Financial Innovation in the UK

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Abstract

This study employs a recent national survey of over 1100 British financial firms to ascertain the determinants of financial innovation and their sales success using Logit and generalised Tobit models. We find the likelihood of financial innovation rises with the size of financial firms, employee education, greater expenditure on research and development, the availability of finance, and the extent to which firms cooperate with each other. R&D, cooperation, and appropriability are the main variables driving the success of financial innovation, measured by the percentage share of innovations sold. Firms in London/the south have a significantly greater tendency to innovate, though Scotland also does well. Stock broking, fund management and related activities are more innovative than firms in the financial intermediation and pension/insurance sectors.

Keywords: Determinants/Success of financial innovation; ISCORE; UK financial sector

JEL classification: G1, G19, G21, G22, G23

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1. Introduction

Economic growth does not just consist of productivity advances in the manufacturing sector. Services may be no less important, and innovation in financial services is also vital. In addition to its direct effects, King and Levine (1993) show it can narrow the margin between deposit and loan rates as well as stimulate permanently faster growth in the rest of the economy.[4]

In finance as elsewhere, innovation is the arrival of a new or better product and/or a process that lowers the cost of producing existing financial services. Innovation embraces the firm that is the first to introduce it and the subsequent spread to others. In the financial sphere, studies have tended to concentrate far more on the latter - secondary development rather than initiation. The principal aim of this paper is to investigate the determinants of financial innovation in the UK, one of the world's leading financial markets.

Although innovation has been a critical part of the financial landscape over the past few centuries, its determinants remain poorly understood. In a review article, Frame and White (2004) identify 39 related empirical studies but most focus on the "back end" of innovation processes, looking at issues such as the way they are diffused, the characteristics of firms that adopt them, consequences for firm performance and social welfare. Only two papers [Ben-Horim and Silber (1977) and Lerner (2002)] test hypotheses on the determinants of financial innovation while Lerner (2006) explores the origins of financial innovation using a firm-specific data base. He stresses the need to "stimulate more theoretical and empirical work on the impact of financial institutions on innovation" (p.225). Scarcity of data appears to be the main explanation for the paucity of empirical studies.

The UK wholesale financial services sector is considered one of the most competitive in the world. Measured by market share, London leads other global financial centres in cross-border bank loans, foreign equities turnover, foreign exchange dealing, over the counter derivatives,

[4] In endogenous growth models, there are two key equations. The first shows a positive link between the real interest rate for households (usually deposits) and the growth rate of consumption, while in the second, there is a non-positive link between the sources of growth (e.g. innovation and/or training) and the real interest rate, typically for borrowing firms. Standard endogenous growth theory treats these two rates as equal but they are not in the presence of either imperfect competition, intermediary costs or distortionary taxation, any of which cause the loan rate to exceed the deposit rate. If financial innovation or the introduction of new products reduces this margin, it will lead to permanently faster economic growth. Hence financial innovation can have a powerful indirect influence over economic growth itself – see King and Levine (1993).

international bonds, and insurance.[5] In 2006, the UK's wholesale finance as a share of country GDP was 3.9%, compared to an EU-25 average of 1.7%. Its country share of EU wholesale finance was 37.6%, followed by Germany (16.2%), France (10.9%), Italy (8%), Spain (6.2%), the Netherlands (5.5%) and Belgium (4.3%).[6] It also has been one of the most innovative services sectors in the UK. Between 2002 and 2004, about 67% of British financial institutions were active in developing or implementing innovations, 10% higher than the national average (Office for National Statistics, 2006).

These observations motivate this study. It seeks to answer several key questions. First, what determines the likelihood of a financial firm engaging in process and product innovation? Second, what factors influence the success of the innovation that takes place? Finally, is there any evidence that some regions or financial sectors are more innovative than others? To address these questions, Logit and generalised Tobit models are estimated using a rich firm level dataset collected by the Fourth *UK Community Innovation Survey* undertaken in 2005 and covering innovative activities from 2002 to 2004, inclusive.

The contribution of this paper to the literature is threefold. First, it is one of the few empirical studies of financial innovation. Second, it focuses on innovation in a key global financial market, and third, it identifies the factors underlying financial innovation and its success.

The main findings are that firm size, a more educated workforce, greater expenditure on research and development (R&D), the availability of external finance and cooperation with other firms increase the likelihood of financial innovation. Problems with endogeneity and reverse causation may explain why perceived economic risk and innovation costs appear to be wrong-signed and significant. R&D and cooperation also influence the extent to which it is successful - measured by the sale of innovations as a proportion of total sales. In addition, the significantly positive sign on appropriabilty suggests that firms able to protect their financial innovation will succeed in generating a higher proportion of innovative sales. Finally, firms in certain financial sectors and regions were found to engage in significantly more financial innovation.

The paper is organized as follows. Section 2 briefly reviews the literature of particular relevance to this study. Section 3 explains the dataset and 4 describes the econometric methods used to answer the questions raised. Section 5 discusses the empirical results, and the

[5] The list is not exhaustive but the US leads in just two areas, corporate finance and exchange traded derivatives. See Heffernan (2005), table 2.2.
[6] Source: Centre for Economic and Business Research and City of London (2007), table 2.1.

final section concludes the paper.

2. Related Theoretical and Empirical Studies

The focus of this paper is to investigate innovations among UK financial institutions. Given the wide range of papers on innovation[7] (albeit few on the empirics of financial innovation), this section sets out the theoretical background and reviews key studies pertinent to the questions raised in the introduction.

Hypotheses on the determinants of innovation include the 'neo-Schumpeterian' literature that investigates the effects of several factors on innovation, firm size being the most prominent. Others (Hoffman et al. 1998; Aghion et al. 2005, etc.) control for firm size and estimate the relationship between innovation and firm-specific characteristics such as financial constraints, the degree of diversification, firm age, and the quality of human capital. Recent literature considers the effects of industry characteristics on innovation, including product market demand, appropriability and technological opportunities. The key ideas are expanded upon below.

2.1 Theoretical Issues

Firm size

Schumpeter (1942) argues that relatively large firms are better suited to pursue innovation, for two key reasons. First, R&D projects usually involve large fixed costs that are only recovered through extensive sales. They are also more likely to enjoy scale and scope economies in the innovation process and have better access to external finance. By contrast, Scherer and Ross (1990) suggest that smaller firms may be more likely to be rapid innovators if R&D in large firms is undermined by loss of managerial control and/or a bureaucratic approach to innovation.

