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Is money all? Financing versus knowledge and demand constraints to innovation.

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Abstract

The paper adds to the scattered empirical evidence on the role of obstacles to innovation in a three-fold way. First, we correct for the usual sample selection bias by filtering out firms not interested in innovation from ?potential innovators?. We then analyse the impact of obstacles on the translation of firms? engagement in innovative activities onto actual innovative outputs. Second, we assess what mostly affects firms? rate of failure in this process, whether finance or, rather, knowledge or demand-related constraints. Third, we do so in a panel framework, which allows to account for endogeneity and firms? unobserved heterogeneity through individual effects.
We find that demand- and market-related factors are as important as financing conditions in determining firms? innovation failures. This evidence puts much of the latest obsession on finance in perspective and brings back into the picture traditional demand and market structure arguments of why firms fail to innovate. The empirical analysis is based on an unbalanced panel of firm data from four waves of the UK Community Innovation Survey (CIS) between 2002 and 2010 merged with the UK Business Structure Database.

Jelcodes:C23,O31

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Keywords: Barriers to innovation, Innovative firms, Potential Innovators
JEL Classification: C23 O31 032 033

1. Introduction

Recent empirical innovation literature has devoted an increasing attention to the perception of (mainly financial) obstacles to innovation and their deterring impact on firms' decisions to engage in innovation activity, the intensity of this engagement and the propensity to innovate (among others, and more in detail in Section 2, 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, 2010).

Assessing the actual impact of obstacles on the innovation failure/success rate is of obvious policy relevance, as removing or alleviating hindrances might be an effective device to enlarge the population of innovators and increase the innovation performance of the existing base of innovators (D'Este et al., 2008 and 2012; D'Este, Rentocchini and Jurado, 2010). However, an overwhelming majority of contributions have confined the analysis to the impact of financial obstacles. The marked emphasis on financial conditions to innovate originates from traditional cash-flow models (see Hall, 2002 for a review) – focusing on firms' financial constraints to carry out R&D investments – and most likely reflects the recent unfavorable financial downturn. Also, the implicit rationale of limiting the analysis on financial constraints is that – once ascertained that firms do not innovate because they lack liquidity or innovation costs are too high– it is straightforward to draw policy implications: financing constraints are removed or at least alleviated by pouring liquidity in the form of additional subsidies/tax credits to increase levels of (mainly R&D) investments.

However, firms might encounter different types of obstacles and persist in their systemic failure in engaging in innovation activities and/or in translating financial effort into the actual introduction of successful new goods, services and processes[1]. It is therefore all the more important for policy purposes to extend the analysis to non-financial obstacles and be

[1] From now on we refer to innovative products to indicate both innovative goods and services.

able to provide evidence on whether firms do not innovate due to the lack of appropriate information on technologies and market, or adequate skills, or, most likely in the midst of a financial crisis, because their destinations markets are sluggish in ensuring adequate levels of demand[2].

This paper aims to add to the evidence on the impact of obstacles to innovation and the implications in terms of innovation policy in four main respects.

First of all, in line with some of the most recent contributions (D'Este et al., 2008 and 2012; Savignac, 2008; Mancusi and Vezzulli, 2010) we are aware of and correct for the potential sample selection bias intrinsic to this type of analysis, by appropriately identifying the relevant sample and filtering out those firms which are not willing to innovate and therefore do not engage in any innovation activity for reasons others than obstacles. This allows overcoming the usual selection bias, which has led to the counterintuitive evidence of a positive relation between intensity of innovative investments and perception of obstacles to innovation (Mohnen and Rosa, 2000; Baldwin and Lin, 2002).

Second, this paper builds on the empirical evidence provided by D'Este et al. (2008, 2012), who distinguish between deterring and revealed barriers[3], and extend it by assessing the impact of 'revealed' barriers on the translation of innovative input into actual innovative output. In doing so, we are able to tell whether – even though firms choose to engage in innovative activities, that is they spend financial resources not only for intramural or extramural R&D but also for capital equipment, training, acquisition of know-how and

[2] Recent empirical evidence at micro and macro level on the effects of the economic downturn on innovation investments of firms and countries is provided in Archibugi and Filippetti, 2011; Archibugi, Filippetti and Frenz, 2012

[3] The distinction is based on the relation between the degree of engagement in innovation activity and the perceived importance of constraints to innovation. Deterring barriers prevent firms from engaging at all in innovation activities, while revealed barriers are experienced "in the making" of innovation and reflect firms' awareness of their constraints as a result of their engagement in innovation inputs.

marketing - the presence of barriers represents a substantial hindrance to the completion of their innovation projects and the launch of new products or processes[4].

Third, we carefully distinguish between financial and non-financial obstacles and, unlike in Tiwari et al. (2008) or Blanchard et al. (2012), we provide evidence on whether other systemic types of obstacles such as those related to access to knowledge, market structure, demand or regulations, have a similar or more important deterring effect than finance in limiting firms' ability to translate innovation activities into new outputs[5].

Fourth, we do so within a panel econometric framework, drawing on the UK CIS4 to CIS7 panel, merged with the UK Business Structure data, in order to account for usual econometric issues such as endogeneity and firms' unobserved heterogeneity. The longitudinal evidence at our disposal also allows pinning down from a descriptive point of view whether a certain degree of persistence occurs in the status of "not innovation oriented", "failed innovator" or "innovator" over time[6]. This information, coupled with the evidence on what type of barrier is most likely to affect firms' innovation status, is of uttermost importance for policy purposes, as it allows identifying the relevant areas and target population for intervention. Policy makers might prioritize the enlargement of the population of innovative-active firms (*innovation-widening)*, by removing or alleviating obstacles that prevent firms to engage in innovation activities; or strengthen the innovation capacity of the existing population of innovative-active firms (*innovation-deepening*), by removing or

[4] 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 less conservative choice of focusing on the simple introduction of a product/process new to the firms *or* new to the market.

