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Academic Entrepreneurship: What are the Factors Shaping the Capacity of Academic Researchers to Identify and Exploit Entrepreneurial Opportunities?

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Abstract:
This paper aims at improving our understanding of the attributes of academic researchers that influence the capacity to identify and exploit entrepreneurial opportunities. We investigate a number of factors highlighted in the literature as influencing the entrepreneurial activities undertaken by academics. Our results show that identification and exploitation of entrepreneurial opportunities are shaped by different factors. While identification of commercial opportunities is driven by prior entrepreneurial experience and the excellence of the academic work, exploitation of entrepreneurial opportunities is driven by the extent of previous collaboration with industry partners, cognitive integration and prior entrepreneurial experience.

Keywords: Academic entrepreneurship; Opportunity identification; Opportunity exploitation; Spin-offs; Patenting; University-business collaboration
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1. INTRODUCTION

Public research organisations, and particularly universities, are becoming increasingly entrepreneurial, embracing a mandate for the realisation of commercial value from research, and searching for new organisational arrangements that bring a closer alignment of scientific research and innovation (OECD, 2003; Siegel, 2006; Rothaermel et al., 2007). The entrepreneurial activity of universities has been epitomised by a rise in patenting, licensing and the creation of spin-off companies among academic researchers (Wright et al., 2007; Siegel et al., 2003). The evidence that entrepreneurial performance differs widely among academics has brought to the forefront the need to understand the factors that differentiate academic researchers in terms of their inclination to engage in knowledge transfer activities and, more particularly, to become academic entrepreneurs (Bercovitz and Feldman, 2008; Hoye and Pries, 2009).

Scholars in the fields of entrepreneurship and innovation studies have long been interested in the entrepreneurial behaviour of university researchers and universities' entrepreneurial activities more generally (Chrisman et al., 1995; Stuart and Ding, 2006; Rothaermel et al., 2007). However, very little is known about the attributes of academic researchers that influence the identification and exploitation of entrepreneurial opportunities. This is a crucial issue for both the entrepreneurship and the university-industry linkages literature in order to reach a better understanding of the entrepreneurial process.

This paper addresses this topic by investigating which academic researchers engage in two types of entrepreneurial activities: inventions (as recorded in patents) and establishment of new firms. The paper examines a number of researcher characteristics highlighted in the entrepreneurship literature as being associated with the identification and exploitation of entrepreneurial opportunities. We investigate in particular: a) knowledge of the marketplace and collaboration with users; b) prior experience in entrepreneurship; c) integration of multiple fields of research; d) excellence of research; and e) extent of the research network.

The paper is structured as follows. Section 2 discusses the conceptual background and proposes a set of hypotheses. Section 3 provides a detailed description of the design of the empirical research. Section 4 presents the results, and Section 5 concludes.

2. BACKGROUND LITERATURE AND HYPOTHESES

2.1. Academic entrepreneurship: Identification and exploitation of profitable opportunities

Entrepreneurship is concerned with the discovery and exploitation of profitable opportunities (Shane and Venkataraman, 2000). The literature on entrepreneurship points to a distinction between opportunity identification and opportunity exploitation, and their importance to entrepreneurship (Venkataraman, 1997; Shane and Venkataraman, 2000). The literature on academic entrepreneurship is focusing increasingly on these two notions, recognising them as being distinct and crucial for the study of entrepreneurship (Wright et al., 2004; Park, 2005). However, rather less is known about the factors that contribute to the development of the entrepreneurial skills among academic scientists, and particularly to the skills necessary for opportunity identification and opportunity exploitation.

The literature on university-industry technology transfer defines an academic entrepreneur as a university scientist who engages in the commercialisation of the results of his/her research, largely by patenting and/or setting up a business. In the context of academic entrepreneurship, identification of a commercial opportunity is often equated with invention disclosure to university technology transfer offices and with academic patenting (Jensen and Thursby, 2001; Colyvas et al., 2002; Shane, 2002; Jensen et al., 2003; Lubango and Pouris, 2007). As shown by Jensen and Thursby (2001), an overwhelmingly majority of university inventions disclosed (over 75%) are no more than a proof of concept at the time of license, indicating the embryonic state of most technologies on which academic patents are based. Indeed, the rationale behind regulation encouraging university patenting is that intellectual property rights would favour bringing academic inventions into practice, inducing firms to invest resources in embryonic inventions that require a protracted development trajectory before materialising into an innovation, in exchange of a license agreement with universities (Jensen and Thursby, 2001; Colyvas et al., 2002; Mowery and Sampat, 2005). In short, it is reasonable to argue that academic patents are a good expression of early stage inventions, suggesting opportunities for potential commercial applications but very far still from commercial use.[1]

Alternatively, opportunity exploitation is epitomised by the academic researcher who sets up a business in order to explore the market potential of his/her discovery. In this case, the commercialisation activity is not limited to identifying a breakthrough with commercial potential, but extends to all the related activities associated with bringing an invention to the market (Mustar, 1997). These activities include the design of a business plan, finding venture capital, and managing (or having and advisory role on) the manufacturing and commercialisation activities of the new company. No doubt establishing a firm is not the only route to commercialization of academic inventions. Licensing to non-academic inventors is a frequent path to commercialisation when patents are an effective mechanism for appropriating the returns to innovation (Shane, 2002). However, we focus here on taking equity and setting up new businesses by academic researchers since these actions allow us to better capture a more direct and comprehensive engagement in the exploitation of entrepreneurial opportunities: that is, an involvement in the wide range of activities associated with bringing into existence new goods or services, and in the organisation of methods that allow outputs to be sold at more than their cost of production (Shane, 2000).

These two entrepreneurial functions - identification and exploitation - differ in a number of important ways including the type knowledge transferred, the

[1] However, patenting is by no means a perfect indicator of identification of potential business opportunities by academics. This is so, as Thursby and Thursby (2002) point out, because: (i) not all academic inventions are eligible for patent protection (such as new software); (ii) only a proportion of the realized inventions are disclosed by academics, since academics are often unwilling to spend time on the applied research and development required for the successful exploitation of their inventions; and (iii) not all academic inventions disclosed are assessed as of commercial potential (by university technology transfer officers) and thus not selected for patent application or license.

degree of complexity inherent in the activity and the risk associated with the activity. Tijssen (2006) distinguishes university entrepreneurship activities based on the transfer of knowledge (e.g. consulting or contract research); the transfer of technology (such as patent/licensing) and the transfer of products and services (e.g. spin offs). He argues that progressing from the transfer of information to the transfer of technology and then to products requires the incorporation by the institution of new functional units, indicating the increased complexity of the activity as well as the risk associated with failure of the venture. Mustar (1997) provides a detailed illustration of the complexity of setting up a hi-tech spin-off, indicating that success in such ventures requires a combination of the skills associated with strengthening ties with academic research laboratories, involving clients from an early stage of product/technology design and the capacity to search for public and private funding sources to support the enterprise.

Entrepreneurship research has proposed some broad categories of factors affecting the probability that particular scientists will identify and exploit profitable opportunities. This literature highlights that prior knowledge of markets and customers' problems positively contributes to the development by academic researchers of new discoveries and technological breakthroughs and leads to potential commercial opportunities (Shane, 2000). On the other hand, identification of a commercial opportunity does not always equate with a realised, valuable commercial application. Identifying a commercial opportunity is qualitatively different from bringing to market a technological breakthrough. Exploitation of commercial opportunities requires very different skills from those involved in identifying a commercial opportunity. Some of the factors indicated in the literature as influencing the decision to exploit an opportunity are associated with access to financial capital (Evans and Leighton, 1989) and the transferability of information gained through prior experience in entrepreneurial activity (Carroll and Mosakowski, 1987).

