J Technol Transf (2013) 38:93–115
DOI 10.1007/s10961-011-9229-4

The role of proximity in university-business cooperation for innovation

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Published online: 24 July 2011

Abstract The potential for universities to contribute positively to business innovation has received much attention in recent years. While the determinants of university-business cooperation have been examined extensively, less attention has been given to the mediating influence of proximity in this relationship. The analysis in this paper builds on the UK business innovation survey (2002–2005) by incorporating measures of the university research environment for each of the 16,500 businesses surveyed. These measures allow us to look beyond business-level characteristics as determinants of the geography of university cooperation and account for the character of the local university environment. Measures include the distance from each business to its nearest university, the quality of local university research and the density of the university research environment. The findings suggest that significant differences exist between those businesses that cooperate with local universities and those that cooperate with non-local universities. These differences relate to business size, sales profile, location, absorptive capacity and innovation activity. In addition, we also find that if a business is located close to a research excellent university, cooperation tends to remain local, however, the distance between businesses and the nearest university is not a significant determinant of university-business cooperation and further, the higher the concentration of universities in the business locale, the more likely businesses are to cooperate with non-local universities.

Keywords University-business · Cooperation · Innovation · Proximity · Knowledge sourcing

JEL Classification O31 · O32 · O33 · O19

1 Introduction

The innovation process is increasingly characterized as multidirectional, iterative and involving multiple actors (Kline and Rosenberg 1986; Malecki 1997; Evangelista 2000;

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Tether 2005). As these actors interact, a flow of knowledge is created that drives R&D, innovation, economic growth and competitiveness (Pianta 1995; DTI 2003a, b; HM Treasury 2003). Conscious of this, numerous government initiatives have sought to stimulate greater interaction between businesses and universities. Although, university-business interaction has always occurred to some extent (Godin and Gingras 2000), greater openness in the innovation process has altered the intensity, the nature and ultimately the importance of cooperating with universities for business innovation (Bekkers and Freitas 2008; Ponds 2009).

Empirical research on businesses' external knowledge sourcing, suggests that there is a strong geographical dimension to university-business interactions or knowledge spillovers, being confined largely to the region in which the research takes place. For example, in the US, while University research was found to have a significant effect on innovation output, this was limited to a 75 mile (120.7 km) radius (Anselin et al. 1997, 2000; Acs et al. 2002). Similar in Germany, over half of all business innovations arising from university research were located within 100 km of the respective university (Beise and Stahl 1999) while in France (Autant-Bernard 2001) again externalities towards private sector innovation arising from public sector research were found to be regionally-concentrated. Other research that has examined a wider range of innovation partners (in addition to universities) has also found that business's search activity is geographically bounded to their immediate vicinity (Stuart and Podolny 1996; Rosenkopf and Almeida 2003).

The accepted explanation for this strong proximity[1] effect in university-business cooperation relates to the generation of informational advantages from agglomeration (Boschma 2005). The creation of new knowledge results not only from the transfer of codified knowledge but also tacit knowledge (Nonaka and Takeuchi 1995) which is facilitated by personal interactions (Lundvall 1992) and therefore sensitive to increasing distance (David and Forey 2003). Yet, knowledge transfer is neither automatic or costless (Acs and Plummer 2005) and therefore as argued by Fristch (2001), where businesses seek to source knowledge from public research organisations, then spatial proximity becomes even more important in facilitating the transfer of knowledge and in particular, tacit knowledge.[2]

In this paper our primary research question is: what is the effect of proximity (physical distance) on business cooperation with universities for innovation? More specifically, if increasing distance results in less effective externalities between agents (Boschma 2005) then we would expect businesses to cooperate with a local university as opposed to a non-local university. Our data analysis is based on the UK Innovation Survey (2002–2005) and specifically on the 906 businesses that had an innovation link with universities for innovation over the survey period. Of these 906 businesses 368 (40.6%) were cooperating with local universities with 538 (59.4%) cooperating with non-local universities.[3] This suggests that businesses may be making two decisions, the first decision being a strategic decision about whether or not to cooperate with a university for innovation, and the second decision being 'tactical', relating to the choice of university with which to cooperate. This raises two questions; is there evidence of a two-stage decision making process by businesses in

[1] Geographical proximity is defined as: "… the spatial or physical distance between economic actors both in its absolute and relative meaning".

[2] See also Zucker et al. (1998) and Almeida and Kogut (1997) for a discussion of the importance of interpersonal contact in explaining the localization of knowledge externalities.

[3] Of these 538 businesses engaged in non-local university cooperation, 133 engaged in both local and non-local university cooperation. As our focus is on identifying if differences exist in the geography of businesses knowledge sourcing activities, these 133 businesses are considered as engaging in non-local cooperation.

cooperating with universities for innovation and second, is it possible to explain why some businesses cooperate with local universities while others develop non-local relationships?

The paper is structured as follows. In Sect. 2 we outline the theoretical background to the research. Specifically, we consider how the appropriability regime, the absorptive capacity of the business sector, the research environment in which businesses are located and the effect of government support for innovation relate to the geography of university-business cooperation. In Sect. 3 we describe briefly the data source, the characteristics of the sample and the econometric technique employed. The findings of the data analysis are presented in Sect. 4 summarizing the determinants of the strategic decision to cooperate with universities for innovation and then the tactical decision to cooperate with a local or non-local university. Section 5 draws together the main findings from the research and considers the implications for businesses, universities and policy makers.

2 Literature review

The innovation process, and our understanding of it, has changed significantly in recent years. Traditional conceptions of a linear innovation process are now limited in their relevance and instead innovation is seen as a multidirectional and iterative process involving multiple actors (Chesbrough 2003; Coombs et al. 2003; Kline and Rosenberg 1986; Malecki 1997; Evangelista 2000; Tether 2005). Perkmann and Walsh (2008) suggest that this growing emphasis on external knowledge sources for innovation is attributable to a number of factors including: greater dispersion of knowledge in the economy, and particularly in fast moving sectors such as biotechnology (Chesbrough et al. 2006); the increase in technology brokering and integration of a greater range of individual technologies in products (Iansiti 1997); the movement in some industries to open standards and modular innovation (Baldwin and Clark 1997); outsourcing strategies now including innovation-intensive components and systems (Harabi 1998); and greater variety in the actors involved in innovation as in the case of user-driven innovation (von Hippel 1987). In addition, improvements in international transportation infrastructure and information communication technologies have acted as enabling factors in facilitating multi-actor, and often international, research collaboration to occur (Ponds 2009).

