DO VENTURE CAPITALISTS HAVE A BIAS AGAINST INVESTMENT IN ACADEMIC SPIN-OFFS? EVIDENCE FROM THE MICRO- AND NANOTECHNOLOGY SECTOR IN THE UK

Federico Munari[i]

Department of Management
University of Bologna
Via U. Terracini 28
40131 Bologna, Italy
Tel. +(39)-(051)-2090208
Fax. +(39)-(051)-2090222
e-mail: federico.munari@unibo.it

Laura Toschi

Department of Management
University of Bologna
Via U. Terracini 28
40131 Bologna, Italy
Tel. +(39)-(051)-2090214
Fax. +(39)-(051)- 2090222
e-mail: laura.toschi@unibo.it

[i] Corresponding author.

Do venture capitalists have a bias against investment in academic spin-offs? Evidence from the micro- and nanotechnology sector in the UK

ABSTRACT

In this paper, we analyse whether venture capital (VC) firms have a bias against investment in academic spin-offs based on empirical evidence from the micro- and nanotechnology sector in the UK. We also investigate the characteristics of academic spin-offs to capture the differences in their ability to attract VC funding. Finally, we examine whether the propensity to invest in such kinds of new ventures varies between private and public VC firms. The results of our regression analyses on a sample of 247 new ventures (123 academic spin-offs and 124 other companies) reject the presence of bias in this type of science-based business. They also highlight intellectual property rights (IPRs), type of business model and the university's scientific prestige as important factors in the academic spin-off's ability to access VC financing.

.

Keywords: Academic spin-off, Venture Capital, Nanotechnology, United Kingdom

INTRODUCTION

Venture capital (VC) firms are financial intermediaries specialised in investing in new ventures with high growth potential and play a fundamental role in fostering national innovation and economic growth (Gompers and Lerner, 1999; Kortum and Lerner, 2000)[1]. However, the availability of VC investments for highly technology-based, early-stage companies can be limited by the high levels of risk, uncertainty and significant monitoring costs involved. Statistics provided by the European Venture Capital Association (EVCA) confirm that the VC industry in Europe remains largely focused on the non-technology sector and late-stage investment activities (EVCA, 2008). In the specific case of the United Kingdom, several studies have shown that in the early and late 1990s VC firms tended to have a bias against investment in the earliest (seed and start-up) stages of the technology life cycle (Murray and Lott, 1995; Lockett et al., 2002).

The risks of under-investment are particularly critical for academic spin-offs – defined as companies created to exploit knowledge that originates within universities – because of a higher degree of uncertainty and potential for information asymmetries. Obtaining capital for academic spin-offs from private external investors can be extremely difficult for at least three different reasons (Shane, 2004): the problematic evaluation of opportunities by investors; the existence of bargaining problems between the entrepreneurs and investors as to the profitability of the opportunity; and the limited availability of collateral to minimise investor risks. The study by Wright et al. (2006) confirms the aforementioned difficulties and identifies some of the most critical problems faced by academic spin-offs seeking to access VC financing, based on interviews with Technology Transfer Offices (TTOs) and VC managers. These are the lack of distinctive knowledge and necessary scientific understanding

to evaluate business proposals, the limited commercial experience of the spin-off's entrepreneurial team and the high uncertainty related to the assignment of IPRs between the company and the university of origin. Furthermore, the lack of adequate experience and training of many universities in exploiting entrepreneurial activities can represent an additional obstacle in the search for equity financing.

For all these reasons, previous research has suggested that VCs might have a bias against investment in academic spin-offs (Wright et al., 2006). To our knowledge, however, existing empirical evidence on this issue is limited to interviews with representatives of TTOs or VC managers and focuses on the perceived problems involved in attracting VC funding for academic spin-offs. Quantitative analyses investigating the actual financing decisions of VCs towards academic spin-offs versus comparable new ventures are lacking in the literature. Moreover, it has not been studied whether such bias, if it really exists, is more or less pronounced in different technological and market contexts. Finally, there is only a limited understanding of the factors facilitating the acquisition of VC financing by academic spin-offs. The only exception is represented by the study by Shane and Stuart (2002) on the performance of 134 spin-offs from MIT from 1980 to 1996. They showed that those spin-offs with more effective patents and richer social ties with third-parties were more likely to obtain financing. However, as this study focuses on a single, largely successful university, it does not consider other characteristics at the university or regional level which might influence VC fund availability.

In this paper, we move from such considerations to provide original empirical evidence on the factors affecting access to VC financing by academic spin-offs. We adopt a broad definition of academic spin-off as a new company founded to exploit knowledge created in an academic institution[2]. We first test the existence of a bias against investment in academic spin-offs by

VCs in the specific case of a science-based businesses, such as those in the micro- and nanotechnology (MNT) sector in the United Kingdom, based on a sample of 247 new ventures, including 123 academic and 124 other companies (i.e., non-academic spin-offs). We then analyse a series of characteristics affecting the likelihood of academic spin-offs receiving VC financing. More specifically, based on the literature examining the heterogeneity of these types of new ventures (Mustar et al., 2006), we assess whether the following characteristics are significantly associated to the ability to receive funding by VC firms: the possession of patents; existence of an equity-based alliance with a business partner (i.e., joint venture spin-off); type of business model adopted; and affiliation to a top-tier research university. Finally, we distinguish between private and public VCs by taking into account the fact that private and public VCs (i.e., state/regional funds, University Challenge Funds, other university funds, incubators) could have different objective functions and investment behaviours[3].

The results of our descriptive, bivariate and logit regression analyses highlight the skewed distribution of spin-off activity and VC investments in UK universities in the field of MNT, consistent with the arguments provided by Wright et al. (2006). However, we do not find the existence of a significant bias by VC firms against academic spin-offs in the MNT sector. Moreover, we show that the ownership of strong IPRs, scientific prestige of the university of origin and presence of high technological ferment for the MNT sector in the area surrounding the spin-offs are important factors increasing the likelihood of receiving VC financing. On the contrary, the adoption of a business model based on services reduces such probability. Finally, we show that the benefits deriving from the creation of close relationships between academia and industrial partners are more significantly valued by the sample of private VC firms.

The rest of the paper is organised as follows. First, we briefly summarise previous literature on the problems accessing external financing faced by academic spin-offs. Moreover, we formulate specific hypotheses on the association between certain characteristics of the academic spin-offs and their likelihood of being financed by a venture capitalist. We then describe the context of the MNT sector, and the sample and variables used in the empirical analysis. We present the results of the bivariate and logit regression analyses. In the final section, we outline the main conclusions to be drawn from the theoretical and empirical analysis, and discuss the implications for future research.

THEORETICAL BACKGROUND AND HYPOTHESES

VC bias against academic spin-offs: theoretical rationale and empirical evidence

Prior research highlights the importance of studying the role played by VC firms in financing new ventures (Gompers and Lerner, 1999). However, analysis of the differences between academic spin-offs and other types of new ventures in their ability to obtain VC financing is an important topic which needs deeper investigation. In particular, it is unclear if and why VCs should be more reluctant to invest in early-stage ventures deriving from universities compared with other types of companies in the same stage of development. On one hand, it has been recognised that all types of early-stage companies (including academic spin-offs) face similar difficulties in establishing a market presence and obtaining VC financing, because of high degrees of uncertainty and information asymmetry (Murray and Lott, 1995; Lockett et al., 2002). On the other hand, these problems could be stronger for and have a major impact on academic spin-offs' abilities to attract VC financing, thus creating an asymmetric distribution of the amount of VC resources received by academic and non-academic spin-offs. This line of reasoning suggests the existence of a bias against VC firms

investing in academic spin-offs (Wright et al., 2006) for the following reasons: (a) the presence of greater *information asymmetries* between the entrepreneur and investors as the technology developed by academic spin-offs requires specialised scientific knowledge to be correctly evaluated; (b) the presence of greater *uncertainty* about the commercial potential of the technology because of its roots in advanced scientific research and low level of maturity; (c) academic entrepreneurs' lack of *commercial skills* needed to introduce the new technology into the market; and (d) uncertainty in the *distribution of IPRs* between the academic spin-off and the mother university.

The theoretical lens to analyse in detail the problems faced by academic spin-offs in attracting VC finance is the agency theory (Jensen and Meckling, 1976; Ross, 1973), which suggests that the founders of a new venture generally have access to more information on the technical and market potential of their technologies than external parties. Under this view, the entrepreneur might not be comfortable in fully disclosing the details of his technology to potential investors and could exploit this asymmetry to create competitive advantage. Consequently, investors face a difficult evaluation of the venture proposals because of this limited information and high uncertainty. The natural output of this loop is the creation of bargaining problems, leading the entrepreneurs and investors to disagree about the economic potential of the opportunity.