Firm age and Learning by doing

In a theoretical model developed by Aron and Lazear (1990), new (or start-up) firms are more likely to initiate new research programs and introduce new products that may result in higher profits over the longer term. Cannibalization is another factor differentiating new and existing firms. Unlike new firms, incumbents must consider potential lost revenues from sales of an existing product if it is a near-substitute for the innovation. An existing firm might also suffer if the cost of producing the current product is adversely affected by the introduction of a new one, possibly causing scope diseconomies. Innovation may also be stimulated by the

[7] Surveys can be found in Cohen and Levin (1989), Cohen (1995) and Unger (2005).

advantage of experience and an early start such as "learning by doing", an idea first explored by Arrow (1962).

R&D, Labour Force Skills and Capital Input

Investment in research and development (R&D) is often found to be a notable source of innovative output because it leads to new products and processes. R&D may result from a highly educated labour force (especially trained scientists and engineers), and is widely recognized as a critical factor contributing to firm innovation (Acs and Audretsch, 1988; Kraft, 1989). On the other hand, Baldwin (1997) argues that R&D is neither a necessary nor sufficient condition for innovation.

Cooperation/Collaboration

Recent studies (e.g. Diederen et al. 2005; Lerner, 2002; Mohnen and Roller, 2005; Porter and Stern, 2000) argue that cooperation among firms complements in-house R&D. It facilitates inter-organizational or international knowledge transfer. Cooperation with customers, suppliers, institutes of higher education or even competitors allows firms to expand their range of expertise, develop specialist products, and achieve other corporate objectives. Lerner (2006) argues that financial firms engage in different forms of collaboration (ranging from joint ventures to syndications of innovative securities), which is facilitated by standardisation.

Appropriability and Spillovers

Several authors such as Lerner (2006) and Tufano (1989) note that unlike manufacturing, the public goods nature of information associated with financial innovations make it unlikely firms can use them to achieve a sustained competitive advantage because they are easily copied. Lerner (2006) argues that even if financial institutions can take advantage of limited opportunities from patents, they are not easily enforced. Likewise for copyright or informal protection such as secrecy/complexity of design. On the other hand, the ineffective protection might be a stimulus to financial innovation - a point developed in a theoretical model by Herrera and Schroth (2002).

Firms that successfully erect barriers to protect their innovations will make it more difficult for spillovers to occur. According to Krugman (1991) knowledge spillovers are likely to be concentrated geographically, especially tacit knowledge. Hence the clustering of firms in a particular area may be an important source of future innovation. Bottazzi (2001) find that the effects of R&D on innovation are quite localised: most of the benefits accrue to the region employing the R&D resources, with evidence of small, positive externalities extending to areas within 300 kilometres of the innovation.

Financial Constraints and Government Aid

Other constraints may include the cost of innovation being too high and/or the lack of available finance; both are expected to reduce financial innovation. As Arrow (1962) noted, information problems associated with R&D makes it difficult to raise external finance, thereby inhibiting innovation, especially if a major capital investment is needed. Stiglitz and Weiss (1981) and Myers and Majluf (1984) formalised this idea in theoretical models. Hence, the question of whether firms with promising projects have sufficient internal capital or can acquire public financial support may be a critical issue. Cohen (1995) argues that cash flow is a good proxy for the amount of internal finance available to the firm - large firms with greater access to internal funds are more likely to innovate. Additionally, firms may be deterred if the cost of the innovation is deemed to be too high given its expected returns. Lerner (2006) finds that more highly leveraged firms are less innovative in his random effects model. He also reports that less profitable firms are significantly more innovative (though profits rise post innovation) and argues this supports Silber's argument (1975, 1983) that smaller, weaker firms should engage in more innovation.

Regulation and other Constraints

Lerner (2006), among others, argues that product innovations are closely scrutinised by regulators, which could act as a deterrent to potential innovators. At the same time regulations themselves may encourage innovation. There is ample anecdotal evidence of innovations to circumvent financial regulations from the growth of the euro dollar markets in the 1960s to the introduction of asset backed securitisation in the late 1980s. Silber (1975, 1983) develops the constraint-induced innovation hypothesis, where financial innovation occurs to remove or lessen the constraints imposed on firms. Firms facing imperfections (e.g. regulation, entry barriers) have the greatest incentive to innovate and boost profits because of the high shadow costs of such constraints.

Other Factors

Boot and Thakor (1997) use a theoretical model to illustrate that the probability of innovation in the financial sector rises with specialisation (boutique firms) and competition. Bhattacharyya and Nanda (2000) show that higher market share and more developed client relationships increase the incentive of investment banks to innovate.

2.2 Empirical Studies

Three econometric papers investigate the sources of financial innovation. Using a linear programming approach, Ben-Horim and Silber (1977) studies New York based banks from

1952 to 1972, and find that regulatory constraints induce innovation such as the negotiable CD.

Lerner (2002) estimates a "financial patent production function" for 25 leading investment banks and 30 universities in the US during three six-year time intervals: 1980-1985, 1986-1991, and 1992-1997. The results show that the patenting activity of US investment banks is positively related to their size and the extent of their indirect academic ties.[8] He also looks at financial patenting by 348 faculty members at well known finance departments of these universities between 1971 and 2000. He finds no link between patents and finance-related research productivity (measured by the share of articles in key finance journals) or the number of academics in a department.

Lerner (2006) investigates the origins of innovation by 15,309 US financial service firms between 1990 and 2002, using Wall Street Journal articles as an innovation indicator. The analysis focuses on the nature of the financial institutions that undertake the innovations. He estimates both pool and random effects panel data models under different specifications (e.g. negative binomial, Poisson). He finds that smaller firms account for a disproportionate share of the innovations, as do less profitable firms though their profitability increases significantly in subsequent years. Older, less leveraged firms and those located in regions with more financial innovation are more innovative. Firms filing patent applications are found to be significantly older and less leveraged, though the dominance of less profitable firms and local spillover effects is no longer apparent.