[5] It is important to point out here (see also Section 3) that within the innovation-survey literature the term "innovation active" refers to the degree to which firms devote financial effort to innovation (innovative inputs). This does not entail that the firm has also managed to introduce a new product or process as a consequence of the innovation investments. This distinction is central to our argument and often undermined in the traditional literature on financing constraints (see Section 2.1).

[6] We fully describe the status of innovator, failed innovator and not innovation-oriented in Section 4.3.

alleviating obstacles that obstruct successful completion of innovation projects and adequate returns to innovation investments. This paper aims to provide evidence to help this type of policy choice.

The paper is structured as follows: Section 2 reviews the literature on barriers to innovation, briefly reporting the econometric issues arising from this analysis. Section 3 describes in depth the relevant variables included in the merged UK CIS4-CIS7 and BSD panel data. Section 4 illustrates the econometric strategy and the decisions undertaken to identify the relevant sample: comparison of the different estimations results shows that these are robust to the sample identified and to other selectivity issues. Other robustness checks are reverted to in the Appendix. Section 5 discusses the results, highlighting the main contributions of this analysis with respect to the existing literature. Section 6 builds upon this evidence to discuss the innovation policy implications of going beyond the financing constraints' "obsession".

2. Finance versus non-finance barriers to innovation

The literature analyzing the factors affecting firms' failure in engaging in innovation is comparatively less extended than the core body of literature focusing on factors of success (briefly reviewed in Section 4.1). This is slightly puzzling, given the policy relevance of identifying factors obstructing firms' decisions to innovate, hampering financial effort devoted to it and completion of successful innovation projects. Identifying factors of success does not implicitly entail pinning down the determinants of failure: it would be a myopic policy assumption to infer this. For instance, if large firms are more likely to introduce an innovation, this does not mean that all small firms face problems in being successful. It is therefore of uttermost importance to identify what kinds of hindrance firms meet at different

phases of the innovation cycle, i.e. in the decision to innovate, the engagement in innovation activities and the successful introduction of a new product/process. Here we systematize the few contributions that have dealt with these issues, distinguishing between financial and non-financial obstacles[7].

2.1 The origins: financing constraints and R&D investments

The large majority of contributions interested in the (direct) effect of hampering factors on innovation activity at large (including both innovation-related expenditures (inputs), and the introduction of innovation outputs) have focused on (external) financing constraints on firms' cash flow sensitivity to afford R&D investments (for a review, see Schiantarelli, 1996 and Hall, 2002; see also Bond et al., 1999 and Hottenrott and Peters, 2012). These contributions are concerned with the effect of financing constraints on the risk of a sub-optimal and welfare-reducing firms' level of investments. In particular, they all focus on investments in R&D for reasons linked to the high uncertainty, asymmetries and market complexity linked to the financial returns of R&D investments and the ability to attract external funds. Most studies test the presence of financing constraints indirectly, by looking at the sensitivity of R&D investments to changes in cash flows, as in Hall (2008). Other studies (Canepa and Stoneman, 2007; Savignac, 2008; Hottenrott and Peters, 2012) employ innovation surveys to access direct information on the perception of financing constraints by firms. Empirical findings tend to confirm that encountering financial constraints significantly lower the likelihood of firms to engage in innovative activities (Savignac, 2008) and this pattern is more pronounced in small firms and high-tech sectors (Canepa and Stoneman, 2007). Drawing on an ideal test for identifying the role of financing

[7] To some extent, this distinction overlaps with that between papers drawing or not on national and cross-country innovation surveys or with direct or indirect indicators on the experience of obstacles to innovation.

constraints put forward by Hall (2008)[8], Hottenrott and Peters (2012) find that firms with higher innovation capabilities are more likely to face financing constraints, holding equal internal availability of funds. More recently, an increasing number of contributions have relied on the use of innovation surveys to assess the relationship between the degree of engagement in innovation activities (input) and the perception of financial and non-financial constraints, briefly reviewed below.

2.2 Facing barriers, engaging in innovation activities and propensity to innovate: CIS evidence

The data provided by CIS allow enlarging the analysis on the role of obstacles in two main directions. First, it provides a *direct* indicator on the perception of obstacles to innovation, which goes beyond the financial obstacles only. This includes perception of knowledge and information-related barriers, market structure, demand and regulation obstacles. Second, it allows investigating whether this whole range of barriers affect firms' behavior at different stages of the innovation cycle, whether on the decision to innovate, the engagement in innovation activities (which go beyond the traditional R&D expenditures) and the successful introduction of a new product/process.

CIS-based literature in this field has variously explored issues of complementarities between different innovation obstacles (Galia and Legros 2004; Mohnen and Röller, 2005); the links between factors affecting the perception of the importance of different barriers to innovation (Baldwin and Lin, 2002; Iammarino et al., 2009; D'Este et al., 2012); the impact of (mainly financial) obstacles to innovation (Tourigny and Le, 2004; Savignac, 2008; Tiwari et al., 2008; Mancusi and Vezzulli, 2010; Blanchard et al., 2012).

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

Two key issues are worth mentioning here. First of all, most of the empirical findings converge in pointing to a positive relationship between engagement in innovation and perception of barriers. In this respect, Savignac (2008) and D'Este et al., (2008) identify a series of sources of potential bias, which explain the positive spurious correlation between innovation intensity and perception of obstacles and the counter-intuitive results emerging from these analyses. These sources of bias include the usual ones - such as the presence of heterogeneous unobserved firms' specific factors or the simultaneity of the status of spending for innovation projects and facing obstacles to innovation. Also, a specific source of bias is linked to an inappropriate selection of the relevant sample for the analysis, which does not distinguish between firms willing and not willing to innovate, as suggested by Savignac (2008) and D'Este et al. (2008, 2012). Building on their work, subsequent contributions have therefore carefully selected the relevant sample (of firms willing to innovate and potentially failed by the presence of obstacles) and obtained expected signs (Mancusi and Vezzulli, 2010; Blanchard et al., 2012)[9].