Following such premises, Wright et al. (2006) suggest that the presence of information asymmetries between the entrepreneurial team and investors is likely to be extremely high in the case of academic spin-offs for several reasons. First, correct assessment of the technical feasibility and market potential of early-stage technologies exiting university laboratories might prove extremely difficult and risky for VC investors, who in many cases lack the distinctive knowledge and scientific understanding necessary to evaluate the business

proposals. Entrepreneurs, having more information about the prospects of their ventures and abilities of the founding team, could exploit their superior knowledge to obtain larger resource commitment. This creates a risk for VCs in investing in new companies, thus increasing the mismatch between the demand and supply side of the venture capital market. This gap between the VC and the academic spin-off's knowledge about the business also implies an extremely expensive due diligence process, thus discouraging the involvement of VCs in small and uncertain investments. VC firms are, therefore, attracted by projects requiring minor screening costs and major understanding of the business developed by the investee company, but this is rare for new technology investments as in the case of academic spin-offs.

A second issue at the base of the problems faced by academic spin-offs seeking to access venture capital is the pool of skills owned by the new venture's team (MacMillan et al., 1985; Kaplan and Stromberg, 2004; Hsu, 2007). Accordingly, the study by Lockett et al. (2002), highlights how potential commercialisation and market size play an important role in the VC funding process. More precisely, the likelihood of obtaining VC financing increases if the academic spin-off has the competencies to make the business plan attractive and clear to financing firms. This requisite is rarely satisfied by academic teams because of their non-commercial nature. They are generally characterised by the presence of a variety of scientific skills but lack of expertise in terms of commercial exploitation of a new technology. Thus, academic spin-offs might advance unrealistic expectations regarding the business development and equity distribution, with negative effects on the venture capitalists' attitudes towards financing.

A third issue increasing the problem of information asymmetry between academic spin-offs and VC firms is the role of social capital. In the private sector, the VC firm's decision to finance new ventures is driven by the knowledge of their partners. VCs rely on their social

networks to better understand the project developed by the start-ups, along a path dependence framework. Starting from knowledge acquired by previous experience, VCs could easily understand the new project and better evaluate the right commitment of financing resources. On the contrary, in the research-based sector, it is likely that an academic network includes actors primarily involved in other academic activities, as people generally tend to create groups where they share the same scientific language. Consequently, VCs do not have an attitude towards experience accumulation, reinforcement of their competencies and better comprehension of the university technology and a vicious circle is created, increasing the gap between demand and supply of VC financing.

A further element hampering a VC firm's willingness to fund an academic spin-off is the uncertain distribution of IPRs, as we will discuss in more depth in the next section. The underlying idea is that investors would be more confident financing academic spin-offs if relevant patents were directly assigned to the company rather than being assigned in return for an equity share in the company.

Finally, the literature on academic entrepreneurs' intentions and motivations (Fini et al., 2009) suggests that academic status is perceived to be one of the most important incentives fostering academics to create a new company, rather than the pursuit of significant commercial returns. Academics' decisions to start up a new company are often strongly influenced by expected outcomes, such as the generation of further stimuli for research activities, the gain of prestige and reputation as leading academics, creation of funding opportunities (grants) for students or research assistants and the possibility of receiving new infrastructure and facilities for academic research activities. This often conflicts with VC expectations, which are usually more directly focused on the growth potential of the investee company and obtaining a positive and rapid financial outcome from the investment through the fast and effective

commercialisation of their new technologies. The importance placed by academic entrepreneurs on the achievement of an improved academic status, at the expense of the commercialisation of their technologies, increases the equity gap between academic spin-offs and VC financing.

All these reasons suggest the existence of an equity gap between academic spin-offs and VC financing, as formalised in the following hypothesis:

H1a: Academic spin-offs have a lower likelihood of receiving VC funding compared with other (i.e., non-academic) new technology-based companies.

However, theoretical arguments and empirical evidence supporting this position fail to consider two important aspects that could lead to different expectations. First, the claim that VC firms have a bias against academic spin-offs does not take into consideration the specifics of the technological or industrial environment in which such companies operate. It is necessary to highlight that in many industries (i.e., semiconductor, biotechnology, advanced materials and nanotechnology) the use of advanced scientific knowledge is a fundamental prerequisite to creating innovative products and solutions. Pisano (2006) coined the term 'science-based businesses' to identify the setting characterised by commercial companies attempting to both create science and capture value from it. A significant part of the economic value of science-based companies is ultimately determined by the existence of strong and direct linkages with universities involved in state-of-the art research, as in the case of the biotech industry (Pisano, 2006). Zucker et al. (1998) demonstrate empirically that the commercialisation of a technology is joined with the development of the underlying science.

Thus, a science-based business faces unique challenges that require different kinds of organisational and institutional arrangements and different approaches to management and investment decisions. In these specific contexts, therefore, the economic value of the enterprise for VC investors should ultimately be largely determined by the quality of the science upon which it rests. In other words, in order to solve the dilemma of VC bias against investment in academic spin-offs, it is necessary to recognise that several differences exist across industries, and more specifically that "what works well in other settings may not work as well in a science-based setting" (Pisano, 2006).

A second consideration regards the stage of development of the enterprises. Previous literature has failed to consider an important feature shared by private and academic ventures. Both are seed/early-stage firms and, thus, share the problems and challenges typical of companies in their initial phase of development of a new technology. They must secure capital, allocate scarce resources (human, financial and intellectual) to highly uncertain projects and design contracts to obtain the financial resources needed to improve their business. VC investors are generally keener to finance spin-offs that have reached later-stage development (Murray and Lott, 1995; Lockett et al., 2002). Indeed, they believe that the appropriate time to invest in a spin-off is not at the beginning, when there is high uncertainty and the spin-off is seeking to prove the principle of its technology, but later on, when the enterprise is engaged in product development. This rational is driven by the fact that investors consider the financial returns deriving from their investments, which are influenced by the length and uncertainty of the development process (Shane, 2006). In other words, VC firms face the same problems evaluating an academic spin-off as they do evaluating a private venture because a lack of a clear performance of early-stage ventures does not allow the adoption of conventional financial methods. Indeed, the major criticism of VC investments is

the difficult and uncertain valuation on which the screening and selection processes are based (Tyebjee and Bruno, 1984; MacMillan et al., 1985; Hsu, 2007). Therefore, to empirically address the bias issue, it is necessary to compare the likelihood of academic spin-offs receiving VC financing compared with other private new ventures at the same stage of development.

Finally, the claim that VC firms have a bias against academic spin-offs ignores the wide heterogeneity which characterises this type of new venture. Several contributions have highlighted that academic spin-offs differ across a whole set of dimensions, including resource endowments, types of business models adopted and institutional affiliation (Chiesa and Piccaluga, 2000; Shane and Stuart, 2002; Druilhe and Garnsey, 2004; Clarysse et al., 2005; Mustar et al., 2006). It is, thus, likely that such differences have an impact on the likelihood of receiving VC financing.

The aforementioned arguments, therefore, lead us to advance the H1a hypothesis, as follows:

H1b: There is no difference in the likelihood of receiving VC funding between academic spin-offs and other (i.e., non-academic) new technology-based companies.

This is the first step of our analysis: providing original empirical evidence on the existence (or not) of a bias by VC firms against investing in academic spin-offs. We then intend to further investigate this issue by addressing a second research question: which factors affect academic spin-offs' access to VC funding? We argue that a deeper understanding of the heterogeneity among these types of companies is fundamental for designing policies and strategies for academic spin-offs to face the aforementioned challenges. In the next sections, we take into

consideration the heterogeneity of academic spin-offs, focusing on a set of characteristics that might influence their likelihood of receiving VC financing.

The heterogeneity of academic spin-offs and its impact on VC financing

A key starting point for analysing the link between VC financing and academic spin-offs is to go beyond the tendency to view academic spin-offs as an undifferentiated category, and instead explore the heterogeneity among academic spin-offs. Mustar et al. (2006) present a strong conceptual foundation for describing how academic spin-offs differ. The authors suggest analysing academic spin-offs using different approaches: (a) the resource-based view (Barney, 1991), which highlights the importance of resources as differentiators and predictors of competitive advantage; (b) the business model approach, describing the different activities developed by spin-offs; and (c) the institutional perspective, focusing on the relationship that academic spin-offs have with their parent organisations (in this case the university). In this paper, we propose a set of hypotheses following this theoretical research classification. In particular, using the resource-based framework we analyse the role played by technological (a spin-off's patents portfolio) and commercial (acquired through collaborations with industrial partners) resources in the academic spin-off's ability to receive VC financing. The second perspective is examined by considering three different types of business models: product-based, technology-based or service-based. Finally, the institution's perspective is used to understand whether the characteristics of parent universities (in terms of research excellence) facilitate the spin-offs' probability of receiving VC funding.

