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The demand and supply of external finance for innovative firms

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Abstract

Access to finance has figured prominently in the debate on barriers to firm growth, even though existing empirical research has not found conclusive evidence of a "finance gap." Moreover, it is not clear to what extent innovation aggravates financial constraints and what role innovation inputs, processes and outputs play in the market for external capital. In this article, we analyze how firm-level innovation affects (i) the likelihood of seeking external finance and (ii) the likelihood of obtaining it. We analyze an original data set of 3095 UK and US firms (small and medium size enterprises and middle-market) containing information on firms' innovation behaviors, performance, and finances for the period 2002–2004. Controlling for firm-specific characteristics, we provide novel and extensive evidence on the links between innovation, in its input, process and output dimensions, and the demand for external capital and its supply.

1. Introduction

The Lisbon Agenda (European Commission, 2000, 2005) placed among its main objectives the creation of a strong knowledge-based economy and identified innovation as a fundamental driver of output and employment growth in the European region. In this process, great emphasis has been placed on young innovative firms because of their capacity to generate radical innovation and trigger structural change in the economy (Acs and Audretsch, 1990).

Access to finance has figured prominently in the debate on barriers to firm growth, especially for small and medium size enterprises (SMEs), but existing empirical research has not found conclusive evidence of a "finance gap" (Storey, 1994; Cosh *et al.*, 2009a). In addition, and despite a number of studies on the cash flow sensitivity of R&D investments, the extent to and the way in

which innovation aggravates the specific financial constraints of firms have arguably been under-researched (Hall, 2009).

This article addresses the connection between innovation and firm financing, a problem on which Schumpeter (1942) commented more extensively than is usually reflected in contemporary Neo-Schumpeterian research (O'Sullivan, 2000). Contrary to most of the literature on firms' financial constraints, this study focuses on SMEs, and unlike the vast majority of extant contributions on the link between financial constraints and innovation investments, it adopts a much richer set of indicators of innovation than the sole measure of its R&D inputs.

Our objective is to investigate two key questions: (1) Which firms seek external finance and (2) Which ones obtain it? While controlling for a broad set of firm-specific characteristics, we explore the effects that firms' innovation activities do—or do not—have on the demand and supply of external capital. We analyze an original data set of 3095 UK and US businesses containing information on firms' innovation behaviors, performance, and finances in the period 2002–2004. The distinctive advantage of the survey data we use is the inclusion of specific information about the search for external finance *and* the outcome of this search, which is missing from standard Community Innovation Surveys (CIS), alongside detailed information on R&D and innovation, which are instead typical of CIS. Importantly, as there is no readily available equivalent of CIS data for the United States, a second advantage of our dataset is that we can identify some differences between the UK and the US innovation systems.

We find that overall the probability of seeking external finance is significantly affected by the human capital-intensity of the business and by the profitability of the firm (both exerting a negative effect) but is not affected by R&D intensity or innovation outputs. US firms are more likely than UK firms to seek external finance, but no more likely to obtain it. On a bivariate basis, R&D intensity exerts a significant negative effect on the probability that firms obtain finance, pointing to the existence of some financial constraints for more R&D-intensive firms, but the significance of this effect disappears in multivariate settings. Other things being equal, innovation indicators—operationalized by measures of R&D output rather than input—are instead strongly, positively and significantly related to the chances of receiving investments, with the exception of organizational innovation, but it is in the US sample that we find a high sensitivity to innovation signals.

The article is structured as follow. In Section 2, we review the literature on the financial constraints of SMEs and the specificity of investments in R&D and more broadly innovation. Section 3 presents our data and methods of analysis. Section 4 contains our results, which we discuss in the following section (5) before concluding with a set of final comments on the contribution of the article and its implications for theory and policy.

2. Firms' financial constraints and innovation: theory and evidence

2.1 SME finance

Access to external finance has been identified as a significant barrier to the growth of SMEs. A specific stream of the literature has focussed on the so-called "finance gap," which is configured where a firm has potentially profitable investment opportunities but insufficient funds to exploit them (Storey, 1994; Deakins, 1996; Jarvis, 2000; NESTA, 2009; Cosh *et al.*, 2009a). It can arise from agency-related costs that drive a wedge between the cost of external and internal funds, thus rendering some projects profitable only if they can be financed through internal funds. When additional outside capital is required, this may come from individual or corporate shareholders, venture capitalists, banks, suppliers or customers, among others, through equity, debt, or hybrid financing mechanisms. Because of market imperfections, leading to sub-optimal allocation of capital, some firms in need of finance would not, however, be able to obtain it (Berger and Udell, 1998, 2006; Gregory *et al.*, 2005). Small or high-tech privately held businesses would face specific disadvantages because unlisted firms are usually not required by law to disclose information to prospective investors, unlike publicly held companies (Ang, 1992). This relative lack of external signals about firm quality can lead to misallocation of financial resources in the economic system.

Evidence has been growing against the Modigliani and Miller theorem (1958; 1961), which predicted that at the margin alternative sources of finance should be perfect substitutes. There is instead increasing empirical support for a pecking order theory of finance (Myers and Majluf, 1984; Myers, 2000) whereby borrowers follow an order of preferences for finance: in the first instance, firms will finance new projects with internal cash flows; they will seek external finance only when internal funds have been exhausted, with external equity as the least preferred form of finance, given the lack of collateral and equity being a residual claim on the firm's value. Internal equity through retained earnings and the owner's private wealth appears to be the main source of finance for SMEs (Ou and Haynes, 2006; Vos *et al.*, 2007; Ughetto, 2008).

Berger and Udell (1998) suggest that SMEs also pursue different capital structures during their life cycle, a long-term behavior that would result in the demand and consequent eventual supply of different sources of capital over time. Internal funds will be the favored source of capital in the firm's early years of operations, whereas access to external finance becomes easier as firms grow older and larger. This has been related to growth in collateralizable assets, to the diffusion of lending technologies capable of reducing information

asymmetries (Berger and Udell, 2006) and to a higher degree of transparency of larger firms in the eyes of lenders (Guiso, 1998). Smaller firms will tend to have better access to external finance if they have above-average growth ambitions (Storey, 1992; 1994; Cosh *et al.*, 2009a).

Overall, it has been difficult to find hard empirical evidence for binding financial constraints. Storey (1994) concludes that the existence of a finance "gap" for small sums of equity is likely due to relatively high transaction costs, but adds that "there has been no evidence of market failure in the sense of a case for government to intervene" (p. 250). Some studies show that only a minority of firms wants to grow and very few use equity finance to do so (Hakim, 1989; Vos *et al.*, 2007). Cressy (1996) even suggests that credit rationing of start-ups might not be correlated to their survival because firms self-select for finance, and once human capital is accounted for, the additional explanatory power of financial capital is zero. Similarly, there is evidence that many small enterprises wishing to grow do not attempt to obtain external funding from sources other than the bank for fear of losing their independence (Jarvis, 2000). However, the lack of growth in small firms might be self-imposed and not due to exogenous restrictions, which Vos *et al.* (2007) refer to as "the financial contentment hypothesis." In Vos *et al.*'s sample of US and UK firms, few SMEs seek external capital, and those who are keener to grow apply for and use external loans relatively more often.[1]

2.2 Idiosyncratic risk and R&D

Firms undertaking high-risk projects tend to have informational advantages over external agents, for example when risk does not arise from commonly observable external sources but is instead idiosyncratic to the firms' activities. The informational opaqueness of a firm's projects can have a profound impact on the lenders' decision to supply finance if they feel they cannot reliably assess the firm's quality on the basis of the perceived value of their innovative activities (Ang, 1992; Avery *et al.*, 1998; Jensen and Meckling, 1976; Stiglitz and Weiss, 1981; de Meza and Webb, 1987, 1992; de Meza, 2002; Carpenter and Petersen, 2002a, 2002b). These difficulties will result in higher costs for finance to compensate for this source of risk. Studies investigating the sensitivity of investment to the availability of internal finance find some support for constraints on raising external finance (Fazzari *et al.*, 1988, 2000), even though the use of an investment cash flow sensitivity framework—including the identification of financial constraint and financial distress—has been challenged on both theoretical and empirical grounds (Kaplan and Zingales, 1997, 2000; Coad, 2010).