Secondly, also within the CIS-based literature, an overwhelming number of contributions focus on financing constraints to innovation, treating the role of non-financial ones as a simple control factor (Tiwari et al., 2008; Mancusi and Vezzulli, 2010; Blanchard et al., 2012). Despite recognizing the fundamental – possibly exacerbating – role of other types of obstacles *indirectly* on the financing ones and *directly* on the innovation intensity of firms, none of these contributions choose to provide a detail picture of other systemic sources of innovation failure[10]. This is the aimed contribution of the present work, in the belief that evidence-based awareness of the characteristics of firms not willing to innovate on the one

[9] In line with these latest contributions, in this paper we carefully identify the relevant sample by filtering out firms not willing to innovate (see Section 4.3).

[10] The only exceptions are Iammarino et al., 2008 and D'Este et al., 2012. However, they both focus on the factors affecting the perception of obstacles, rather than their actual impact on innovation performance.

hand and those of firms willing to innovate, spending in innovation and failing introduction of new products on the other hand is crucial to target policy intervention.

Policy makers might prioritize the enlargement of the population of innovators, by removing or alleviating obstacles targeted to those firms that decide not to engage in innovation activities due to barriers (for an *innovation-widening* policy strategy); and/or strengthen the innovation capacity of the existing population of innovators, by removing or alleviating obstacles affecting firms who do not manage to translate financial effort devoted to innovation projects into the actual introduction of new product/process (for an *innovation-deepening* policy strategy).

3. Data

The empirical analysis is based on firm-level data from four waves of the UK Community Innovation Survey (UKIS) for the period 2002 -2004 (UKIS 4); 2004-2006 (UKIS 5); 2006-2008 (UKIS 6) and 2008-2010 (UKIS 7). The UKIS is traditionally based on a stratified random sample (namely sector, region and size-band) drawn from the ONS (Office for National Statistics) Inter-Departmental Business Register (IDBR), and is representative at both the sector and the firm size level 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 measuring the firms' engagement in innovation activity, economic and non-economic measures of the effects of innovation, subjective evaluations of factors hampering or

[11] This additional information was drawn from the UK Business Structure Database.

fostering innovation[12], participation in cooperative innovation activities and some complementary innovation activities such as organisational change and marketing[13].

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[14]). Unfortunately, the high presence of missing values combined with the relatively short time series dimension of the panel leads to many variables being observed either never or just once for a considerable number of firms. Moreover, in line with what discussed in the previous section, filtering out the firms that are not willing to innovate and focusing on the "relevant sample" (i.e. the cohort of the so called 'potential innovators', see Section 4.3), leads to a further reduction of the sample size. Thus, the trade-off here is between applying panel econometric techniques that allow us to perform more precise estimations, though leading to a significant reduction of the sample size, or wiping out the time series dimension in favour of a higher level of representativeness of the sample used for the analyses. We choose to opt for the first option, as we prefer to prioritise taking into account the unobservable firm heterogeneity[15]. Accordingly, after dropping those firms - pertaining to both the total sample and the relevant sample - that are observed for just one year (31,577); those operating in the primary and construction sectors (2,767 observations); those with missing values in all the variables used for our analysis (9,280 observations) we ended up with an unbalanced panel of 16,316 firms-year observations. Table 1 shows that about 60% of the 6,696 firms included in

[12] The appendix reports the section of the UKIS questionnaire on barriers to innovation. These include cost, knowledge, market and regulation barriers.

[13] The information on group belongings and on public financial support for innovation are not available due to slightly changes in the questionnaire designs through the four surveys.

[14] 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.

[15] As a robustness check we estimated a pooled probit model using a sample that includes also those firms observed just for one year. The results -available upon request - are consistent (both in terms of the sign and statistical significance of the estimated coefficients) with those discussed in Section 4.4.

the final sample are observed for two periods; one third are observed for three periods while only a very negligible percentage of firms (less than 6%) are observed for the entire reference period of four years. No particular differences emerge between the two distinct panels (total and relevant sample) in terms of the percentage of firms observed each year.

< INSERT TABLE 1 >

4. Empirical analysis

4.1 Econometric strategy and specification

We analyse the impact of different types of obstacles to innovation on the firm's propensity to innovate[16]. In doing so we consider the following equation:

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

Where $I[\cdot]$ is an indicator function that takes on values 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 a firm's decision to innovate, Z_{it} is a vector of variables identifying different obstacles to innovation, c_i is the time invariant unobserved individual effect, and ε_{it} an idiosyncratic error term.

As for the set of traditional determinants of innovation (X_{it}), we first consider firm size measured as the logarithm of the firm's total number of employees (LSIZE). As initially

[16] Since we are interest in the output side of the innovation activities, we qualified as 'innovative' those firms that have introduced or developed a new product or process or that have been in process of doing so during the surveyed period (answered positively at least one of the three questions listed in Table A2).

pointed out by Schumpeter (1942), and subsequently emphasised by several authors, larger firms are more inclined to engage in innovation activity because they are less likely to be affected by liquidity constraints (easier access to external finance and larger internal funds) and can exploit the advantages deriving by economies of scale (see Cohen and Klepper, 1996; Mairesse and Mohnen, 2002).

Another important factor that can influence the firm propensity to innovate is represented by the market conditions in terms of competitiveness. In this respect, a firm operating in an international context should be more prone to engage in innovation activity because of the high level of competition that characterises the global arena (e.g. Archibugi and Iammarino, 1999; Narula and Zanfei, 2003). Accordingly, we use a binary indicator of international competition (EXPORT_d) which equals to 1 if a firm's most significant destination market is international, and to 0 otherwise.

As suggested by Piva and Vivarelli (2009), higher manpower skills can be related to a higher firm propensity to innovate. In fact, skilled workers in comparisons with their unskilled counterparts are more able to dealing with complexity, and more successful in exploiting innovative ideas (Song *et al.,* 2003). We therefore introduce a variable proxing the proportion of high skilled employees (engineers and graduates) within a firm (EDUHIGH).