The resource-based perspective: the importance of technological and commercial resources in accessing VC financing

Given the problems generated by uncertainty and asymmetric information, the acquisition of capital involves the practice of signalling pursued by entrepreneurs to demonstrate the value of their ventures to potential investors. Indeed, as suggested by the previous literature (Tyebjee and Bruno, 1984; MacMillan et al., 1985; Hsu, 2007), investors, in their screening and selection processes, rely on a subjective assessment procedure driven not only by the start-ups' business plans, but also by a multidimensional list of characteristics (financial aspects, product-market attractiveness, technological characteristics, strategic-competitive impact, management team and deal criteria). In the particular case of a university context, analysing business plans is often of limited value because of the very early-stage nature of the spin-off companies. This increases the relevance of other qualitative criteria. We focus here on the presence of a proprietary technology. Academic spin-offs can be defined as new companies "founded by employees of the university around a core technological innovation which had initially been developed at the university" (Wright et al., 2004). Thus, the creation of an academic spin-off is often directly linked to the role played by IPRs. The category "technological resources" refers to the firm-specific products and technology developed by the company (Borch et al., 1999) and is a key driver for VC firms to differentiate among new ventures in terms of degrees of innovation (Wright et al., 2007).

We argue that VC investors tend to favour academic spin-offs with a strong patent portfolio for two main reasons. First, patents are widely considered a measure of a firm's ability to innovate. Second, a patent is recognised as the main tool for protecting a technology. These two aspects in unison suggest that patents provide external evidence of competitive advantage, which investors positively evaluate. In other words, investors can be confident that a spin-off with high patenting rates is able to innovate, appropriate the returns and succeed in the subsequent commercialisation of its technology. In the specific context of academic spin-

offs, a further clarification is needed. The incidences of patents being awarded to academic scientists or universities has grown over the last two decades in many countries and many universities now have TTOs to manage the commercial exploitation of academic inventions. However, in some cases, the uncertain distribution of IPRs between the university and the academic spin-off can become a particular concern for VC companies. Investors might be uncomfortable about investing in academic spin-offs when IP is licensed by the university to the company, as opposed to being assigned in return for an equity share in the company. In many cases, the assignment of IPRs to the spin-off represents a required precondition to assure that it can develop without interference, as well as representing a valuable asset that can be recovered and sold off. In a study of 135 spin-offs from public research organizations across five European countries, Clarysse et al. (2007) suggest that the rise in number and quality of academic spin-offs is accelerated by the ownership of IPRs by TTOs, rather than by the faculty. Their findings support the existence of a positive relationship between perceived quality of the technology and amounts of starting capital obtained from VC firms. As investors usually have difficulties valuing new spin-offs, they rely on indirect indicators to measure the potential of a new venture. Patents represent one of these tools. In previous literature, this topic has been investigated in the broader context of start-ups. For instance, the work by Baum and Silverman (2004) found that start-ups with high patent applications and grants generally obtain more VC financing. Mann and Sager (2007) highlight the same result in the software and biotechnology industries; patenting is positively related to the likelihood of start-up firms receiving VC financing. Therefore, we hypothesise:

H2: Academic spin-offs possessing a larger patent portfolio have a higher likelihood of receiving VC funding.

In addition to the spin-off's set of technological resources, the presence of commercial knowledge to bring the new technology to market is also critical for VC firms' assessment of the quality and potential of an academic spin-off. It is widely recognised that private sector investors in academic spin-offs tend to favour spin-offs founded by people who fit the profile of successful entrepreneurs. Investors prefer founders with the industry and management experience to identify and successfully exploit their businesses. However, as previously mentioned, academic spin-offs are characterised by teams with highly scientific-based skills, but generally lacking the commercial expertise required to exploit a new technology. In this context, a fundamental requisite to improving the chance of receiving VC funding could be the creation of a set of complementary assets supporting the commercialisation of the new product or technology. Joining scientific knowledge with the capability to transform it into a profit could be a strategic way of increasing the probability of receiving VC funding.

Academic spin-offs can pursue this aim by creating relationships with private companies. These firms could help spin-offs commercialise their technology and act as an intermediary between them and the VC investors. The collaboration between the private and university worlds may be an effective tool for the academic spin-off to overcome its resource constraints. Shane (2004) suggests that the creation of an academic spin-off can follow two different models: university faculty starts a new company with the aim of commercialising a university discovery, or an external entrepreneur searches for a collaboration with the university to improve his own company. Wright et al. (2004) have subsequently added a third option. The authors examine in detail the so-called *joint venture spin-outs*, which occur when the university works with existing private firms to create joint venture spin-out companies (JVSO).

A JVSO is defined as a “new venture in which the technology is assigned or licensed into a new company that is jointly owned by the university and the industrial partner” (Wright et al., 2004). This form of spin-off presents several advantages. First, seeking support from external parties to alleviate the spin-off's lack of commercial capabilities is one of the main benefits. Second, private firms’ knowledge of their industries, in terms of how to serve markets and address customer problems, may be a tool for academic spin-offs to better develop successful opportunities from scientific discoveries. Third, in a JVSO the two parties (the private and the academic companies) may be better able to cooperate in assembling the right mix of resources (technological and commercial assets) to exploit the technology and increase the speed with which products are developed and introduced into the market. Fourth, the signalling theory suggests that the private firm's reputation can be a key driver in accessing financial resources (Wright et al., 2004). Finally, the probability of success of a JVSO can be higher because the transparency in the relationship between university and private partners is greater than between academic spin-off and VC firm. All these aspects could increase the probability of attracting VC financing. Focusing on the cases in which a VC participation is required, we suggest the following hypothesis:

H3: Academic spin-offs formed as joint ventures between universities and industrial partners (joint venture academic spin-offs) have a higher likelihood of receiving VC funding.

The business model perspective: product-based, technology-based and service-based

The business model taxonomy presented by Mustar et al. (2006) suggests a second relevant factor affecting the academic spin-off’s probability of receiving VC financing: what types of business ventures are more likely to attract VC firms. We address this issue by examining

three different types of business model: product-based, technology-based and service-based. This classification matches the distinction proposed by Stankiewicz (1994), which is based on the main modes of activities in which firms operate; academic spin-offs can be *product-oriented*, *technology-oriented* or *consultant*. The product-oriented mode is organised around a well-developed product concept, the technology-oriented mode relates to the development of technologies sold through licenses/partnerships and the consultancy mode supplies services exploiting distinctive competencies. On one hand, research services require activities which are not generally based on patents and do not demand significant technological development. In contrast, creating a product/technology requires huge investment in each step of the development process (Druilhe and Garnsey, 2004). Thus, product-oriented business models are considered "high potential companies" created to exploit commercial research findings. Service-oriented companies, also labelled "lifestyle", are instead created to exploit tacit knowledge accumulated from academic experience (Timmons, 1994). Thus, this last group strengthens the non-commercial nature of academic spin-offs. Moreover, service-based spin-offs present a limited growth potential compared with product- and technology-based ones, given that they require the direct involvement of the founders. This is likely to create constraints in terms of the business and geographical scope of activities. For these reasons, we argue that VC firms should be less confident in investing in academic spin-offs adopting service-oriented business models. Thus, the following hypothesis is suggested:

H4: Academic spin-offs with service-oriented business models have a lower likelihood of receiving VC funding.

The institutional perspective: the impact of a university's scientific reputation on VC financing

The institutional prospective suggests the presence of different relationships between the academic spin-off and parent university. More precisely, depending on the scientific quality and prestige of the parent organisation, academic spin-offs have different chances of attracting the attention of VC companies. Academic spin-offs created by "top universities" with a large critical mass of researches, experience in creating entrepreneurial businesses, established links with the private sector and a strong propensity to patent their technologies are of critical importance for searching the venture capital market. Shane (2006) points out that the ability to raise private capital for early-stage companies varies across institutions, but that spin-offs from prestigious institutions are more likely to raise external capital from the VC market at the time of formation. In a study of 98 universities in the United Kingdom, Lockett and Wright (2005) show that the business development capabilities of university TTOs are significantly linked to the number of spin-offs receiving external equity investment.