Clearly there are many reasons why businesses cooperate with external organisations for innovation. Similarly there are also a range of partners with which they can cooperate and different transmission channels by which information and knowledge can be accessed and acquired. The most commonly cited partners for innovation are those in the value chain, whether this is suppliers or customers (Abreu et al. 2008). However, attention has focused increasingly on the role of universities as sources of knowledge for innovation. D'Este and Patel (2008) in pointing to the findings of Mansfield and Lee (1996) note that the majority of university-industry interactions are motivated by factors other than immediate commercial outcomes, and include obtaining knowledge of scientific and technological advances, getting access to students and faculty and solving specific problems. Similarly, Cohen et al. (2002) argue that businesses look to universities for various reasons including access to research findings, instruments, experimental materials, highly trained human capital and research techniques. Indeed, access to university expertise and knowledge is most commonly identified, with university-based knowledge facilitating more efficient and effective innovation activity in the business (Cockburn and Henderson 2001; Rappert et al. 1999). Lawton-Smith and Bagchi-Sen (2006) conclude that the priority

for industry in collaborating with universities is less about acquiring technology and more about gaining access to talent.

The evidence-base pertaining to the benefits of university-business cooperation is derived largely from empirical research suggesting a positive relationship between cooperation and innovation and/or business performance.[4] These studies are predominantly econometric analyses of the relationship between universities and business innovation (largely through CIS data or equivalent) or studies of bibliometric data and patent citations (e.g. Griliches 1979; Jaffe 1989; Blind and Grupp 1999). A range of university-business knowledge transfer channels are covered by these studies including research publications, use of university patents and licenses, collaborative research, contract research and consultancy etc. The effect of university research on business innovation is summarized by the finding that approximately 10% of new product and process innovations would not have occurred (or been significantly delayed) where university research had not been accessed (Mansfield 1991, 1998 and Beise and Stahl 1999 as quoted in Bekkers and Freitas 2008). At the same time, Fabrizio (2006) observes that the positive effect of university research on business innovation is not automatic. Rather, the benefit of university research is conditioned by the appropriability regime i.e. the ability of knowledge to spillover to businesses,[5] and the competencies of businesses to identify and exploit university-derived knowledge.

2.1 Appropriability of university knowledge

In a tight appropriability regime the 'leakage' or 'spillover' of knowledge from the university sector would be low, whereas in a loose appropriability regime knowledge would be expected to spillover easily to businesses (Gulati and Singh 1998). At least two interrelated factors are important in shaping the appropriability regime: the type of knowledge being exchanged (as reflected in the co-operation channels), and the distance over which knowledge travels, i.e. proximity of innovation partners.

Focusing first on the type of knowledge, we see that much public sector investment in University research has occurred on the basis that in the long-run the potential for knowledge spillovers from universities to business may positively impact on innovation, productivity and economic growth. Indeed, much of the public investment in research, and particularly that in Universities, is designed to have a strong public good element; by its very nature it should be disseminated or leak out into the private sector at low or zero marginal cost and be used for economically significant innovations and/or productivity gains (EU 2004). In recent years a move towards 'Academic Capitalism' (Slaughter and Leslie 1997) in the University sector has seen a move away from the Open Science model and dissemination of research through scientific publications towards a greater emphasis on the protection of University based intellectual property through patenting, licensing and applied research (Siegel et al. 2003; Lockett and Wright 2005; EU 2004). At the same time, businesses have increasingly found 'pure knowledge spillover' channels such as scientific publications and patents to be a less effective means of dissemination and instead require more tailored knowledge transfer channels, including collaborative research and

[4] While much of this research is US-based (Mansfield 1998; Jaffe 1989; Adams 1990; Acs et al. 1992, 1994; Feldman 1994) similar studies in the EU (Kaufmann and Todtling, 2001; Arvanitis et al. 2005; Beise and Stahl 1999; Becker 2003; Monjon and Waelbroeck 2003) all tend to point to a strong positive link between university research (HERD) and innovation activity across different industries.

[5] 'Spillovers' in this context is interpreted broadly to include both pure knowledge spillovers as well as those arising from formal links between different actors.

information contacts (Antonelli 2008; Bekkers and Freitas 2008).[6] Relating this to the appropriability regime, implies that as universities become more entrepreneurial in protecting their research this has created a tighter appropriability regime. Simultaneously, as Universities have become more 'engaged' (OECD 1999; Chatterton and Goddard 2000; Holland 2001) with businesses through a diversity of channels—including collaborative and contract research, consultancy, the use of facilities and equipment, professional education and training as well as the licensing of patents—the importance of tacit knowledge has increased. Both of these factors therefore accentuate the importance of proximity between universities and their innovation partners.

Empirical research provides support for arguments that proximity is an important factor in determining university-business cooperation. In general this research finds that the benefits of university research are not evenly distributed over space, but instead are sensitive to distance and regionally concentrated (Acs et al. 2002; Beise and Stahl 1999; Autant-Bernard 2001). In general, as distance increases then the efficiency by which communication is transferred decreases (Freel 2002) and the benefits from collaboration are reduced (Audretsch and Feldman 1996; Branstetter 2001; Boschma 2005; Freel 2002). Indeed, this effect is found to be more pronounced for communication and innovation links between businesses and public research institutes than with customers or suppliers (Fristch 2001; Zucker et al. 1998[7]). For research/innovation cooperation, particularly between businesses and universities, tacit knowledge and proximity remain important (Fristch 2001; Zucker et al. 1998). Indeed Arundel and Geuna (2004, p. 561) suggest that 'the importance of being physically close to public science should decline when useful knowledge is in a codified form, such as in patents and publications, and increase when useful knowledge is only available in tacit form, requiring personal contact'. As university-business cooperation is likely to comprise both codified and tacit knowledge, the evidence-base therefore leads to our first hypothesis:

Hypothesis 1: Proximity Where businesses cooperate with universities for innovation this will occur with local universities.

2.2 Businesses' competencies to identify and exploit university knowledge

Another factor in the ability of businesses to identify and exploit university knowledge relates to their competencies. Fabrizio (2006, p. 154) concludes that "Locating close to a knowledge source appears to promote knowledge transfer. However, location is not enough. By developing internal research expertise related to basic science research, business researchers are able to better identify and make use of relevant public science." A substantial literature has developed around this notion of absorptive capacity (Cohen and Levinthal 1990) and its importance in a business's ability to identify, assimilate and apply new knowledge.