3. Data

The dataset comes from the 2005 *Fourth UK Community Innovation Survey*[9] published by the Office for National Statistics (2006) on behalf of the Department for Innovation, Universities and Skills.[10] It is undertaken every 2 years by EU member states to monitor Europe's progress in the area of innovation. The UK Innovation Survey 2005 is the largest conducted to date and was posted to 28,000 UK enterprises with 10 or more employees. The (voluntary) response rate is 58%. The survey covers 9 regions in England plus Scotland, Wales and Northern Ireland. It obtains information on UK innovation over three years (2002 to 2004). The questionnaire includes sections on innovation performance, innovation inputs,

[8] The indirect academic link is measured by the average number of each banks' employees on the editorial or advisory boards of two academic/practitioner journals.
[9] A copy of the questionnaire can be found on http://www.berr.gov.uk/dius/innovation/innovation-statistics/cis/cis4-qst/page11578.html
[10] Formerly the Department of Trade and Industry or DTI. In 2007, its functions were transferred to the Department for Business, Enterprise and Regulatory Reform (BERR) and the Department for Innovation, Universities and Skills (DIUS).

factors that hamper innovation, types of innovative collaboration, sources of information used, and the impact of innovation on the business. It also compiles data on the general characteristics of individual firms such as their industry of affiliation, sales, employment, etc.

Given the main objectives of this paper are to look at the determinants of the probability and success of financial innovation, we focus on the parts of the survey that questioned financial institutions on whether they have engaged process or product innovations, factors that hamper or encourage them, and the impact of innovation on their business. Within this group, the survey distinguished between three sub-sectors in line with the Standard Industrial Classification of Economic Activities SIC (2003):
SIC65: financial intermediaries, with the exception of insurance and pensions
SIC66: insurance and pensions, excluding mandatory social security payments.
SIC67: activities auxiliary to financial intermediation, such as stock broking and fund management.[11]

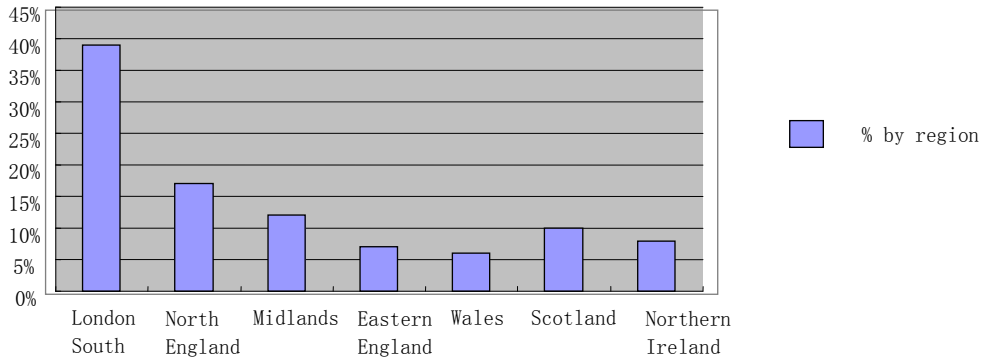
Of the 1,185 sampled financial firms 675 (57%) responded.[12] Missing observations and inconsistent answers to questions reduced this number to 539, or 45.5% of those surveyed. Of these, 50% cite security broking and fund management (SIC67) as their main business, 30% are financial intermediaries and 20% are involved in insurance and pensions or other activities. As can be seen in Chart 1 below, the greatest number of firms are based in London and the South (39%), followed by Northern England (17%), the Midlands (12%), and Scotland (10%). Within the cleansed sample 14% are new/start-up firms, less than 3% relied on public financial support, the average R&D expenditure accounts for just 1.2% of total turnover, 55% engaged in formal/strategic methods to protect their innovations, and 20% cooperated/collaborated with other firms/institutions on innovative activities.

About 43% of the sample firms engage in financial innovation and there were more product than process innovators. Roughly 31% report that they sold their innovations but the rest fail to generate any innovation revenue during the survey period. On average, the sale of innovations as a percentage of total sales is 10.5%. In the 2005 CIS questionnaire, firms are asked to state whether a product being adopted is new to the market. We call this group the true "*innovators*". Alternatively, the product could be new to the firm: as "*imitators*",[13] they sell a new good or service already offered by one or more competitors.[14] The share of total

[11] Source: www.statistics.gov.uk/methods_quality/sic/downloads/UK_SIC_Vol1(2003).pdf
[12] Source: www.berr.gov.uk/innovation/innovation-statistics/cis/page10957.html
[13] In the manufacturing literature, this is known as "diffusion innovation". See among others Dosi (1988), Freeman (1994), Ray (1984) and Reinganum (1989)
[14] The survey questions do not explicitly state that the good/service had to be a relatively new innovation. So it is

turnover contributed by innovator product sales is 1.8%, but it is higher for imitators at 8.6%. A few firms (14) report that 100% of their total turnover was due to the sale of their innovations. Of these, 5 are start-up true innovators and the rest are established firms offering products largely new to the firm.

Chart 1 - Sample of Financial Firms



Source: Office for National Statistics (2006)

4. The Model and Methodology

4.1 *Estimating the likelihood of financial innovation*

Innovation is frequently divided into either innovative inputs or outputs. Typical measures of innovative input include R&D expenditure and personnel involved in R&D, while the main proxies for innovative output are the number of patents or innovations, and various indices of the market value of innovations.[15] According to Fisher and Temin (1973), Schumpeter's hypothesis refers to the relationship between firm size and innovative output as opposed to input. Given the nature of the data obtained from the survey this study adopts the innovative output approach, focusing on the finished product or new process.

Based on the theoretical and empirical review, we assess the determinants of financial innovation in the UK. The rich database makes it possible to test for most factors mentioned in the previous section. One exception is the effect of regulation because the firms surveyed were not asked any questions about it nor were there any major reforms between 2002 and 2004.

Though Mohnen and Roller (2005) have quite different objectives, parts of their empirical

possible that firms giving an affirmative answer could have decided to offer a product that had been on the market for years. However, given the survey was about financial innovation (which dates quickly) over a specified period, most firms probably interpreted the question as offering goods/services recently launched on the market by innovators. After consultation with the DIUS we interpreted a positive answer to be imitators selling relatively new innovations already on offer by competitors. The questionnaire allowed firms to report sales of innovations that were either new-to-the-market or new-to-the-firm; they were treated as mutually exclusive.