This rationale fits perfectly with the institutional perspective suggested by Mustar et al. (2006), which analyses how the parent institute shapes the initial configuration of its spin-offs. In particular, the strength of the parent-venture link is related to the proximity and richness of the university research environment (Lindelof and Lofste, 2004; Link and Scott, 2004). This evidence suggests that universities play an indirect role in the support of their academic spin-offs. Indeed, the scientific reputation of the research organisation may signal the quality of the new venture to private investors. The underlying principle is that the research excellence and prestige of the academic institution of origin can reduce the high level of information asymmetry surrounding academic spin-offs and help obtain access to external financing (Di Gregorio and Shane, 2004). Consequently, we hypothesise that:

H5: Academic spin-offs from universities with a high research quality have a higher likelihood of receiving VC funding.

METHOD

The context: the micro- and nanotechnology sector in the United Kingdom

Nanotechnology can be defined as the study and use of the unique characteristics of materials on the nanometer scale, between the classical large-molecule level to which traditional physics and chemistry applies and the atomic level in which the rules of quantum mechanics take effect (Lemley, 2005). Peculiar characteristics of nanotechnology reside in its inter-disciplinarity (attracting scientists from many areas of science) and the wide spectrum of potential market applications from different businesses (such as computers, flat-panel displays, diagnostic products sensors, lighting devices and many others). Although nanotechnology is still at an early stage of development and its full market potential will disclose in the next years, there has been a real global boom in nanotech patents and start-ups during recent years, and a significant amount of VC investment has been dedicated to the promises of the new technological revolution. Broadly, nanotechnology involves the study and control of phenomena and materials at length scales below 100 nm. However, it is difficult to find a universally accepted definition. The inaugural issue of *Nature Nanotechnology*, for instance, asked 13 researchers from different areas what nanotechnology meant to them and their responses varied markedly (Nature Nanotechnology, 2006). In order to circumvent such definition problems, we apply a broader definition including the micro-

and nanotechnology (MNT) sector as the study and use of the unique characteristics of materials between the micron and nanometer scales.

Therefore, we focused on studying the MNT sector in the UK, an optimal setting to address our research questions. First, the UK is one of the most advanced European countries in developing research and business activities in the emerging field of MNT. Part of this growth has been spurred by the strong commitment of the government, which envisages nanotechnology playing a strategic role in industrial policy. According to a 2004 report by the Department of Trade and Industry (DTI), the UK has the second highest European funding level in the MNT sector after Germany. In July 2003, the Science and Innovation Minister Lord Sainsbury announced a cash injection of £90 million (124 million Euros) over six years to help industry harness the commercial opportunities offered by nanotechnology. Within this initiative, the DTI allocated £50 million for an applied research programme to support collaborative research and development projects and technology transfer initiatives, and £40 million for 'capital projects' to progress a UK Micro and Nanotechnology Network (MNT Network). The MNT Network was funded in 2004, receiving half its budget from the Department of Science and Innovation and half from all the regional and development agencies combined. One of the first activities was to conduct a detailed survey to establish details of the industrial landscape for MNT in the UK, in order to monitor the rate of change and growth of this sector over time.

Second, previous research by Libaers et al. (2006) using three data-sets based on patents, co-publications and firm data has shown that academic spin-offs play a significant, although not dominant role, in the field of nanotechnology in the UK. The nanotechnology sector in the UK is evenly divided among three main players: multinational companies; new technology-based firms founded by non-university affiliated entrepreneurs; and academic spin-offs.

Finally, the UK venture capital industry is the largest and most developed in Europe, accounting for nearly 40% of total annual private equity investment, and is second to the USA in world importance (BVCA, 2005). For all these reasons, therefore, the micro- and nanotechnology sector in the UK represent an ideal context to study the relationship between VC investment and academic spin-offs.

Sample and data sources

Our data gathering was structured in two steps. We first identified all the MNT companies in the UK using the *Industrial Map of UK MNT in 2004/05* compiled by the MNT Network in association with the DTI. This survey identified 372 companies active in the MNT sector (defined as the study and use of the unique characteristics of materials between the micron and nanometer scale[4]) in the UK in 2004. The quantitative survey provided a profile for each company, including technical information (a description of MNT activities in the classes of materials, devices or processes) and non-technical data (turnover, employees, corporate origin, year of incorporation and business model). We were then able to classify each company into three macro classes: corporate subsidiary; academic spin-off; and other new venture. The first class refers to internal divisions or R&D centres of established corporations active in the MNT field, whereas the last two classes refer to new ventures created by academic and non-academic entrepreneurs respectively. Our analysis is based on this latter sample of 247 new ventures, encompassing 123 academic spin-offs and 124 other ventures (including 65 corporate spin-offs). For the purpose of this study, we adopted a broad definition of academic spin-offs as new ventures created to commercially exploit knowledge, technology or research results initially developed within a university (Birley, 2002; Wright et al., 2004)[5].

We then used the *Venture Expert* database (Thomson Financial) in order to identify all the MNT new ventures to have been financed by VC funds as of December 2007. We complemented this information with the research by Shah (2004)[6] and company websites. Thus, we identified 61 VC-backed new ventures operating in the MNT field in the UK (39 academic spin-offs and 22 other new ventures). For each VC-backed company, we collected information about the total amount of financing obtained by VC firms, the VC firms involved, the number of deals and the date of each financing round. We then collected information on the identity of each VC investor, identifying four different classes (independent, financial, corporate and other venture program).

A critical issue for correctly testing hypotheses H1a and H1b is separating new ventures funded by private VC from those funded by government-supported VC programs. In fact, the UK has implemented a wide range of policy initiatives from the mid-1990s to improve small firms' access to equity financing (Baygan, 2003). Among such actions, government equity has been used to leverage private VC financing for small deal sizes. New VC schemes introduced from 2000 (e.g., the High Technology Fund, Regional Venture Capital Funds, Community Development Venture Fund and the Early Growth Fund) have combined government funding with private expertise to target financing to smaller enterprises, start-ups and outlying regions. In particular, the University Challenge Fund was established to strengthen public-private partnerships by facilitating the transfer of science, engineering and technology from universities to commercial application. The fund provides capital for early-stage financing to enable universities to develop business proposals and start-up companies. We, therefore, identified all companies in our sample (both academic spin-offs and other new ventures) which were financed by at least one government-supported fund[7]. Ultimately, we identified three different categories of VC-backed companies in our sample: companies funded

exclusively by private VC funds (37); companies funded exclusively by government-supported VC funds (12); and companies funded by public/private funds (in which at least one government-supported VC fund co-invested with one or more private VC funds) (12).

Finally, we used the *Delphion* database to identify patent applications requested at the European Patent Office (EPO) by the companies included in our sample. In addition, we identified all the EPO patents in the nanotechnology class assigned to universities from the UK by using the Y01N class recently introduced by the EPO to tag nanotech patents.

Variables

Dependent variables

VC funded is a dummy variable taking the value one if the start-up received VC financing as of December 2007. *Private VC funded* is a dummy variable taking the value one if the start-up was financed primarily by private VC funds, and zero in all other cases[8]. From this latter group, therefore, those companies financed exclusively by public VC funds, such as business development funds, government-affiliated programs, university-affiliated programs and incubators, are excluded

Independent variables

Academic spin-off is a dummy variable taking the value one for all university-based spin-offs included in our sample, and zero in all other cases. We used this dummy variable to test the competing hypotheses H1a and H1b. In order to test H2, we constructed the variable *Patents* to measure the number of patent applications requested at the EPO by each company up to December 2007. In order to test H3, we created the variable *Joint venture academic spin-off*, which identified those academic spin-offs (12 companies) jointly formed by universities and

industrial partners. Again, the dummy variable takes the value one, and zero in all other cases. With respect to H4, the *Industrial Map of UK MNT in 2004/05* provides information about four possible types of business models adopted by the spin-offs under analysis. Accordingly, we added three dummies indicating the start-up's adoption of one of these business models. The set of companies with a business model characterised as *Integrators* is taken as the baseline case for such dummies. These companies do not realise products directly based on the MNT sector, but they integrate an MNT process into the manufacture of their products. The three dummies, instead, indicate the start-up's adoption of one of the following business models: technology-based, product-based and service-based (Stankiewicz, 1994). The first group includes companies engaged in the design and prototype of MNT products/materials. Such companies are generally searching to licence and/or upscale a proprietary process. The second group includes companies manufacturing MNT products/materials in medium or high volumes, or suppliers of MNT equipment/processes. The third group includes providers of specialised services to the MNT industry. In order to test H5, we identified those academic spin-offs affiliated to universities with a high reputation and scientific excellence in MNT. The dummy *High quality university spin-off* takes the value one in the case of academic spin-offs from the first four universities active in nanotech patenting in the UK (Oxford University, Cambridge University, Glasgow University and Imperial College respectively), and zero in all other cases. Taken together those four universities account for 58% of all the EPO patents assigned to UK universities in the field of nanotechnology (55 nanotech patents out of 95).