To date research has focused on the effect of absorptive capacity on the propensity of businesses to form links with universities with less attention given to how absorptive capacity can affect the geography of innovation collaboration. Research findings concur that business's absorptive capacity is of particular importance to innovation links with

[6] This mirrors the reasons already discussed as to why businesses access university research and knowledge, being motivated less by commercial innovation outcomes and more by obtaining knowledge of scientific and technological advances, getting access to students and faculty and solving specific problems (D'Este and Patel 2008).

[7] Zucker et al. (1998) identified that geographical proximity to high quality university researchers enhanced firm's ability to capture knowledge spillovers.

universities, and specifically the importance of internal basic science capability in forming links with university researchers (Gambardella 1992; Cockburn and Henderson 1998; Zucker et al. 1998). In relation to proximity, geographical proximity to high quality university researchers enhances a business's ability to capture knowledge from the university (Zucker et al. 1998). While proximity is regarded as being static, it is mediated by the dynamic effect of absorptive capacity as businesses enhance their ability to identify, assimilate and exploit university knowledge sources. In some instances a substitutive relationship has been found between absorptive capacity and networking with an increase in R&D resulting in a decrease in networking activity (Love and Roper 1999), while other research has suggested that this substitution effect is sector specific, being complementary for high tech sectors and acting as substitutes in low tech sectors (Audretsch et al. 2005). Drejer and Vinding (2007) conclude that businesses with lower absorptive capacity are more likely to network locally and those with higher absorptive capacity are more likely to be connected to global networks. In other words, absorptive capacity is important for forming university links for innovation; however, proximity—between businesses and universities—is likely to be more important where absorptive capacity is lower.

Hypothesis 2: Absorptive capacity

2a: As absorptive capacity increases, businesses become more likely to cooperate with universities for innovation.

2b: As absorptive capacity increases, businesses become more likely to cooperate with non-local universities for innovation.

2.3 University environment

As outlined earlier, the reasons why businesses cooperate with universities for innovation are driven less by achieving short term commercial returns and more in terms of gaining access to specialist knowledge and expertise, research findings and research techniques etc. (Cohen et al. 2002; Lawton-Smith and Bagchi-Sen 2006). Recent research has investigated heterogeneity in the university sector (Hewitt-Dundas 2009; Cosh et al. 2006) and the effect of this on knowledge transfer activity. If all universities were similar in terms of their research expertise, use of specialist equipment and provision of training etc. then businesses would not need to search for the most appropriate university for their innovation needs. Instead, assuming that efficiency in the transmission of information decreases with distance (Freel 2002), businesses would cooperate with their closest university for innovation. However, heterogeneity in the university sector (regionally, nationally and internationally) means that businesses have to identify the appropriate university partner cognizant of their innovation goals.

In the UK university environment, Hewitt-Dundas (2009) has highlighted significant variations in research capability across the UK and the effect of this on the type, scale and regional orientation of knowledge transfer activities. In particular, research intensive universities were found to undertake a considerably greater amount of knowledge transfer activity (per academic), both locally (<100 miles of the university) and further away, than less research oriented universities. In contrast, universities established originally as vocational colleges (i.e. former polytechnics in the UK) are more likely to provide continuous professional development courses for businesses. It is reasonable to expect that where university-business cooperation is focused on innovation activities i.e. new or improved products/services and processes, then knowledge transfer channels such as collaborative research, consultancy and licensing are more likely to be used than generic

education and training courses. In other words, the research quality of local universities may be an important determinant of businesses choice of university partner for innovation. Therefore, accounting for the local university environment and in particular the research quality of local universities is important in trying to understand the role of proximity in university-business cooperation for innovation. This leads to our third hypothesis:

Hypothesis 3: Local University Environment—Research Quality Businesses will cooperate for innovation with a local university where the university is recognized as being research excellent.

Another factor relating to the university environment which may be important to business decision to cooperate with local rather than non-local universities is the richness of the research environment. Huggins et al. (2009) argue that it is only those businesses and organizations located in a geographical environment rich in relevant knowledge sources that can take competitive advantage of the co-location of other knowledge actors. In terms of the university environment it would be expected that where the local environment has a high concentration of universities then businesses would be more likely to cooperate with local universities. In contrast, for a business located in an area with few universities then it is much more likely that cooperative innovation links will occur with non-local universities.

Hypothesis 4: Local University Environment—University Concentration Businesses located in a dense university environment will be more likely to cooperate for innovation with a local university.

2.4 Government support

The final factor considered in this paper to influence the geography of university-business cooperation for innovation is the role of government support. Along with businesses and universities, government is seen as the other strand in the Triple Helix formulation (Etzkowitz and Leydesdorff 1997). In the UK, as in many other countries, government policy has actively sought to promote greater university-business cooperation. This has occurred in various ways, including government initiatives such as Engineering Research Centres in the US and Competence Research Centres in Europe that directly finance university-business engagement for R&D and innovation; innovation vouchers (Netherlands, Ireland and the UK) to encourage business engagement with universities often for the first time; and funding support to the university sector to establish technology transfer offices (also referred to as industrial liaison offices) etc. Much of this government intervention and financial support at the business-level is granted to leverage the complementary expertise of university researchers with businesses, with eligibility typically confined to the national or regional level. In other words, government support at the regional level will seek to nurture university-business links at the regional level. This leads us to our final hypothesis:

Hypothesis 5: Government support for Innovation Businesses in receipt of government assistance for innovation are more likely to cooperate with local universities for innovation.

3 Data and methods

The analysis is based on the UK Innovation Survey (2002–2005) (UKIS), *augmented* with information on the UK university sector (research environment) and proximity measures.

The UKIS (2002–2005) is the fourth wave of the EU-wide Community Innovation Survey, based on a core questionnaire developed by the European Commission (Eurostat) and Member States. In the UK the survey was voluntary and administered by post. The UKIS sampled over 28,000 enterprises having 10 or more employees, stratified by Government Office Region in England, Scotland, Wales and Northern Ireland and including both manufacturing and service sectors. A final dataset of 16,445 businesses was obtained equivalent to a response rate of 58%.