The occurrence of other forms of innovation, with particular reference to those involving changes in the organisational structure of a firm has been shown to be complementary to more traditional sources of innovation (see Bresnahan *et al.*, 2002; Hitt and Brynjolfsson, 2002). Accordingly, we expect a positive impact of the binary variable 'IORG_d' - that identifies the implementation of major changes to organisational structure - on the firm' probability to engage in innovation.

We also use firm's age (AGE) to control for age related effects. We do not advance any hypothesis on the possible effect of firm's age on the probability to innovate because no

univocal evidence has been provided by the literature. Keppler (1996) proposes a theoretical model according to which the number of innovations per firm at a given moment is higher, the younger the cohort of firm is. This should imply a negative relationship between the firm's age and its probability of innovating. However, as Galande and De la Fuente (2003) pointed out, the firm's age can also be seen as a proxy of the firm' knowledge and experience accumulated by the time and consequently it should be positively related to innovation.

Also, we introduce a dummy variable (INNEXP_d) that takes on value 1 if a firm has invested in innovation activity[17].

In addition, we control for the important role played by specific sector and technological factors in affecting the firm's propensity to introduce a new product/process, by including a complete set of industry dummies. Finally, in all the specifications we include time dummies to take into account possible business cycle effects, and regional dummies in order to control for unobserved heterogeneity across different UK regions.

The vector Z_{it} in equation (1), includes 4 different dummies variables that take on value 1 if the firm has faced obstacle to innovation related to: 1) costs factors (HIND_COST_d); 2) knowledge factors (HIND_KNOW_d); 3) market structure and demand factors (HIND_MARK_d); 4) regulation (HIND_REG_d)[18].

Table A3 in the appendix summarises the list of variables employed in the empirical analyses and their definition.

To estimate the coefficients in (1) we apply a probit random effect model. As it well known in literature, the implementation of this econometric method is conditional on the strong assumption that the time invariant error component c_i is uncorrelated with the

[17] In principle, it would have been better to consider a continuous variable measuring a firm's total investment in innovation activity; however to improve the readability of the results, we opted in favour of a dummy variable. Results based on the inclusion of the continuous variable indicating level of innovation expenditure are consistent with the binary variable and available on request by the authors.

[18] Table A4 in the appendix contains details on the UKIS questionnaire section related to obstacles.

covariates[19]. However, this could be an unrealistic assumption since that it is very likely that unobservable factors in c_i are correlated with the variables included in X_{it} and Z_{it} (for example, managerial ability could be related to the occurrence of major changes in the firm' organisational structure). To overcome this problem, Mundlak (1987) proposes to break down the time invariant error term so that it takes the following form: $c_{1i} = \bar{X}_i\theta_1 + \bar{Z}_i\theta_2 + a_i$, where $\bar{X}_i$ and $\bar{Z}_i$ denote the mean of X_{it} and Z_{it} over time. This simple approach allows us to move the correlated component to the set of covariates. Accordingly, equation (1) can be reformulated as:

$$Y_{it} = I\,[\beta' X_{it} + \delta' Z_{it} + \theta'_1 \bar{Z}_i + \theta'_2 \bar{X}_i + a_i + \varepsilon_{it} > 0] \qquad (2)$$

However, as can be easily understood looking at equation (2) this method could lead to biased results (because of multicollinearity problems) if the dataset used for the estimation shows a little within variation and consequently if the regressors are highly correlated with their Mundlak mean. Unfortunately, as shown in Table 2, this is what exactly happens with the data at our disposal. All the explanatory variables show a correlation coefficient with their within means always above 70%. As a consequence, when equation (2) is estimated most of the variables become uninformative and turn out to be insignificant (see columns 3 and 6 of Table 3). Accordingly, we opt to rely on the specification without the means (equation (1))[20].

< INSERT TABLE 2 >

[19] The incidental parameter problem (Neyman and Scott, 1948) leads to inconsistent results if a fixed approach is used to estimate a probit model.

[20] Although the dataset at our disposal would allow us to perform some dynamic analysis by taking into account the lags of the dependent variables, due to short time dimension of our panel we prefer to confine our analysis to static specifications (see Table 3). However, we performed some robustness checks controlling for the effect of the state dependence by applying a dynamic probit model method proposed by Wooldridge (2005). As can be seen the results in Table 8 mainly confirm the conclusions based on the discussed in section 4.2.

4.2 Full sample results: counter-intuitive findings

Table 3 (columns 1-3) shows the marginal effects of the probit model. Specifically, columns 1 reports the results of a simple pooled probit, while columns 2 and 3 show the results of the random effects model in the two cases, i.e. with and without including the vectors of means as covariates. Since pooled probit estimations ignore the cross-correlation between the composite error terms in different periods for the same individuals, the correspondent results are used as a benchmark. However, the high level of significance of the likelihood ratio test for Rho equal to zero (lower part of columns 2) suggests that the unobserved heterogeneity appears to be important in explaining the innovative decision of a firm thus supporting the choice of a random effects specification.

Looking at the results in columns 2, we find the expected signs for all the traditional determinants of innovation activities. More in details, larger firms, firms that have introduced organisational changes, and that are more oriented towards international markets are also more likely to translate their innovative effort into innovative outputs. Moreover, as expected, those firms that invest in innovation activities, as well as those that hire high qualified workers seem to be more prone to introduce innovation activity. As for the impact of the variable AGE, our results seem to support the evidence that younger firms are more likely than their mature counterparts to realise innovative products and/or processes.