In short, although both patenting and spin-offs start from the willingness of the academic researcher to exploit an invention originating within the university, spin-offs involve the specific activity of creating an independent venture to exploit the invention, while patenting can be seen as expressing a technological advance which its inventor perceives as having commercial potential. This distinction is central to our discussion since it expresses the idea that patenting is associated with recognising an opportunity while spin-offs are associated with its exploitation.

2.2. Factors influencing academic entrepreneurship

An area of concern in the literature on university-industry linkages relates to the importance of understanding the factors shaping the behaviour of academic entrepreneurs, and particularly the factors that influence the development of entrepreneurial skills among academic researchers. Entrepreneurship research provides a natural starting place in the search for a conceptual framework to investigate these issues, since this literature is concerned with why some people (and not others) discover and exploit profitable opportunities.

However, there are a number of schools of thought explaining the discovery and exploitation of entrepreneurial opportunities (Shane, 2000). In this paper we aim to deepen our understanding of whether information asymmetry and experience influence who discovers and exploits entrepreneurial opportunities. Drawing on entrepreneurship research literature that highlights the importance of prior knowledge and idiosyncratic experience to explain entrepreneurial behaviour, we identify a number of factors that might influence the capacity of academic researchers to recognise and exploit entrepreneurial opportunities. These factors are: a) knowledge of the marketplace and collaboration with users; b) prior entrepreneurial experience; c) extent of research network; d) integration of multiple fields of research; and e) impact of academic research. This section discusses each of these factors and proposes a set of hypotheses.[2]

[2] It is important to note here that all these factors may be heavily moderated by contextual features. Thus, for instance, academic researchers in different organisational settings may find it easier (or more difficult) to engage in entrepreneurial activities (regardless of the individual features). While these moderating effects are not directly addressed in this paper, we try to control for some institutional features in the empirical part of this study.

2.2.1. Experience in collaboration with industry

Entrepreneurship research points to the importance of transferring information from previous experience to a current entrepreneurial opportunity (Shane and Venkataraman, 2000). Experience of working with industry, for example, has often been identified in the university-industry linkages literature as a good predictor of effective technology transfer. For instance, Grandi and Grimaldi (2005) and Landry et al. (2007) show that the relational capital of academic researchers with users is positively and significantly associated with the extent to which the academic researcher engages in knowledge transfer activities. At the organisational level, Feldman and Desrochers (2004) and Jong (2006) show that universities and departments with an established tradition in collaborative research with firms, are more likely to recognise the commercial opportunities of their research activities. Along the same lines, Ponomariov and Boardman (2008) show that fostering informal links between university and industry favours later collaboration.

Indeed, collaboration with industry on the one hand, and awareness and ability to exploit commercial opportunities on the other, are likely to be self-reinforcing. This is because the higher the level of interaction with industry, the more likely it is that academic researchers will recognise the potential applications of their research and the better will be their understanding of market conditions and business processes. And, vice versa, the stronger the taste for commercial opportunities and the higher the level of entrepreneurial skills among academic researchers, the greater will be their inclination to search for funding from industry and strengthen linkages with business. As Shane (2000) shows, recognising and exploiting a business opportunity is strongly associated with the entrepreneur's idiosyncratic prior knowledge about markets, technologies and costumer needs. Therefore, we would expect that:

> Hypotheses 1. *The stronger the prior experience in research collaborations with industry, the more likely it will be that academic researchers will (a) identify and (b) exploit entrepreneurial opportunities.*

2.2.2. Prior entrepreneurial experience

Entrepreneurship research also highlights that prior entrepreneurial experience increases the probability of identification and exploitation of entrepreneurial opportunities since it helps to develop the mindset and skills necessary to undertake such functions (Shane and Venkataraman, 2000; Shane, 2000). For instance, Wright et al. (2004) and Hoye and Pries (2009) point to increasing evidence of the phenomenon of recurrent academic entrepreneurs, that is, researchers who undertake multiple entrepreneurial ventures. Similarly, Bercovitz and Feldman (2008) show that academic researchers who have disclosed inventions to their university technology transfer offices in the past are likely to repeat this behaviour. Prior experience in identifying entrepreneurial opportunities is likely to increase a researcher's perception of the commercial potential of his/her current research activities. We propose, therefore, that:

> Hypotheses 2a. *The greater the prior entrepreneurial experience, the more likely it is that academic researchers will (a) identify and (b) exploit entrepreneurial opportunities.*

However, prior entrepreneurial experience can have a dual effect on entrepreneurship. On the one hand, it may contribute to a better understanding of user needs and business operations, a learning effect; on the other hand, it might provide a heightened appreciation of the (high) risks associated with, and the (huge) complementary assets required for, the exploitation of entrepreneurial opportunities. Prior experience, therefore, could undermine the extreme optimism frequently found in novice entrepreneurs (Cooper et al., 1988). Thus, we would expect that, beyond a certain threshold, entrepreneurial experience might undermine the likelihood of engaging in new ventures, as academic researchers may be more cautious about and selective in whether or not to undertake a new venture. Therefore, we hypothesis that:

> Hypothesis 2b. *The probability of engaging in the identification and exploitation of entrepreneurial opportunities is curvilinearly (taking an inverted U-shape) related to prior entrepreneurial experience.*

2.2.3. Integration of multiple fields of research

Entrepreneurial research shows that individuals with interdisciplinary backgrounds are in a better position to recognise and act upon innovation opportunities (Venkataraman, 1997; Shane, 2000; Bercovitz and Feldman, 2008). Individuals who are able to integrate different bodies of knowledge in their research activities and, therefore, are familiar with multiple methodological perspectives, are particularly likely to develop the skills required to propose novel approaches and to bridge the worlds of scientific research and application. For instance, Bercovitz and Feldman (2008) show that academic researchers with boundary-spanning attributes, measured by their affiliation to multiple academic departments, are more likely to disclose inventions to their university technology transfer offices. Similarly, Shane (2000) finds several instances of entrepreneurs who identified business opportunities for a patented manufacturing technology as a consequence of their research experience in several fields of research (e.g. clinical pharmacology and materials science). According to this literature, we could expect that academic scientists who have managed to integrate different bodies of knowledge in their research activities (as measured by the cognitive breadth of the academic scientist's research activities), are more likely to consider the uses and applications of their research and have a greater awareness of its commercial potential.

