	516	134
Renting of machinery and equipment	230	202	325	112	240	96
Computer programming and consultancy	918	217	258	303	137	145
Scientific research and development	400	161	101	92	72	104
Other business activities	2,558	409	2,525	341	1,829	376
Sewage and refuse disposal	90	50	75	37	74	185
	15,576	353	13,097	246	9,059	242

Notes: Due to the paucity of observations, for confidentiality reasons, figures referring to the 'Recreational, cultural and sporting activities, sector are not reported.

Table A6. The variables: acronyms and definitions.

Variables identifying the different sub-samples of firms according to our definitions	
Potential innovators	Dummy =1 if firm is a potential innovator (whether it has engaged in innovation activities and/or has experienced any barrier to innovation activities during the 3-year period), and 0 otherwise.
Innovators	Dummy =1 if firm has introduced new or significantly improved products/processes or has any innovation activities that had abandoned or which were ongoing at the end of the 3-year period, and 0 otherwise.
Failed Innovators	Dummy =1 if firm wanted to innovate, but did not manage to do so because of barriers to innovation activity during the 3-year period, and 0 otherwise.
Not-Innovation Oriented	Dummy =1 if firm has no innovative activities and did not experience any barriers to innovation during the 3-year period, and 0 otherwise.
Explanatory variables	
ln (Age)	Natural logarithm of firm age.
Exporter	Dummy =1 if the firm has traded in an international market during the 3-year period, and 0 otherwise.
High education	Ratio of highly educated personnel in total employment (figures refer to the last year in each of the 3-year periods).
Innovative exp. (turn)	Total amount of the firm's investment in innovation activity normalised by total turnover.
Organization	Dummy=1 if the firm has implemented major changes to its organisational structure (e.g. introduction of cross-functional teams, outsourcing of major business functions) during the 3-year period, and 0 otherwise.
ln (Size)	Log of the total number of the firm's employees (figures refer to the last year in each of the 3-year periods).

Table A6 (continued). The variables: acronyms and definitions.

Obstacles to innovation	
Excessive perceived economic risks	Dummy=1 if the firm faced excessive perceived economic risks during the 3-year period, and 0 otherwise.
Too high innovation costs	Dummy=1 if the firm faced too high innovation costs, and 0 otherwise.
Costs of finance	Dummy=1 if the cost of finance was an obstacle, and 0 otherwise.
Availability of finance	Dummy=1 if the firm was deterred by the availability of finance, and 0 otherwise.
Lack of qualified personnel	Dummy=1 if the firm was deterred by lack of qualified personnel, and 0 otherwise.
Lack of information on technology	Dummy=1 if the firm faced a lack of information on technology and 0 otherwise.
Lack of information on markets	Dummy=1 if the firm faced a lack of information on markets, and 0 otherwise.
Market dominated by established enterprises	Dummy=1 if the firm was faced with a market dominated by established enterprises, and 0 otherwise.
Uncertain demand for innovative goods or services	Dummy=1 if the firm faced uncertain demand for innovative goods or services, and 0 otherwise.
Regulation obstacles	Dummy=1 if the firm saw regulation as an obstacle to innovation, and 0 otherwise.