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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, but existing empirical research has not found conclusive evidence of a ?finance gap?. Moreover, it is not clear to what extent innovation worsens firm financial constraints and what role innovation inputs, processes and outputs play in the market for external capital. In this paper we analyse how firm-level innovation affects 1) the likelihood of seeking external finance and 2) the likelihood of obtaining it. We analyse an original dataset of 3,095 UK and US small and medium size businesses containing information on firms? innovation behaviours, performance and finances for the period 2002?2004. Controlling for firm-specific characteristics, we provide novel and extensive evidence on the effects of innovation, in its input, process and output dimensions, on the demand for external capital and on its supply.

Jel codes: O30, G32

1. Introduction

Access to finance has figured prominently in the debate on barriers to firm growth, especially for small and medium size enterprises (SMEs). Existing empirical research does not, however, find conclusive evidence of a 'finance gap' (Storey, 1994; 2009; Cosh et al. 2009). 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 worsens the specific financial constraints of firms have arguably been under-researched (Hall, 2010).

This paper addresses the connection between innovation and firm financing, a problem upon 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 analyse an original dataset of 3,095 UK and US businesses containing information on firms' innovation behaviours, 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, since there is no readily available equivalent of CIS data for the US, 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 less likely to obtain it. Profitability and leverage exerts the expected – respectively positive and negative – effects on the supply of external finance. 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. All things being equal, innovation indicators – operationalised 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 organisational innovation, but it is in the US sample that we find a higher sensitivity to innovation signals.

The paper 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 paper 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 small and medium size enterprises. A specific stream of the literature has focussed on the so-called 'finance gap' (Storey, 1994; Deakins, 1996; Jarvis, 2000; NESTA, 2009; Cosh et al.,

2009). A finance gap is configured where a firm has potentially profitable investment opportunities but insufficient funds to exploit them. It can arise from agency-related costs that drive a wedge between the cost of external and internal funds, thus rendering some projects viable only if they can be financed by internal funds. Firms in need of external finance, however, might not be able to obtain it because of capital market imperfections (Berger and Udell, 1998). The nature and scope of these imperfections may vary together with the form of capital that is demanded and supplied, and with the agents' ability to bridge information gaps (Myers et al., 1976; Berger et al., 2001; Berger and Udell, 1998; 2006; Gompers and Lerner, 1999; 2001).

Evidence has been growing against the Modigliani and Miller theorem (1958; 1961) which predicts 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). This view is compatible with a life-cycle view of firm financing: as Berger and Udell (1998) suggest, SMEs might pursue different capital structures over their life cycle, a long-term behaviour that would result in the demand and consequent eventual supply of different kinds of capital over time. Internal funds will be the favoured source of capital in the firm's early years of operations, whereas access to external finance becomes easier as firms grow older and larger.

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; Stiglitz and Weiss, 1981; de Meza and Webb, 1992; de

[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).

Meza, 2002; Carpenter and Petersen, 2002). 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).

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. 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: since 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 (for example, 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.

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 in order 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 due 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).

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 are patents (Jaffe et al. 2001) which signal the know-how firms deem worthy of legal protection. Patents have proved to be useful in quantifying and exploring the outcome of R&D as indicators of invention with some degree

[2] As Hall (2005) remarks, this is the R&D version of Akerlof's (1970) 'lemons market' problem.

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, for example 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. In fact, the overall attitude of the firm towards protecting its IP is highly relevant. The value of IP remains unproven and crucially dependent on subjective judgements prior to the test of the market. Since 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.

In order for the potential value of a novel idea to be realised 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 organisations (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 utilisation of innovation inputs is expected to result in superior products or services, methods of production or ways of organising 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 majority of existing studies cannot distinguish empirically, depend on a composite set of firm-specific characteristics. These include their economic fundamentals, their financial characteristics and their profiles as innovators. The aim of this contribution is to identify and explain 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 paper builds on a unique comparative survey of UK and US businesses jointly carried out by [*anonymised for submission*]. The basis for the sampling was the Dun & Bradsheet (D&B) 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 by size 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 US and 17.5 % for the UK), followed by a postal survey of large firms in Spring 2005 leading to a total sample of 1,540 US firms and 2,129 UK firms.