Moreover, Shane (2000) shows that individuals with a direct experience in manufacturing, in addition to having a strong scientific research profile, were particularly capable of identifying business opportunities and acting upon them. Indeed, the exploitation of entrepreneurial opportunities involve mastery of a wider range of skills, and the shouldering of heavier managerial responsibilities, compared to only the identification of an entrepreneurial opportunity. For instance, according to Tijssen (2006), creating a spin-off involves the development and exchange of marketable products which require effective organisation of different functions than the mere recognition that an invented technology has potential, for example, formulating a patent application. We argue that this increased complexity requires strong boundary-spanning attributes. In other words, we would expect academics with greater boundary spanning skills should be more likely to engage in both the identification and exploitation of entrepreneurial opportunities (compared to academics with a narrower cognitive breadth). Therefore, we propose:

Hypotheses 3. *(a) Identification and (b) exploitation of entrepreneurial opportunities are more likely among cognitive boundary-spanning academic researchers as compared to researchers specialised within narrow disciplinary fields.*

2.2.4. The quality of academic research

Entrepreneurial research shows that working at the frontier gives academic scientists a comparative advantage in identifying new breakthrough opportunities (Zucker et al., 1998). Moreover, as Franzoni and Lissoni (2007) highlight, the best scientists probably enjoy superior access to high-value knowledge and a stronger natural excludability, leading to a comparatively stronger capacity to identify high-value entrepreneurial opportunities and exploit them.

In fact, there is a large body of empirical research showing that researchers who are very active in commercialisation, tend to be particularly prominent in their respective fields. For instance, Meyer (2006) shows that academic researches who engage in frequent patenting activity are also more productive in terms of publishing. Similarly, Louis et al. (1989), Zucker et al. (1998), Deeds et al. (1997), Agrawal and Henderson (2002), Powers and McDougall (2005), Landry et al. (2007) and Torero et al. (2007) (among others) consistently find that academic engagement in knowledge transfer activities is positively associated with superior academic performance.

However, while much of the evidence in the university-industry literature shows that knowledge transfer activities generally originate in good research conducted by successful scientists in the field (Etzkowitz, 1989), we investigate whether the academic performance of a scientist is associated with a particular type of academic entrepreneurship. Since scientific excellence may often be relatively distant from any immediate commercial application, academics involved in high-quality research associated with commercial potential may be more inclined to *secure* inventions through some form of intellectual property (e.g. by seeking patent protection) rather than by engaging directly in very risky and managerially-demanding entrepreneurial activities such as the creation of a new venture (Jensen et al., 2003). Therefore, we would expect that while conducting high impact research may be conducive to the identification of business opportunities, it does not necessarily favour the decision to act upon such business opportunities. Thus, we put forward the following hypothesis:

> Hypothesis 4. *The higher the scientific excellence of the academic researcher, the more likely it is that he/she will identify commercial opportunities arising from his/her research.*

2.2.5. Ties to external academic research networks

Networking and extended social capital have long been associated with the enhancement of entrepreneurial skills. Among other benefits, networks enhance the opportunity recognition capabilities of entrepreneurs (Hills et al., 1997; Nicolau and Birley, 2003), provide access to critical resources (Aldrich et al., 1987) and enable the entrepreneur to capitalise quickly on market opportunities (Uzzi, 1997; Nicolau and Birley, 2003). Indeed, Stuart and Ding (2006) show that exposure to entrepreneurial colleagues increases the propensity of an academic to be entrepreneurial himself.

Academic research networks with other research organisations represent a particular sub-group of an academic researcher's social capital and, arguably, a very important part of the researcher's professional network. Participation in research collaborations occurs for a range of reasons including: access to complementary expertise; access to additional equipment and resources; and acquisition of prestige, visibility and recognition (Bammer, 2008). The cross-institutional collaboration networks established by a researcher are frequently reported as the means to mobilise the social resources required to achieve the cognitive diversity needed for a research objective at the interface of more than one disciplinary field (Rafols, 2008) and to enhance cross-fertilisation among disciplines (Bammer, 2008). Consequently, academics with wide cross-institutional collaboration networks are likely to be exposed to multiple research perspectives and methods in their research activities, which favour the identification of new scientific and technological breakthroughs. However, it is not possible from the evidence in the literature to make consistent predictions about the impact that the breadth of the research collaboration network will have on the probability of a researcher engaging in exploitation of entrepreneurial opportunities. We therefore anticipate that:

> Hypothesis 5. *Identification of entrepreneurial opportunities is more likely among academic researchers with a wide cross-institutional research collaboration network.*

3. METHOD

3.1. Data Collection

The analysis builds upon four sets of data, combining primary and secondary data sources. In this section we describe each data source and the connections between them.

First, we use data from a survey of UK academic researchers in the fields of Engineering and Physical Sciences, aimed at obtaining information on their interactions with industry and the commercialisation of inventions stemming from their research. The sample of researchers was obtained from the records of principal investigators on grants awarded by the UK Engineering and Physical Sciences Research Council (EPSRC)[3] over the period 1999-2003. In order to ensure that the list of university researchers was representative of the overall population of active researchers, the range of scientific fields was restricted to the engineering, chemistry, physics, mathematics and computer science. Since these fields represent the main remit of EPSRC funding, researchers from these disciplinary fields are likely to rely on the council as their primary source for research funding. This sampling strategy resulted in a

[3] The EPSRC distributes funds on the basis of research proposals, mainly from university-based investigators, in response to open calls for applications. It distributes some 23% of the total UK science budget and is responsible for funding research in engineering and the physical sciences. The EPSRC actively encourages partnerships between researchers and potential users of the research. Partners might include people working in industry, government agencies, local authorities, National Health Service Trusts, non-profit organisations, and the service sector. As a result, almost 45% of EPSRC funded research grants involve partnerships with industry or other stakeholders.

list of 4,337 university researchers across the UK, all of whom were sent a questionnaire.

The survey was conducted in the first half of 2004 and resulted in 1,528 valid returned questionnaires, a response rate of 35%. There were no statistical differences in the response rate across scientific disciplines, which ranged from 30.2% for computer science to 39.7% for general engineering (see Table 1, column 3).

[TABLE 1 in here]

Second, we use data from the UK 2001 Research Assessment Exercise (RAE) in order to get information on the publication profiles of the set of university researchers who responded to the survey. The RAE is the UK's national research evaluation system, covering all research disciplines and higher education institutions in the UK. The main purpose of the RAE is to assist in the allocation of block grant funding according to a retrospective peer-based quality assessment (Barker, 2007; Whitley, 2007). The process requires that every 'unit of assessment' in each university (corresponding largely to a department or school) presents several sets of data, the core of which are the four items of research output per research staff member, produced during the relevant time period (i.e. 1995-2000 in the case of RAE 2001).

Complete copies of submissions, including data on each individual's submitted publications are available on the web;[4] they provide information on 203,743 different research outputs from 53,455 submitting individuals. Although the large majority of this research output is journal articles (141,789 out of 203,743, i.e. about 70%), it also includes items such as: patents, book chapters, reports, new designs, artefacts, etc.

[4] www.hero.ac.uk

For the purpose of this investigation, we are particularly interested in the data providing information on the journal articles submitted for assessment in the RAE. In identifying journal articles, our objective was to obtain insights into: a) the type of research conducted by the individual (e.g. degree of collaboration with other institutions and range of subject topics addressed in the research); and b) the quality of research (as measured by citations to the publications). To obtain information on citations to the journal articles submitted to RAE 2001, we collected information from a third source: the Institute for Scientific Information - *Web of Science* (ISI–WoS).