The UKIS was augmented with data on the UK university environment, obtained through the Higher Education Funding Council for England (HEFCE) and specifically, data from their Higher Education–Business and Community Interaction (HE-BCI) survey which is an annual survey of all UK universities. The HE-BCI survey collects information on a range of 'third stream' activities reflecting the contribution of HEIs to both business and the community.[8] This data is publicly available and provides information at the level of the individual HEI.[9] The 2007 survey reports data for 158 HEIs across the UK and is regarded as providing a census of activity across the sector (HEFCE 2007/17). For each of the universities, postcode data was used to determine latitude and longitude indicators. By also calculating latitude and longitude for all 16,445 businesses in the UKIS and applying the Haversine formula (Sinnott 1984) this allowed the 'shortest' or 'as the crow-flies' distance between each business and University in the UK to be calculated.

Haversine formula in excel was calculated as follows:

$$D = ACOS(SIN(Lat1) \times SIN(Lat2) + COS(Lat1) \times COS(Lat2) \times COS(Lon2 - Lon1)) * 6{,}371$$

To convert the distance from km to miles, the output was then divided by 1.609344.

To determine the research quality of universities, all UK universities were assigned to one of four groups: first, a group of high quality research intensive universities (Russell Group universities), a group of middle-tier research universities (Group 1994 universities), a third group of universities, comprising new universities established in the late 1960s and 1970 along with polytechnic colleges mostly established during the same period, but granted university status in 1992 (New and Post 1992 Universities)[10] and a final group dominated by more specialist universities, such as teacher training colleges and art and design universities etc. Combining this data on research quality of each UK university, with the closest university identifier for each business, it was possible to determine if a business's closest university was a first-tier research (Russell Group) university, a middle-tier research (Group 1994) university, a new or former polytechnic university, or a more

[8] The HE-BCI survey defines 'businesses' as both public and private sector partners of all sizes and sectors and 'Community' as society as a whole outside the HEI, including all social, civic and cultural organizations and individuals. (see HEFCE 2007, p. 4).

[9] The Report and Data can be accessed at: http://www.hefce.ac.uk/pubs/hefce/2007/07_17/.

[10] The research excellence of the Russell group is reflected in the following statistics: In 2004/5, Russell Group Universities accounted for 65% (over £1.8 billion) of UK Universities' research grant and contract income, 56% of all doctorates awarded in the United Kingdom, and over 30% of all students studying in the United Kingdom from outside the EU. In the 2001 national Research Assessment Exercise, 78% of the staff in Grade 5* departments and 57% of the staff in Grade 5 departments were located in Russell Group Universities, and in 2004/5 Russell Group Universities were allocated approximately 64% of the total quality-related research funding (QR) allocated by the Funding Councils. While Group 1994 universities also have strong research capabilities, the extent of international research contracts and research council funding is significantly below that of the Russell Group. Post 1992 Universities then include 32 universities formerly established as polytechnics and 28 Universities that were established as 'modern' Universities in the 1960s.

Table 1 Business cooperation for innovation by type of partner

	No. firms	% UKIS (2002–05)
Other enterprises	1338	8.14
Suppliers	1863	11.33
Customers	1810	11.01
Competitors	1096	6.66
Consultants and labs	1103	6.71
Government/public research	781	4.75
University links	906	5.51
Local (<100 miles)	501	3.04
National (>100 miles)	486	2.95
Other European	101	.61
All other countries	67	.41
Local only	368	2.24
Local and non local	133	.81
Non local	405	2.46

Source UK innovation survey (2002–2005)

specialist university. In addition, to estimate the concentration of universities in the 'local' environment, the number of universities within a 100 mile radius of each individual business was also calculated. Other variables reflecting the conceptual underpinnings of the research were calculated directly from UKIS data and all variables are listed in the "Appendix".

In calculating proximity of university-business cooperation,[11] businesses indicated in the UKIS if they cooperated with local universities (within 100 miles of their business), or non-locally (this included over 100 miles distance from the business in the UK or internationally). The results (Table 1) highlight that businesses were more likely to cooperate for innovation with all other types of partner than with universities and government/public research labs. However, where university cooperation occurs (906 businesses), there is a clear split between those businesses cooperating with local universities (368 businesses or 40.6% of those with university links) and those cooperating with non-local universities (538 businesses or 59.4%).[12] This leads us to reject our first hypothesis proposing that where businesses cooperate with universities for innovation this would occur with local universities.

Our approach in this paper adopts a similar approach to that used elsewhere in estimating the determinants of business's knowledge sourcing activity (Love and Roper 1999). The first model estimates the probability of cooperating with a local university. To control for selection bias, that is, the likelihood of businesses cooperating with universities for innovation and the effect of this on business's choice of university partner (as defined by being local or non-local), a maximum likelihood two-stage probit estimation with selection, i.e. a heckman probit model was estimated. In other words, the decision to cooperate with a university is seen as having two dimensions: a strategic decision on whether or not

[11] UKIS measured innovation co-operation between 2002 and 2004. Innovation co-operation was defined as 'active participation with other enterprises or non-commercial institutions on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active co-operation.' (UKIS, 2005, Questions 17–18).

[12] Of the 538 (59.4)% of businesses cooperating with non-local universities 133 of these businesses were *also* cooperating with local universities.

to cooperate with a university, and a tactical decision relating to the choice of university with which to cooperate i.e. local or non-local knowledge sourcing. The analysis therefore comprises two probit models with sample selection, the first model estimating the determinants of university cooperation and the second model—being conditional on the first model—examining the determinants of knowledge sourcing from local or non-local universities.

The functional form of these models is as follows:

(1) $U = f\,[C, A, I, B, G]$
(2) $UL = f\,[C, A, I, B, UE, G]$

where U is a binary response variable of whether or not businesses have cooperated with universities for innovation in the previous 3 years period. Independent variables include measures of: the enterprise characteristics 'C'; businesses absorptive capacity 'A'; their innovation activity 'I'; the perceived barriers to innovation 'B'; and the receipt of government financial support for innovation 'G'. In the second-stage of the heckman probit model, UL is again a binary response variable taking the value 1 if the business cooperated 'only' with a local university (<100 miles from business) and taking the value 0 if collaboration involved non-local universities ($\geq$100 miles from business). As with the first model the same variable constructs are included, supplemented with measures on the quality and density of the research environment, the distance between the business and nearest university (UE) and more specific information on the sources of government support for innovation.

Absorptive capacity is estimated with various measures including the existence of internal R&D activity in the business and if they were undertaking extramural R&D. To capture non R&D measures of absorptive capacity, data on business investment in training along with the proportion of science and engineering graduates they employed and how this compared to the industry average were also included.