Looking at the main variables of interest, the signs of the coefficients of the different obstacles to innovation are in line with the counterintuitive findings of most of the literature mentioned in Section 2.2. Three out of four of these variables, namely 'HIND_COST_d', 'HIND_KNOW_d' and 'HIND_MARK_d' turn out to have a positive and highly significant impact on the firm's propensity to innovate. The only variable that shows an expected negative sign is the variable 'HIND_REG_d', (5% of significance level). As already mentioned in Section 2.2, these counter-intuitive results are known as a recurrent problem in

the CIS-literature on barriers to innovation, due to several sources of bias (D'Este et al., 2008, 2012; Savignac, 2008; Mancusi and Vezzulli, 2010). We deal with this in the next two sections by appropriately selecting the relevant sample of firms.

4.3 Selecting the relevant sample

One of the possible causes of the counterintuitive positive impact of experiencing barriers and propensity to innovate emerging from our pooled sample results and coherent with a good deal of contributions in the innovation literature reviewed in Section 2.3 is related to the specific design of the CIS questionnaires. These, although mainly focused on 'innovation-related' questions, also gather information on not innovative firms. Further, all the surveyed firms are requested to answer the section referred to the obstacles to innovation (see Table A4 and A5). Firms might then well decide that they do not need to innovate due to lack of interest, or because they have already innovated recently (and therefore in principle they do not experience obstacles); firms might also decide that they do innovate and indeed spend in innovation activities (potential innovators) but they do not manage to introduce any new product/process (failed innovators); some firms do innovate and indeed devote financial resources to innovation activities and manage to introduce a new output (innovators).

Figure 1 in the Appendix describes the dynamics of the firm's innovative decision process according to the CIS questionnaire (see relevant sections in Tables in the Appendix) framework and the role played by the obstacle to innovation. More specifically, we identify the following categories of firms, which allow us to target the relevant sample for our analysis.

Not-innovation Oriented Firms: firms that are not willing to innovate, as they have declared to have not introduced any new product and/or process innovation and were not in process of doing so. At the same time, they did not experience any barriers to innovation (i.e.

had not experienced any of the 10 obstacles included in the question on barriers, see Table A4) regardless of whether they have invested or not in any innovation activities[21].

Potential Innovators: firms that are willing to innovate, either as they managed to introduce new products/processes (i.e. that has answered positively at least one of the three questions listed in Table A2) or they engaged in innovation activities (investments). At the same time, they have experienced at least one of the barriers to innovation.

Failed Innovators: firms that are willing to innovate (i.e. that are part of the sample of 'potential innovators'), i.e. they did engage in innovation activities but did not manage to translate innovation inputs into actual introduction of a new product/process[22].

Innovators: firms that are willing to innovate (i.e. that are part of the sample of 'potential innovators') and that have managed to introduced new or significantly improved product or process regardless of whether they have or not experienced any barriers to innovation.

< INSERT FIGURE 1 >

The distribution of the firms in the total sample as well as some descriptive statistics computed according these four categories are shown in Table 4.

< INSERT TABLE 4 >

[21] In order to select the sample of 'not-innovators oriented firms' it could have been possible to refer to a specific question in the CIS questionnaire (see table A5). However, the variables referred to this question are affected both by the presence of several missing values (not answer) and inconsistency response patterns (i.e. firms that have answered to that question but that have also reported to introduced any product or process innovations).

[22] As all firms included in this category have declared to experience at least one obstacle to innovation, it is reasonable to infer that they were not able to innovate because of the hindrances encountered. Since CIS questionnaire is based on self-reported answers and since other reasons, apart from the obstacle to innovation, could determine the firm's choice we prefer to do not explicitly stress this aspect.

Table 4 shows that only 2,233 observations (around 14% of the total sample) are included in the sub-sample of 'not-innovation oriented firms', while the remaining 14,085 observations (86% of the total sample) pertain to firms that can be defined as 'potential innovators'. Among this latter categories, 8,642 observations (61%) relate to the group of 'innovators' while the remaining 5,441 (39%) to the category of 'failed innovators'.

Looking at the descriptive related to our interest variables (mid-part of Table 4), not surprisingly, the large majority of 'innovators' (85%) have invested in at least one of the 7 categories of innovation activities included in the UKIS questionnaire, this percentage decreasing to 66% and 38% respectively for the categories of 'failed innovators' and 'not-innovation oriented firms'[23]. Moreover, notable differences among the different categories of firms can be detected with reference to the other variables of interest. In fact, the 'innovators' in comparison with the two other categories of firms (failed and not innovation oriented firms) turn out to be more oriented towards external market, more prone to implement organizational change and hire highly educated people.

As for the variables identifying the different obstacles to innovation, from the lower part of Table 4, surprisingly, no particular differences emerge between the category of 'failed innovators' and 'innovators'. The percentage of firms that have experienced obstacles to innovation is always very high ranging from 68% of 'failed firms' that have experienced regulations factors, to the 90% of 'innovators' that have experienced at least one of the 4 different cost factors obstacles.

Table 5 and 6 shows the transition probabilities respectively from the 'not innovation-oriented' to the 'potential innovator' status and from the 'potential innovator' to the

[23] Due to the specific design of the UKIS questionnaire, also non innovative firms have to reply to the innovation inputs questions, some of the Not-innovation oriented firms in our sample show a positive expenditure in innovation activity (see also footnote 3).

'innovator' status. More in detail Table 5 gives us an idea of the frequency of a firm changing status over time from 'not-innovation oriented firms' to 'potential innovators' (and vice versa), while Table 6 gives this information with respect to the status of 'failed innovators' and 'innovators' (in both directions). Unsurprisingly, the 'willingness' to innovate is the firm' characteristic that show the highest level of persistence over time, with roughly 94% of 'potential innovators' in one period persisting in this status during the following time period[24]. On the other hand a not negligible percentage (around 43%) of firms that in one time period belonged to the category of 'not-innovation oriented' turn out to be willing to innovate in the subsequent time period. By the same token, Table 6 shows that while the status of 'innovators' shows a relatively high persistence over time (almost 74% of firms remain in the same status over time), it appears that nearly 47% of firms that belonged into the category of 'failed innovator' in t-1 have changed their status in t becoming 'innovators'.