[15] See Cohen and Levin (1989) for more detail.

approach are adopted for our study. The logit model is used to identify the determinants of a firms' probability of innovation. Thus:

$$FI_i = \alpha_1 + \sum_{i=1}^{n} \kappa_i WC_i + \upsilon_i \qquad (1)$$

where

FI_i : a binary variable which equals 1 if a financial firm i reports that it has been innovative and 0 otherwise

α_1 : the constant term

WC_i : a vector of sector and firm-specific variables affecting a firm's probability of being innovative , including three measures of constraint.

v_i : the error term

The same equation is also used to test the determinants of product (PI) and process innovation (PSI) by financial firms: the introduction of new or significantly improved methods in the way goods and services are supplied, excluding organisational or managerial changes.

The estimated coefficients obtained from equation (1) can be used to derive an innovation index, from which it is possible to score each firm:

$$ISCORE_i = \frac{e^{\alpha_1 + \sum_{i=1}^{n} \kappa_i WC_i}}{1 + e^{\alpha_1 + \sum_{i=1}^{n} \kappa_i WC_i}} \qquad (2)$$

which is converted into percentages for ease of exposition, and can vary from 0 to 100%. The higher the firm's score the more it innovates relative to others in the sample.[16]

4.2 Measuring the success of product innovation by financial firms

To test for the determinants of the success of a firm's innovation, the dependent variable is the innovation sales ratio. Of the 181 (out of 539) firms that introduced innovative products, 93% reported positive sales, implying the innovation was successful. But since just 31% of the sample engaged in product innovation, there is a problem with selection bias which is addressed by employing a generalized Tobit model. The correlation between the error terms in equations (3) and (4) (see below) is found to be significantly high (roughly unity),[17] which according to Cragg's (1971) hurdle test for selection bias means the generalised (as opposed to standardized) Tobit model (Heckman, 1979), should be employed.

Recently, the propensity score matching method has been a popular way of estimating sample data from surveys if the sample bias is due to a treatment effect[18] – an important concern for

[16] The equivalent of the ISCORE was developed by Cosh et al. (2004).
[17] See table 5.
[18] The propensity score matching model is used to correct for sample selection bias derived from observable

certain types of survey data (Dehejia and Wahba, 2002; Winship and Morgan, 1999). But the principal problem here is one of basic sample selection bias and in the absence of a treatment effect, generalised Tobit is the model of choice.

Generalised Tobit is a two-stage procedure. In stage one the probability of successful innovation is estimated as follows:

$$SI+_j = \alpha_2 + \sum_{j=1}^{m} \gamma_j W_j + u_j \qquad (3)$$

where

$SI+_j$: a binary variable denoting successful product innovation, which equals 1 if a firm *j* reports positive sales of innovative products, and 0 otherwise.

α_2 : the constant term

W_j : a vector of firm and sector-specific variables that affect the firm's probability of the innovation being successful, which are the same as those used to estimate Eq. (1), but excludes three constraint variables.

u_j : the error term

SI+ is further divided into two categories: "new to the firm" ($SI+_{NF}$) and "new to the market ($SI+_{NM}$) to take account of the imitator and innovator groups. Like SI+, these dependent variables are binary: they are assigned values of 1 if the firm reports that it has been successful in selling an imitated or innovative product and 0 otherwise.

The second stage provides a more precise indicator of successful financial innovation: the sale of innovations as a share of total sales or the extent to which the innovation is reflected in total sales. Thus:

$$SI_j = \alpha_3 + \sum_{j=1}^{m} \beta_j X_j + \varepsilon_j \qquad (4)$$

where

SI_j : the innovation sales ratio, i.e. the sale of technologically new or improved products (introduced in the same period) as a percentage of firm *j*'s total sales

α_3 : the constant term

X_j : a vector of firm and sector-specific variables that affect the firm's share of new sales

ε_j : the error term

The independent variables are chosen from the key influences on financial innovation as discussed in section 2.1, subject to the availability of data. Those common to both *WC* and *W* which are

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differences between the treatment and comparison groups (Dehejia and Wahba, 2002). Greene (2003) provides a good example of treatment effects. Suppose earnings are used to measure the value of a university education because the researcher cannot divide a group into whether or not they were educated to university standard. Here there is a potential problem with self-selection: an individual might enjoy higher earnings independent of whether or not they attended university. Our sample does not suffer from this problem. However, SI is only observed if SI+ = 1, (a different type of sample selection bias) best addressed through a generalised Tobit model.

estimated in Eqs.(1) and (3) include:

- Firm size, measured by both the number of employees (SIZE) and log(SIZE), reflects access to internal finance and possibly, a greater likelihood of scale economies. By including both the level and a log, it is possible to test for the presence of an "upside down U", described by Kamien and Schwartz (1975), which would suggest that middle sized firms are the most innovative if the coefficients on the level and the log are found to be respectively, negative and positive. If log(SIZE) is significantly positive, then larger firms do innovate more, with diminishing returns.
- A firm age dummy (D_A), which takes the value 1 if firms were established after 01/01/2000, and 0 otherwise, capturing a "learning by doing" effect.
- A public financial aid dummy (D_{PS}): equals 1 if firms reported that they received financial support to develop innovative techniques from government (at any level) or the European Union via tax credits or deductions, grants, subsidised loans, and loan guarantees; and 0 otherwise. It excludes research activities contracted by the public sector.
- Labour force skills or the quality of human capital (HC): the log of the proportion of employees educated to degree level or above.
- R&D investment intensity (IRD): the ratio of expenditure on both intramural (in house) and extramural R&D to total turnover, to assess whether greater expenditure on R&D has a positive impact on innovation.
- Cooperation dummy (D_{COOP}), equals 1 if firms cooperated on any of the innovation activities with other enterprises or institutes, such as suppliers of equipment/services/software, clients, competitors, consultants, commercial labs, and higher education institutions, and 0 otherwise, allowing for a direct test of whether collaboration significantly influences financial innovation.
- Sector and regional dummies: The sample firms come from three sectors and 12 regions, so the dummies are D_{s1} to D_{s3} and D_{r1} to D_{r12}, respectively. Following common practice, one sector and one regional dummy is dropped to avoid collinearity problems. They will establish whether sectors and/or regions are significant determinants of financial innovation.

