

**DO VENTURE CAPITALISTS HAVE A BIAS AGAINST INVESTMENT
IN ACADEMIC SPINOFFS? EVIDENCE FROM THE MICRO AND
NANOTECHNOLOGY SECTOR IN THE UK**

Federico Munari¹

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

Laura Toschi

*Boston University
School of Management.
595 Commonwealth Avenue.
Boston University, Boston
and
Department of Management
Università di Bologna
Via U. Terracini 28
40131 Bologna, Italy
Tel. +(39)-(051)-2090214
Fax. +(39)-(051)- 2090222
e-mail: laura.toschi@unibo.it*

¹ Corresponding author.

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ABSTRACT

In this paper, we provide original empirical evidence to resolve the dilemma about the existence of a VCs' bias against investments in academic spin-offs. We also investigate in more detail the nature of university spin-offs to capture the heterogeneity at the base of differences in their ability to attract VC funding. Finally, we examine whether their valuation varies between private and public VC firms. Our results on a sample of 247 spin-offs in the micro and nanotechnology sector in the UK reject the presence of the bias, highlighting the importance of the IPRs and the university's scientific prestige in the academic spin-off's ability to access to VC financing. Also, different investing behaviours are pointed out among VCs, with a stronger attention given by private VCs to the benefits deriving from academic-industrial collaborations.

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

INTRODUCTION

Venture capital (VC) firms are financial intermediaries specialized in investing in new ventures with high growth potential, thus playing a fundamental role in fostering national innovation and economic growth (Gompers and Lerner, 1999; Kortum and Lerner, 2000). However, the availability of VC investments for high-technology based, early-stage investments can be limited by high levels of risk and significant monitoring costs. The statistics provided by the European Venture Capital Association confirm that the VC industry in Europe still remains largely focused in non-technology sectors and in late stage investment activities. 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*, since the degree of uncertainty and the potential for information asymmetries may be higher, thus creating major impediments in accessing equity finance to fuel the growth prospects. Obtaining capital from private sources might be extremely difficult for academic spin-offs 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; the limited availability of collateral to minimize investors' risks. Also, the study by Wright et al. (2006) confirms the above mentioned difficulties and identifies some of the most critical problems faced by academic spin-offs seeking to access venture capital: lack of the distinctive knowledge and scientific understanding necessary to evaluate the business proposals, limited commercial experience, high uncertainty related to the assignment of IPRs between the company and the university of origin.

For all these reasons, previous research has suggested that VCs might have a bias against investments in academic spin-offs (Wright et al, 2006). To our knowledge, however, existing empirical evidence is only based on interviews with representatives of Technology Transfer Offices (TTOs) or VC managers, focusing 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 *vis-à-vis* comparable new ventures are still 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, or investigated the factors facilitating capital acquisition by university spin-off. 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, showing 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 the access to VC financing by academic spin-offs. We first test the existence of a bias against investments in academic spin-offs by VCs, in the specific case of a science-based business, such as the micro and nanotechnology (MNT) sector in the United Kingdom. We then analyze a series of characteristics affecting the likelihood of receiving VC financing by academic spin-offs. More specifically, based on the literature examining the heterogeneity of this type of new ventures (Mustar et al., 2006), we assess whether the following characteristics - the possession of patent application; the existence of an equity-based alliance with a business partner (i.e. joint-venture spin-off); the type of business model adopted; the affiliation to a top-tier research university – are significantly associated to the ability to receive funding by VC firms.

We test our hypotheses on a sample of 247 new ventures operating in the field of micro- and nanotechnology in the United Kingdom, including 123 academic and 124 other (i.e. non-academic spin-offs) new ventures. Our analyses highlight the skewed distribution of spin-off activity and VC investments in MNT in UK universities, consistently with the arguments provided by Wright et al. (2006). However, we do not find the existence of a bias by VC firms against academic spin-offs in a science-based business such as MNT, either considering all types of VC investments or focusing only on investments made by private VC firms. Moreover, we show that the ownership of strong IPRs, the scientific prestige of the universities of origin and the presence of high technological ferment for MNT in the area surrounding the spin-offs are important factors increasing the likelihood to receive VC financing of an academic spin-off. On the contrary, the adoption of a business model based on services reduces such probability. Finally, the benefits deriving from the creation of close relationships between academia and industrial partners are positively perceived only by the sample of private VC firms. This result suggests the importance for this kind of VCs to invest

in spin-offs having access to commercial resources in order to address the problem of lack of managerial expertise which could limit the possibilities to obtain returns by the commercialization of their technology.