This survey shares with the European Community Innovation Surveys (CIS) an 'object' oriented 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 to CIS data is that the latter generate very 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 paper, the dataset we use has the advantage of providing separate firm-level observations for the search of external finance and for success at obtaining it.

Since there is no equivalent to CIS data for the US, the database also gives us a rare opportunity to observe whether and where there are differences between the UK and the US, the latter often being 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 US, for example as systems with developed equity markets in contrast to many continental European countries. On the one hand, the UK is traditionally seen as a much less efficient translator of invention into innovation than the US, 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. Since 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 or more 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 below) where observations are found missing. Second, imputation methods are employed 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 FAME (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 prior to 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 unreasonable 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.[3]

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 US and 86 % in the UK. 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, while average (log) size is 3.8 in the US and

[3] Note that we never use imputed values for missing observations of dependent variables in our estimations.

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 organisational improvements.

3.3. Variables

We estimate separate models for the probability that a firm seeks external finance and for the probability that it obtains it. The first set of control variables we use includes essential firm characteristics such as *size*, *age* and *sector* and introduces indicators to qualify the degree of *internationalisation* and the intensity of competition from foreign firms, their *growth ambition* and an indicator of *human capital* (the percentage of staff with a university degree). We expect larger and older firms to be less financially constrained relative to smaller and younger firms. Manufacturing businesses could be more constrained than services due to higher (physical) capital intensity; however, an increased reliance on tangible as opposed to intangible resources might produce the opposite effect due to the availability of collateral. The growth orientation of firms, which is likely to require expansion investments, should lead to a higher probability of seeking finance while knowledge-intensity as measured by human capital could be associated with higher idiosyncratic risks or asymmetric information and therefore cause difficulties in obtaining finance. The characteristics of the market in which firms operate (sector, scope and competition) reflect different opportunities but also different levels of capital requirements and risk; consequently, they are expected to lead to higher demand for external finance but not necessarily to a higher probability of obtaining it.

After this first set of indicators of economic characteristics, a second set of control variables covers some important financial characteristics of firms. We include indicators for *profit margins*, *leverage*, *replacement investments*, receipt of *government support*, and the independent vs. subsidiary *status* of the firm. Unfortunately, and despite our best efforts to obtain these data through available sources (including Worldscope, Compustat and Orbis), we only have leverage (debt/assets) data for the UK sample due to lack of available data on unlisted US companies. We expect the demand for finance by healthy or established businesses to be weaker since they can source capital through retained earnings, although they might have advantages in obtaining external capital from risk-averse lenders. The need for finance should be stronger for independent firms, even though it is plausible that this does imply better chances of obtaining capital.

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 (2010) in her recent review paper, we address the problem with a richer set of indicators of innovation *input* (R&D intensity), *intermediate output* (patents) and *innovation output* (product, process and organisational innovations). To date only very few papers 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 *intellectual property protection* and the length of firms' project *pay-off periods* are risk factors and consequently sources of further asymmetric information.

Table 1 contains the list and description of our economic, financial and innovation variables.

TABLE 1 ABOUT HERE

(Both descriptive statistics and correlation tables are available but could not be included in this version of the paper because of space constraints).

The data we use in this paper are cross-sectional and might pose endogeneity problems. In order 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 behaviours three years prior to the survey (that is to say in 2000/2001). These lagged observations are not available for our indicators of innovation, but it is very unlikely that causal mechanisms could go from the probability of seeking and obtaining finance to innovation over 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. Also, while the survey asked respondent about their innovation activities over the previous three years, the financing questions addressed the shorter period of the previous two years. Finally, when simultaneity cannot be ruled out on theoretical grounds, we explicitly test for endogeneity following Wooldridge (2002, p. 474, Procedure 15.1) and adapted our estimation strategy accordingly 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 behaviour 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 to 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 employ 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.[4]

For each one of the questions we ask in the paper we run a first set of baseline estimations with economic, 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 US 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] Firm status (independent firm) and government support provide two exclusion restrictions on the second step because they are individually insignificant in this equation.