WC in equation (1) also includes risk, cost and finance constraints that could affect the likelihood of FI, though not its subsequent success (SI). Unfortunately the survey did not collect firm-specific accounting data in relation to these constraints. But Question 19 of the CIS questionnaire asks firms to grade the degree to which certain factors affected their

decision not to innovate and/or constrained their innovative activities.[19] Three dummies are derived from their answers:

- Risk dummy (D_{RISK}): equal to 1 if firms reported that the excessive perceived economic risk was medium to high and 0 otherwise.
- Cost dummy (D_C): equal to 1 if firms reported that direct innovation costs and/or the cost of finance were medium to high and 0 otherwise.
- Finance dummy (D_F): equal to 1 if firms reported that the cost of raising finance were medium to high and 0 otherwise.

The vector X in Eq. (4) contains the same explanatory variables as Eq. (3) but includes a dummy for appropriability (D_{APP}), - equal to 1 if firms use any formal (e.g. copyright, patents, etc) or strategic (e.g. secrecy, complexity of design) methods to protect innovations; 0 otherwise, and excludes the risk, cost, and finance dummies. Table 1 provides a summary of all of the variables described above.

(Table 1 inserted here)

Table 2 supplies the descriptive statistics of all the dependent and independent variables used in the estimation of equations (1) through (4).

(Table 2 inserted here)

5. Empirical Results

Table 3 reports the results from estimating Eq. (1) for the three categories of innovation. The significance of chi squared statistics at the 1% level shows that the coefficients in each regression are jointly significantly different from zero. The pseudo R^2 ranges between 0.61 and 0.68 testifying to these models' goodness-of-fit. The correct classification ranges between 69.8% and 76.6%, which is acceptable when compared to other studies such as Parisi et al. (2006).[20]

Beginning with the probability of financial innovation (FI), the significantly positive sign on the log(SIZE) coefficient means larger financial firms are more likely to engage in innovation (with diminishing returns), which is consistent with Lerner (2006) and the general hypothesis put forward by Schumpeter (1942). There is no evidence to support the Scherer and Ross (1990) view that smaller firms innovate more because too much bureaucracy inhibits R&D in

[19] No information on firm-specific internal funding is available.
[20] In Parisi et al. (2006), the percentage of correct classification ranges between 64% and 73%.

larger organisations. The absence of a significant coefficient on the SIZE variable means middle-sized firms are not the most prolific innovators.[21] Firms with a higher quality of human capital and/or greater R&D expenditure are also more likely to be innovators, as are those that cooperate with other entities. Given that standardization is an important factor in facilitating interaction among financial firms, the latter result supports the Lerner (2006) argument that externally imposed standards may be conducive to greater collaboration and consequently, innovation.

The coefficients on the same four variables (the log of firm size, quality of the labour force, R&D investment intensity and cooperation) are also positive and significant for the likelihood of product innovations (PI) and process innovations (PSI) except for HC in the PSI estimation, which is positive but insignificant.

Table 3 also shows the results for the risk, cost, and finance dummies which are included in the estimation of equation (1). The coefficient on finance constraint is negative and significant suggesting that problems with raising finance reduces the likelihood of FI. But those on risk and cost are positive and significant, suggesting that financial innovation actually increases with perceived risk and cost of innovation. Campbell (1988), Frame and White (2004) and Tofano (2003) assert that increased perceptions of risk stimulate innovation, which is a plausible argument especially among financial firms which face different forms of market risk (e.g. interest rate, forex risks). However this interpretation is at odds with the wording of the survey Question 19. Nor does it explain the counter-intuitive sign on the cost dummy. In a mean difference t-test[22] the mean of risk and cost dummies are significantly higher for innovators than non-innovators, which is consistent with Mohnen and Roller (2005) who note a problem with endogeneity due to reverse causality: firms that do innovate perceive their economic risks and costs to be higher than those that do not. There is no endogeneity issue with the availability of finance: firms that are unable to raise finance cannot invest to innovate. Despite the potential endogeneity problems, the cost and risk dummies are retained in the final estimating equation because they raise interesting issues about the perceptions of risk and cost among innovators. Their exclusion does not affect the signs on the coefficients of other variables or the diagnostics.

(Table 3 inserted here)

[21] Though SIZE and log(SIZE) were found to be highly correlated with each other, both were included in the estimations because of the importance of testing for whether mid-sized firms are significant innovators. The significant correlation is not concern because the size coefficient is insignificant and estimations without size (not reported) did not alter the results.

[22] The results of the test are available from the authors upon request.

Table 4 reports the factors contributing to successful product innovation (SI) which is also divided into new to the market (SI_{NM}), and new to the firm (SI_{NF}), based on testing the generalized Tobit model - a two-stage procedure, with the joint estimation of Eqs. (3) and (4). Beginning with Eq. (3), the estimated Rho is significant, confirming the presence of a selection effect, which supports the use of the generalized as opposed to standard Tobit model. The size variables are insignificant except for the coefficient log(SIZE) in the SI_{NM} estimation, meaning that for true innovators, larger firms contribute to successful sales . The IRD and D_{COOP} coefficients are significant and positive in all three estimations. Thus firms that are part of cooperative innovation and/or have proportionately greater R&D expenditure are more likely to have a higher sales innovation ratio. The SIZE variables are now insignificant except for log (SIZE) which is significant at 10% for SI_{NM} . So size is not a factor determining the success of the innovation unless the firm is a true innovator, selling the new product/service for the first time.