Innovation projects have many of the characteristics that could lead to difficulties in obtaining finance under the traditional view of asymmetric information and agency problems. It is, however, unclear whether the

mechanisms of innovation finance constitute a difference in kind or simply aggravate the potential financing problems of other types of investment. What characteristics distinguish R&D projects from other investment opportunities? The classic argument about sub-optimal investments in R&D goes back to the seminal contributions by Nelson (1959) and Arrow (1962) on the economic characteristics of knowledge: as knowledge can only be appropriated with difficulty by its original developers, private incentives to invest in knowledge goods will be weak and will need to be reinforced by the design of institutional instruments (e.g. patents and copyrights or R&D tax incentives), which can guarantee a sufficient degree of rival and excludible use of new and economically valuable knowledge. The existence of effective incentives to invest in R&D does not, however, imply that the costs of finance for R&D projects will be independent from the source of capital: whenever the supplier of finance differs from its beneficiary, the private (supplier's) rate of return also differs from the cost of capital.

R&D investments are highly uncertain and information about their success or failure is only gradually revealed over time; they create idiosyncratic intangible capital with limited marketability; they typically need to be smoothed over time for the firm to retain valuable employees and avoid dispersing its knowledge base (Hall, 2010). Smoothing should lead to a preference for long-term capital owing to the high adjustment costs of knowledge capital, and external equity might be the preferred source of innovation finance, after the re-investment of the firms' own profits, because of a lack of collateral associated with investments in intangible assets.

From the viewpoint of the lender, the evaluation of R&D projects tends to require a different skill set from other kinds of ordinary investments (typically a degree of technical or scientific knowledge). This can exacerbate moral hazard problems to the extent that no market for external capital might exist given the impossibility of complete disclosure—and complete understanding—of all the signals that would be necessary to adequately assess the value proposition of the innovator.[2] The supply of external capital will then be at a premium, and this premium can subject R&D investments to especially severe financial constraints as is the case in studies that estimate the sensitivity of R&D investments to cash flow (Hall, 1992; Brown and Petersen, 2009, 2011; Bond *et al.*, 2003, 2010; Mulkay *et al.*, 2001; Harhoff, 1998; Carpenter *et al.*, 1998).

2.3 Innovation inputs, processes, and outputs

Following the Schumpeterian lesson and through a series of later seminal contributions (including Nelson and Winter, 1982; Pavitt, 1984; Kline and Rosenberg, 1986; Dosi, 1988; Freeman and Soete, 1997), innovation scholars have developed a finely articulated understanding of the different dimensions of innovation well beyond its identification with R&D (Fagerberg *et al.*, 2005).

As is well known, R&D should be interpreted as an input, rather than output, of innovation. As an indicator of innovation, it is the one that bears the highest degree of uncertainty, given the unpredictability of the discovery process and of new product development. As we have pointed out, this can be a costly process, but at the same time one that is distinctively opaque for external investors that might contribute to its financing.

One of the intermediate outputs of R&D and now the core of a specialized field of the economics of technical change are patents (Jaffe and Trajtenberg 2002). Patents capture the output of the R&D investment process that the firm deems to be worthy of legal protection. Patents have proved useful in quantifying and exploring the outcome of R&D as indicators of invention with some degree of potential value. From an investment viewpoint, the informational content of patents is superior to that of R&D, and the public character of patents as legal documents increases the transparency of firms. Other forms of intellectual property (IP) protection, e.g. copyright, can play the same role of buffers against risk; but this is not the case for a number of informal IP protection mechanisms, including secrecy and complexity of design, which can instead significantly decrease the transparency of potential borrowers. The overall attitude of the firm toward protecting its IP is highly relevant. The value of IP remains unproven and crucially dependent on subjective judgements before the test of the market. As the financing process entails the disclosure of private information, unwillingness to share information with external agents, including investors, is likely to affect financing decisions. As a consequence, over-protectiveness can have significant detrimental effects not only on the firm's innovative performance (Laursen and Salter, 2005) but also a direct negative effect on the probability that firms obtain external finance.

For the potential value of a novel idea to be realized in the marketplace, where Schumpeter placed innovations as opposed to inventions, firms will still need to invest a substantial amount of resources to finance periods of experimental development of technologies and to align complementary assets (Teece, 1992). Some of these complementary assets can be accessed by collaborating with other organizations (Pisano, 1991; Powell *et al.*, 1996; Ahuja, 2000; Baldwin and von Hippel, 2010) and through the acquisition of new technology in the form of equipment or intermediate inputs (Stoneman, 2001). Ultimately, the successful utilization of innovation inputs is expected to result in superior products or services, methods of production, or ways of organizing the business. These will be observable outcomes of innovation activities. Again, from an investment viewpoint, these facets of innovation are complementary indicators of idiosyncratic risk: they will constitute a cost to the firm, thus potentially affecting the demand for external finance, and will work as signals to potential investors, thus affecting the supply of external finance.

To sum up, the demand for external finance and its supply, which the vast majority of existing studies cannot distinguish empirically, depends on a set of firm-specific characteristics that include firms' economic fundamentals, financial characteristics, and their profiles as innovators. On these premises, we want to identify the drivers of the market for external capital, with a specific focus on whether and in what ways innovation affects the decision to seek finance and whether and to what extent investors are sensitive to the firm's innovation activities and their characteristics as signals of their risk profile and likely returns. Are more innovative firms more or less likely to seek external finance? Are they more or less likely to obtain it than less innovative ones? And what conditions need to be met to invest in innovative firms?

3. Data and methods

3.1 Data *sources*

This article builds on a unique comparative survey of UK and US businesses jointly carried out by the Centre for Business Research of the University of Cambridge and the Industrial Performance Center of MIT in 2004–2005.[3] The basis for the sampling was the Dun & Bradsheet database, which contains company-specific information drawn from various sources, including Company House, Thomson Financial, and press and trade journals. The sample was stratified by sector and firm size. It covered manufacturing and business service sectors and used progressively lower sampling fractions as firm size decreases, given the larger number of firms in smaller size classes. A telephone survey was launched between March and November 2004 (response rate: 18.7% for the United States and 17.5% for the UK), followed by a postal survey of large firms in Spring 2005 leading to a total sample of 1540 US firms and 2129 UK firms.

This survey shares with the European CIS a "subject" approach to innovation (Smith, 2005), which allows us to investigate different aspects of innovation including, but not limited to, R&D expenditures. But in addition to questions about the firms' innovation activities, this survey covered more detailed questions about the financial profile of the sampled businesses. The added value of these data compared with CIS data is that the latter generate little information about firm finances with questions generally limited to whether the lack of finance constitutes a barrier to innovation for firms. Furthermore, and crucially for the purposes of this article, the data set we use has the advantage of providing separate firm-level observations for the search of external finance and for success at obtaining it.

As there is no equivalent to CIS data for the United States, the database also gives us a rare opportunity to observe whether and where there are differences

between the UK and the United States, which is often taken as a model for innovation investments, despite the lack of comparable disaggregated firm-level innovation data. On the one hand, the literature usually stresses the similarities between the UK and the United States, e.g. as systems with developed equity markets in contrast to many continental European countries. On the other hand, the UK is traditionally seen as a much less efficient translator of invention into innovation than the United States, which could be related to the way in which lenders react to signals of R&D and innovation in potential recipients of investments.