This evidence, although based on descriptive analyses, shows how important is identifying the relevant areas of intervention in order to implement targeted policy instruments.

< INSERT TABLE 5 >

< INSERT TABLE 6 >

4.4 Dealing with selection: relevant sample results

The estimation results (marginal effects) for the "relevant sample" of firms are reported in columns 4 to 6 in Table 3. The first remarkable result is that the estimated coefficients associated to the relevant variables show the excepted negative sign in three cases out of four, the only variable still showing a positive coefficients being

[24] Due to the particular construction of CIS questionnaires, here one time period refers to 2 years.

'HIND_KNOW_d'[25]. In particular, confining the attention to the probit RE model (column 5) it turns out that the presence of obstacles to innovation related to costs/market/regulations factors significantly reduce the firm's propensity to fall into the category of 'innovators' by respectively 24,5%, 12,7% and 11,6%. Accordingly, although the cost related factors appear to be still the most relevant constraint to the firm' realisation of innovative outputs, our results clearly show a noticeable "hindrance effect" of other obstacles to innovation (namely market/demand and regulations related factors). This evidence can potentially have important policy implications, because it explicitly points out to the need of going beyond the financing constraints' "obsession" and to consider also other systemic failures hindering the firms' innovative performance (see next section for a more detailed discussion of the policy implication of these results). The relevance of these results is further corroborated by their robustness across the different models. In particular, comparing the results of the probit RE without means (columns 5) and with means (columns 6) we can see that the estimated marginal effects of the variables "HIND_COST_d", "HIND_MARK_d" and "HIND_REG_d" are extremely close in terms of magnitude.

Looking at the other regressors (the 'traditional' determinants of innovation) and in line with the results obtained using the total sample, larger, younger firms, firms implementing organizational change and more prone to trade in international market are also more likely to introduce innovative outputs. Moreover, it is worth noting that these results are very similar in terms of magnitude to the estimated marginal effects with those one in columns 2.

[25] Although still positive the impact of this variable on the firm's propensity to innovate is negligible in terms of magnitude and no longer significant. Moreover, the marginal effects of this variable turn out to be negative in the 'RE with means' model (columns 6).

6. Concluding remarks

This paper aims to provide some evidence to allow innovation policy maker to be aware of what are the systemic failures hampering firms' engagement in innovation activities and innovation performance. As in Savignac (2008) and D'Este et al. (2008 and 2012), we identify different policy target categories on the basis of firms' self-declarations in terms of willingness, need and not need to innovate. We then corroborate this a-priori classification by testing the actual impact of different obstacles to innovation on the propensity to innovate – given the engagement in at least one innovation investment.

Once selected the appropriate sample of firms 'willing to innovate' we then test whether, to what extent (and which) barriers affect the changing status of 'potential innovators' into 'failed innovators', i.e. which of the main systemic obstacles mostly affect the lack of returns of innovation investments in terms of new product/process.

We find that market structure and lack of demand are as important hindrances for firms as the financing constraints that most traditional literature had emphasized on the basis of cash-flow models. We therefore infer that the presence of strong competitors and the lack of demand are as decisive for firms to give up innovation projects despite an initial investment, as are financial constraints.

It is therefore of uttermost importance for policy makers aiming at sustaining innovation to focus not just on the traditional increase of liquidity via, e.g. R&D tax credits, but also to be able to construct a concerted 'policy platform' with responsible of competition and macro-economic policy. Economic downturn, raising unemployment and lack of adequate final demand not only affect macro-economic recession directly but also indirectly via reducing incentives for firms to invest in innovation (for a discussion, see Archibugi and Filippetti, 2011).

Regulation constraints – which turn out to be significantly affecting the propensity to innovate, though more weakly – have to be considered as a potential area for intervention too, though more in depth investigation on the nature of these types of constraints must be carrier out, possibly from a qualitative perspective.

Overall, as already mentioned, policy makers might prioritize the enlargement of the population of innovators, by removing or alleviating obstacles targeted to those firms that decide not to engage in innovation activities due to barriers (for an *innovation-widening* policy strategy); and/or strengthen the innovation capacity of the existing population of innovators, by removing or alleviating obstacles affecting firms who do not manage to translate financial effort devoted to innovation projects into the actual introduction of new product/process (for an *innovation-deepening* policy strategy). In any of these cases, the evidence presented in this paper allows a better identification of the relevant policy targets.

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Table 1.Composition of the panel (All sample - relevant sample)

	ALL SAMPLE			RELEVANT SAMPLE		
Time obs.	N° of firms	%	N° of obs.	N° of firms	%	N° of obs.
2	4,141	61.84	8,282	4,222	70.11	8,444
3	2,186	32.65	6,558	1,561	25.92	4,683
4	369	5.51	1,476	239	3.97	956
Total	6,696	100	16,316	6,022	100	14,083

Table 2. Correlation between the explanatory variables and their corresponding Mundlak means

AGE	0.99
EXPORT_d	0.92
EDU_HIGH	0.87
INNEXP_d	0.73
IORG_d	0.74
LSIZE	0.99
HIND_COST_d	0.79
HIND_KNOW_d	0.78
HIND_MARK_d	0.78
HIND_REG_d	0.75