Control variables

Age captures the age of company (in number of years from the founding date) as of December 2007. *MN materials* and *MN devices* are two dummies classifying the main technological

areas in which the companies operate (the class "MNT processes" is taken as the baseline case). *MNT scope* measures the scope of activities performed in the MNT field. This variable is created by counting the number of the 14 MNT sub-classes in which the company operated. For each company, *MNT regional density* measures the number of companies (subsidiaries, R&D labs, new ventures) active in the MNT sector in its region, according to the *Industrial Map of UK MNT*. To calculate the variables, all companies were aggregated into 12 different regions of the UK: East Midlands, East of England, Greater London, North East, North West, Northern Ireland, Scotland, South East, South West, Wales, West Midlands and Yorkshire and Humberside.

ANALYSES AND RESULTS

Descriptive statistics

We first present some descriptive analyses to highlight the distribution of spin-offs and VC investments in MNT in UK universities (See Figure 1).

--- Insert Figure 1 around here ---

Our results are consistent with the high skewness in the distribution of academic spin-offs in the UK found by Wright et al. (2006). Indeed, about 30% of the academic spin-offs are concentrated in the first four universities (Imperial College, Cambridge University, Oxford University and Southampton University). Interestingly, the distribution of academic spin-offs funded by VC firms is significantly more concentrated; around 50% of VC-backed academic spin-offs are affiliated to the first four universities. If we look at the distribution of spin-offs

funded by private VC firms, excluding those primarily funded by public VC firms, the concentration ratio drops to 48%. This evidence suggests that high quality spin-offs in the field of MNT, as measured by their capacity to attract private equity financing, tend to be unevenly distributed across UK universities, instead concentrating on a restricted set of universities with a high excellence in scientific and technological development.

--- Insert Table 1 around here ---

Table 1 shows descriptive statistics for the whole sample and the sub-sample of academic spin-offs. In our sample, 25% of the companies (31% in the case of academic spin-offs) received funding by a VC company at the end of 2007, whereas this percentage decreases to 20% (24% for academic spin-offs) when considering only private VC firms. The companies in our sample have an average age of 8.7 years (8.3 for academic spin-offs) and presented 4.6 (4.0) patent applications at the EPO. The majority tends to adopt a technology-based business model (46% for the whole sample, 54% for academic spin-offs), followed by service-based (21% and 17%) and product-based (17% and 14%), with the *Integrators* comprising the remaining cases. Twelve academic spin-offs were formed as joint ventures between universities and industrial partners.

Cross-tabulation analyses

We then performed bivariate cross-tabulation analyses to assess whether the start-up affiliation to a university increases the likelihood of receiving financing by VC firms (Tables 2 and 3).

Frequency and percentage cross-tabulations are useful for assessing whether two variables co-vary and, if so, to highlight patterns of co-variation (Knoke and Bohrnstedt, 1994). We performed a chi-square test of statistical significance to determine the likelihood two variables are unrelated in the population. We tested the null hypotheses that the two dummy variables *Academic spin-off* and *VC funded* (and *Private VC funded* in Table 3) are statistically independent and no co-variation exists between them in the population. Results from this analysis (Table 2) indicate that the likelihood of receiving VC financing is higher for academic spin-offs in a statistically significant way (at the 5% level). Indeed, almost one-third (31.7%) of MNT academic spin-offs in the UK received VC funding, whereas this percentage decreases to 17.7% for non-academic start-ups.

--- Insert Tables 2 and 3 around here ---

If we focus on investment made by private VC firms (Table 3), the percentage of VC-backed academic spin-offs remains higher than VC-backed other new ventures (23.6% and 16.1% respectively), however, the difference is not statistically significant at conventional levels. In any case, these first analyses do not provide support for the existence of a bias against academic spin-offs by VC firms in the specific case of a science-based businesses such as MNT. It seems, therefore, that newly created companies aiming to develop and commercialise new materials, products or processes in the field of MNT have to be strongly dependent on the evolution of scientific knowledge of such disciplines. In this sense, academic spin-offs which can leverage the results of state-of-the-art university research can have a comparative advantage over other newly established companies.

Regression analyses

Finally, we used a logit specification to analyse the determinants of VC fundraising by MNT new ventures. The results of our regression analyses are reported in Table 5; Table 4 presents the correlation matrix for the variables of interest on the whole sample.

--- Insert Table 4 around here ---

In the first model (Table 5, Column 1), we test the two competing hypotheses H1a and H1b on the whole sample of 247 new ventures, the main dependent variable of interest being the dummy *VC funded*. In the second model (Table 5, Column 2), the dependent variable is represented by the dummy *Private VC funded* to consider the chances of being financed by private VC firms. This excludes the new ventures primarily financed by public VC firms (i.e., state/regional funds, University Challenge Funds, other university funds and incubators), which could have the direct and explicit mission to support academic spin-offs.

In the first model, the coefficient of the dummy *Academic spin-off* is positive (0.933) and significant at the 1% level, signalling that the affiliation to a university enhances the ability to receive VC financing in the field of MNT. Even when we consider only private VC investments in Model 2 (Table 5, Column 2), the coefficient of the dummy *Academic spin-off* remains positive (0.628) and statistically significant, although at the 10% level. In both Models 1 and 2, the coefficients of the variable *Patents* are positive (0.041 and 0.050 respectively) and statistically significant (in both cases at the 5% level), thus suggesting that the possession of a large patent portfolio facilitates access to external financing. The strong presence of MNT facilities in the region also has a positive influence on the likelihood of

receiving VC financing (in both models the variable *MNT regional activity* is positive and statistically significant). On the other hand, the adoption of a business model based on the offer of services to the MNT industry has a negative impact on obtaining VC financing, given that in both Model 1 and 2 the variable *Service-based business model* is negative (-1.053 and -1.153 respectively) and significant at the 10% level. In summary, the results of our logit regressions do not support the existence of a bias against academic spin-offs by VC funds in the specific case of MNT, even focusing on investments made by private VC firms only as in Model 2. The MNT sector is an example of a science-based business, characterised by the existence of enterprises that attempt to both create science and capture value from it (Pisano, 2006). In this specific context, therefore, the economic value of the enterprise for VC investors is ultimately largely determined by the quality of the science upon which it rests, and strong linkages with university research represent a strategic resource.

--- Insert Table 5 around here ---

We then moved to test H2, H3, H4 and H5 to investigate the factors which facilitate access to VC financing. Columns 3 and 4 of Table 5 report the results of the logit regression analyses performed on the sub-sample of 123 academic spin-offs, using the dummies *VC funded* (Model 3) and *Private VC funded* (Model 4) as dependent variables respectively. We find support for H2 in both Models 3 and 4, given that the coefficient of the variable *Patents* is positive (0.095 and 0.154 respectively) and statistically significant (at the 5% and 1% levels respectively). On the other hand, we notice interesting differences in testing the remaining three hypotheses if we focus on investments made by private VC firms (Model 4), instead of considering those made by all types of VC firms (Model 3).

With respect to H3, the coefficient of the variable *Joint venture academic spin-off* is positive in both Models 3 and 4 (0.408 and 1.309 respectively), although it is statistically significant (at the 10% level) only in Model 4. It seems, therefore, that private VC firms tend to value positively the existence of equity partnership with industrial partners in their financing decisions as a way of gaining access to commercial capabilities, financial means and managerial expertise. From the JVSO point of view, this result also suggests that this form of academic spin-off seeks to gather huge sums of capital from private VC firms, as they tend to provide greater amounts and more dedicated support than public VC firms.

Turning to H4, the coefficient of the variable *Service-based business model* is negative in both Models 3 and 4 (-1.056 and -2.287 respectively), but it is statistically significant (at the 10% level) only in Model 4. In line with our hypothesis, this suggests that private VC companies tend not to invest in academic spin-offs adopting business models based on service, presumably because of the limited growth opportunities of this kind of strategy.