This third set of data comes from matching the journal articles submitted to 2001 RAE to the papers in journals indexed in the *WoS*. We submitted a query to the *WoS* based on author name, publication year, journal title and article title, in order to establish a match and retrieved citation counts for the matched articles. A cut off of citations within the first five years of publication (including self-citation) was applied. This resulted in a match for 91% of the articles submitted in the RAE 2001 within the fields of Engineering and Physical Sciences identified on the *WoS*.[5]

Finally, our fourth source of data was based on matching the names of the principal investigators in our survey with the names of inventors on patents granted by the European Patent Office (EPO) over the period 1978-2001. The matching fields were researcher name (i.e. last name and initials) and general postcode (i.e. first two letters of the postcode). This identified which of our respondents were inventors (based on EPO granted patents), and the number of patents on which were named as the inventor over the period 1978 to 2001.[6]

Our use of these secondary data sources in addition to the data collected through the survey, was aimed at achieving a robust analysis, providing information at individual level that was retrospective but not self reported,

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[5] For further details on the algorithm used to link the individual items of RAE 2001 journal articles with papers in the WoS, see Mahdi et al., 2008.

[6] For further details on this matching procedure see Crespi et al. (2009).

thereby avoiding problems of reporting-bias and simultaneity among our various constructs. However, this reduced our working sample to 916 university researchers, which is significantly smaller than the original sample of 1,528 survey respondents (see last two columns in Table 1). This smaller sample is a consequence of two mismatches. On the one hand, about 26% of our 1,528 survey respondent researchers did not appear in the RAE 2001 submission. This happens because a proportion of those academics who where active researchers and responded to our questionnaire in 2004 were not eligible for inclusion in the RAE by 2001 (e.g. they had not achieved a status of staff members at the time the research assessment or they were non-UK researchers over that period). It is actually the case that this 26% of non-matched individuals are younger and of lower academic status than the researchers in our survey that were included in RAE 2001.[7]

On the other hand, of the 1,125 survey respondents that made a submission to RAE 2001, we selected only those for whom we had information on three or four journal articles submitted to the RAE 2001. This means that researchers that did not submit journal articles or for whom less than 3 articles were subsequently matched in the *WoS*, were excluded from our analysis. The reason for imposing this constraint is that, since a substantial proportion of the measures we use in this paper are based on information provided from the papers submitted to the RAE, for comparison, we decided to limiting the sample to those cases where *at least three* publications had matches in the *WoS*.

As Table 1 shows, the distribution of researchers across scientific fields in the final sample (i.e. 916 cases) is largely comparable with the survey population, though there are two notable differences. In particular, we are under-sampling researchers in the fields of Computer Science and oversampling researchers in the field of Chemistry. In the case of Computer Science, this is likely to be a consequence of the comparatively large proportion of researchers in this field who submitted research outputs other than journal articles to RAE 2001 (e.g.

[7] For instance, while only 35% of the non-matched researchers had professorial status, that proportion rises to 51% for those that appear in both the survey and the 2001 RAE submissions.

monographs and conference abstracts) (see also Mahdi et al., 2008). Therefore, the criterion of a match in the *WoS* imposes constraints on how comprehensively we can capture the behaviour of researchers across all the scientific fields in our study.

3.2. Measurement of constructs

3.2.1. Dependent variables

In order to obtain a measure of the capacity of academic researchers with respect to identification and exploitation of entrepreneurial opportunities, we draw on the responses to two questions in our survey. The first relates to patenting activities, and asks university researchers to indicate involvement in any sort of patenting activity between 2002 and 2003, including whether the researcher applied for a patent or was recorded as an inventor on patents applied by a third party. The second question asks university researchers to report on the frequency of their engagement in setting up equity interests in companies and especially establishing spin-off companies, in the period 2002-2003.

This information allows us to construct two binary variables capturing: a) *opportunity identification* - whether a university researcher is involved in inventions as recorded in patenting activities; and b) *opportunity exploitation* - whether a university researcher participates in the formation of new companies or has been involved in setting up equity interests in companies. For our sample of 916 university researchers, 14% reported involvement in spin-offs while 29% reported patenting activity (see Table 2).[8]

[TABLE 2 in here]

[8] It is important here to highlight that the condition we impose which reduces our sample to 916 cases, does not lead to substantial bias with respect to our dependent variables. We examined whether by selecting those cases for which we have three or four paper submissions matched in the *WoS*, we were undersampling (or oversampling) those individuals that are more likely to engage in entrepreneurial activities, since we might have excluded a significant proportion of individuals who submitted patents or artefacts rather than journal papers. For the large majority of disciplines the proportion of researchers who engage in either patenting or spin-offs does not significantly differ between the two samples - the one with 3 or 4 articles matched in the *WoS* vs the one where individuals had 0 or less than 3 articles matched. In other words, by selecting individuals with 3 or 4 papers matched in the *Web of Science*, we are not discriminating against entrepreneurial researchers.

Table 2 presents the differences across disciplinary fields with respect to the extent of the entrepreneurial phenomenon among university researchers. As Table 2 shows, the extent of opportunity identification and opportunity exploitation differs significantly across disciplines, with the phenomenon being particularly frequent in disciplines such as Electrical and Electronic Engineering and General Engineering, and rare in disciplines such as Mathematics.

3.2.2. Explanatory variables

To measure *past collaborations with industry*, we consider the number of collaborative grants awarded to a university researcher by the EPSRC over the period 1991-2001. To measure prior entrepreneurial experience we compute the number of times that an individual researcher is recorded as the inventor in an EPO patent over the period 1978-2001 – *prior entrepreneurial experience*. To capture the extent to which an individual researcher has been able to expand research activities across a range of scientific fields – *cognitive integration* – we compute the number of research subjects (as reported for each publication in the *WoS*) associated with the three or four publications submitted to the RAE 2001, to measure the range of research areas that the researchers have been able to integrate in their research activities. This variable takes a minimum value of 0.25 if the researcher's four publications are associated with the same research subject, and a maximum value of 3, meaning that the researcher integrates (or combines) on average 3 distinct scientific subjects in her publications reported to the RAE 2001.

To measure *scientific excellence*, we compute the average number of citations received by the papers submitted to the RAE 2001 within the five years after publication. This variable takes a minimum value of zero and a maximum value of 210 citations per submitted paper. Finally, to measure the *extent of the research network*, we compute the number of organisations a researcher has collaborated with, measured by the different institutional addresses on the three or four articles submitted to RAE 2001 (normalized by the number of articles). Different institutional addresses refer to the count of distinct affiliation postcodes that appear on the researcher's publications. The variable has a minimum value of 0, if the researcher has not collaborated with authors in an organisation different to his/her own, and reaches a maximum of 8 - a researcher who collaborated with authors affiliated to 8 different institutions, having normalized by the number of articles submitted.[9]

3.2.3. Control variables

Since some individual characteristics may favour (or be detrimental to) participation in entrepreneurial activities by university researchers, we include in our analysis some individual features that might influence a disposition towards entrepreneurship. First, we seek to control for individual heterogeneity with regards to *lack of motivations* to undertake entrepreneurial actions. To do this, we assessed the extent to which a researcher operates in a research domain that is unfavourable for the identification and exploitation of business opportunities or whether academic career aspirations are not well served by entrepreneurial actions. We computed a scale including the following three items from the survey: ‘The nature of my research is not linked to industry interests or needs’; ‘My professional networks include no links with industry’; and ‘Proprietary knowledge (e.g. patents) is of negligible importance in the field’. All three items were measured on a five-point scale from ‘not at all’, if the item was assessed as not reflecting a constrain for collaboration with industry, to ‘very much’ if the item was assessed as reflecting a strong barrier to collaboration with industry. The resulting scale is reliable, with a Cronbach’s alpha coefficient equals to 0.78. Second, we include researcher’s *age* and academic status (i.e. being a *professor*) since the career life cycle is found to influence the likelihood of engagement in entrepreneurial activities (Bercovitz and Feldman, 2008).[10] To construct these latter two variables we also use the information reported by the respondents to our survey.