3.2 Sample

We include in our sample all SMEs with sufficient information on dependent variables. As we can control systematically for size effects and because these are also under-researched relatively to large firms, we also include middle market firms, but drop observations on firms with an average number of employees of ≥1000 at the time of the survey. We performed several tests on medium-sized firms to ensure that these firms can be included in our analyses. These included verification that no zero cell counts occur in cross tables with our dependent variables, which could otherwise lead to complete separation in probit models.

As with most survey data, we face the problem of missing data in dependent as well as independent variables. The procedure of preparing the data for estimation consists of two steps. First, the survey data are cleaned and integrated with other sources (see later in the text) where observations are found missing. Second, imputation methods are used to address the problem of missing data in independent variables. To arrive at a consistent data set, we clean the data from implausible values (e.g. a firm founding date in the future; profits higher than sales) and convert all USD figures to GBP using the interbank exchange rate mid-point at the end of the financial year in question. Missing data are extracted from the Financial Analysis Made Easy database wherever available: we use the financial year 2003 for total assets, turnover and profits, and the financial year 2000 for total assets, turnover, and profits 3 years before the survey (or 2001 if 2000 is missing). Ratios calculated from survey variables, such as profit margins or R&D intensity, are censored at the 1%/99% quantiles before imputation to eliminate outliers with implausible values. Finally, we winsorize variables that are not themselves imputed but which are obtained by dividing two other variables at the 2% and 98% quantile.[4]

The dependent variables of this study are binary indicators for whether firms seek external finance, and whether their search is successful. External finance is defined in the survey as any finance “additional to retained earnings and depreciation.” In our sample, 42% of US firms seek finance against 32% in the

UK. The proportion of firms that succeed in obtaining finance is 87% in the United States and 86% in the UK. Most firms obtain either the full amount they apply for, or nothing. The average firm obtains 80% of the capital sought, as can be seen in Table 2. These proportions are in line with prior studies on the financing behavior of small and medium-sized firms (Eckhardt *et al.*, 2006; Cosh *et al.*, 2009a).[5] There are no major differences between the two subsamples in key demographic and innovation variables. Average firm (log) age is 3.0 in both countries, whereas average (log) size is 3.8 in the United States and 3.7 in the UK. On average and as a percentage of assets, US firms spend 6% more on R&D than UK firms. US firms seem to be slightly more innovative than their UK counterparts also when we look at indicators of innovation outcomes. About 48% of US firms and 43% of UK firms report the introduction of a new or significantly improved product or service. For process innovation, these proportions are 32% and 25%, respectively, and 17% and 13% for organizational improvements.

3.3 Variables

Table 1 contains the list and description of our demographic and market, financial, and innovation variables. Table 2 presents the variables' descriptive statistics, and Table 3 presents the variables' correlation matrix. We estimate separate models for the probability that a firm seeks external finance and for the probability that it obtains any positive amount. The first set of controls we use includes essential firm characteristics such as age, size, and sector, and whether the firm is based in the United States or the UK, without making any a priori assumption about the relative efficiency of the two countries' external capital markets and their capacity to reduce information asymmetries. The degree of internationalization and the intensity of competition from foreign firms capture different aspects of a firm's output market. The firm's potential access to intra-group capital markets is indicated by a dummy variable for being an independent firm.

Table 1
Variable definitions

Variable name	Definition
External finance sought	A dummy variable equal to one if the firm answered "yes" to the question "Have you made attempts to obtain additional external finance (i.e. additional to retained earnings and depreciation)?" in the 2002–2004 period
External finance obtained	A dummy variable equal to one if the firm obtained any amount of external finance in the 2002–2004 period

Firm age	The natural log of the number of years from incorporation until 2005
US firm	A dummy variable equal to one if the firm is located in the United States and zero otherwise
Firm size	The natural log of the average number of employees 3 years ago
Independent firm	A dummy variable equal to one if the firm is independent
Manufacturing	A dummy variable equal to one if the firm is in the manufacturing sector (ISIC Rev. 3.1 codes 15–37)
Profit margin 2001	Pre-tax profits/Turnover; both 3 years before the survey
Debt/Assets	Debt/total assets in 2002; available for UK firms only
Replacement investment need (%)	Replacement investments as a percentage of total capex
Replacement investment need n/a	A dummy equal to one if the value for replacement investments is missing
Government support	The natural log of (amount of financial assistance received in the past 3 years in GBP thousands + 1)
Internationalization	The number of world regions in which the firm does business; coded numerically 1 = national to 7 = global
Foreign competitors	The proportion of the firm's main competitors that are overseas firms
Growth ambition	Expected turnover in 10 years, coded 0 = "A lot smaller" to 4 = "A lot larger"
Human capital staff	Approximate number of workforce that have a university degree as a percentage of the total number of employees
R&D expenditures/Assets 2001	Total R&D expenditure/total assets 3 years before the survey
Product innovation	The firm developed a novel manufacturing or service product innovation, which is new to the industry; dummy variable.
Process innovation	The firm developed a novel manufacturing or service process innovation, which is new to the industry; dummy variable.
Organizational innovation	The firm developed novel supply chain methods or a new method of supply, storage or delivery, which is new to the industry; dummy variable.
Log (Number of patents)	The natural log of the firm's number of patents plus one

Breadth of IP protection	Number of innovation protection methods used (registration of design, trademarks, patents, confidentiality agreements, copyright, secrecy, complexity of design and lead-time advantage on competitors)
Forms of technology acquisition	Number of technology acquisition forms used
Collaborations	Number of collaborative or partnership arrangements
Pay-off period of innovation	The firm perceives long pay-off periods of innovation as a barrier to innovation, coded 0 = Insignificant barrier to 4 = Crucial barrier, treated as cardinal.

Table 2
Descriptive statistics

Variable	Mean	Med.	Std. Dev.	Min	Max	Obs.	Impute
External finance sought	0.363	0.000	0.481	0.000	1.000	3095	0%
External finance obtained (%)	80.466	100.000	35.924	0.000	100.000	1007	0%
Demographic and market							
Firm age	3.043	3.045	0.855	0.000	5.720	3095	0%
Firm size	3.742	3.584	1.206	0.000	7.171	3095	32%
US firm	0.420	0.000	0.494	0.000	1.000	3095	0%
Independent firm	0.795	1.000	0.404	0.000	1.000	3095	0%
Manufacturing	0.667	1.000	0.472	0.000	1.000	3095	0%
Internationalization	2.595	2.000	1.594	1.000	7.000	3095	22%
Foreign competitors	0.267	0.000	0.355	0.000	1.000	3095	11%
Financial							
Profit margin 2001	0.063	0.050	0.164	-1.000	1.000	3095	45%
Debt/Assets	0.750	0.688	0.450	0.000	2.441	1795	34%

Replacement investment need (%)	26.474	5.000	34.366	0.000	100.000	3095	38%
Replacement investment need n/a	0.381	0.000	0.486	0.000	1.000	3095	0%
Growth ambition	4.536	5.000	0.800	1.000	5.000	3095	2%
Government support	0.642	0.000	1.711	0.000	12.429	3095	4%
Innovation							
Human capital staff	0.312	0.176	0.320	0.000	1.000	3095	6%
R&D expenditures / Assets 2001	0.556	0.024	1.955	0.000	13.617	3095	34%
Product innovation	0.447	0.000	0.497	0.000	1.000	3095	1%
Process innovation	0.281	0.000	0.450	0.000	1.000	3095	1%
Organizational innovation	0.148	0.000	0.355	0.000	1.000	3095	1%
Log (Number of patents)	0.385	0.000	0.784	0.000	5.638	3095	4%
Breadth of IP protection	4.334	4.000	2.698	0.000	8.000	3095	0%
Forms of Technology Acquisition	1.728	1.000	1.497	0.000	9.000	3095	0%
Collaborations	1.314	1.000	1.656	0.000	9.000	3095	0%
Pay-off period of innovation	2.426	2.000	1.333	1.000	5.000	3095	1%