The first stage, estimating Eq. (3), also yields results for SI+, $SI+_{NM}$ and $SI+_{NF}$. but they are not discussed here because they are very similar to those of equation (4)[23] and stage two gives a more precise indication of success since the dependent variable is continuous (the sale of innovations as a percentage of total sales) rather than binary. The coefficient on HC is significantly positive when SI and SI_{NF} are the dependent variables but for SI_{NM}, positive and significant coefficients are found on log(SIZE) and D_A. Thus, firms with a more educated work force generate a higher share of sales revenue whether they are innovators or imitators, but larger and/or younger financial firms are more successful product innovators. This is consistent with the predictions made by Aron and Lazear (1990). One cannot exclude the possibility that one or more of these young firms with their new to the market innovations may have sprung up to exploit a new idea developed by its inventor rather than discovering it after foundation. The insignificance of the appropriability dummy (D_{APP}) is consistent with Tufano's (1989) argument that even if financial firms apply for formal protection methods such as patents, it is difficult for them to generate revenue because of ineffective enforcement. The public financial aid dummy (D_{PS}) is also insignificant. In the manufacturing sector the impact of state aid produces mixed results.[24] The absence of a significant coefficient on D_A

[23] The only difference is that for SI+, SI_{+NF} and SI_{+NM}, the log(SIZE) coefficient is positive and significant at 1%, whereas this variable is only significant (at 10%) for the coefficient on SI_{NM}.

[24] In a comprehensive review article by David et al. (2000), one third of the studies find public R&D funding behaves as a substitute for private funding (at firm level), rising to just under 50% for studies conducted at industry or higher levels of aggregation. Hall and Van Reenen (2000) review the evidence on fiscal incentives for R&D across OECD countries and conclude that $1 in tax credit results in $1 of additional R&D. Nguyen (2007), in a study using CIS survey data for Luxembourg concludes that innovative firms in the manufacturing sectors receive more public funding compared to the service sector. Independent of the sector, large firms appear to benefit more from public subsidies.

for SI_{NF} is to be expected – there is no reason why a firm's age would affect its decision to imitate, but the positive and significant human capital coefficient may indicate that a well educated labour force is better able to spot the innovations that are likely to generate more revenue.

The coefficient on the dummy for firm age (D_A) is positive for SI and SI_{NM}, but only significant for SI_{NM}. It is negative and insignificant for SI_{NF}. Thus the messages are mixed for the age variable. Younger innovating firms are likely to generate a higher shares of sales revenue, but this is not true of the imitators or for innovation in general (SI). The mixed signs and insignificance means the evidence to support Arrow's (1962) idea that more experienced firms benefit from "learning by doing" is weak; it also contrasts with Lerner's (2006) empirical findings. Drawing on Aron and Lazear's (1990) model, a possible explanation is that younger firms only enter the market if revenues exceed costs, while imitators do so to remain competitive but could lose revenue from some near substitute they already sell.

The robustness of the logit and the generalized Tobit models is checked by adding the sector and regional dummies. Their respective coefficients are insignificant in the estimation of Eqs. (1), (3), and (4), so they were dropped from the final regressions reported in tables 3 and 4, with no change in either goodness of fit or the sign/significance of individual variables. Their insignificance is not surprising in an age when information spreads rapidly, and in a country where distances are short. Their insignificance may also suggest that additional knowledge spillover effects among firms within a local neighborhood are modest, though there is other evidence (see below) which somewhat discounts this view.

(Table 4 inserted here)

Table 5 reports the innovation scores (ISCORE) obtained from equation (2). ISCORE is a relative measure of the average degree of innovation by sector and region. Based on mean difference t-tests, the sector made up of stock broking, fund management, and other auxiliary activities has a significantly higher score, suggesting that they are more innovative than the other two sectors: financial intermediaries and pensions/insurance[25]. The finding may be linked to Tofano's (2003) argument that the timing of certain innovations are due to advances in supply side related IT. For example, securitization has benefited from IT advances that have led to new methods for underwriting securities, putting together stock portfolios, and

[25] This does not contradict earlier finding which showed no sector or region was a factor affecting the likelihood of FI. Tthe ISCORE shows London & the South to be significantly more innovative compared to other regions.

executing transactions. So firms from this sector may have had a greater opportunity to innovate.

London & the South,[26] scores the highest in terms of their relative tendency to innovate - significantly so compared to all other regions except Scotland, which ranks second. Given the other findings on the determinants of financial innovation and its success (measured by sales), this result is not too surprising because of the large number of financial firms located in this area. They, in turn, may be indicative of and/or encourage the benefits of clustering by attracting a well educated workforce, encouraging cooperation and R&D, and facilitating knowledge spillovers.

(Table 5 inserted here)

6. Conclusions

This paper is motivated by the contrast between the importance of financial innovation in growth and the paucity of empirical work on financial innovation. It sets out to consider three issues in relation to innovation by financial firms based in the UK. The data come from the CIS (2005) survey for the period 2002 - 2004. Once cleansed, the sample makes up 45.5% of over 1100 firms to which questionnaires were sent. Based on the survey answers, this study sought to address three questions: what are the determinants of financial innovation, what factors contribute to successful innovation, and do regions and/or sectors influence the likelihood of innovation? Where possible variables linked with key theoretical and empirical models are used in the estimations including firm size, risk, cost, and finance constraints, intensity of R&D, human capital and firm cooperation, among others. We find that the larger the firm, the greater the likelihood of financial innovation, albeit with diminishing returns, which is consistent with most of the literature that has examined innovation in this and other sectors. Other factors found to be significant contributors include the quality of human capital, the availability of finance, the degree of R&D expenditure, and cooperation among firms in the innovative process.

Likewise, human capital, expenditure on R&D, and cooperation influence the success of innovation - measured by the sales innovation ratio. Firms that protect their innovation via patents and/or strategic moves do not generate greater revenue, which confirms the common view that financial innovations are all too easily copied. Nor is the size of the firm influential with the exception of the true innovators. Finally, mean difference t-tests on the ISCORE

[26] For the purposes of this discussion the number of regions is reduced to nine (in line with chart 1) because the scores for certain adjacent regions were so similar.

show stock broking and pension funds are significantly more innovative than financial intermediaries, pension funds, or insurance. The tendency to innovate is significantly greater in London and the South, though Scotland, notably, is also a more innovative region.

This study is not without its limitations. First, economic conditions change over time and are an important source of financial innovation. It is not possible to address this issue because of the cross-section nature of the sample. Second, the firms' names were coded in the survey, so we were unable match the information with other firm-level datasets. Consequently, more detailed firm-specific data could not be tested in the model. Nor was it possible to test for the effects of regulation, considered an important driver of financial innovation, though this problem may not be serious because there were no major financial reforms during the survey period. Finally, there are features in the survey itself that should be clarified or changed. For example, innovations that are new to the market and new to the firm are not necessarily mutually exclusive yet firms answering the questions had to choose one or the other. It is possible that firms are both innovators (new to the market) and imitators (new to the firm). It would also be useful to have firms supply accounting information (e.g. leverage) so finance and cost constraints can be more accurately measured.