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[9] It is important to bear in mind that this measure includes different instances of cross-institutional interaction. On the one hand, it may include cases of collaboration across different universities, or between universities and non-university organizations. It may also include collaborations between research units housed on the same university campus. On the other hand, it may also include instances where a researcher is affiliated to more than one institution. While this latter instance cannot be defined strictly as collaboration, it does capture a dimension of the phenomenon we want to measure: the capacity of a researcher to draw on interactions in different organizational settings.

[10] The inclusion of these two individual features is also important to control for the time-scale of some of our explanatory variables, such as the prior number of collaborations with industry, which may be strongly influenced by the length of the career lives of our focused researchers.

Similarly, certain characteristics of the departments and universities to which researchers are affiliated may influence their disposition to engage in entrepreneurial activities (Tornquist and Kallsen, 1994; Di Gregorio and Shane, 2003; Jensen et al., 2003). We therefore consider a number of organisational characteristics. We include a proxy for size of the department (*department size*) as measured by the number of individuals submitting research outputs to the RAE 2001 in a particular department or school. To account for an environment favourable to interactions with industry, we include the volume of funding from industry per active researcher (*industry funding pc*, measured in £'000 per capita and logarithmically transformed), using information from units of assessment to the RAE 2001. We also consider two binary variables for the score awarded to the department by the RAE 2001: top-rank, taking the value 1 if the university department was ranked as 5*; and low-rank, which takes the value 1 if the department was ranked 4 or below (the reference category is a score of 5). Finally, we consider a dichotomous variable that takes the value 1 if the university to which a researcher is affiliated belongs to the Russell Group (the group of the largest and most prestigious research universities in the UK).[11] Finally, we include nine discipline dummies, to account for systematic differences across disciplinary fields (with Chemistry as the reference category).

4. ANALYSIS AND RESULTS

This section presents the descriptive statistics and relations for the variables included in our analysis, and our results. Table 3 reports the descriptive statistics and bivariate correlations for the variables considered in our analysis. As can be seen from Table 3, bivariate correlations between our set of five explanatory variables are generally not significant or weakly correlated. Moreover, there is no indication of significant multi-collinearity amongst the independent variables (i.e. the Variance Inflation Factor ranges from 1.14 to 3.32, well below the threshold level of 5).

[11] By 2000, the Russell Group was composed of 17 UK universities. For further details see: www.russell_group.uk

[TABLE 3 in here]

Table 4 presents the results of the probit regression analyses for the two types of academic entrepreneurial engagement considered in this study. We report unstandardised estimated coefficients, with robust standard errors in parenthesis. Models 1a and 1b relate to ‘Opportunity Identification’, and Models 2a and 2b to ‘Opportunity Exploitation’. The only difference between the two specifications for each of our dependent variables is the inclusion of the quadratic effect for *prior entrepreneurial experience*. Table 4 shows the following results.

[TABLE 4 in here]

Past collaborations with industry show a positive and significant impact only for the case of ‘opportunity exploitation’, while there is no statistically significant impact in the case of ‘opportunity identification’. The results in Table 4 indicate that a discrete change in past collaborations from zero to the maximum level of past collaborations in our sample would increase the estimated probability of opportunity exploitation by 0.25 (holding all other variables at their means). Therefore, these results provide only partial support for hypothesis 1: a significant relationship between past collaborations with industry and opportunity exploitation, but not with opportunity identification.

Prior *entrepreneurial experience* (as proxied by the number of patents on which the researcher has been an inventor) has a positive and significant impact on ‘opportunity identification’ and ‘opportunity exploitation’. When examining the impact of entrepreneurial experience (including the quadratic effects), we observe that a discrete change from zero to the maximum level in prior patenting involvement increases the estimated probability of opportunity identification by 0.22, and the probability of opportunity exploitation by 0.15 (holding all other variables at their means).

Moreover, we can see that there is a curvilinear relationship for both ‘opportunity identification’ and ‘opportunity exploitation’, though it is only statistically significant in the former. That is, beyond a certain threshold of entrepreneurial experience (i.e. around 9 patents), the estimated probability of 'opportunity identification' and 'opportunity exploitation' decreases. Thus, our results support hypothesis 2a but only partially hypothesis 2b.

Cognitive integration has a positive impact on both identification and exploitation of entrepreneurial opportunities, although it is only statistically significant in the latter case. Therefore, academic researchers with the ability to embrace a broader range of disciplinary fields in their research activities are more likely to exploit entrepreneurial opportunities. More precisely, an increase in *cognitive integration* from its minimum to its maximum increases the estimated probability of 'opportunity exploitation' by 0.18 (holding all other variables at their means). These results are only partially consistent with hypothesis 3.

The scientific impact - *scientific excellence* - of research activities has a strong impact on the identification of entrepreneurial opportunities, but not on the researcher's exploitation of entrepreneurial opportunities. In particular, an increase from the minimum to the maximum level of scientific excellence increases the estimated probability of 'opportunity identification' by 0.48 (holding all other variables at their means). This result supports hypothesis 4.

Research network has a negative effect on the probability of university researchers engaging in opportunity identification and a positive effect on opportunity exploitation, though in both cases the estimated coefficients are not statistically significant. Therefore, we find no support for hypothesis 5.

With respect to the control variables, Table 4 shows that most control variables have a marginal impact on the probability of engaging in identification or exploitation of entrepreneurial opportunities. Only *lack of* *motivations* for collaboration with industry has a significant and negative impact on both *opportunity identification* and *opportunity exploitation*. [12]

5. DISCUSSION AND CONCLUSIONS

The results have several implications for entrepreneurship theory. First, the results stress the importance of individual-level features for entrepreneurship, and in particular, uncover a range of knowledge-based backgrounds that favour the entrepreneurial process. In that respect, the findings of this study support the significant role of prior knowledge and experience in the recognition and exploitation of business opportunities (Shane, 2000; Shane and Venkataraman, 2000). These findings indicate that, regardless of the disciplinary field or the organisational setting, academic researches who have acquired certain research profiles and/or collaboration experiences are more capable or willing to undertake entrepreneurial actions.

Second, the study distinguishes between opportunity identification and opportunity exploitation, and the results show that individual level features impact differently in the likelihood of engaging in one or the other. While scientific excellence of research and prior entrepreneurial experience shape opportunity identification; it is the capacity of combining multiple bodies of knowledge and the experience in collaboration with users that most distinctively shape opportunity exploitation. These are important findings since previous research has rarely focused on both entrepreneurial functions simultaneously (Shane, 2000; Wright et al., 2004).

This section discusses the individual level features associated with prior knowledge and experience that are found to significantly shape entrepreneurial opportunity identification and/or entrepreneurial opportunity exploitation.