Variables on business's innovation activity were also included in the model, including whether they were conducting product innovation, service innovation and the degree of novelty of innovation activity. Reflecting differences in the reasons why businesses form cooperative links with universities, variables on the barriers businesses were facing in undertaking innovation were also included. Although, barriers in the UKIS were collected on a categorical scale ranging from not important, low, medium and high importance, these were recoded into a dummy variable with a response of medium or high importance allocated a value of 1, and not important or low importance being coded 0.

Variables reflecting the university environment included the log of the distance to the nearest university, whether the nearest university was a first-tier, second-tier or third-tier (former polytechnic and new) university, and finally the number (density) of universities within a 100 mile radius of the business. In addition dummy variables were also included on business's receipt of government financial support for innovation between 2002 and 2005. Three dummy variables were included in the analysis; if government financial support for innovation had been received; if this support was from local or regional government sources; and if financial support had been received from the European Union through the Framework Program.

Control variables included in the analysis reflected differences in business size, location in each of the 12 UK Government office regions, sector, employment growth (log) and the percentage of sales in export markets.

4 Findings and discussion

4.1 Cooperation with universities for innovation

Those factors identified in the first stage of our model (Table 2) as affecting the probability of cooperating with universities for innovation are consistent with previous research studies. Particularly strong in this model are measures of absorptive capacity in the business. For example, having internal R&D capability is found to be strongly associated with university cooperation. This suggests the complementarity of internal R&D and external networking and that internal capability is necessary in identifying external knowledge, assimilating this and exploiting it in the business. This is supported further in relation to the relative educational levels of the workforce. Controlling by sector, where businesses have above average levels of graduates then they are significantly more likely to be collaborating with universities for innovation. This provides support for Hypothesis 2a that as absorptive capacity increases, businesses become more likely to form innovation links with universities.

Where business's innovation process is more 'open', that is, they are seeking knowledge from outside the business or investing in extra-mural R&D then the probability of cooperating with universities for innovation increases. This supports other research (Roper and Love 1999) in arguing that as businesses move towards a more distributed innovation model, then accessing, co-producing and exploiting university research and knowledge will become more important.

We also find that university cooperation is more likely where businesses are producing new to the market or 'novel' innovations. This may reflect the type of knowledge and/or

Table 2 Probability of business cooperation with universities for innovation

Dependent variable—university cooperation (1/0)	Coeff	SE	Sig
Enterprise characteristics			
Sector: construction	.208793	.07782	***
Ln employment growth	−.11473	.054941	**
Export sales (1/0)	.197851	.04483	***
Absorptive capacity			
Invest internal R&D (1/0)	.310531	.049589	***
Invest external R&D (1/0)	.484451	.048906	***
Acquire ext knowledge (1/0)	.315087	.04709	***
Above average graduates (1/0)	.258555	.041763	***
Innovation activity			
New to market sales (1/0)	.398301	.045392	***
Barriers to innovation			
Barrier information on technology (1/0)	.124329	.024782	***
Government support for innov			
Govt support (1/0)	.559637	.049041	***
Govt support EU FP(1/0)	.930506	.128246	***
Constant	−1.97046	.260153	***
Athrho	−.32397	.137134	.018
Rho	−.3131	.123691	−.0551

technology that is accessed through university co-operation: being more applied and derived from exploratory research, with the application of this leading to major changes to existing products (often through recombinant technological innovations) or the introduction of new to the market products. Further, we find that where businesses identify a lack of information about appropriate technology as a barrier to innovation, they are more likely to form cooperation links with universities. In other words the model suggests that businesses, faced with a lack of information on technology may approach universities as a source of information. Therefore, although, causality cannot be determined from the data, it is likely that technological developments occurring as a result of university cooperation are enabling more novel products to be introduced to the market.[13] Associated with this is a business's market profile, with sales into export markets being associated with a higher probability of university co-operation.

The role of government support for innovation is found to have a positive and significant effect on the probability of university cooperation. This applies not only to government support in general, but also to EU support through the Framework Programmes. Although, the EU Framework Programmes are set-up as collaborative projects, this is not always the case for other forms of Government support for innovation, particularly at the national and regional level. Such programmes include R&D tax credits which are not specifically targeted at collaborative innovation activity, or more focused supports including innovation vouchers or funding for competence research centres etc. The positive and significant coefficients suggest that government support for business level innovation positively affects the probability of business-university cooperation. Further, public financial support for innovation may be a key element in bringing business and universities together with government, in a Triple Helix model (Etzkowitz and Leydesdorff 1995).

4.2 Cooperation with local or non-local universities?

Our main concern in this paper is the second element of the econometric analysis. Specifically, with the data suggesting that there is a choice between staying local in cooperating with universities for innovation or searching further away for university partners, the probit model is constructed to explore these relationships. Having accounted for potential selection bias in the model (the probability of having cooperative innovation links with universities—Table 2) the models are then re-estimated (Table 3). We test for the probability of cooperating with only local universities, non significant variables are excluded and the model is then re-estimated. In these models, the dependent variable equals 1 where the business has cooperated with a local university between 2002 and 2005, and takes a value of 0 where cooperation for innovation has occurred with non-local universities. For each of the models, marginal effects are reported.

As outlined earlier, UK businesses that cooperate with Universities for innovation are more likely to cooperate with non-local universities than local universities. However, the marginal effects reported in Table 3, refine this conclusion and emphasize that under certain conditions, local university cooperation is more likely to occur.

Looking first at the enterprise characteristics of businesses cooperating with local and non-local universities, we find that small businesses (<50 employees) are significantly more likely to cooperate with local universities while larger businesses (>250 employees) are more likely to cooperate with non-local universities. Abreu et al. (2008) suggest that for

[13] Correlation coefficient between having new to market products (0/1) and experiencing a lack of information on technology as a barrier to innovation (0/1) is .1768.