Table 3

Correlation matrix

		1	2	3	4	5	6
1	External finance sought						
2	External finance obtained						
3	Firm age	−0.07***	0.07**				
4	Firm size	−0.01	0.14***	0.31***			
5	US firm	0.10***	0.03	0.01	0.05***		
6	Independent firm	0.14***	0.02	−0.05***	−0.31***	0.15***	
7	Manufacturing	0.04**	0.04	0.23***	0.07***	0.14***	−0.03
8	Internationalization	−0.05***	−0.01	0.14***	0.21***	0.03*	−0.15***
9	Foreign competitors	0.02	−0.11***	0.07***	0.17***	−0.23***	−0.24***
10	Profit margin 2001	−0.14***	0.01	0.06***	0.00	−0.02	0.00
11	Debt/Assets	0.05**	−0.16***	−0.20***	−0.01		−0.09***
12	Replacement investment need (%)	0.00	−0.01	0.11***	0.03*	0.04**	−0.01
13	Replacement investment need n/a	−0.10***	0.02	−0.04**	0.00	−0.14***	−0.04**
14	Growth ambition	0.08***	−0.01	−0.17***	0.03*	0.10***	0.02
15	Government support	0.13***	0.04	−0.03	0.04**	−0.04**	0.00
16	Human capital staff	0.00	−0.06*	−0.25***	−0.13***	0.22***	0.01
17	R&D expenditures / Assets 2001	0.02	−0.07**	−0.13***	−0.11***	−0.05**	0.03
18	Product innovation	0.05***	0.00	−0.08***	0.05***	0.06***	0.00

19	Process innovation	0.06***	0.09***	−0.05***	0.04**	0.08***	0.02
20	Organizational innovation	0.04**	0.01	−0.03	0.04**	0.05***	0.03*
21	Log (Number of patents)	0.01	−0.04	0.01	0.21***	0.08***	−0.14***
22	Breadth of IP protection	0.04*	−0.08**	−0.02	0.18***	−0.18***	−0.16***
23	Forms of technology acquisition	0.08***	0.10***	−0.03	0.20***	−0.01	−0.08***
24	Collaborations	0.10***	0.00	−0.09***	0.11***	0.11***	−0.03*
25	Pay-off period of innovation	0.08***	−0.09***	0.01	0.06***	0.05***	−0.06***

		11	12	13	14	15	16	17
12	Replacement investment need (%)	0.00						
13	Replacement investment need n/a	0.00	−0.60***					
14	Growth ambition	0.07***	−0.06***	−0.02				
15	Government support	0.02	−0.03*	−0.01	0.07***			
16	Human capital staff	0.07***	−0.02	0.02	0.17***	0.13***		
17	R&D expenditures / Assets 2001	0.07***	−0.05***	−0.01	0.07***	0.11***	0.16***	
18	Product innovation	0.04	−0.05***	−0.01	0.16***	0.14***	0.16***	0.11***
19	Process innovation	0.04	−0.03*	−0.01	0.10***	0.06***	0.10***	0.03*
20	Organizational innovation	0.05**	−0.02	−0.02	0.07***	0.04**	0.04**	0.01
21	Log (Number of patents)	0.02	−0.08***	0.01	0.11***	0.14***	0.14***	0.07***
22	Breadth of IP	0.03	−0.07**	0.02	0.15*	0.17**	0.15**	0.13*

	protection		*		**	*	*	**
23	Forms of technology acquisition	0.04	−0.02	−0.03*	0.11***	0.17***	0.16***	0.04*
24	Collaborations	0.02	−0.04**	−0.01	0.12***	0.19***	0.31***	0.08**
25	Pay-off period of innovation	0.04*	0.01	−0.04**	−0.03	0.06***	0.02	−0.02
		21	22	23	24			
22	Breadth of IP protection	0.41***						
23	Forms of technology acquisition	0.19***	0.28***					
24	Collaborations	0.22***	0.27***	0.38***				
25	Pay−off period of innovation	0.09***	0.11***	0.12***	0.10***			

Pairwise Pearson correlations; observations on external finance obtained are conditional on seeking finance.

Significance levels: ***$P < 0.01$; **$P < 0.05$; *$P < 0.1$.

We expect larger and older firms to be less financially constrained relative to smaller and younger firms owing to greater availability of information and collateral, as suggested by pecking order theory. Manufacturing businesses could be more constrained than services owing to higher (physical) capital intensity; however, increased reliance on tangible as opposed to intangible resources might produce the opposite effect owing to the availability of collateral. As to the characteristics of the market in which firms operate (sector, scope, and competition), these may reflect different opportunities but also different levels of capital requirements and risk. Consequently, the degree of internationalization is expected to lead to higher demand for external finance, but not necessarily to a higher probability of obtaining it. Both higher internationalization and a high degree of foreign competition can be associated with loss of investment “transparency” and increased agency risk, which could lead to capital supply problems.

The second block of variables corresponds to financial aspects of the firm and its growth opportunities. We include indicators for profit margins, leverage,

replacement investments, government support, and the firm's growth ambition. Unfortunately, and despite our best efforts to obtain these data through available sources (including Worldscope, Compustat and Orbis), we can include leverage (debt/assets) data only for the UK sample owing to lack of available data on unlisted US companies.

We expect the demand for finance by healthy or established businesses to be weaker, as they can source capital through retained earnings, although they might have advantages in obtaining external capital from risk-averse lenders. The growth ambition of firms, which is likely to require expansion investments, should lead to a higher probability of seeking finance. Two additional indicators for capital requirements are the proportion of replacement investments as a percentage of total capital expenditures (capex) and, derived from the same survey question, a dummy variable that corresponds to missing values in this survey question. A small proportion of replacement investments can indicate a growing firm (owing to high net investment) and could therefore be positively related to the likelihood of seeking finance. Missing data on replacement investment, on the other hand, can act as an indicator for no capex and therefore smaller capital requirements. As these variables are related to the need for finance, we expect them to explain a firm's finance-seeking behavior, but not the likelihood to obtain external funds. Finally, government support might lead to an increased likelihood of seeking and obtaining finance owing to its certification effect and a possible reduction of information asymmetries by government agencies. It could also reduce the risk of bankruptcy, which should improve the firm's chances of obtaining external finance.

The focus of this article is on the effects of innovation on external finance, which we aim to capture through a group of variables that measure different facets of a firm's innovation process. Contrary to the vast majority of prior contributions, we are not limited to the use of one indicator for innovation—R&D expenditure—in our analysis of the market for external finance. As called for by Hall (2009) in her recent review article, we address the problem with a richer set of indicators of innovation input (R&D intensity and human capital), intermediate output (patents), and innovation output (product, process, and organizational innovations). To date, only few articles have used indicators of innovation instead of, or in combination with, the more traditional measure of R&D (Canepa and Stoneman, 2008; Savignac, 2008).

As we have argued, these indicators reflect different levels of risk as well as informational content that can be used to mitigate information asymmetries between potential investors and investees. We also include in our analysis information on additional characteristics of the innovation process: forms of technology acquisition and collaborations with external partners are used as proxies for possible (but not cost-free) substitutes to internally generated

innovation; the extent of IP protection (a count variable that captures the use of different IP protection mechanisms as listed in CIS questionnaires) and the length of firms' project pay-off periods are risk factors and consequently sources of further asymmetric information.