[12] Since ‘opportunity identification’ and ‘opportunity exploitation’ are not independent from each other, we conducted a bivariate probit analysis to capture the possible interdependence between these two entrepreneurial functions. The results are obtained with a STATA routine due to Cappellari and Jenkins (2003). Table A1 reports the results for the bivariate probit model, showing that results are in line with those reported in Table 4.

a) Collaboration with users and networking

While collaboration and networking are important factors in academic entrepreneurship (Shane, 2000; Nicolau and Birley, 2003; Bercovitz and Feldman, 2008), the type of networks that the researcher belongs to matters. Our results indicate that it is important to establish collaborations with potential users (in particular, businesses) in order to develop the skills required for entrepreneurship, while research collaboration networks seem to have a minor impact on the development of these skills. Moreover, prior experience in collaboration with users has a much stronger impact in shaping the exploitation of entrepreneurial opportunities (as opposed to identification of entrepreneurial opportunities). This indicates that this type of collaborations are particularly well suited to equipping academic researchers with the sets of complementary skills necessary to engage in highly complex and risky entrepreneurial activities, such as developing marketable products/services and establishing viable business strategies.

b) Prior entrepreneurial experience

Our results strongly support the view that prior experience in entrepreneurial activities matters for future academic entrepreneurship. There is a clear reinforcing effect on those academics who have been involved in inventorship, making them more likely to see the potential entrepreneurial opportunity in their research results and more able to engage with the intricacies of exploitation of such opportunities. However, academic entrepreneurship is likely to be recurrent up to a point: there seems to be a saturation level beyond which further engagement in the entrepreneurial process becomes unlikely. To what extent recurrent entrepreneurs exhibit unique features compared to sporadic and non-entrepreneurial academics or what are the factors that favour recurrent academic entrepreneurship are both questions for future research.

c) Combining multiple bodies of knowledge

Our results indicate that cognitive boundary spanning individuals will be more likely to integrate different pieces of knowledge to complement their specialist scientific knowledge to further exploit their technology inventions to produce saleable goods and services. In other words, academics who combine multiple bodies of knowledge in their research activities and are able to find associations between their research expertise and business related activities, will be better equipped to exploit the commercial opportunities resulting from their research, for example, by creating a spin-off, than narrowly specialised colleagues.

d) Scientific Excellence

Finally, we find a significant impact of scientific excellence on the likelihood of becoming an entrepreneur, particularly in terms of recognising an entrepreneurial opportunity. However, while we observe a significant impact of scientific excellence in an academic researcher on the identification of entrepreneurial opportunities, we find no significant impact of scientific excellence on the exploitation of entrepreneurial opportunities. Our interpretation of this result is that although scientific excellence in research may represent an important factor (or starting point) in the discovery and identification of entrepreneurial opportunities (i.e. a substantial proportion of patents emerge from breakthrough findings from research), there are counter-factors such as the rights to publishing (and exploiting) research outcomes (e.g. Blumenthal et al., 1997), and the uncertainty regarding the readiness of this research for development into a commercial application (e.g. Gulbrandsen and Smeby, 2005) that may undermine the chances that the academic will exploit such opportunities. In other words, while scientific excellence is relevant for identification of entrepreneurial opportunity, something more than excellent science is needed for opportunity exploitation.

Overall, our results confirm our initial proposition that identification and exploitation of entrepreneurial opportunities are shaped by substantially different academic researcher characteristics. We believe these results are important in order to gain a better understanding of the phenomenon of academic entrepreneurship, and to inform the design of policies aimed at building a favourable climate for knowledge exchange and university – business interactions.

This article has a number of limitations pointing to future research. First, although the study is based on a large sample of academic researchers, there may be a sample bias towards senior and/or highly successful fundraising researchers. This would call for an extension of this study to include active researchers who, for instance, have not been principal investigators. Second, although the study finds strong evidence supporting asymmetric information as importantly shaping entrepreneurship, it does not rule out other alternative explanations. An extension of this work should help disentangle whether unobserved heterogeneity is driving the relationships found in this study (for instance, psychological individual attributes like willingness to bear risk or tolerance for ambiguity). Finally, the investigation has not *directly* explored whether the incentive structures under which academics operate moderates their willingness or capacity to engage in entrepreneurship. This should be explicitly considered in further research.

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REFERENCES

Agrawal A., Henderson R. 2000. Putting patents in context: exploring knowledge transfer from MIT. Management Science 48 (1), 44-60.

Aldrich, H.E., Rosen B., Woodward W. 1987. The impact of social networks on business founding and profit. Frontiers of Entrepreneurship Research. Babson College, Wellesley, MA.

Bammer, G. 2008. Enhancing research collaborations: three key management challenges. Research Policy 37 (5), 875-887.

Barker, K. 2007. The UK Research Assessment Exercise: the evolution of a national research evaluation system. Research Evaluation 16 (1), 3-12.

Bercovitz, J., Feldman, M. 2008. Academic entrepreneurs: organizational change at the individual level. Organization Science 19 (1), 69-89

Blumenthal, D., Campbell, E.G., Anderson, M.S., Causino, N., Louis, K.S. 1997. Withholding research results in academic life science – evidence from a national survey. The Journal of the American Medical Association 277 (15), 1224-1228.

Carroll, G., Mosakowski, E. 1987. The career dynamics of self-employment. Administrative Science Quarterly 32, 570-589.

Chrisman, J.J., Hynes, T., Fraser, S. 1995. Faculty entrepreneurship and economic development: the case of the university of Calgary. Journal of Business Venturing 10 (4), 267-281.

Colyvas, J., Crow, M., Gelijns, A., Mazzoleni, R., Nelson, R.R., Rosenberg, N., Sampat, B.N. 2002. How do university inventions get into practice? Management Science 48 (1), 61-72.

Cooper, A., Woo, C., Dunkelberg, W. 1988. Entrepreneurs' perceived chances for success. Journal of Business Venturing 3, 317-332.

Crespi, G., D'Este, P., Fontana, R., Geuna, A. 2009. The impact of academic patenting on university research and its transfer. International Centre for Economic Research. Working Paper Series, WP. No. 01/2009. www.icer.it/docs/wp2009/ICERwp01-09.pdf

Deeds, D.L., Decarolis, D., Coombs, J.E. 1997. The impact of firm specific capabilities on the amount of capital raised in an initial public offering : evidence from the biotechnology industry. Journal of Business Venturing 12 (1), 31-46.

Di Gregorio, D., Shane, S. 2003. Why do some universities generate more start-ups than others? Research Policy 32 (2), 209-227.

Etzkowitz, H. 1983. Entrepreneurial scientists and entrepreneurial universities in American academic science. Minerva 21 (2-3), 198-233.

Etzkowitz, H. 1989. Entrepreneurial science in the academy – a case of the transformation of norms. Social Problems 36 (1), 14-29.

Evans, D., Leighton, L. 1989. Some empirical aspects of entrepreneurship. American Economic Review 79, 519-535.

Feldman, M., Desrochers, P. 2004. Truth for its own sake: academic culture and technology transfer at Johns Hopkins University. Minerva 42, 105-126.

Franzoni, C., and Lissoni, F. 2005. Academic entrepreneurs: critical issues and lessons from Europe. Paper presented ESSID, the European Summer School of Industrial Economics, held in Corsica, September 2005.

Grandi, A., Grimaldi, R. 2005. Academics' organizational characteristics and the generation of successful business ideas. Journal of Business Venturing 20, 821-845.

Gulbrandsen, M., Smeby, J.C. 2005. Industry funding and university professors' research performance. Research Policy 34 (6), 932-950.

Hills, G.E., Lumpkin, G.T., Singh, R.P. 1997. Opportunity recognition: perceptions and behaviours of entrepreneurs. Frontiers of Entrepreneurship Research. Babson College, Wellesley, MA.