Table 3 Determinants of businesses cooperation with local universities

Dependent variable: university cooperation local (1/0)	Marginal effects	SE	Sig.	Marginal effects	SE	Sig.
Enterprise characteristics						
Small bus	.049124	.03846		.119211	.03999	***
Large bus	−.105715	.04289	**	–	–	
Region north east	.13947	.06901	**	.150358	.07001	**
Region Yorkshire and Humberside	.107524	.06368	*	.112881	.06477	*
Selling in export market (1/0)	−.076251	.04396	*	−.096958	.04516	**
Absorptive capacity						
Invest in internal R&D	.094974	.04098	**	.093808	.04377	**
Science and engineering graduates (%)	−.002403	.00096	**	−.002470	.00093	***
Perform training for innovation	−.08535	.04245	**	−.086681	.04326	**
Exp. training (% of turnover)	.002035	.00577		–	–	
Innovation activity						
Goods innovator	−.087739	.04688	*	−.095307	.04752	**
Services innovator	.031094	.03103		–	–	
Barrier to innovation						
Lack of qualified personnel	.025608	.01616	*	.02720	.01572	*
University characteristics						
Ln distance to nearest Uni	.002811	.01228		–	–	
Russell group Uni. nearest Uni	.078597	.03946	**	.091392	.04107	**
No. Uni within 100 miles	−.002472	.00101	**	−.002937	.00104	***
Government support for innovation						
Govt support—local	.107884	.04466	**	.124757	.04629	***
Govt support—EU	−.149350	.06381	**	−.174451	.06565	***
LR test of indep. eqns (rho = 0): $chi^2(1) =$		8.83		8.28		
Prob > chi^2		.003		.0004		

Dependent variable takes the value of 1 where university cooperation for innovation is with a local university (<100 miles) and 0 where the business engages in university cooperation which is non-local (≥100 miles)

small businesses, transaction costs may be important in partner selection. Small businesses, they argue, 'do not have staff dedicated to dealing with university interactions. Proximity may therefore be a more relevant factor for small companies compared to larger firms' (ibid. p. 39). For large business however, transaction costs will be outweighed by finding the most appropriate partner, irrespective of whether this is local or non-local.

For some of the UK regions, the North East and Yorkshire & Humberside, businesses located here are significantly more likely to cooperate with local universities. It is difficult to determine why this might be the case for these two regions, yet both have a strong history of traditional manufacturing and strong cultural ties or social capital. It is interesting to note that following the survey period, to 2005, two initiatives were launched in these regions to support greater university-industry cooperation. The first was the N8—a research partnership formed to strengthen university-business cooperation. The N8 comprises 8 universities (2 of which are in the North East and 1 is in Yorkshire and Humberside) with annual turnover of £1.75 bn, research income in excess of £620 m,

approximately 8,000 academic staff and 160,000 students. This is similar to that for the combined universities of Oxford, Cambridge, Imperial College London, University College London and the London School of Economics (Secher 2008). The second was the UK Science Cities initiative with the delineation of the City of Newcastle in the North East and York in Yorkshire and Humberside as Science Cities.[14] Therefore, both of these regions not only have a long history of traditional manufacturing with strong social capital and a strong research base, but as reflected in recent initiatives there is potential to strengthen the relationship between the science base and businesses in pursuit of regional economic growth.

In relation to the geographical profile of business sales again we find that where businesses have sales into export markets, then not only are they more likely to be cooperating with universities for innovation (Table 2), but this cooperation is more likely to be with non-local universities (Table 3).

Referring back to Hypothesis 1 we can conclude that where businesses cooperate with universities for innovation, this is most likely to be with non-local universities. However, local cooperation is much more likely for small businesses, those with a national customer base i.e. non-exporters, and where the business is located in specific regions with strong social capital and a rich research base.

The relationship between business's absorptive capacity and university cooperation is unambiguous (Table 2) suggesting that as absorptive capacity increases, then university cooperation becomes more likely. This relationship is less clear in terms of whether university cooperation will be with local or non-local businesses. Where cooperation is more likely to occur with local universities, businesses are investing in internal R&D capability or they are experiencing a lack of qualified personnel. In contrast, where cooperation is more likely with non-local universities, these businesses tend to have a higher proportion of science and engineering graduates and are undertaking training for innovation, however, they are less likely to be undertaking internal R&D.

Investing in internal R&D can take various forms from informal and ad hoc research activities to a formal R&D department with dedicated personnel and facilities. Data from the UKIS does not specify if undertaking internal R&D relates to formal or informal activity and we can only assume therefore that it includes both types of activity. What is clear from the findings is that where internal R&D occurs then university cooperation is more likely to occur with local universities. Abramovsky and Simpson (2008) also found that for pharmaceutical businesses in particular, there was a deliberate attempt to locate R&D labs near to leading university research departments and this led to cooperation between the two. Although, this relationship was less evident for businesses in the chemicals or vehicles sectors a tendency still existed for their labs to engage with local universities. Our results in this paper suggest that where internal R&D activity is being undertaken, then geographical proximity is important in university-business cooperation. This provides support to other research on the importance of tacit knowledge and the localization of knowledge spillovers from university research.

Interestingly our results also support other research on the reasons why businesses cooperate with universities. Business cooperation with universities is more likely where the business is experiencing a lack of information on technology, however, local links are more associated with a lack of qualified personnel (albeit statistically insignificant). This

[14] Science Cities were established in September 2005 'to lead the development of deeper links between business and the science base and ensure that science, technology and innovation succeed in becoming the engine of economic growth' (Times Higher Education 2005).

finding is consistent with Lawton-Smith and Bagchi-Sen (2006) that access to talent is a key driver of business links to universities. In addition, as the share of the workforce with science and engineering degree level qualifications increases or businesses invest in employee training for innovation, this association with local universities diminishes and instead businesses are more likely to cooperate with non-local universities.

This leads us to conclude that the relationship between absorptive capacity and the geography of university links is not straightforward. As educational/skill levels increase then the ability to search for appropriate knowledge and university partners increases with this being associated with cooperation between more distant partners. This perspective adds to the growing literature exploring different elements of proximity (Boschma 2005; Torre and Rallet 2005) and in particular a growing emphasis on cognitive proximity (Nooteboom 2000). In other words, as cognitive proximity increases[15] then this reduces the dependency on co-location as a means of exchanging knowledge. At the same time, undertaking internal R&D (whether formally or informally) is associated with local university cooperation. Trying to reconcile these two findings would suggest that where internal R&D occurs, externally sourced knowledge complements internal development leading to the co-production and adaptation of knowledge. Tacit knowledge both in the production and transfer of knowledge is important in this process and as a result localization of knowledge spillovers is more likely. Conversely, in the absence of internal R&D activity, then external knowledge sourcing acts as a substitute for internal activity. There is less co-development of knowledge and the emphasis is placed more on the transfer and exploitation of knowledge. In this case, of greatest importance are the skills to identify appropriate external knowledge sources and the exploitation of this. Cognitive proximity is therefore more important than geographical proximity in this situation.