Knowledge intensity as measured by human capital or R&D expenses could be associated with higher idiosyncratic risks or asymmetric information and therefore cause difficulties in obtaining finance. Firms with larger human capital might also have fewer tangible assets, aggravating potential financing problems. We therefore expect these variables to be negatively associated with the likelihood of obtaining finance. External certification by patent offices or by verifiably introducing new products processes or organizational structures should theoretically reduce agency risk, which in turn increases the availability of external finance. Similarly, if a firm protects its IP, we expect it to be more successful in obtaining finance.

Collaboration and acquisition of externally developed technology can both indicate an increased need for finance. However, if a firm acquires external knowledge, the purchase of such knowledge reduces informational risks for investors as opposed to internally created knowledge. We can therefore expect a higher probability to obtain finance in firms that engage in knowledge acquisition. Long pay-off periods for innovation investments are similar in that they might cause firms to seek additional external funds for these investments, whereas at the same time, aggravating agency problems owing to the uncertain outcome of these projects.

The data we use in this article are cross-sectional and might pose endogeneity problems. To reduce this risk, wherever possible, we use lagged values referring to the beginning of the period of observation for the regressors, which are derived from specific questions on the firm's characteristics or behaviors 3 years before the survey (that is to say in 2000/2001). These lagged observations are not available for our indicators of innovation. However, it is unlikely that causal mechanisms could go from the probability of seeking and obtaining finance to innovation during the same period, given that any investment in innovation takes time to generate any outcome and that the consequences of investments, in the cases where finance was obtained, could only be observed in the following, unobserved, 3-year period. In addition, although the survey asked respondent about their innovation activities during the previous 3 years, the financing questions addressed the shorter period of the previous 2 years.

Spurious correlation between finance and innovation could also be induced through serial correlation in the probability of obtaining finance if prior success in external capital markets also determines whether the firm innovates in the current period. But it is unlikely that the probability of obtaining finance depends on prior success conditional on firm and market

characteristics because investors evaluate *current* firm characteristics, for which we can control. Against the potential problem of unobserved heterogeneity, we can exploit an unusually rich set of data and include a broad range of firm characteristics. Finally, when simultaneity cannot be ruled out on theoretical grounds, we explicitly test for endogeneity following Wooldridge (2002, p. 474, Procedure 15.1) and adapt our estimation strategy accordingly to rule out the occurrence of this problem in all the models we use.

3.4 Model estimation

The nature of the survey data and scale types of our variables suggest the use of probit models to estimate the determinants of financing decisions. At the most basic level, indicators for firms' finance seeking behavior and subsequent success in obtaining finance are dichotomous variables that can be modelled by probit or logit models. We choose probit models because these can be used in bivariate setups with endogenous selection and thus allow for consistent models of both decisions to seek and obtain finance. A second reason to choose binomial models is the higher propensity of respondents to answer simple questions as compared with questions that involve estimation of financial quantities, which mitigates missing data problems. In the case of obtaining finance, firms usually obtain either nothing or the total amount of finance sought, leaving little variation between the extremes to be explained by a linear or tobit model. Instead of the usual two-step Heckman correction for linear models, we use the equivalent technique of a bivariate probit model with selection (van de Ven and van Praag, 1981) to estimate the likelihood of obtaining finance by full maximum likelihood.

We use firm status (independent firm) as an exclusion restriction in the second stage model. We expect that if a firm is a member of a group, it is less likely to seek external finance owing to the potential availability of an intra-group capital market. Moreover, if a firm has exhausted funds available within the group and it approaches external capital markets for capital, the existence of an internal market should not matter for the firm's chances to obtain external funding. We can therefore exclude this variable from the second stage equation.[6]

For each one of the questions we ask in the article, we run a first set of baseline estimations with control, financial and R&D variables, and a second set with indicators of intermediate and final innovation output. Potential collinearity problems are addressed by estimating additional models where necessary. We estimate two models, one for the UK and one for the United States to identify the source and magnitude of the differences between the samples. We then add estimations on the pooled data, with the inclusion of a dummy to detect country effects. All estimations are based on multiple random imputations of the data, in which we impute missing values by random regression and

average coefficients over five such imputations and adjust standard errors accordingly.

4. Results

The first set of models focuses on the probability of seeking external finance. Models 1 and 2 in Table 4 present results for the UK and the US subsamples, and Model 3 is an estimation on the full sample. As expected, firm age exerts a negative and significant effect reflecting the search for finance by younger firms, a pattern that seems to be particularly strong for the United States.[7] Independent firms are more likely than subsidiaries or affiliated firms to seek finance, and manufacturing businesses seek finance more often than service firms or other businesses, although this cannot be confirmed for the US subsample where this effect is not significant. Firms with higher degrees of internationalization are less likely to look for external finance, but UK firms that are subject to foreign competition in their home market will be relatively more inclined to need outside capital. The fact that the degree of foreign competition has no effect in the US sample may reflect that the United States is a large continental economy.[8] As internationalization and foreign competition relate to similar product market characteristics, there is some degree of correlation between them (see Table 3). Results are robust if we include one variable at a time.

Table 4
Seeking finance

	UK (1)	US (2)	All (3)	UK (4)	US (5)	All (6)
Firm age	−0.072 (0.04)*	−0.180 (0.06)***	−0.113 (0.03)***	−0.069 (0.04)*	−0.168 (0.06)***	−0.109 (0.03)**
Firm size	0.041 (0.03)	0.049 (0.04)	0.045 (0.02)*	0.025 (0.03)	0.015 (0.04)	0.024 (0.02)
US firm			0.234 (0.06)***			0.237 (0.06)**
Independent firm	0.445 (0.08)***	0.585 (0.12)***	0.473 (0.07)***	0.455 (0.08)***	0.588 (0.12)***	0.482 (0.07)**
Manufacturing	0.171 (0.08)**	0.000 (0.10)	0.103 (0.06)*	0.203 (0.08)**	0.031 (0.11)	0.141 (0.06)**
Internationalization	−0.060 (0.03)**	−0.077 (0.03)***	−0.071 (0.02)***	−0.065 (0.03)**	−0.079 (0.03)**	−0.074 (0.02)**
Foreign competitors	0.321 (0.10)***	0.123 (0.14)	0.287 (0.08)***	0.306 (0.10)***	0.106 (0.15)	0.263 (0.08)**

Profit margin 2001	−0.792 (0.23)***	−1.458 (0.28)***	−1.066 (0.18)***	−0.762 (0.22)***	−1.424 (0.28)***	−1.036 (0.19)**
Debt/Assets	0.153 (0.08)*			0.156 (0.08)*		
Replacement investment need (%)	−0.077 (0.12)	−0.428 (0.13)***	−0.243 (0.09)***	−0.055 (0.12)	−0.390 (0.13)***	−0.216 (0.09)**
Replacement investment need n/a	−0.201 (0.08)**	−0.476 (0.10)***	−0.333 (0.06)***	−0.180 (0.09)**	−0.450 (0.10)***	−0.310 (0.06)**
Growth ambition	0.109 (0.04)***	0.072 (0.05)	0.099 (0.03)***	0.104 (0.04)***	0.065 (0.06)	0.091 (0.03)**
Government support	0.094 (0.02)***	0.090 (0.02)***	0.093 (0.01)***	0.083 (0.02)***	0.079 (0.02)***	0.081 (0.02)**
Human capital staff	−0.082 (0.13)	−0.348 (0.14)**	−0.186 (0.09)**	−0.162 (0.14)	−0.456 (0.15)***	−0.269 (0.10)**
R&D expenditures / Assets 2001	0.008 (0.02)	−0.017 (0.03)	0.002 (0.01)	0.007 (0.02)	−0.017 (0.03)	0.000 (0.01)
Product innovation				−0.067 (0.07)	0.001 (0.09)	−0.037 (0.06)
Process innovation				0.118 (0.09)	0.038 (0.09)	0.082 (0.06)
Organizational innovation				−0.071 (0.11)	0.124 (0.10)	0.029 (0.07)
Log (Number of patents)				−0.069 (0.05)	−0.027 (0.06)	−0.053 (0.04)
Breadth of IP protection				0.016 (0.01)	0.012 (0.02)	0.015 (0.01)
Forms of technology acquisition				0.038 (0.02)	0.049 (0.03)*	0.041 (0.02)**
Collaborations				0.041 (0.02)*	0.054 (0.02)**	0.047 (0.02)**
Pay-off period of innovation				0.043 (0.02)*	0.074 (0.03)***	0.057 (0.02)**
Intercept	−1.193 (0.26)***	−0.005 (0.33)	−0.731 (0.19)***	−1.349 (0.26)***	−0.222 (0.34)	−0.912 (0.20)**
Observations	1795	1300	3095	1795	1300	3095
LR test	131.534	149.152	285.130	151.400	173.252	326.224