4. Results

The first set of models focuses on the probability of seeking external finance (Table 2). Models 1 and 2 present results for the UK and the US subsamples, 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 US. *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 internationalisation* are less likely to look for external finance but UK firms who 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 US is a large continental economy.[5]

TABLE 2 ABOUT HERE

The indicator for *human capital* – the percentage of staff with a degree – exerts a negative effect on US and UK, 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 exerts a significant effect, even though the result appears to be driven by the UK sample. Significant positive effects are also found

[5] Foreign competition might not pose as big a threat to firms operating in large domestic market compared to 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.

for the firms' reliance on external technology sourcing (*technology acquisition*) and *collaborations* with other organisations, 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 capital expenditures (capex) can serve as a proxy for its financing needs. When we construct a measure of capital expenditures 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 capital expenditure data yields a highly significant negative coefficient, which reassures us of the consistency of our data.

In addition to this indicator for missing capex information the data contain another, and even stronger, indictor related to capital expenditure: the percentage of capital expenditures used for *replacement investments*. Interestingly, firms seeking finance tend not to answer this survey question, which is also the case for the question on capital expenditures, albeit with less significance. One likely explanation of this effect is that firms did not answer a question asking for a percentage, because the denominator – capital expenditures – was zero. A firm having no capital expenditures would also be less likely to need finance. We find additional evidence in favour of this explanation in a probit regression of our indicator for missing replacement investment data on capital expenditures, where the coefficient on capital expenditures is negative and highly significant. The percentage of replacement investments is negatively related to finance seeking behaviour, which we interpret as an indicator of growing companies with a large amount of the capital expenditures for new and additional assets.

Leverage (*Debt/Asset*s), which unfortunately we can only compute for UK firms due 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 government support does not solve the problem of SMEs' financial constraints.

If we look at the effects of R&D, the message is quite 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 finance demand side R&D does not worsen the need for finance. Similarly, when we try to unpack the characteristics of the firms' innovative activities (Models 4, 5 and 6), neither the *number of patents* nor the scope of *intellectual property rights protection* (the first indicator capturing the number of strong formal rights and the second capturing the extent of use of secrecy, complexity of design, lead time advantages and confidentiality agreements as a count variable, as is done in the literature on breadth vs. depth of IP protection) are significant. A focus on the nature of firms' innovative output as opposed to input reveals that the introduction of *product, process* and *organisational innovation* are 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 reassuringly 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 very sensitive to *firm size*, which has a positive and strongly significant effect of 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 reward healthier companies: the effect of *profit margins* is positive in the base model (7), and for the UK the indicator for *leverage* has the

expected negative sign and strong significance (models 7 and 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.[6]

TABLE 3 ABOUT HERE

We obtain very 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 (note that 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. *Organisational* innovation shows a consistently negative effect, possibly because of a higher risk of adjustments to more complex changes in the division of labour (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

[6] Note that when we adopt a hierarchical modelling strategy it is not the inclusion of this variable, but instead the inclusion of the control of firm size, that weakens the significance of the effect of our R&D variable.

the effect of *technology acquisition* in models 10-12).[7] 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. Since coefficients in the UK model (4) might be insignificant due to collinearity, we also try to include innovation variables one by one, but results do not change.

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. While 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

[7] 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 'organisational innovation' for which we find a strongly negative relation to the probability of obtaining finance in the US but a positive, albeit insignificant coefficient for UK firms.

between the decision to seek finance and a firm's probability to obtain it is limited. 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 2.6 percent for the model using the full sample (model 9 in table 3). As a robustness check we therefore drop the first stage and estimate the likelihood of obtaining finance directly. Results shown in table 4 support the hypothesis of independence between the seeking and obtaining finance stages. The model's fit is very close to our prior results, and all main determinants of success in obtaining finance remain significant.[8]

TABLE 4 ABOUT HERE

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 favourable macroeconomic outlook. As a consequence, our findings can only be generalised with a sufficient degree of confidence to periods of normal operations of 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. What we can say about the demand and supply of

[8] 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.

external capital for normally operating markets is that the demand for external capital of R&D-intensive firms is no higher than 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 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.

While innovation indicators do not make any difference on the demand for capital – a relatively unexplored area of both theoretical and empirical investigation due to lack of data on finance seeking behaviours – 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 organisational 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. 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 Guiso (1998).

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 well identified in the literature on firm financial constraints.