Hoye, K., Pries, F. 2009. 'Repeat commercializers', the 'habitual entrepreneurs' of university-industry technology transfer. Technovation 29, 682-689.

Jensen, R., Thursby, M. 2001. Proofs and prototypes for sale: the licensing of university inventions. American Economic Review 91, 240-259.

Jensen, R.A., Thursby, J.G., Thursby, M.C. 2003. Disclosure and licensing of University inventions: 'The best we can do with the s**t we get to work with'. International Journal of Industrial Organization 21, 1271-1300.

Jong, S. 2006. How organizational structures in science shape spin-off firms: the biochemistry departments of Berkeley, Stanford, and UCSF and the birth of the biotech industry. Industrial and Corporate Change 115 (2), 251-283.

Landry, R., Amara, N., Ouimet, M. 2007. Determinants of knowledge transfer: evidence from the Canadian university researchers in natural sciences and engineering. Journal of Technology Transfer 32, 561-592.

Louis, K.S., Blumenthal, D., Gluck, M.E., Stoto, M.A. 1989. Entrepreneurs in academe: an exploration of behaviours among Life scientists. Administrative Science Quarterly 34 (1), 110-131.

Lubango, L.M., Pouris, A. 2007. Industry work experience and inventive capacity of South African academic researchers. Technovation 27, 788-796.

Mahdi, S., D'Este, P., Neely, A. 2008. Citation Counts: Are They Good Predictors of RAE Scores? A bibliometric analysis of RAE 2001, London: AIM Report.

Meyer, M. 2006. Are patenting scientists the better scholars ? An exploratory comparison of inventor-authors with their non-inventing peers in nano-science and technology. Research Policy 35 (10), 1646-1662.

Mowery, D.C., Sampat, B.V. 2005. The Bayh-Dole Act of 1980 and university-industry technology transfer: a model for other OECD Governments? Journal of Technology Transfer 30 (1/2), 115-127.

Mustar, P. 1997. How French academics create hi-tech companies: the conditions for success and failure. Science and Public Policy 24 (1), 37-43.

Nicolau, N., Birley, S. 2003. Academic networks in a trichotomous categorisation of university spinouts. Journal of Business Venturing 18 (3), 333-359.

OECD. 2003. Turning science into business, patenting and licensing at public research organisations. OECD: Paris.

Park, J.S. 2005. Opportunity recognition and product innovation in entrepreneurial hi-tech start-ups: a new perspective and supporting case study. Technovation 25, 739-752.

Powers, J.B., McDougall, P.P. 2005. University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship. Journal of Business Venturing 20 (3), 291-311.

Ponomariov, B., Boardman, P.C. 2008. The effect of informal industry contacts on the time university scientists allocate to collaborative research with industry. Journal of Technology Transfer 33, 301-313.

Rafols, I. 2008. Strategies for knowledge acquisition in bionanotechnology. Why are interdisciplinary practices less widespread than expected? Innovation 20 (4), 395-412.

Rothaermel, F.T., Agung, S.D., Jiang, L. 2007. University entrepreneurship: a taxonomy of the literature. Industrial and Corporate Change 16 (4), 691-791.

Shane, S., Venkataraman, S. 2000. The promise of entrepreneurship as a field of research. Academy of Management Review 25 (1), 217-226.

Shane, S. 2000. Prior knowledge and the discovery of entrepreneurial opportunities. Organization Science 11 (4), 448-469.

Shane, S. 2002. Selling university technology: patterns from MIT. Management Science 48 (1), 122-137.

Siegel, D.S. 2006. Technology entrepreneurship: institutions and agents involved in university technology transfer. Vol 1. Edward Elgar: London.

Siegel, D.S., Waldman, D., Link, A. 2003. Assessing the impact of organizational practices on the productivity of university technology transfer offices: an exploratory study. Research Policy 32 (1), 27-48.

Stuart, T.E., Ding, W.W. 2006. When do scientists become entrepreneurs ? The social structural antecedents of commercial activity in the academic life sciences. American Journal of Sociology 112 (1), 97-144.

Thursby, J.G., Thursby, M.C. 2002. Who is selling the ivory tower? Sources of growth in university licensing. Management Science 48 (1), 90-104.

Tijssen, R.J.W. 2006. Universities and industrially relevant science: toward measurement models and indicators of entrepreneurial orientation. Research Policy 35 (10), 1569-1585.

Torero, M., Darby, M.R., Zucker, L.G. 2001. The importance of intellectual human capital in the birth of the semiconductor industry. Working Paper. UCLA Anderson School, Los Angeles, CA.

Tornquist, K.M., Kallsen, L.A. 1994. Out of the ivory tower: characteristics of institutions meeting the research needs of industry. Journal of Higher Education 65 (5), 523-539.

Uzzi, B. 1997. Social structure and competition in interfirm networks: the paradox of embededness. Administrative Science Quarterly 42, 33-67.

Venkataraman, S. 1997. The distinctive domain of entrepreneurship research: an editor’s perspective. In Katz J and Brockhaus R. (eds.) Advances in entrepreneurship, firm emergence and growth. Vol.3: 119-138. Greenwhich, CT: JAI Press.

Whitley, R. 2007. The changing governance of the public sciences: the consequences of research evaluation systems. In Whitley R., Glaser J. and Barker K. (eds.) The changing governance of the sciences: the advent of research evaluation systems. Springer; 2007.

Wright, M., Birley, S., Mosey, S. 2004. Entrepreneurship and university technology transfer. Journal of Technology Transfer 29, 235-246.

Wright, M., Clarysse, B., Mustar, P., Lockett, A. 2007. Academic entrepreneurship in Europe. Edward Elgar: Cheltenham, UK.

Zucker, L.G., Darby, M.R., Brewer, M.B. 1998. Intellectual human capital and the birth of US Biotechnology enterprises. The American Economic Review 88 (1), 290-306.

Table 1. Proportion of our 'final sample' relative to the population surveyed

Disciplines	Population surveyed (A)	Survey respondents (B)	Response rate (%) (A/B)	Survey–WoS Matched Sample (C)	% Population Surveyed (C/A)
Chemical Engineering	174	62	35.6	39	22.4
Chemistry	754	271	35.9	205	27.2 *
Civil Engineering	242	86	35.5	42	17.4
Computer Science	536	162	30.2	39	7.3 *
Electrical & Electronic Eng.	496	172	34.7	98	19.8
General Engineering	292	116	39.7	70	23.9
Mathematics	563	216	38.4	129	22.9
Mechanical, Aero & Manuf. Eng.	484	179	37.0	109	22.5
Metallurgy & Materials	201	69	34.3	53	26.4
Physics	595	195	32.8	132	22.2
Total	*4,337*	*1,528*	*35.2*	*916*	*21.1*

Note: * indicates that the proportion of cases in a particular discipline that appears in our final matched-sample, is significantly higher/lower than the proportion of cases (that appears in the final matched-sample) for all other disciplines combined (using Chi-square tests at the 5% level of significance).