Table 3. Results from the panel probit estimates

	ALL SAMPLE			RELEVANT SAMPLE		
	(1) Pooled Probit	(2) RE Probit	(3) RE with means	(4) Pooled Probit	(5) RE Probit	(6) RE with means
AGE	-0.005***	-0.006***	-0.041**	-0.005***	-0.006***	-0.035*
	(0.001)	(0.002)	(0.020)	(0.001)	(0.002)	(0.019)
EXPORT_d	0.292***	0.336***	0.008	0.285***	0.324***	-0.008
	(0.026)	(0.034)	(0.064)	(0.027)	(0.036)	(0.068)
EDU_HIGH	0.002***	0.003***	0.001	0.002***	0.003***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
INNEXP_d	0.859***	0.993***	0.708***	0.817***	0.953***	0.695***
	(0.030)	(0.037)	(0.046)	(0.032)	(0.040)	(0.051)
IORG_d	0.533***	0.615***	0.438***	0.523***	0.606***	0.434***
	(0.026)	(0.033)	(0.043)	(0.027)	(0.034)	(0.045)
LSIZE	0.033***	0.048***	0.023*	0.036***	0.049***	0.035***
	(0.009)	(0.012)	(0.012)	(0.009)	(0.012)	(0.013)
HIND_COST_d	0.361***	0.417***	0.224***	-0.206***	-0.245***	-0.206***
	(0.040)	(0.049)	(0.064)	(0.043)	(0.053)	(0.069)
HIND_KNOW_d	0.174***	0.202***	0.082	0.038	0.036	-0.038
	(0.038)	(0.047)	(0.060)	(0.038)	(0.047)	(0.061)
HIND_MARK_d	0.131***	0.145***	0.058	-0.098***	-0.127***	-0.139**
	(0.038)	(0.046)	(0.059)	(0.038)	(0.046)	(0.061)
HIND_REG_d	-0.082***	-0.091**	-0.084*	-0.098***	-0.116***	-0.105**
	(0.029)	(0.036)	(0.047)	(0.029)	(0.036)	(0.048)
Intercept	-1.078***	-1.270***	-1.921***	-0.168*	-0.165	-0.543***
	(0.090)	(0.123)	(0.139)	(0.099)	(0.134)	(0.153)
N. of Obs.	16,316	16,316	16,316	14,083	14,083	14,083
lnL	-8,102.88	-7,919.81	-7,753.45	-7,392.13	-7,228.56	-7,151.22
ρ		0.352	0.364		0.358	0.361
		(0.018)	(0.018)		(0.019)	(0.019)
LR test $\rho = 0$		366.141	378.364		327.147	325.720
p-value		0.000	0.000		0.000	0.000
σ_u		0.738	0.756		0.747	0.752
		(0.029)	(0.030)		(0.031)	(0.032)

Notes; ***, ** and * indicate significance on a 1%, 5% and 10% level, respectively. Standard errors in brackets (calculated using the delta method). Time, industry and regional dummies are included. In all the specifications the dependent variable is a dummy that takes on value 1 if the firm can be defined as an innovator

Table 4. Descriptive statistics: mean and standard deviation (overall) of the variables: Total sample - Potential innovators -Failed Innovators - Innovators – Not innovation oriented firms

	Total Sample		***Pot. Innovators***		***Failed Innovators***		***Innovators***		***Not Inno. Or.***	
	Mean	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*	*Mean*	*St. Dev.*
Variables identifying the different sub-samples of firms according to our definitions										
POTEN_INN	0.86	0.34	1	0	1	0	1	0	0	0
INNOVATORS	0.53	0.5	0.61	0.49	0	0	1	0	0	0
DISCOURAGED	0.33	0.47	0.39	0.49	1	0	0	0	0	0
NOINN_OR	0.14	0.34	0	0	0	0	0	0	1	0
Explanatory variables										
AGE	22.12	10.11	22.15	10.13	22.11	10.09	22.18	10.15	21.89	9.98
EXPORT_d	0.45	0.50	0.49	0.50	0.37	0.48	0.56	0.50	0.24	0.43
EDU_HIGH	16.67	25.63	17.73	26.1	13.74	23.63	20.25	27.24	9.97	21.28
INNEXP_d	0.72	0.45	0.78	0.42	0.66	0.47	0.85	0.36	0.38	0.49
IORG_d	0.28	0.45	0.31	0.46	0.21	0.4	0.38	0.48	0.08	0.27
LSIZE	4.49	1.51	4.55	1.5	4.32	1.46	4.69	1.5	4.18	1.51
Obstacles to innovation										
HIND_COST_d	0.77	0.42	0.90	0.30	0.89	0.31	0.90	0.30	0	0
HIND_KNOW_d	0.72	0.45	0.83	0.37	0.80	0.4	0.85	0.35	0	0
HIND_MARK_d	0.73	0.45	0.84	0.36	0.83	0.38	0.85	0.35	0	0
HIND_REG_d	0.60	0.49	0.69	0.46	0.68	0.47	0.71	0.46	0	0
N. of Observation	16,316		14,083		5,441		8,642		2,233	

Table 5. Descriptive statistics: standard deviation (Between and Within) of the variables: Total sample - Potential innovators -Failed Innovators – Innovators – Not innovation-oriented firms

	Total Sample		***Pot. Innovators***		***Failed Innovators***		***Innovators***		***Not Inno. Or.***	
	St. Dev		*St. Dev*		*St. Dev*		*St. Dev*		*St. Dev*	
	Between	*Within*	*Between*	*Within*	*Between*	*Within*	*Between*	*Within*	*Between*	*Within*
Variables identifying the different sub-samples of firms according to our definitions										
POTEN_INN	0.31	0.18	0	0	0	0	0	0	0	0
INNOVATORS	0.40	0.31	0.38	0.32	0	0	0	0	0	0
FAIL_INN	0.36	0.31	0.38	0.32	0	0	0	0	0	0
NOINN_OR	0.31	0.18	0	0	0	0	0	0	0	0
Explanatory variables										
AGE	9.97	1.68	10.02	1.68	10.11	1.18	10.19	1.50	9.99	1.24
EXPORT_d	0.46	0.20	0.46	0.20	0.47	0.15	0.48	0.17	0.42	0.15
EDU_HIGH	22.55	12.68	23.06	12.59	22.92	9.27	25.26	10.80	20.62	9.41
INNEXP_d	0.34	0.30	0.31	0.28	0.42	0.25	0.33	0.20	0.43	0.28
IORG_d	0.34	0.30	0.35	0.31	0.38	0.20	0.41	0.29	0.27	0.14
LSIZE	1.49	0.21	1.49	0.20	1.48	0.13	1.50	0.19	1.55	0.16
Obstacles to innovation										
HIND_COST_d	0.34	0.26	0.22	0.22	0.28	0.17	0.25	0.18	0	0
HIND_KNOW_d	0.36	0.28	0.27	0.26	0.35	0.21	0.31	0.21	0	0
HIND_MARK_d	0.36	0.28	0.27	0.25	0.34	0.20	0.31	0.21	0	0
HIND_REG_d	0.38	0.32	0.34	0.32	0.43	0.24	0.39	0.27	0	0
N. of Observation	16,316		14,083		5,441		8,642		2,233	