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, these firm should be able to obtain finance more easily. Our measure for the degree of external technology acquisition is positively related to the probability of this outcome, which supports the idea that information problems play a role in firm financing since inputs procured through the market entail much 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 to 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 Cressy (1996). If anything, firms that would obtain finance do not tend to apply for it, as indicated by a negative – but insignificant – correlation coefficient between the selection equations and the main equations in table 3. This effect is driven by profit margins, which are low for firms that seek finance, but high for those which obtain it.

The vast majority of 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, while Vos et al. (2007) favour 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.

This paper 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, by performing direct tests and by adopting 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 behaviours, here we cannot address in any detail the problem of the quality of finance and we focus on external finance without distinguishing between different types. An empirical investigation of this issue could provide more extensive evidence of pecking order theory as well as new evidence of the reaction of specific groups of investors to innovation signals. This would, however, require a different modelling strategy and estimations and as a consequence has to be the subject of a separate study. Last but not least, it would be crucial to investigate in what way the patterns of

innovation finance change through a financial crisis. Work is in progress to answer this urgent set of questions.

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Table 1: Variable definitions

Variable name	Definition
External finance sought	A dummy variable equal to one if the firm attempted to obtain external finan (i.e. in addition to retained earnings and depreciation) in the 2002–2004 period
External finance obtained	A dummy variable equal to one if the firm obtained 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 US and zero otherwise
Firm size	The natural log of the average number of employees three 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 three years prior to the survey
Debt/Assets	Debt / total assets in 2002; available for UK firms only
Replacement investment need (%)	Replacement investments as a percentage of total capital expenditures
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 last 3 years in GBP thousands + 1)
Internationalisation	The number of world regions in which the firm does business; coded numerically 1=national to 7=international
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 three years prior to 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.
Organisational 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: Seeking finance

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.

	UK (1)	US (2)	All (3)	UK (4)	US (5)	All (6)
Firm age	-0.072*	-0.180***	-0.113***	-0.069*	-0.168***	-0.109***
Firm size	0.041	0.049	0.045*	0.025	0.015	0.024
US firm			0.234***			0.237***
Independent firm	0.445***	0.585***	0.473***	0.455***	0.588***	0.482***
Manufacturing	0.171**	0.000	0.103*	0.203**	0.031	0.141**
Internationalisation	-0.060**	-0.077***	-0.071***	-0.065**	-0.079**	-0.074***
Profit margin 2001	-0.792***	-1.458***	-1.066***	-0.762***	-1.424***	-1.036***
Debt/Assets	0.153*			0.156*		
Government support	0.094***	0.090***	0.093***	0.083***	0.079***	0.081***
Replacement investment need	-0.077	-0.428***	-0.243***	-0.055	-0.390***	-0.216**
Replacement investment need n/a	-0.201**	-0.476***	-0.333***	-0.180**	-0.450***	-0.310***
Foreign competitors	0.321***	0.123	0.287***	0.306***	0.106	0.263***
Growth ambition	0.109***	0.072	0.099***	0.104***	0.065	0.091***
Human capital staff	-0.082	-0.348**	-0.186**	-0.162	-0.456***	-0.269***
R&D expenditures / Assets 2001	0.008	-0.017	0.002	0.007	-0.017	0.000
Log (Number of patents)				-0.069	-0.027	-0.053
Product innovation				-0.067	0.001	-0.037
Process innovation				0.118	0.038	0.082
Organisational innovation				-0.071	0.124	0.029
Breadth of IP protection				0.016	0.012	0.015
Forms of Technology Acquisition				0.038	0.049*	0.041**
Collaborations				0.041*	0.054**	0.047***
Pay-off period of innovation				0.043*	0.074***	0.057***
Intercept	-1.193***	-0.005	-0.731***	-1.349***	-0.222	-0.912***
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

Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 3: Obtaining finance

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 3. 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.