Finally, we notice that spin-offs from the first four universities in the UK for a number of nanotech patents (as a proxy for their excellence in this area) have a significantly higher probability of receiving VC funding (the coefficient of the dummy *High quality university spin-off* is positive and significant at the 5% level in Model 3). However, such a result does not hold for the model considering only deals by private VC firms (Table 5, Column 4), given that the coefficient, although positive, is not significant. A possible explanation for this finding is the fact those high level universities also have internally promoted large and effective VC funds (in part under the University Challenge Fund measure, as in the case of Cambridge Enterprises, ISIS Innovations and Imperial Innovations). Such VC funds significantly contribute to financing spin-offs emerging from such institutions, and help explain the results obtained in Model 4. For what concerns the control variables, in Model 3

the coefficients of *MNT scope* and *MNT regional activity* are positive and statistically significant (at the 10% and 5% levels respectively), whereas *MNT devices* is negative and significant at the 10%. In Model 4, on the contrary, only *MNT devices* remains statistically significant at the 5% level.

CONCLUSIONS

In this paper, we provided three main contributions to the literature on academic entrepreneurship. First, we provided original empirical evidence on the presence (or not) of a bias by VC firms against investment in academic spin-offs, in the specific context of a science-based business such as micro- and nanotechnology. Second, we recognised the heterogeneity of academic spin-offs and analysed the impact of company-specific characteristics on the likelihood of receiving VC financing, seen as a significant proxy of the firm's success. As stated by Mustar et al. (2006) in their review of the literature on academic spin-offs, "a little examined topic is the impact on firm performances of differences in the resource endowment, institutional links and business model of research-based spin-offs". We made a step in this direction by focusing on the characteristics emerging from the literature on academic entrepreneurship: technical resources endowment, with reference to the possession of IPRs; linkages to business partners, by comparing joint venture spin-offs to independent ones; types of business model, separating service-oriented, product-oriented and technology-oriented business models; and institutional affiliation, comparing companies spun off from high quality universities with others. Third, we highlighted that there exists a high heterogeneity among VC firms in their financing decisions, and that private and public investors have different investment behaviours towards academic spin-offs.

Our results based on a sample of 247 new ventures from the micro- and nanotechnology sector in the UK do not support the existence of a bias by VC firms against academic spin-offs operating in this specific field. This finding is confirmed for all types of VC investments (without splitting the population between private and public VCs) and for deals made by private VC firms. One possible explanation of these findings regards the science-based nature of the MNT sector (Pisano, 2006). VC firms investing in a science-based business consider the quality of the science at the base of the new venture and the strong linkages with university research as the key drivers to determining the economic value of the enterprise.

Our results also highlight the necessity to consider further the heterogeneity of academic spin-offs to fully capture their performance, in terms of ability to attract external financing. In particular, we show that the existence of a strong technological portfolio (IPRs), the scientific excellence and reputation of the parent university and presence of a high number of MNT companies (subsidiaries, R&D labs and new ventures) in the spin-off's region are positively related to the likelihood of receiving VC financing. The two last results, however, are not confirmed if the analysis is restricted to private VC firms. Excluding public VC firms from the original sample, two further interesting results emerge. First, adopting a service-based business model reduces the probability of attracting private VC funding. Second, private VC firms value the creation of collaborative relationships with industrial partners as a positive signal which enables academic spin-offs to address the problems related to their lack of commercial resources.

In terms of policy implications, our analyses suggest the need to move beyond the simple consideration of the number of spin-offs created by universities as a sign of their ability to promote technology transfer. The significant variation observed among spin-offs in their ability to attract external financing shows the existence of strong differences in their quality

and growth potential. In the valuation exercise, which can be carried out by the same university's TTO or by regional or government agencies, access to VC investment, and in particular to private ones, can be used as a proxy of the sustainability of the venture and likelihood of future financial and economic success. This is also emphasised by the Lambert Report, the guidelines for science and innovation policy in the UK. It highlights that: "[T]he best way to judge quality is by looking at the ability of a spin-out to attract external private equity. […] But almost a third of the universities that created spin-outs in 2002 did not bring in external equity for any of their new companies. This strongly suggests that some of the public funding invested in recent years has not been sufficiently focused on quality. In the future, public funding should be concentrated on high quality spin-outs, as measured by their ability to attract funds from the private sector wherever this is possible." Our study provides further evidence on the heterogeneity in access to VC financing and suggests precise characteristics of the company which can be interpreted by TTO executives, investors and policy makers as antecedents.

Thus, what should an academic entrepreneur do to attract VC financing? First, the highlighted importance of technological and commercial capabilities as drivers for the success of spin-offs suggests that the presence of a well-balanced entrepreneurial team where different types of resources (with both technological and commercial skills) interact is necessary. It is critical to not only exploit the technological excellence of the researchers, but also develop more lucrative commercial opportunities from these scientific abilities. As pointed out by Wright et al. (2007), this goal can be achieved by either increasing the number and quality of collaborative relationships with industrial partners or promoting the association between business schools and universities with a stronger technical orientation. Second, academic spin-offs need to play a key and direct role in the market for technology to be successful and

attract VC funds. This means that problems between investors and TTOs regarding IPR ownership must be resolved. VC firms favour financing academic ventures with assigned patents rather than licensed (Clarysse et al., 2007). However, TTOs tend to be reluctant to facilitate this process because of the potential loss of economic value. Third, the influence of TTOs on the way academic spin-offs start their businesses must not be underestimated. The objectives of the TTOs have a direct impact on the commercialisation results and their way to evaluate patents is a key driver in defining the nature of the academic spin-offs, which consequently impacts on the probability of receiving VC financing (as shown by our analyses). Finally, the probability of an academic spin-off receiving VC financing directly depends on the type of VC selected by the entrepreneurial team because of the heterogeneity in the selection criteria used by investors in their financing decisions. Thus, to increase the chances of attracting the attention of VC firms, an academic spin-off needs to decide precisely which types of investors are more appropriate. If the choice falls on private VC firms, efforts made by academic researchers to increase their commercial abilities through joint ventures or other forms of collaborations with industrial companies will be needed. However, service-based spin-offs have only a small probability of attracting these types of investors, as they tend to invest in spin-off companies where the focus is on product or technological activities. On the other hand, public VC firms prefer academic spin-offs operating in industries where the number of companies active in the area surrounding the spin-offs and where the university of origin has a good reputation in terms of research excellence. Thus, the academic spin-off must leverage on the correct characteristics to increase the likelihood of being financed by the VC selected.

We conclude with some limitations and directions for future research. First, our analysis relied on data from a single new sector characterised by a high degree of uncertainty.

However, this kind of specificity raises problems about the ability to draw general conclusions. The same can also be said for focusing only on the UK environment, which did not allow us to capture industry or technology differences among countries. Indeed, it is plausible to suppose that such peculiarities have influenced the types of academic spin-offs developed by universities. Future research could extend these analyses in both directions. Second, as VC firms' investment decisions are influenced by technological factors, we should also consider some specific characteristics of TTOs to capture diversity among universities in terms of their experience and policy in the transfer of technology to academic spin-offs. There are, therefore, interesting opportunities for analysing whether other determinants of the university spin-off link are taken into consideration by VC firms in their investment choices. Third, in constructing the measure to capture the prestige and excellence of universities, we rely on a proxy based on nanotech patents. The underlying logic is investigating whether the ability of universities to create technological output (number of patents) in the MNT sector is positively related to the ability of the academic spin-off to attract VC financing. However, this is only one of the attributes shaping the reputation of a university. Future works could also take into consideration the possibility of gathering data about the mass of researches and experience in entrepreneurial businesses, rating score of graduate schools, number of links and collaborations with the industrial sector and propensity to patent their technology (also in other sectors). Finally, this signalling effect of reputation is a kind of indirect support to academic spin-offs in their race to attract financing from investors and potential partners in order to reduce the extent of information asymmetries. It could also be important for introducing the effects of direct efforts made by universities in creating contacts and links with potential investors or partners for their spin-offs.

FUNDING

Financial support provided by the European Investment Bank (Project EVPAT "The Economic Valuation of Patents", EIBURS Programme) is gratefully acknowledged.

REFERENCES

Barney, J. B. (1991), 'Firm resources and sustained competitive advantage', *Journal of Management*, **17**, 99–120.

Baum, J. A. C. and B. S. Silverman (2004), 'Picking winners or building them? Alliance, intellectual and human capital as selection criteria in venture financing and performance of biotechnology startups', *Journal of Business Venturing*, **19**(3), 411–436.