Nonetheless, substantial progress has been made in obtaining answers to the three questions posed earlier. Based on these results, future work should be aimed at further development of theoretical and empirical models, and investigating the extent to which these findings carry over to other countries.

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Table 1: A Summary of the Variables

	Description
Dependent Variables	
FI	Binary variable for financial innovation: firm innovates (1) or it does not (0)
PI	Binary variable for product innovation: firm product innovates (1) or it does not (0)
PSI	Binary variable for process innovation: firm process innovates (1) or it does not (0)
SI+	Binary variable for successful product innovation/ imitation (1) or not (0)- new to the market or new to the firm
$SI+_{NF}$	Binary variable for successful product imitation of an existing product (new to the firm): firm reports positive sales (1) or it does not (0)
$SI+_{NM}$	Binary variable for successful product innovators (new to the market): firm reports positive sales (1) or it does not (0)
SI	Successful sales innovation: the sale of innovations as a percentage share of total sales
SI_{NF}	The percentage share of imitated innovations sold (new to the firm)
SI_{NM}	The percentage share of innovative sales that are new to the market, that is, sold by innovators
Independent Variables	
Log(SIZE)	Log (Firm Size): the log of the number of employees in the firm
SIZE	Firm Size: the number of employees in the firm
D_A	Dummy for firm age, which =1 if firms were established after 01/01/2000; 0 otherwise.
D_{PS}	Dummy for public financial support; which =1 if firms received government support for an innovation; 0 otherwise
HC	Human capital: the log of the proportion of employees educated at degree level or above.
IRD	R&D investment intensity: the ratio of intramural + extramural R&D to total turnover
D_{COOP}	Dummy for cooperation, which equals 1 if they cooperated; 0 otherwise
D_{APP}	Dummy for appropriability, which equals 1 if firms used formal or strategic methods to protect innovations; 0 otherwise
D_{RISK}	Dummy for economic risk, which equals 1 if firms reported that the excessive perceived economic risk was medium to high, thereby affecting their decision not to innovate and/or constraining their innovative activities; 0 otherwise.
D_C	Dummy for innovation costs which equals 1 if firms reported that direct innovation costs and/or the cost of finance were medium to high, thereby affecting their decision not to innovate and/or constraining their innovative activities; 0 otherwise.
D_F	Dummy for availability of finance, which equals 1 if firms reported that the availability of external finance was medium to high thereby affecting their decision not to innovate and/or constraining their innovative activities; 0 otherwise.

This table summarises the 9 dependent variables used in the estimation and the firm-specific independent variables. The first three dependent variables are used to identify the determinants of financial, product, and process innovation; the remaining six look at successful innovation, measured by whether or not a firm sells the innovation and by the sale of innovations as a percentage of total sales. Source: www.berr.gov.uk/innovation/innovation-statistics/cis/cis4-qst/page11578.html

Table 2: Descriptive Statistics

Dependent Variables				
	Mean	Std.	Min	Max
Financial Innovation, Product, and Process Innovations				
FI	0.430	0.496	0	1
PI	0.336	0.473	0	1
PSI	0.273	0.446	0	1
Successful Product Innovation				
SI+	0.308	0.462	0	1
$SI+_{NM}$	0.130	0.336	0	1
$SI+_{NF}$	0.284	0.451	0	1
SI	0.105	0.232	0	1
SI_{NM}	0.018	0.086	0	1
SI_{NF}	0.086	0.203	0	1
Independent Variables				
	Mean	Std.	Min	Max
SIZE	286.941	990.629	10	15277
Log(SIZE)	1.741	0.679	1	4.184
D_A	0.141	0.348	0	1.000
D_{PS}	0.026	0.159	0	1.000
HC	0.906	0.689	0	2.004
IRD	0.012	0.057	0	0.770
D_{COOP}	0.202	0.402	0	1
D_{APP}	0.553	0.498	0	1
D_{RISK}	0.341	0.475	0	1
D_C	0.388	0.488	0	1
D_F	0.171	0.377	0	1
Number of observations	539			

This table supplies the descriptive statistics for all variables used in the estimation of the equations (1), (3) and (4). See table 1 for a description of the variables.

Table 3: The Determinants of Financial Innovation

Dependent Variables	***FI***		***PI***		***PSI***	
Independent Variables	Coefficient	p value	Coefficient	p value	Coefficient	p value
Constant	-2.337*** (0.401)	0.000	-2.600*** (0.415)	0.000	-2.917*** (0.451)	0.000
Log(SIZE)	0.562** (0.238)	0.018	0.496** (0.243)	0.041	0.446* (0.263)	0.090
SIZE	.5792D-05 (0.000)	0.976	-.2638D-04 (0.000)	0.889	0.0001 (0.000)	0.454
D_A	-0.216 (0.287)	0.451	-0.474 (0.320)	0.138	0.023 (0.319)	0.942
D_{PS}	-0.231 (0.816)	0.777	-0.199 (0.773)	0.797	0.074 (0.724)	0.918
HC	0.248* (0.147)	0.093	0.301* (0.155)	0.053	0.248 (0.168)	0.139
IRD	18.326*** (6.793)	0.007	18.644*** (5.979)	0.002	8.238*** (2.502)	0.001
D_{COOP}	1.606*** (0.275)	0.000	1.331*** (0.263)	0.000	1.362*** (0.263)	0.000
D_{RISK}	0.774*** (0.263)	0.003	0.977*** (0.269)	0.000	0.141 (0.283)	0.619
D_C	0.500* (0.278)	0.072	0.049 (0.287)	0.864	0.836*** (0.294)	0.005
D_F	-0.745** (0.325)	0.022	-0.189 (0.324)	0.559	-0.507 (0.334)	0.129
Log likelihood	-294.441		-274.604		-250.079	
Chi squared	129.2***	0.000	115.707***	0.000	88.135***	0.000
Pseudo R-squared	0.614		0.643		0.675	
Correct classification	69.573		72.356		76.623	
Number of observations	539		539		539	

The Logit model is used to estimate the determinants of a firm's probability of innovation. Log likelihood shows the log likelihood function at the maximum. Chi squared presents the chi squared statistic for testing the null hypothesis of all the slope coefficients in the logit model are zero (excluding the constant). Pseudo R-squared reports the R^2 developed by Ben-Akiva and Lerman (1985) and Kay and Little (1986). $R^2=1/n\Sigma yF+(1-y)*(1-F)$. Correct classification shows the percentage of correct predictions. *, **, *** denotes significance at the 10%, 5%, and 1% confidence intervals, respectively. Standard errors are in parentheses.