Our third and fourth hypotheses relate to the characteristics of the local research environment and how this might influence local university-business cooperation. In relation to research quality, it was suggested that larger businesses will cooperate with the most appropriate research partner, irrespective of the transactions costs involved (Abreu et al. 2008). E*x ante* we anticipated therefore that where local university research was of an excellent quality then businesses (and larger businesses in particular) would be more likely to cooperate locally. The reverse of this being that where appropriate research expertise is not located locally; larger businesses will identify and cooperate with non-local partners. The marginal effects (Table 3) support this hypothesis, with being located next to a Russell group (first tier research) university positively associated with local university cooperation for innovation. We can therefore accept the hypothesis that businesses will cooperate with a local university where the university displays research excellence.

The distance to the nearest university was not found to have a significant effect on the geography of university-business cooperation. This implies that physical distance per se has limited effect on determining university-business relationships. However, the density of the knowledge environment as measured by the concentration of universities within 100 miles of each business is found to be significantly related to the geography of cooperation, but not in the way proposed in Hypothesis 4. Ex Ante, we anticipated that where businesses were located in a dense university environment, then this would be conducive to cooperation with local universities. This hypothesis is rejected and instead we find that as the number of universities in a 100 mile radius of a business increases, so too does the likelihood of the business cooperating with non-local universities. In contrast, in an

[15] Cognitive proximity refers to the common expertise and knowledge base of individuals (Nooteboom 2000).

environment with a low concentration of universities, businesses are much more likely to cooperate with local universities. One possible explanation for this relates to both transaction costs and awareness of universities' capabilities. For example, in an environment with a low concentration of universities, businesses may be more aware of the research strengths of local universities and transaction costs of searching for the appropriate partner are low. Conversely, in a rich university environment, with a high concentration of universities, the research expertise of one university relative to another may be unclear. Businesses will therefore incur higher transaction costs as they search (even within their local 100 mile radius) for the most appropriate partner. In such circumstances, incurring 'search' costs weaken the effect of distance, with businesses more likely to identify non-local university partners. This leads us therefore to reject our hypothesis that where a business is located in a dense university environment it will cooperate for innovation with local universities.

Government support for innovation was found to have a positive effect on the likelihood of university-business cooperation (Table 2). The geography of university-business partners is complicated however, by the source of funding. Where funding is from a local government source, then local cooperation is more likely. In contrast, where funding is from non-local sources, in this case the EU Framework Programme, then businesses are significantly more likely to form non-local cooperation partnerships. Our hypothesis that businesses in receipt of government assistance for innovation are more likely to form innovation links with local universities is accepted where the government funding source is local. However, where funding for business innovation is non-local or regional, i.e. at an EU level, then this encourages cooperation with non-local universities. This suggests that government support for innovation may be instrumental in shaping the geography of university-business cooperation.

5 Conclusions

The focus of this paper has been on cooperation between businesses and universities for innovation and the role of proximity in this. Although, businesses are more likely to cooperate with customers and suppliers for innovation than with universities, the potential for universities to contribute to business innovation has increased. This reflects changes in the business innovation process towards knowledge intensive activities, the growing dispersion of knowledge among diverse actors and more open innovation systems (Perkmann and Walsh 2008). Alongside this, the university environment has experienced the development of an Entrepreneurial University culture, a move to protect intellectual property and a greater desire to engage with businesses in the exploitation of knowledge (Slaughter and Leslie 1997). Nationally, government policy—particularly in the UK—has sought to promote university-business cooperation for innovation through at least two main channels: direct procurement and/or provision in public facilities such as universities and the financial support to establish knowledge transfer capability; and secondly, through incentives to promote greater private investment in R&D (tax incentives or R&D subsidies) and cooperative university-business engagement (innovation vouchers, knowledge transfer partnerships, Competence Research Centres etc.).

This policy approach has focused on strengthening the innovation system whether at the national or regional level through inter-organisational linkages, based on the notion that cooperation for innovation tends to be spatially restricted. Yet, as highlighted by Bercovitz and Feldmann (2006, p. 178) 'the role of spatial proximities, or other idiosyncratic

factors—have not yet been studied in detail'. Research contributions in this area have come mainly from the spillovers and industrial organization literatures and have suggested that as distance increases between actors, the effectiveness with which knowledge is transferred (and spillovers occur) decreases. This perspective is supported by empirical studies in the US, Germany and France where innovation output derived from university research was limited to a 100 km radius of the university. One of the main explanations for this has related to tacit knowledge and informational advantages from agglomeration economies (Boschma 2005). Indeed, recent research on the co-location of R&D labs and university research suggests that proximity does influence collaboration, with this being particularly important for knowledge intensive sectors such as pharmaceuticals (Abramovsky and Simpson 2008). At the same time, research is increasingly pointing to the internationalization of knowledge (Huggins et al. 2009) through knowledge sourcing across borders. This perspective challenges theories on the localization of knowledge and cooperation relationships, and suggests that co-location is not necessary for effective university-business partnerships. In this paper we highlight that in the UK (UKIS 2005) businesses were more likely to be cooperating with non-local universities for innovation (44.7% of businesses with a university link) than with local universities (40.6%). As this is contrary to what would be expected where knowledge spillovers are localized the analysis has explored if the geography of university-business cooperation can be explained by business characteristics as well as the characteristics of the research environment and the proximity between businesses and universities.

Our findings support other research relating to the characteristics of businesses that engage with universities for innovation. In particular, we find that the probability of university-business cooperation increases where an 'open' knowledge sourcing strategy is used by businesses, where absorptive capacity increases, where businesses are experiencing a lack of information on technology and where government is providing support for innovation. However, the second stage of our analysis relating to the geography of these university-business links refines these findings. Here we find that local cooperation is not automatic with business-level and research environment characteristics influencing the geography of cooperation. In particular, for small businesses (<50 employees), where sales are predominantly in the national market and for some UK regions (Yorkshire and Humberside and the North East) university-business cooperation is much more likely to occur between local partners.

A number of implications can be inferred from the research for the business community, for universities and for policy markers. First, for businesses, the data analysis supports the notion that businesses make two decisions in cooperating with universities for innovation. The first is a strategic decision reflecting their decision on whether or not to source knowledge from university actors. The second decision is then a more tactical decision, reflecting businesses choice of university partner. It is at this second stage that the importance of proximity is better understood. For example, small businesses in particular and those trading solely in the domestic market are more likely to cooperate with local university partners for innovation. Second, where businesses have an internal R&D capability then cooperation is more likely to occur with local universities. However, recruiting graduates into the workforce, and in particular science and engineering graduates, as well as training employees to undertake innovation appears to facilitate non-local university cooperation. In this paper we propose that substitution may be occurring with cognitive proximity acquired through the education and training of employees overcoming the need for physical proximity. At the same time, it is also possible that co-location and cooperation between business and universities partners is focused on the co-production of

knowledge whereas non-local cooperation may be associated with identifying appropriate knowledge sources and transferring or adopting these to the business context.