Baygan, G. (2003), 'Venture Capital Policy Review: United Kingdom' *OECD Science, Technology and Industry Working Paper 2003/1*, 2003, Paris.

Birley, S. (2002), 'Universities, academics, and spinout companies', *International Journal of Entrepreneurship Education*, **1**(1), 133-153.

Borch, O. J., M. Huse and K. Senneseth (1999), 'Resource configurations, competitive strategies and corporate entrepreneurship: an empirical examination of small firms', *Entrepreneurship Theory and Practice*, **24**, 49–70.

BVCA (2005). *BVCA private equity and venture capital performance measurement survey 2004*. PriceWaterHouseCoopers and BVCA. http://www.bvca.co.uk/home.

Chiesa, V. and A. Piccaluga (2000), 'Exploitation and diffusion of public research: the general framework and the case of academic spin-off companies'. *R&D Management*, **30**, 329–340.

Clarysse, B., M. Wright, A. Lockett, E. Van de Velde and A. Vohora (2005), 'Spinning out new ventures: a typology of incubation strategies from European research institutions', *Journal of Business Venturing*, **20**(2), 183–216.

Clarysse B., M. Wright, A. Lockett, P. Mustar and M. Knockaert (2007), 'Academic spin-offs, formal technology transfer and capital raising', *Industrial and Corporate Change*, **16**(4), 609–640.

Cumming, D. J. (2007), 'Government policy towards entrepreneurial finance: innovation investment funds', *Journal of Business Venturing*, **22**(2), 193–235.

Di Gregorio D. and S. Shane (2004), 'Why do some universities generate more start-ups than others?', *Research Policy*, **32**, 209–227.

Druilhe, C. and E. Garnsey (2004), 'Do academic spin-outs differ and does it matter?', *Journal of Technology Transfer*, **29** (3–4), 269–285.

EVCA (2008). *EVCA 2008 Yearbook*. www.evca.com.

Fini, R., R. Grimaldi and M. Sobrero (2009), 'Factors fostering academics to start up new ventures: an assessment of Italian founders' incentives', *Journal of Technology Transfer*, forthcoming.

Gompers P. and J. Lerner (1999), *The Venture Capital Cycle*. MIT Press: Cambridge, MA.

Hsu, D. H. (2007), 'Experienced entrepreneurial founders, organisational capital and venture capital funding', *Research Policy*, **36**, 722–741.

Industrial Map of UK MNT 2004/05, Micro and Nano Technology Network, United Kingdom, 2005.

Jensen, M. and W. Meckling (1976), 'Theory of the firm: managerial behaviour, agency costs and ownership structure', *Journal of Financial Economics*, **3**, 305–360.

Kaplan, S. and P. Stromberg (2004), 'Contracts, characteristics, and actions: evidence from venture capitalist analyses', *Journal of Finance*, **59**, 2173–2206.

Knoke, D. and G. W. Bohrnstedt (1994). *Statistics for social data analysis* (3rd ed.). Peacock: Itasca, IL.

Kortum S. and J. Lerner (2000), 'Assessing the contribution of venture capital to innovation', *RAND Journal of Economics*, **31**(4), 674–692.

Lemley, M. A. (2005). 'Patenting nanotechnology', *Standford Law Review*, **61**, 601-630.

Lerner, J. (2002), 'When bureaucrats meet entrepreneurs: the design of effective 'public venture capital' programmes', *Economic Journal*, **112**(477), F73–F84.

Libaers, D., Meyer, M. and Geuna, A. (2006). The role of university spinout companies in an emerging technology: the case of nanotechnology. *Journal of Technology Transfer*, 31(4), 443–450.

Lindelof, P. and H. Lofsten (2004), 'Proximity as a resource base for competitive advantage: university–industry links for technology transfer', *Journal of Technology Transfer*, **29** (3–4), 311–326.

Link, A. N. and J. T. Scott (2004), 'Opening the Ivory Tower's door: an analysis of the determinants of the formation of US university spin-off companies. Paper presented at the Technology Transfer Society Meetings, Albany, NY, September 30, 2004.

Lockett A., Murray G. and Wright M. (2002), 'Do venture capitalists still have a bias against technology based investments?', *Research Policy*, **31**, 1009–1030.

Lockett A. and M. Wright (2005), 'Resources, capabilities, risk capital and the creation of university spin-out companies', *Research Policy*, **34**, 1043–1057.

MacMillan, I. C., R. Siegel and P. N. S. Narasimha (1985), 'Criteria used by venture capitalists to evaluate new venture proposals', *Journal of Business Venturing*, **1**(1), 119–128.

Mann, R. J. and T. W. Sager (2007), 'Patents, venture capital and software start-ups', *Research Policy*, **36**, 193–208.

Murray G. And J. Lott (1995), 'Have UK venture capitalists a bias against investment in new technology-based firms?', *Research Policy*, **24**, 283–299.

Mustar P., M. Renault, M. G. Colombo, E. Piva, M. Fontes, A. Lockett, M. Wright, B. Clarysse and N. Moray (2006), 'Conceptualising the heterogeneity of research-based spin-offs: a multidimensional taxonomy', *Research Policy*, **35**, 289–308.

Nature Nanotechnology (2006), 'Feature. nan'o·tech·nol'o·gy n', 1, 8–10.

Pisano G. P. (2006), *Science business: the promise, the reality and the future of biotech*. Harvard Business School Press: Boston, MA.

Ross, S. (1973), 'The economic theory of agency: The principal's problem', *American Economic Review*, **63**, 134–139.

Rothermael, F. T., S. D. Agung L. and Jian (2007), 'University entrepreneurship: A taxonomy of the literature', *Industrial and Corporate Change*, **16**(4), 691–792.

Shah, D. (2004). Success Analysis of Start-ups in the field of Microsystems and Nanotechnology in the UK. MSc Microsystems Engineering Dissertation, School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh.

Shane S. (2004), *Academic entrepreneurship. University spin-offs and wealth creation*. Edward Elgar: Cheltenham, UK.

Shane S. and T. Stuart (2002), 'Organisational endowments and the performance of university start-ups', *Management Science*, **48**(1), 154–170.

Stankiewicz, R. (1994), 'University firms: spin-off companies from universities', *Science and Public Policy*, **21**(2), 99–107.

Timmons J. A. (1994), *New Venture Creation* (4th edition). Irwin: Burr Ridge, IL.

Tyebjee, T. T. and A. V. Bruno (1984), 'A model of venture capitalist investment activity', *Management Science*, 30(9), 1051–1066.

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

Wright M., A. Lockett, B. Clarysse and M. Binks (2006), 'University spin-out companies and venture capital', *Research Policy*, **35**(4), 481–501.

Wright M., A. Vohora and A. Lockett (2004), 'The formation of high-tech university spinouts: the role of joint ventures and venture capital investors', *Journal of Technology Transfer*, **29**(3–4), 287–310.

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

TABLES AND FIGURES

Figure 1. Distribution of nanotech patents, MNT spin-offs and VC-backed MNT spin-offs across UK universities (%)

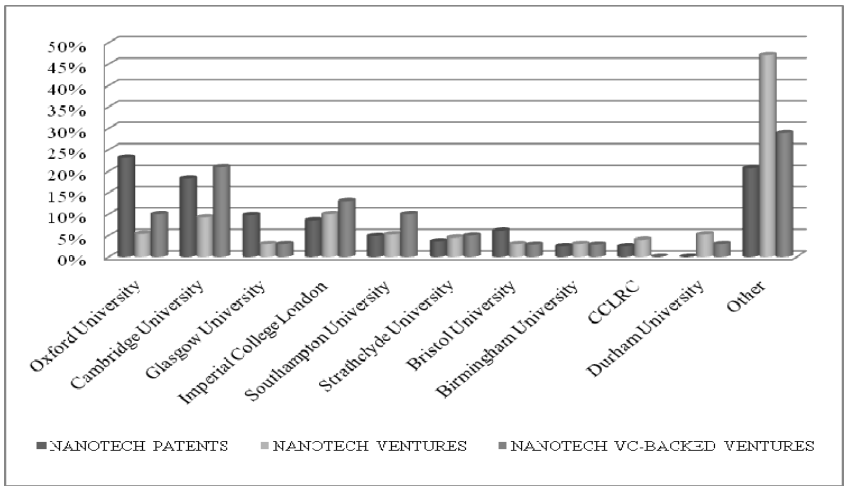

Table 1. Descriptive statistics for the full sample (N=247) and for the academic spin-offs (N=123)