P-value	0.000	0.000	0.000	0.000	0.000	0.000
Log-likelihood	−1064	−809	−1886	−1054	−797	−1865
McFadden R^2	0.058	0.084	0.070	0.067	0.098	0.080

The dependent variable in these probit models is equal to one if a firm sought finance over the survey period and zero otherwise. Debt is observed for UK firms only. Standard errors are shown in parentheses.

Significance levels: ***$P < 0.01$; **$P < 0.05$; *$P < 0.1$.

The indicator for human capital—the percentage of staff with a degree—exerts a negative effect on the demand for finance, which might be interpreted as evidence that overall the demand for external capital of knowledge-intensive firms will be lower than less knowledge-intensive firms. The growth ambition of the firm also has a significant effect, even though the result appears to be driven by the UK sample. Significant positive effects are also found for the firms' reliance on external technology sourcing (technology acquisition) and collaborations with other organizations, which are both resource-intensive activities. Long pay-off periods, which imply higher uncertainty or complexity of the innovation process, exert a similar positive effect.

With respect to firms' finances, unsurprisingly, low profit margins are a negative and strongly significant predictor of the search for external finance. This is exactly what we would expect if firms were financing projects first by internal cash flow and only later through capital markets. A firm's capex can serve as a proxy for its financing needs. When we construct a measure of capex scaled by total assets from the survey data, this variable shows many extreme values and about a third of all values are missing. It is therefore possible that the effect of this variable is insignificant because of data problems. However, the inclusion of an indicator for missing capex data yields a highly significant negative coefficient (not shown), which suggests that firms without capex tend not to answer this survey question.

In addition to this indicator for missing capex information, the data contain another, and even stronger, indicator related to capex: the percentage of capex used for replacement investments. Interestingly, firms seeking finance tend not to answer this survey question, which is also the case for the question on capex, albeit with less significance. One likely explanation for this effect is that firms did not answer a question asking for a percentage because the denominator—capex—was zero. A firm having no capex would also be less likely to need finance. We find additional evidence in favor of this explanation in a probit regression of our indicator for missing replacement investment data on capex, where the coefficient on capex is negative and highly significant. The percentage of replacement investments is negatively related to finance

seeking behavior, which we interpret as an indicator of growing companies with a large amount of capex for new and additional assets. Leverage (Debt/Assets), which unfortunately we can only compute for UK firms owing to lack of data on unlisted US companies, is positively, if weakly, associated with our dependent variable. Government support exerts a positive and significant effect, a likely indication that financial government support does not by itself solve the problem of SMEs' financial constraints.

If we look at the effects of R&D, the message is clear: R&D-intensive (higher R&D/Assets) firms will not be more likely than less R&D-intensive firms to look for external finance. This result indicates that at least on the demand side of external capital markets, R&D does not aggravate the need for finance. Similarly, when we unpack the characteristics of the firms' innovative activities (Models 4, 5 and 6), neither the number of patents nor the scope of IP rights protection is significant. A focus on the nature of firms' innovative output as opposed to input reveals that the introduction of product, process, and organizational innovation is overall inconclusive. Reassuringly, comparing results for UK and US firms reveals that whenever we find a significant predictor for the likelihood to seek finance in one subsample, the same variable's coefficient for the other subsample shows the same sign.

Analyses of the supply of external capital (Models 7–12) reveal different patterns. The simultaneous estimation of a bivariate probit model with selection shows that investors are sensitive to firm size, which has a positive and highly significant effect on the probability that firms obtain finance, but not age. In addition, lenders seem to react negatively to firms exposed to intense competition from foreign companies, whose effect we find is strongly significant. Overall, investors seem to reward healthier companies (see for example the effect of leverage in Models 7 and 10). Government support, on the other hand, does not show the expected positive effect on SMEs' finances. Instead, its impact is limited to an increased demand for finance.[9] Past profits strongly predict the demand for finance, but not firms' success in obtaining it.[10]

On a bivariate basis, R&D intensity exerts a significant negative effect on the probability that firms obtain finance, which can be interpreted as a weak indication of risk aversion in external investors evaluating R&D projects, resulting in tighter financial constraints for R&D-intensive firms. The significance of this effect, however, vanishes in the multivariate setting. Complementary evidence on the negative role of uncertainty is provided by the strongly significant negative effects of the length of the pay-off period for innovation.[11]

We obtain interesting results when we look beyond innovation inputs and consider innovation outputs. The indicator for patents is insignificant, but here, contrary to our tests on the demand for external capital, different types of

innovation generate strong significant results: having innovated a process significantly helps firms to obtain finance (these innovations are new to the market, not simply to the firm). Product innovation exerts a consistently positive effect, an indication that investors reward this signal of potential future returns. Organizational innovation shows a consistently negative effect, possibly because of a higher risk of adjustments to more complex changes in the division of labor (as opposed to the typically cost-cutting effects of process innovations). Most interestingly, all these results are found in the US sample, which seems to suggest a superior ability to assess or to value innovation in US investors. UK firms seem to be more likely to obtain external finance when they outsource technology as opposed to generating their own innovation (see the effect of technology acquisition in Models 10–12).[12] Results for these innovation variables are unchanged if we interact each of them with the country indicator and include this variable in the full sample Model 12. As there is a risk that coefficients in the UK model (4) might be insignificant due to collinearity, we also include the innovation variables one by one, but results remain unchanged.

Results for US firms show that suppliers of capital reward innovative firms to a degree that is not found in the UK. This can be due to different levels of risk-aversion specific to innovation or to different (perceived) average quality of innovation in the two countries. Although we cannot empirically distinguish these two effects in our estimation, we find evidence of higher selectivity and responsiveness to innovation signals by US investors.

We also find that the breadth of IP protection mechanisms pursued by the firm has a detrimental effect on the probability of obtaining finance. This finding is interesting and perhaps counter-intuitive. It could be explained by firms having a higher degree of intangible assets, which require more protection (a symptom of a high risk of imitation) or by what Laursen and Salter (2005) call "myopia of protectiveness" in their study of appropriability strategies and innovation performance: some firms might become too focused on technology exploitation (too protective of their proprietary knowledge) and, for example, divert managerial attention away from securing complementary resources that are key to the success of their innovation in the market.