	UK (7)	US (8)	All (9)	UK (10)	US (11)	All (12)
Firm age	0.062	-0.040	0.049	0.072	-0.052	0.029
Firm size	0.197***	0.209***	0.196***	0.192**	0.250***	0.212***
US firm			-0.191*			-0.215*
Manufacturing	0.013	0.133	0.093	0.093	0.209	0.167
Internationalisation	0.008	0.013	0.017	0.002	0.057	0.031
Profit margin 2001	0.410	0.655	0.590*	0.409	0.764	0.540
Debt / Assets	-0.400***			-0.390**		
Replacement investment need	0.111	-0.110	-0.016	0.170	-0.179	-0.052
Replacement investment need n/a	0.288	0.199	0.228*	0.357*	0.115	0.207
Foreign competitors	-0.458**	-0.816***	-0.573***	-0.380*	-0.858***	-0.567***
Growth ambition	-0.030	-0.087	-0.055	-0.016	-0.146	-0.075
Human capital staff	0.250	-0.115	0.097	0.277	0.181	0.209
R&D expenditures / Assets 2001	-0.033	-0.027	-0.033	-0.036	-0.024	-0.036
Log (Number of patents)				-0.094	0.006	-0.051
Product innovation				-0.047	0.348**	0.114
Process innovation				0.034	0.616***	0.327**
Organisational innovation				0.221	-0.485**	-0.202
Breadth of IP protection				-0.041	-0.094**	-0.050**
Forms of Technology Acquisition				0.100	0.102*	0.104**
Collaborations				0.072	-0.083*	-0.021
Pay-off period of innovation				-0.059	-0.252***	-0.127***
Intercept	1.223**	1.308**	1.048***	1.028	1.825***	1.174**
Observations, 2nd stage model	486	521	1007	486	521	1007
Observations, selection model	1701	1276	2977	1701	1276	2977
Pseudo R^2, 2nd stage model	0.069	0.076	0.055	0.108	0.190	0.102
Pseudo R^2, selection model	0.074	0.091	0.088	0.081	0.104	0.096
Pseudo R^2, full model	0.074	0.089	0.083	0.085	0.121	0.097
Wald test full model	38.954	29.624	56.426	41.968	59.322	76.596
P-value	0.000	0.004	0.000	0.003	0.000	0.000
Rho (indep. models)	-0.681	-0.533	-0.609	-0.534	-0.822	-0.510
P-value for LR-test on Rho	0.069	0.199	0.026	0.202	0.117	0.095
Log-Likelihood full model	-1119	-957	-2094	-1107	-924	-2063

Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Table 4: Obtaining finance – Without selection step

This table shows results for probit models without accounting for possible selection into the seeking-finance regime. The dependent variable is equal to one whenever a firm obtained any amount of finance.

	UK (7b)	US (8b)	All (9b)	UK (10b)	US (11b)	All (12b)
Firm age	0.032	-0.090	0.011	0.053	-0.122	-0.002
Firm size	0.214***	0.236***	0.217***	0.192**	0.291***	0.220***
US firm			-0.078			-0.128
Manufacturing	0.099	0.147	0.145	0.188	0.289	0.237*
Internationalisation	-0.026	-0.015	-0.015	-0.025	0.022	0.007
Profit margin 2001	0.134	0.225	0.245	0.213	0.174	0.259
Debt / Assets	-0.398**			-0.375**		
Replacement investment need	0.117	-0.249	-0.101	0.186	-0.377	-0.116
Replacement investment need n/a	0.153	0.047	0.070	0.266	-0.116	0.080
Foreign competitors	-0.381*	-0.839***	-0.530***	-0.309	-0.982***	-0.533***
Growth ambition	0.048	-0.061	-0.005	0.044	-0.117	-0.037
Human capital staff	0.249	-0.199	0.044	0.242	0.064	0.146
R&D expenditures / Assets 2001	-0.028	-0.030	-0.030	-0.032	-0.030	-0.034
Log (Number of patents)				-0.123	-0.013	-0.068
Product innovation				-0.051	0.438**	0.136
Process innovation				0.087	0.724***	0.381***
Organisational innovation				0.236	-0.521**	-0.206
Breadth of IP protection				-0.048	-0.110**	-0.056**
Forms of Technology Acquisition				0.132**	0.147**	0.133***
Collaborations				0.092	-0.058	-0.004
Pay-off period of innovation				-0.053	-0.265***	-0.121***
Intercept	0.474	1.092	0.517	0.349	1.483**	0.667
Observations	486	521	1007	486	521	1007
LR test	26.438	28.578	41.398	41.184	71.588	77.480
P-value	0.010	0.004	0.000	0.004	0.000	0.000
Log-likelihood	-178	-174	-359	-171	-152	-341
Pseudo R^2	0.069	0.076	0.055	0.108	0.190	0.102

Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$