Third, where businesses are located close to a high quality, first-tier research intensive university, then the expertise needed for innovation is accessed locally. Again there are limitations to the empirical analyses, in that it is not possible to determine if businesses strategically choose to locate close to leading research universities, as would be suggested by other research (Abramovsky and Simpson 2008 in the UK and Audretsch et al. 2005 in Germany) or whether location close to universities leads to the development of social networks which foster future cooperation. Finally, where businesses receive government support for innovation this is associated with university cooperation. However, the source of this funding effects the geography of cooperation with local government funding being associated with local university links whereas EU funding is more likely to be associated with non-local cooperation.

In relation to universities again a number of points arise from the analysis. First, in searching for business partners, non-local links are more common than local links suggesting that universities should avoid adopting an exclusive focus on the locality (100 km radius). Second, where local business links occur, these are more likely to be with small businesses, with businesses focusing on the domestic market and with those that perceive a lack of expertise as constraining their innovation activities. In addition, university researchers may have an important role to play in providing expertise to local businesses and compensating for shortcomings in the business. In this regard existing public sector initiatives such as KTPs and innovation vouchers are designed to meet this need. Third, where local businesses have an R&D capability then these businesses are more likely to source their knowledge from local universities. Strengthening networks with these businesses may therefore be mutually beneficial. Finally, while proximity is static, certainly in the short to medium term, investing in research excellence is found to have a dynamic effect on business cooperation. Strengthening the quality of research output in a university will increase the probability of business innovation links and encourage local businesses to remain local in their relationships with universities as opposed to searching from further afield.

For policy makers the findings for the North East of England and Yorkshire and Humberside suggest that over *time social capital* can be developed and a stronger innovation system nurtured through appropriate initiatives to foster cooperation between the actors in a regional innovation system. Secondly, the findings suggest that where policy makers attempt to maximize the economic and social return from investments in university research, account should be taken of both the research and the local/regional business environments. For example, in a region with low business sector absorptive capacity and R&D capability, government attempts to promote greater university-business cooperation may lead universities to undertake applied or market-focused research and knowledge transfer activities. However, the problem with this approach is where it results in a weakening of research quality as research effort is directed away from basic research and towards the application of knowledge to specific business problems. This leads-on to our third point emphasizing the importance of research excellence. Where there is a first-tier research university, businesses will attempt to cooperate with that university, irrespective of the business location. The implication of this being that public sector investment in high quality research is likely to stimulate university-business cooperation. Of course there is still the chance that this (university) knowledge will be exploited by non-local or indeed non-national businesses, however, there are still significant benefits to be gained including the attraction of R&D labs to the region to be close to the university as well as knowledge

spillovers to other local businesses whether through cooperative innovation partnerships or other knowledge spillover channels. Where it is not feasible for the public sector to invest in research leading universities, then the findings suggest that investment in businesses education, skills and training for innovation is critical as this will equip businesses to identify, access and assimilate non-local knowledge.

Acknowledgments This research paper is part of a program of research supported by the National Endowment for Science Technology and the Arts (NESTA), London. The views expressed in this paper are the sole responsibility of the author.

Appendix

See Table 4.

Table 4 Data definitions and descriptive statistics (full sample n=16,445)

Variable label	Variable definition	Mean	SD
Enterprise characteristics			
Sector—construction (1/0)	Firm is in the construction sector: dummy variable	.0980	.2974
Ln employment growth	Log employment growth 2002–2004	4.6661	.3670
Export sales (1/0)	Enterprise selling into export markets (outside the UK): dummy variable	.3220	.4672
Absorptive capacity			
Invest internal R&D (1/0)	Firm committing financial resources to internal R&D activity: dummy variable	.3153	.4646
Invest external R&D (1/0)	Firm committing financial resources to external R&D activity: dummy variable	.1232	.3286
Acquire ext knowledge (1/0)	Firm engaged in acquiring knowledge externally: dummy variable	.1424	.3495
Perform training for innov	Internal or external training for employees for innovation: dummy variable	.4152	.4927
Exp. on training for innov relative to turnover	Level of investment in training (training inv/turnover)	.2455	1.544
Science and engineering graduates (%)	Proportion of total employees in the firm that are science and engineering graduates (%)	5.353	14.677
Above average graduates (1/0)	Firm has above average proportion of graduates as a share of workforce, controlled by sector calculated at 2-digit SIC level: dummy variable	2.688	.4433
Innovation activity			
New to market sales (1/0)	Firm introduced product/service innovations between 2002 and 2005 that were new to the market: dummy variable	.1637	.3700

Table 4 continued

Variable label	Variable definition	Mean	SD
Goods innovator	Firm had introduced a new or modified product innovation 2002–2004: dummy variable	.1970	.3977
Services innovator	Firm had introduced a new or modified service innovation 2002–2004: dummy variable	.1845	.3879
Barriers to innovation			
Barrier information on technology (1/0)	Lack of information on technology identified as important/very important barrier to innovation activity in the firm: dummy variable	.06899	.8160
Lack of qualified personnel (1/0)	Lack of qualified personnel identified as important/very important barrier to innovation activity in the firm: dummy variable	.8849	.9714
Government support for innov			
Govt support (1/0)	Firm in receipt of government financial support for innovation 2002–2004: dummy variable	.1054	.3072
Govt support—local (1/0)	Firm in receipt of *local or regional* government financial support for innovation 2002–2004: dummy variable	.0571	.2321
Govt support EU FP (1/0)	Firm in receipt of *EU, framework programme* financial support for innovation 2002–2004: dummy variable	.0092	.0955
Enterprise characteristics			
Small bus	Firm with 50 or fewer employees: dummy variable	.5532	.4971
Large bus	Firm with 250 or more employees: dummy variable	.2068	.4050
Region north east	Firm located in north east England government office region: dummy variable	.0577	.2333
Region York and Humberside	Firm located in Yorkshire and Humberside government office region: dummy variable	.0819	.2743
University characteristics			
Ln dist to nearest Uni	Distance in miles to nearest university (log value)	2.066	1.280
Russell group Uni. nearest Uni	Closest university to firm is a research intensive (Russell group) university: dummy variable	.2552	.4360
No. Uni within 100 miles	Number of universities within 100 mile radius of the firm	28.166	20.523

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