Table 6. Transition probabilities of the Potential Innovators status

		Status in t		
		No Inn Or. Firms	Potential Innovators	Tot
Status in t-1	No Inn Or. Firms	56.92	43.08	100
	Potential Innovators	5.81	94.19	100

Table 7. Transition probabilities of the Innovators status

		Status in t		
		Failed Innovators	Innovators	Tot
Status in t-1	Failed Innovators	52.78	47.22	100
	Innovators	26.03	73.97	100

Appendix

Table A1. Probit estimations (with lagged dependent variable)

	ALL SAMPLE		RELEVANT SAMPLE	
	(1) Wool. (no means)	(2) Wool. (with means)	(3) Wool. (no means)	(4) Wool. (with means)
INNOVATORS_1	0.495***	0.428***	0.493***	0.451***
	(0.071)	(0.075)	(0.068)	(0.071)
AGE	-0.002	-0.038	-0.002	-0.080***
	(0.002)	(0.028)	(0.002)	(0.027)
EXPORT_d	0.227***	0.031	0.214***	0.002
	(0.041)	(0.091)	(0.045)	(0.099)
EDU_HIGH	0.001*	0.001	0.002**	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
INNEXP_d	0.812***	0.699***	0.822***	0.753***
	(0.055)	(0.069)	(0.061)	(0.078)
IORG_d	0.542***	0.428***	0.538***	0.410***
	(0.043)	(0.059)	(0.046)	(0.063)
LSIZE	0.004	-0.009	0.018	-0.000
	(0.013)	(0.014)	(0.014)	(0.015)
HIND_COST_d	0.406***	0.362***	-0.265***	-0.274***
	(0.065)	(0.088)	(0.071)	(0.097)
HIND_KNOW_d	0.161***	0.102	0.044	-0.005
	(0.061)	(0.083)	(0.061)	(0.086)
HIND_MARK_d	-0.024	-0.050	-0.271***	-0.292***
	(0.059)	(0.081)	(0.061)	(0.085)
HIND_REG_d	0.012	-0.010	-0.006	-0.041
	(0.045)	(0.065)	(0.045)	(0.067)
INNOVATORS_0	0.363***	0.373***	0.343***	0.377***
	(0.083)	(0.086)	(0.079)	(0.082)
INTERCEPT	-1.611***	-1.769***	-0.653***	-0.718***
	(0.151)	(0.167)	(0.162)	(0.180)
Obs	7,427	7,427	6,240	6,240

Table A2. CIS questionnaire (innovation output related questions)

We qualified as innovative those firms that have positively answered 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 have any innovation activities to develop product or process innovations that you had to abandon or which were ongoing at the end of 2004?	☐	☐

Table A3. The variables: acronyms and definitions.

Variables identifying the different sub-samples of firms according our definitions	
POTEN_INN	Dummy =1 if firm is a potentially innovative firms (whether the firm has been engaged in innovation activities and/or has experienced any barrier to innovation activities during the three year period); 0 otherwise.
INNOVATORS	Dummy =1 if firm has introduced new or significantly improved products/processes or has any innovation activities that had abandon or which were ongoing at the end of the three year period ; 0 otherwise.
FAILED_INN	Dummy =1 if firm wanted to innovate but did not managed to do so because has experienced any barriers to innovation activity during the three year period; 0 otherwise.
NOINN_OR	Dummy =1 if firm has no innovative activities and did not experienced any barriers to innovation during the three year period; 0 otherwise.
Explanatory variables	
AGE	Years elapsed since founding.
EXPORT_d	Dummy =1 if the firm have traded in an international market during the three year period; 0 otherwise.
EDUHIGH	Ratio of highly educated personnel over total employment (these figures refer to the last year of each of the three years periods).
INNEXP_d	Dummy=1 if the firm has invested in at least one out of the 7 categories of innovation activity included in the questionnaire.
IORG_d	Dummy=1 if the firm have implemented major changes to its organisational structure (e.g. Introduction of cross-functional teams, outsourcing of major business function) during the three year period; 0 otherwise.
LSIZE	Log of the total number of firm's employees (these figures refer to the last year of each of the three years periods).
Obstacles to innovation	
HIND_COST_d	Dummy=1 if the firm has faced obstacle to innovation related to costs factors in the three years period; 0 otherwise.
HIND_KNOW_d	Dummy=1 if the firm has faced obstacle to innovation related to knowledge factors; 0 otherwise.
HIND_MARK_d	Dummy=1 if the firm has faced obstacle to innovation related to market factors; 0 otherwise.
HIND_REG_d	Dummy=1 if the firm has faced obstacle to innovation related to other factors during the three year period; 0 otherwise.

Table A4. CIS questionnaire: barriers to innovation

During the three years period ---- how important were the following factors as constraints to your innovation activities or influencing a decision to innovate?

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

Table A5. CIS questionnaire: Enterprise with no innovation activity.

If your enterpeise had no innovation activities during the three-year period ----, please indicate why it has not been necessary or possible to innovate:	YES	NO
No need due to prior innovation	☐	☐
No need due to market condition	☐	☐
Factor constraining innovation	☐	☐

Figure1. The dynamics of the firm's innovative process and the role of the obstacles to innovation.