Table 4: The Determinants of Successful Product Innovation by Financial Firms

Dependent Variables	***SI***		***SI_{NM}***		***SI_{NF}***	
Independent Variables	Coefficient	p value	Coefficient	p value	Coefficient	p value
Constant	-0.746*** (0.166)	0.000	-0.770*** (0.130)	0.000	-0.757*** (0.172)	0.000
Log(SIZE)	0.119 (0.091)	0.189	0.121* (0.067)	0.071	0.109 (0.087)	0.210
SIZE	-0.136D-04 (0.000)	0.900	-0.401D-04 (0.702D-04)	0.567	-.339D-05 (0.803D-04)	0.966
D_A	0.004 (0.087)	0.962	0.189*** (0.064)	0.003	-0.076 (0.095)	0.426
D_{PS}	0.059 (0.230)	0.797	-0.054 (0.160)	0.734	0.129 (0.254)	0.611
HC	0.088* (0.052)	0.088	-0.006 (0.042)	0.888	0.115** (0.054)	0.033
IRD	2.297*** (0.411)	0.000	1.396*** (0.223)	0.000	1.575*** (0.445)	0.000
D_{COOP}	0.401*** (0.083)	0.000	0.354*** (0.055)	0.000	0.300*** (0.086)	0.001
D_{APP}	0.024 (0.094)	0.801	0.019 (0.083)	0.816	0.022 (0.099)	0.824
Log likelihood	-270.256		-105.940		-257.369	
Estimated Rho	0.999*** (0.001)	0.000	0.999*** (0.000)	0.000	0.999*** (0.001)	0.000
Number of observations	539		539		539	

This table show the results of the generalized Tobit model, which is used to investigate the determinants of the success of financial innovation, where the dependent variables are SI: the sale of innovations as a percentage of total sales plus SI_{NM} and SI_{NF} - SI new to the market (innovators) and new to the firm (imitators), respectively. Rho is a test statistic for the error term: high Rho indicates the presence of a significant selection effect, which means the generalized Tobit model should be used rather than standard Tobit. *, **, *** denotes significance at the 10%, 5%, and 1% confidence intervals, respectively. Standard errors are in parentheses.

Table 5: Are Some Sectors and/or Regions Relatively more Innovative than Others?

ISCORE (%) by sector																				
	Firms	Variable	Mean	Mean Diff.	S.D.	Min	Max		Variable	Mean	Mean Diff.	S.D.	Min	Max		Variable	Mean	Mean Diff.	S.D.	Min	Max
Auxiliary Activities	160	***FI***	44.55		21.99	14.46	99.99		***PI***	36.28		21.09	8.87	99.98		***PSI***	28.05		17.94	9.41	93.29
Financial Intermediaries	107		41.08	3.47*	20.30	17.17	99.99			32.97	3.32*	19.37	10.49	99.95			26.09	1.96	18.50	9.54	96.00
Insurance and Pensions	272		40.05	4.50**	21.12	14.46	100.00			31.88	4.41**	19.43	8.87	100.00			25.00	3.05**	17.72	9.41	99.88
Average			41.59	2.96*	21.28	14.46	100.00			33.40	2.88*	19.98	8.87	100.00			26.12	1.93	17.96	9.41	99.88
ISCORE (%) by region																					
	Firms	Variable	Mean	Mean Diff.	S.D.	Min	Max		Variable	Mean	Mean Diff.	S.D.	Min	Max		Variable	Mean	Mean Diff.	S.D.	Min	Max
London and South	212	***FI***	46.54		23.53	15.13	99.99		***PI***	38.06		22.70	9.28	99.95		***PSI***	30.22		20.60	9.54	96.00
North England	94		37.73	8.81***	19.30	14.46	93.57			29.75	8.31***	17.46	8.87	86.87			23.06	7.16***	14.56	9.41	69.25
Midlands	67		39.77	6.77**	20.01	17.30	99.99			31.81	6.25**	18.99	12.84	99.98			24.53	5.69**	18.08	9.54	93.09
Eastern England	36		40.17	6.37*	21.57	14.46	100.00			31.93	6.13*	20.10	8.87	100.00			25.17	5.05*	19.09	9.41	99.88
Wales	31		35.62	10.92***	16.83	16.26	78.56			27.46	10.60***	14.07	9.94	64.13			22.10	8.12***	13.36	9.54	66.43
Scotland	56		43.68	2.86	19.15	18.08	93.56			35.04	3.02	17.75	12.08	88.90			26.91	3.31*	15.68	9.89	79.26
Northern Ireland	43		31.30	15.24***	13.67	17.30	73.02			24.34	13.71***	11.48	12.84	64.15			17.76	12.46***	8.10	9.54	41.99
Average			41.59	4.95***	21.28	14.46	100.00			33.40	4.66***	19.98	8.87	100.00			26.12	4.10***	17.96	9.41	99.88

This table compares the degree of innovation by sectors and regions, using the ISCORE. A mean difference t-test is applied to assess whether the difference between the highest sector/regional ISCORE and corresponding ISCOREs for other sectors/regions is significantly greater than zero. The three sectors are, respectively, financial intermediaries (SIC65), insurance and pensions (SIC66), and activities auxiliary to financial intermediation, e.g. stock broking and fund management (SIC67). *, **, *** denotes significance at the 10%, 5%, and 1% confidence intervals, respectively. The general finding is that stock broking, fund management and other auxiliary activities are significantly more innovative as is London and the South. FI, PI, PSI denote financial, product and process innovation respectively. To conserve space the results for successful product innovation that is new to the market or firm ($SI+_{NM}$; $SI+_{NF}$) and successful innovation (SI+) are not reported but the findings are similar and available on request from the authors.