	Full Sample (N = 247)				*Academic spin-offs (N = 123)*			
Variable	*Mean*	*Std. Dev.*	*Min*	*Max*	*Mean*	*Std. Dev.*	*Min*	*Max*
VC funded	0.247	0.432	0	1	0.317	0.467	0	1
Private VC funded	0.198	0.4	0	1	0.236	0.426	0	1
Academic spin-off	0.498	0.501	0	1				
Patents	4.599	14.817	0	155	4.041	11.846	0	121
Product-based business model	0.174	0.38	0	1	0.138	0.347	0	1
Technology-based business model	0.462	0.5	0	1	0.545	0.5	0	1
Service-based business model	0.211	0.409	0	1	0.171	0.378	0	1
Age	8.696	4.448	3	23	8.293	4.483	3	23
MNT scope	8.696	4.448	3	23	1.398	0.583	1	3
MNT materials	1.433	0.593	1	3	0.333	0.473	0	1
MNT devices	0.316	0.466	0	1	0.374	0.486	0	1
MNT regional activity	0.356	0.48	0	1	37.39	18.555	14	67
High quality university					0.276	0.449	0	1
Joint venture academic spin-off					0.098	0.298	0	1

Tables 2 and 3. Bivariate cross-tabulation between type of spin-off (academic versus private) and likelihood of receiving VC financing (Table 2) or private VC financing (Table 3). (Percentages are in parentheses.)

Academic spin-off	VC funded 0	1	Total
0	102	22	124
	(82.26)	(17.74)	(100)
	(54.84)	(36.07)	(50.2)
1	84	39	123
	(68.29)	(31.71)	(100)
	(45.16)	(63.93)	(49.8)
Total	186	61	247
	(75.3)	(24.7)	(100)
	(100)	(100)	(100)

Table 2. Pearson chi2 = 6.4757 Pr = 0.011

Academic spin-off	Private VC funded 0	1	Total
0	104	20	124
	(83.87)	(16.13)	(100)
	(52.53)	(40.82)	(50.2)
1	94	29	123
	(76.42)	(23.58)	(100)
	(47.47)	(59.18)	(49.8)
Total	198	49	247
	(80.16)	(19.84)	(100)
	(100)	(100)	(100)

Table 3. Pearson chi2 = 2.1541 Pr = 0.142

Table 4. Correlation matrix. Full Sample (N=247)

		1	2	3	4	5	6	7	8	9	10	11	12
1	VC funded	1.00											
2	Private VC funded	0.87	1.00										
3	Academic spin-off	0.16	0.09	1.00									
4	Patents	0.22	0.25	-0.04	1.00								
5	Product-based BM	0.03	0.04	-0.09	-0.01	1.00							
6	Technology-based BM	0.09	0.05	0.17	0.11	-0.43	1.00						
7	Service-based BM	-0.16	-0.13	-0.10	-0.10	-0.24	-0.48	1.00					
8	MNT scope	-0.07	-0.03	-0.09	0.05	0.03	-0.20	0.08	1.00				
9	MNT materials	0.07	0.03	-0.06	0.04	-0.01	0.02	0.03	0.03	1.00			
10	MNT devices	0.10	0.06	0.04	0.14	-0.20	0.26	-0.24	-0.01	0.02	1.00		
11	MNT regional activity	0.01	0.01	0.04	0.08	-0.17	0.26	-0.22	-0.04	0.01	-0.16	1.00	
12	MNT scope	0.13	0.14	-0.13	0.18	0.05	-0.01	0.02	0.15	-0.04	-0.06	0.04	1. 00

Table 5. Logit Regressions for likelihood of VC financing (Standard errors are in parentheses. *, **, *: levels of significant at the 1%, 5% and 10% respectively).**

	(1) *Full sample*	(2) *Full sample*	(3) *Academic spin-offs only*	(4) *Academic spin-offs only*
Variable	*Dep. Variable: VC funded*	*Dep. Variable: Private VC funded*	*Dep. Variable: VC funded*	*Dep. Variable: Private VC funded*
Academic spin-off	.933***	.628*		
	(.337)	(.356)		
Patents	.041**	.050**	.095**	.154***
	(.021)	(.023)	(.048)	(.0516)
Product-based business model	-.023	-.204	.008	-.522
	(.568)	(.592)	(.917)	(.923)
Technology-based business model	-.242	-.427	.082	-.854
	(.457)	(.478)	(.711)	(.732)
Service-based business model	-1.053*	-1.153*	-1.056	-2.287*
	(.628)	(.664)	(1.026)	(1.223)
Age	-.050	-.040	-.061	-.064
	(.040)	(.042)	(.060)	(.067)
MNT scope	.397	.213	.696*	.386
	(.262)	(.283)	(.387)	(.425)
MNT materials	.205	-.024	-.085	-.525
	(.376)	(.406)	(.560)	(.631)
MNT devices	-.250	-.259	-1.101*	-1.395**
	(.376)	(.400)	(.590)	(.650)
MNT regional activity	.018**	.017*	.027**	.0212
	(.008)	(.009)	(.0127)	(.014)
High quality university			1.070**	.230
			(.514)	(.583)
Joint venture spin-off			.408	1.309*
			(.790)	(.765)
Constant	-2.408***	-2.110**	-2.48**	-1.40
	(.809)	(.843)	(1.134)	(1.140)
LR Chi2	31.39	24.67	32.45	31.00
Prob > Chi2	0.0005	0.0060	0.0006	0.0011
N. obs in regression	247	247	123	123

[1] The distinction between venture capital and private equity funds is not precise, since differences in definitions exist in different contexts, such in Europe as compared to the United States (Gompers and Lerner, 1999). For the sake of simplicity, in the rest of the paper we will use the term venture capital with reference to those equity investments made in companies at an early stage of their development (i.e., launch, early development or expansion of a business). We do not refer to later-stage development activities or management buy-outs which, on the contrary, tend to refer to more established and mature companies.

[2] A wide and differentiated range of companies originate from universities, leading to different available definitions of university spin-offs in the literature. A narrow definition defines university spin-offs as new companies founded to exploit a piece of intellectual property created in an academic institution (i.e., Shane, 2004; Lockett and Wright, 2005). This definition is in line with that used by the Association of University Technology Managers in the US. In this paper, however, we adopt a broader definition of academic spin-offs as companies created to exploit knowledge that originates within universities, not necessarily dependent on the institution's IP. Such a definition is more coherent with the reality of academic spin-offs in Europe and the US, as well as showing that a significant number of entrepreneurial activities by academics occur outside a university's formal IP system (Mustar et al., 2006; Fini et al., 2009; Rothaermel et al., 2007).

[3] In particular, the economic rationale at the base of public intervention in VC investments could be significantly affected by the characteristics of the selected target companies (Lerner, 2002; Cumming, 2007) and, thus, public VCs could have the direct and explicit mission to support academic spin-offs rather than private spin-offs, as pointed out by Shane (2004, p. 224): "The initial capital obtained by university spin-offs [...] does not come from private investors, creating a funding gap in the development of university spin-offs." The author also asserted that: "In some cases, the government serves as a catalyst for private sector financing by paying for the initial test that proves the value of a technology and so motivates private investors to make subsequent investments." (Shane, 2004, p. 228)

[4] More precisely, MNT was categorised according to products or processes. The first classification of MNT places companies in three different classes (materials, products or processes), which were further split into 14 sub-classes.

[5] See Note 3.

[6] This work analyses 60 spin-offs active in the MNT sector in the UK and, by means of survey data, identifies those which have received support from venture capital providers.

[7] We classified a VC fund included in our sample as government-supported by adopting a two-step procedure. We first checked whether the fund was classified by *Venture Expert* as "Other Venture Program". This category is used to tag business development funds, government-affiliated programs, university-affiliated programs and incubators. In order to complement information taken from *Venture Expert*, we then identified the names of all VC funds launched under the following actions – University Challenge Fund, High Technology Fund, Regional Venture Capital Funds, Community Development Fund and Early Growth Fund – and checked

whether the VC funds included in our sample were part of such lists. In such cases, we coded the fund as government-supported.

[8] In the case of companies financed by a syndicated network including both private and public VC firms, we checked on *Venture Expert* if private VC funds invested in the company contributed a larger amount of money than public funds. In such cases, the dummy variable *Private VC funded* assumed the value one (and the value zero in the opposite case). We repeated the analyses adopting a narrower definition of *Private VC funded* taking the value one for companies which received financing exclusively by private VC funds. Results did not significantly differ from the analyses reported in this paper.