Most firms that seek finance in our sample obtain at least some of the additional capital they are looking for. This might justify accounting for possible selection effects in a model that predicts firms' likelihood to obtain finance. However, evidence for a causal link between the decision to seek finance and a firm's probability to obtain it is limited, contrary to findings by Eckhard *et al.* (2006). Error correlations between the selection (finance seeking) step and the main equation are insignificant if innovation variables are added to the model. Without innovation variables, the maximum *P*-value is 6.1% for the model using the US sample (Model 8 in Table 5). As a robustness

check, we therefore drop the first stage and estimate the likelihood of obtaining finance directly. Results shown in Table 6 support the hypothesis of independence between the seeking and obtaining finance stages. The model's fit is close to our prior results, and all main determinants of success in obtaining finance remain significant.[13]

Table 5
Obtaining finance

	UK (7)		US (8)		All (9)		UK (
Firm age	0.061	(0.08)	−0.167	(0.09)*	0.041	(0.07)	0.06
Firm size	0.204	(0.07)***	0.152	(0.07)**	0.207	(0.05)***	0.20
US firm					−0.161	(0.13)	
Manufacturing	0.016	(0.17)	0.067	(0.15)	0.104	(0.13)	0.13
Internationalization	0.006	(0.06)	−0.063	(0.04)	0.008	(0.04)	−0.0
Foreign competitors	−0.473	(0.20)**	−0.544	(0.27)**	−0.591	(0.15)***	−0.3
Profit margin 2001	0.399	(0.44)	−0.629	(0.58)	0.550	(0.38)	0.32
Debt/Assets	−0.408	(0.16)**					−0.4
Replacement investment need (%)	0.125	(0.24)	−0.442	(0.19)**	−0.033	(0.18)	0.19
Replacement investment need n/a	0.288	(0.19)	−0.346	(0.19)*	0.193	(0.15)	0.30
Growth ambition	−0.030	(0.09)	−0.017	(0.09)	−0.049	(0.07)	0.00
Government support	0.026	(0.05)	0.108	(0.03)***	0.033	(0.03)	0.04
Human capital staff	0.221	(0.27)	−0.444	(0.21)**	0.054	(0.20)	0.20
R&D expenditures / Assets 2001	−0.035	(0.03)	−0.043	(0.04)	−0.037	(0.03)	−0.0
Product innovation							−0.0
Process innovation							0.04
Organizational innovation							0.24

Log (Number of patents)							−0.1
Breadth of IP protection							−0.0
Forms of technology acquisition							0.11
Collaborations							0.08
Pay-off period of innovation							−0.0
Intercept	1.187	(0.56)**	0.704	(0.52)	0.951	(0.44)**	0.76
Observations, second stage model	486		521		1007		486
Observations, selection model	1701		1276		2977		1701
Pseudo R^2, second stage model	0.077		0.083		0.061		0.11
Pseudo R^2, selection model	0.081		0.104		0.096		0.08
Pseudo R^2, full model	0.081		0.102		0.091		0.08
Wald test full model	38.780		48.676		52.988		40.6
P-value	0.000		0.000		0.000		0.00
Rho (indep. models)	−0.656		0.851		−0.483		−0.2
P-value for LR-test on Rho	0.137		0.061		0.177		0.60
Log-Likelihood full model	−1110		−944		−2077		−110

This table shows results for bivariate probit models with selection for the likelihood of obtaining finance. The dependent variable is equal to one whenever a firm obtained any amount of finance. Coefficients for the selection equation that is estimated simultaneously are not shown but are highly similar to the results in Table 4. Rho is the error term's correlation between the selection and main equations with the associated test of the null hypothesis that both equations are independent. Standard errors are shown in parentheses.

Significance levels: ***$P < 0.01$; **$P < 0.05$; *$P < 0.1$.

Table 6
Obtaining finance—without selection step

	UK (7b)		US (8b)		All (9b)	
Firm age	0.030	(0.09)	−0.093	(0.12)	0.011	(0.07)
Firm size	0.222	(0.08)***	0.226	(0.08)***	0.217	(0.05)***
US firm					−0.055	(0.12)
Manufacturing	0.096	(0.19)	0.139	(0.20)	0.141	(0.13)
Internationalization	−0.031	(0.07)	−0.018	(0.06)	−0.019	(0.04)
Foreign competitors	−0.415	(0.23)*	−0.870	(0.26)***	−0.559	(0.16)***
Profit margin 2001	0.132	(0.49)	0.296	(0.78)	0.279	(0.37)
Debt /Assets	−0.416	(0.17)**				
Replacement investment need (%)	0.138	(0.27)	−0.258	(0.25)	−0.094	(0.18)
Replacement investment need n/a	0.132	(0.20)	0.039	(0.21)	0.056	(0.14)
Growth ambition	0.033	(0.10)	−0.070	(0.12)	−0.016	(0.07)
Government support	0.072	(0.05)	0.063	(0.04)	0.063	(0.03)**
Human capital staff	0.137	(0.31)	−0.274	(0.28)	−0.041	(0.20)
R&D expenditures / Assets 2001	−0.035	(0.03)	−0.044	(0.05)	−0.038	(0.03)
Product innovation						
Process innovation						
Organizational innovation						
Log (Number of patents)						
Breadth of IP protection						

Forms of technology acquisition						
Collaborations						
Pay-off period of innovation						
Intercept	0.515	(0.56)	1.185	(0.68)*	0.548	(0.40)
Observations	486		521		1007	
LR test	29.322		31.160		46.362	
P-value	0.007		0.003		0.000	
Log-likelihood	−176.552		−172.538		−356.469	
Pseudo R^2	0.077		0.083		0.061	

This table shows results for probit models without accounting for possible selection into the seeking-finance regime, but conditional on seeking finance. The dependent variable is equal to one whenever a firm obtained any amount of finance. Standard errors are shown in parentheses.

Significance levels: ***$P < 0.01$; **$P < 0.05$; *$P < 0.1$.

5. Discussion and conclusion

The overall picture we derive from our exploratory analyses shows limited evidence for financing constraints in SMEs and broad support for a pecking order theory of finance. The majority of firms in our sample do not seek external finance and the vast majority of those who do obtain it. We must stress that the point in time at which our survey data were collected broadly reflects a favorable macroeconomic outlook. As a consequence, our findings can only be generalized with a sufficient degree of confidence to periods of normal operations of UK and US firms and capital markets and might not reflect changes in the macroeconomic background at a time of financial and economic turmoil. At the time of writing, the specific short-term and long-term effects of the post-2007 financial crisis are an open question on which further research is much needed, but it might be worth pointing out that there is evidence that at the onset of the crisis, although innovators seem to have been hit harder than non-innovators by rising costs of capital, UK firms expressed stronger concerns about market demand than about the availability of finance (Cosh *et al.*, 2009b).

What we can say about the demand and supply of external capital in normally operating markets is that the demand by R&D-intensive firms is no higher than in the case of less R&D-intensive firms. Our analyses give some indication that uncertain innovation activities negatively affect the supply of finance, in line with the expectation that businesses undertaking risky projects will incur higher external costs of capital and will have access to suboptimal levels of financial resources. However, the strongest results of this study concern the observation of "revealed" innovation beyond the performance of R&D.

Although innovation indicators do not make any difference on the demand for capital—a relatively unexplored area of both theoretical and empirical investigation owing to lack of data on finance seeking behaviors—they do exert strong and significant effects on the probability that lenders will provide finance. This finding confirms that the supply of finance will respond in different ways to projects with different risk profiles and growth opportunities. With our data, we are able to demonstrate the limited validity of the use of R&D as the sole measure of innovation related to firm financial constraints. When we distinguish between different types of innovation, product and especially process innovation tend to attract external capital, but organizational innovation does not. Importantly, the effect exerted on the probability of obtaining finance by innovation indicators is driven by the US sample, which we interpret as an indication of the superior ability of US investors to assess or reward innovation relative to their UK peers.