Table 2. Percentage of university researchers involved in opportunity identification and opportunity exploitation, by scientific discipline

Disciplines	Opportunity Identification (inventions) (%)	Opportunity Exploitation (Spin-offs) (%)	Number of university researchers
Chemical Engineering	33.3	15.4	39
Chemistry	35.6	9.8	205
Civil Engineering	16.7	16.7	42
Computer Science	12.8	15.4	39
Electrical & Electronic Eng.	48.0	23.5	98
General Engineering	35.7	24.3	70
Mathematics	3.9	1.6	129
Mechanical, Aero & Manufact. Eng.	30.3	22.0	109
Metallurgy & Materials	37.7	15.1	53
Physics	29.5	8.3	132
Total	*29.1%*	*13.5%*	*916*

Table 3. Descriptive statistics and correlations*

Variable	Mean	S. Dev.	Median	Min.	Max.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Opportunity Identification	0.29	0.45	0.00	0	1														
2. Opportunity Exploitation	0.14	0.34	0.00	0	1	**0.365**													
3. Collaboration with industry	1.07	1.52	1.00	0	13	**0.191**	**0.197**												
4. Entrepreneurial Experience	0.52	1.61	0.00	0	17	**0.317**	**0.184**	**0.246**											
5. Cognitive Integration	0.87	0.42	0.75	0.25	3	0.016	**0.138**	**0.096**	0.019										
6. Scientific Excellence	12.27	16.32	7.00	0	209.75	**0.082**	-0.024	-0.043	**0.065**	**-0.149**									
7. Research Network	0.70	0.53	0.50	0	8	**-0.083**	-0-038	-0.058	-0-048	**-0.067**	**0.188**								
8. Lack of Motivations	2.24	1.18	2.00	1	5	**-0.334**	**-0.211**	**-0.330**	**-0.221**	**-0.172**	0.015	**0.161**							
9. Age	46.54	9.85	45.00	24	75	0.043	0.050	**0.204**	**0.144**	**0.085**	-0.058	-0.044	**-0.115**						
10. Professor	0.53	0.50	1.00	0	1	**0.104**	**0.112**	**0.280**	**0.150**	0.034	0.020	**-0.101**	**-0.164**	**0.575**					
11. Department Size (Ln)	3.47	0.69	3.43	1.10	5.12	**0.107**	0.038	**0.069**	**0.092**	-0.006	**0.187**	-0.022	**-0.106**	-0.012	**-0.065**				
12. Industry fund. p.c. (Ln)	3.24	1.35	3.65	0	5.39	**0.232**	**0.172**	**0.291**	**0.157**	**0.182**	-0.050	**-0.148**	**-0.439**	0.024	0.027	**0.278**			
13. Top rank department	0.29	0.46	0.00	0	1	0.035	0.045	**0.073**	0.038	0.019	**0.091**	**-0.072**	**-0.094**	0.052	0.044	**0.440**	**0.118**		
14. Low rank department	0.28	0.45	0.00	0	1	0.009	-0.005	-0.003	-0.033	**0.102**	**-0.081**	0.001	-0.040	-0.013	-0.059	**-0.342**	0.041	**-0.400**	
15. Russell Group	0.54	0.50	1.00	0	1	0.004	-0.035	0.042	0.050	**-0.096**	**0.077**	0.027	0.032	-0.030	0.000	**0.299**	0.011	**0.340**	**-0.419**

* Number of observations equals 916. Correlations in bold are significant at $p < 0.05$.

Table 4. Results of Probit Regression Analyses: factors influencing academic entrepreneurship

	Opportunity Identification (*Inventions*)		Opportunity Exploitation (*Spin-offs*)	
	Model 1a	Model 1b	Model 2a	Model 2b
Past Collaboration with industry	0.028	0.021	0.081 **	0.080 **
	(0.035)	(0.035)	(0.035)	(0.036)
Prior Entrepreneurial Experience	0.231 ***	0.415 ***	0.103 ***	0.186 ***
	(0.068)	(0.072)	(0.032)	(0.069)
Cognitive Integration	0.007	-0.013	0.352 ***	0.349 **
	(0.129)	(0.129)	(0.137)	(0.137)
Scientific Excellence	0.006 **	0.006 **	0.002	0.002
	(0.003)	(0.003)	(0.004)	(0.004)
Research Network	-0.149	-0.153	0.072	0.072
	(0.105)	(0.107)	(0.119)	(0.119)
Prior Entrep. Experience Squared	---	-0.023 ***	---	-0.008
		(0.006)		(0.006)
Lack of Motivations	-0.359 ***	-0.351 ***	-0.206 ***	-0.198 ***
	(0.052)	(0.053)	(0.067)	(0.067)
Age	-0.009	-0.008	-0.008	-0.008
	(0.006)	(0.006)	(0.007)	(0.007)
Professor	0.146	0.131	0.212	0.199
	(0.126)	(0.127)	(0.147)	(0.148)
Size Department	0.012	0.013	-0.078	-0.082
	(0.098)	(0.098)	(0.108)	(0.109)
Industry funding p.c.	0.105	0.113	0.019	0.022
	(0.070)	(0.070)	(0.089)	(0.089)
Top ranked department	-0.065	-0.047	0.117	0.133
	(0.134)	(0.134)	(0.149)	(0.150)
Low ranked department	0.022	0.039	-0.077	-0.068
	(0.134)	(0.134)	(0.149)	(0.149)
Russell Group Univ.	0.034	0.031	-0.158	-0.161
	(0.112)	(0.114)	(0.130)	(0.131)
Constant	0.022	-0.076	-0.877	-0.929
	(0.521)	(0.517)	(0.587)	(0.590)
Discipline Dummies	Included	Included	Included	Included
Log Likelihood	-423.10	-418.30	-303.30	-302.42
Wald Chi^2	160.88 ***	186.99 ***	99.91 ***	100.52 ***
Mckelvey and Zavoina Pseudo R^2	0.42	0.42	0.29	0.30
Number of observations	882	882	882	882

Note: Unstandardised coefficients are reported, with robust standard errors in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix.

Table A1. Results of bivariate probit analysis.

	Opportunity Identification (*Inventions*)	Opportunity Exploitation (*Spin-offs*)
Past Collaboration with industry	0.017	0.078 **
	(0.035)	(0.037)
Prior Entrepreneurial Experience	0.419 ***	0.188 ***
	(0.072)	(0.069)
Cognitive Integration	-0.006	0.357 **
	(0.129)	(0.142)
Scientific Excellence	0.006 *	0.001
	(0.004)	(0.004)
Research Network	-0.163	0.085
	(0.113)	(0.122)
Prior Entrep. Experience Squared	-0.024 ***	-0.009
	(0.007)	(0.006)
Lack of Motivations	-0.353 ***	-0.229 ***
	(0.057)	(0.069)
Age	-0.008	-0.009
	(0.006)	(0.008)
Professor	0.131	0.232
	(0.129)	(0.153)
Size Department	0.014	-0.073
	(0.102)	(0.112)
Industry funding p.c.	0.111	0.006
	(0.071)	(0.081)
Top ranked department	-0.039	0.148
	(0.137)	(0.155)
Low ranked department	0.052	-0.037
	(0.134)	(0.154)
Russell Group Univ.	0.039	-0.169
	(0.117)	(0.132)
Constant	-0.083	-0.788
	(0.528)	(0.605)
Discipline Dummies	Included	Included
	Rho1	
Rho2	0.595 (0.057)	
Observations	882	
LL	-685.12	
LL_0	-720.72	
Wald $\chi^2(46)$	221.92	

Note: Two tailed t-test: * p < 0.10; ** p < 0.05; *** p < 0.01. Standard errors between brackets.