Although the decision of firms to apply for funding can be predicted to some extent by variables related to the availability of internal funding, market characteristics and innovation activities within the firm, there are only a few strongly significant predictors for the success of such applications.[14] Most notably, larger firms are more likely to obtain finance, a result that is explained by their greater informational transparency and consequent reduction of information asymmetries, along the lines of Berger and Udell (1998, 2006) and Myers and Majluf (1984). Pay-off periods of the firm's innovation projects are strongly and negatively associated with the likelihood of obtaining finance. They clearly signal the greater business risk of long-term projects, which should in general not be a financing constraint, because it would be accounted for by increased costs of capital if information about business risk was symmetric between agents. Long pay-off periods are a significant source of asymmetric information, whereby firm insiders have better access to a project's risk and return characteristics than outside investors, thereby creating the adverse selection problem for potential sponsors identified in the finance literature.

Asymmetric information problems tend to be most severe in firms with intangible capital. If project quality can be assessed by investors, for example, if the firm acquires outside technology instead of developing it within the firm,

access to external finance should be easier. Our measure for the degree of external technology acquisition is positively related to the probability of obtaining finance, which supports the idea that information problems play a role in firm financing, as inputs procured through the market entail lower levels of asset-specific risk. Moreover, the reliance of firms on their intellectual capital as measured by the number of protection mechanisms they use reduces the likelihood of obtaining finance, which again suggests that high-tech firms might be at a disadvantage when trying to raise funds compared with other firms with tangible assets.

A firm's application for finance can be predicted to some degree, but does not seem to influence the likelihood of obtaining finance, which means that there does not seem to be a self-selection process for finance, contrary to the findings of Eckhardt *et al.* (2006) and Cressy (1996).[15] Is it possible that firms do not seek external capital because they do not think they are going to obtain it? Our data do not contain direct information on a possible "discouraged borrowers effect" (Kon and Storey, 2003). However, complementary studies of different—but comparable—samples of UK firms that do contain questions about the reasons underlying finance seeking behaviors provide clear evidence that the overwhelming majority of firms that did not seek external finance did not need any (Cosh and Hughes, 2007; Fraser, 2009).

Finally, most of the firms in our sample are growth-oriented, whereas Hakim (1989) and Vos *et al.* (2007) suggest that the apparent lack of finance in SMEs is due to only a minority of firms wanting to grow. Furthermore, although Vos *et al.* (2007) favor a financial contentment hypothesis, where the lack of growth in small firms could be self-imposed and not due to financial restrictions, this is not the case in our sample where, in contrast to their finding, many firms with similar characteristics do apply for finance. As a consequence, the case for policy intervention cannot be ruled out at least on this ground.

To sum up, in an attempt to deepen the micro-foundations of innovation finance behaviors, the original contribution of this article is 3-fold. First, contrary to the vast majority of existing studies, we have investigated the determinants of finance seeking behaviors before considering the outcome of investment decisions. Second, we have analyzed the probability that firms obtain finance conditional on whether they seek finance. Third, we have explored the effects of innovation—in its input, process and output dimensions—on the likelihood that firms seek and obtain external capital.[16]

This article has, of course, its limitations. Our results are generated by cross-sectional analysis and might be affected by endogeneity and selection bias. We have addressed both problems by lagging variables for which the survey provided observations for a prior period, by performing direct tests whenever necessary and by using a Heckman correction or equivalent techniques (which show that the risk of selection bias is negligible). A unique advantage of our

analysis is that it is based on original data that contain information on economic, financial, and innovation-related characteristics of firms. Of crucial importance has been the possibility to work with separate observations for the demand and the supply of capital instead of inferring the nature of borrowing and lending decisions from indirect observations of their outcomes (cash-flow sensitivity of investment).

There are, of course, many more questions that need to be answered by further research. For example, given the complex nature of firm financing behaviors, we cannot address in any detail the problem of the quality of finance here, and we focus on external finance without distinguishing between different types. An empirical investigation of this issue would provide further tests of pecking order theory as well as new evidence on the reaction of specific groups of investors to innovation signals, including the important case of high-growth firms. This would, however, require a different modeling strategy and estimations and as a consequence has to be the subject of a separate study. Lastly, it would be essential to investigate how the patterns of innovation finance may change through a financial crisis and with what consequences.

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[1]These authors argue that this is a result of social connections of SMEs providing direct utility to their owners instead of merely facilitating financial success through relationship lending (in line with Petersen and Rajan, 1994, 1995, 2002).

[2]As Hall (2009) remarks, this is the R&D version of Akerlof's (1970) "lemons market" problem.

[3]Cosh *et al.* (2006) contains a full description of the survey design, sampling, and instrument.

[4]We never use imputed values for missing observations of dependent variables in our estimations.

[5]One might suspect that these proportions are biased by firms that claim not to have sought finance if they did not obtain it. This would induce a positive correlation between the likelihood to seek finance and the likelihood to obtain it, which we do not find in our results. To the contrary, firms might have an incentive to strategically overstate their financing problems if they expect the study to have policy impact.

[6]All models would be identified by functional form without imposing any restrictions. Excluding this otherwise insignificant variable, however, improves the precision of our results.

[7]The data include a small number of young firms: 4 firms with age = 1 year and 35 with age = 2 years. A dummy that indicates a firm age smaller than 3 years does not yield significant coefficients in either stage of our models.

[8]Foreign competition might not pose as big a threat to firms operating in large domestic market compared with foreign competitions to firms operating a smaller market, such as the UK. To verify this hypothesis with the pooled sample, we also constructed a country dummy interaction term for the degree of foreign competition in models analogous to models 3 and 6. Results are qualitatively identical to those obtained from separate regressions, foreign competition being significant in the UK, but not for US firms.

[9]One anonymous referee pointed out the possible endogeneity of financial government support, a problem that may occur if firms interpret external finance to include government support. The survey question about government support is separate from the question about external finance and is asked in a different section of the survey instrument prior to our dependent variables. This substantially decreases the risk that respondents relate the two questions to one another. Moreover, the piloting of the survey—which included several runs with different samples—did not reveal any confusion in the interpretation of this question. A second indication that firms did interpret the questions as the research team expected is that more than half of the firms receiving government support did not apply for external finance. From the open responses contained in the data, we can also see that firms understand financial government support to mean tax credits, loan guarantees, and grants from national government or regional development agencies. This is finally confirmed by the direct test of checking the amount of government support received by firms against the amount of external finance obtained. Only in 13 cases (<1.5% of the relevant sample), these amounts are identical.

[10]Consistently with pecking order theory, investors care about future, but not past, profitability when supplying finance.

[11]When we adopt a hierarchical modeling strategy, it is not the inclusion of this variable, but instead the inclusion of the control for firm size, that weakens the significance of the effect of our R&D variable.

[12]For this set of findings, coefficients for the UK and US subsamples point in the same direction if at least one of them is significant. The only exception is “organizational

innovation" for which we find a strongly negative relation to the probability of obtaining finance in the United States but a positive, albeit insignificant coefficient for UK firms.

[13]The indicator for missing information about replacement investments loses significance but remains positive in most cases. Similarly, US firms are no more likely to obtain finance than UK firms, although the coefficient is negative.

[14]The magnitude of these individual effects is also limited. Detailed results are available from the authors on requests.

[15]In their study of firms' financing choices, Cosh *et al.* (2009a, b) find a significant selection effect for one type of external finance only ("Hire purchase or leasing firms"). For all other types of finance, model stages are uncorrelated. We do find a selection effect in one specification for the US sample (Model 8 in Table 5). This correlation appears to be driven by the omission of significant variables in the outcome equation. If we use a richer specification, this correlation becomes insignificant.

[16]Note as well that in doing so, we have considered the demand for (and supply of) finance in general, not simply in relation to innovation.

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