The rest of the paper is organized as follows. We first briefly summarize previous literature on the problems faced by academic spin-offs in accessing external financing. Moreover, we formulate specific hypotheses on the association between certain characteristics of the academic spin-offs and the likelihood to be financed by a VC. We then describe the context of MNT, the sample and the variables used in the empirical analysis. We present the results of the different 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 points out the importance to study the role played by VC firms in financing new ventures (Gompers and Lerner, 1999). However, the differences between industry-based and research-based spin-offs in their ability to obtain VC financing is an important topic which needs to be more deeply investigated. It is not clear if VCs are more reluctant to invest in early stage ventures deriving from universities, in respect to private (non academic) spin-offs. On one hand, it has been recognized that both private ventures generally and research-based spin-offs face similar difficulties in establishing a market presence and obtaining VC financing. In this sense, high degrees of uncertainty and information asymmetry characterizing early stage investments play an important role. On the other hand, these problems could be stronger for and have a major impact on the academic spin-offs' ability to attract VCs financing, thus creating an asymmetric distribution of the amount of VC resources received by academic and non-academic spin-offs. This second line of reasoning suggests the existence of a bias against VC investing in research-based new ventures (Wright et al., 2006).

The study by Wright et al. (2006) tries to understand which problems the university spin-offs face in attracting VC finance. The theoretical lens to analyze this topic is the agency theory which suggests that the founders of university (or private) spin-offs often have more

information than other parties about the technical and market potential of their technologies. The entrepreneur is not comfortable in disclosing details of his technology to the potential investors and also tries to exploit this asymmetry to create competitive advantage. As a consequence, the investors face a difficult evaluation of the new proposals due to limits in information and uncertainty. The natural output of this loop is the creation of bargaining problems, leading the entrepreneurs and investors to disagree about the potential of the opportunity. More precisely, Wright et al. (2006) suggest that the presence of information asymmetries between the entrepreneurial team and the investors is likely to be extremely high in the case of academic spin-offs, for several reasons. First, the correct assessment of the technical feasibility and the market potential of early-stage technologies exiting from the university laboratories might prove extremely difficult and risky for VC investors, in many cases lacking the distinctive knowledge and scientific understanding necessary to evaluate the business proposals. Entrepreneurs, having more information about the prospects of their ventures and the 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 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 thus attracted by projects requiring minor screening costs and major understanding of the business developed by the investee company.

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, Siegel and Narasimha, 1985; Kaplan and Stromberg, 2004; Hsu, 2007). Accordingly, the study by Lockett et al. (2002), points out how the potential commercialization and the market size play an important role in the VC funding process. More precisely, the likelihood to obtain a VC financing increases if the university spin-off has the competences to make the business plan attractive and clear to the financing firms. This requisite is often not satisfied by academic teams due to their non-commercial nature. They are generally characterized by the presence of different qualified scientific skills, but lack the 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 VCs' attitude towards financing.

A third issue increasing the problem of information asymmetry between academic spin-off and VC firms is the role of social capital. In the private sector, the VC's decision to finance new ventures is driven by the knowledge of their partners. VCs could rely on their social networks to better understand the project developed by the start-ups, along a path dependence framework. Starting from the knowledge acquired by previous experience, VCs could easily understand the new project and better evaluate the right commitment of financing resources needed to the spin-off. 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 could not have the attitude toward experience accumulation, reinforcement of their competences and better comprehension of the university technology and a vicious circle is created increasing the gap between demand and supply of VC financing.

Finally, a further element which might hamper VC's willingness to fund an academic spin-offs is represented by the uncertain distribution of intellectual property rights between the university and the academic spin-off, as we will discuss in more depth in the next section. The underlying idea is that investors might be more confident in financing university spin-offs if the patent is directly assigned to the company, rather than being assigned in return of an equity share in the company. For all these reasons, we suggest:

H1a: Academic spin-offs have a lower likelihood to receive VC funding as compared to other (i.e. non-academic) new technology-based companies.

However, theoretical argumentation and empirical evidence sustaining this first position do not consider two important aspects which could lead to advance different expectations. First of all, the general claim that VC might have a bias against academic spin-offs does not take into consideration the specificities of the technological or industrial environment in which such companies operate. First, although spin-offs can be classified as academic or private, a more important feature which could be critical to explain the differences among spin-offs in their ability to search for VC financing is the science at the base of the technology developed

by the spin-off. The importance to consider the kind and quality of technology developed by a firm is that the presence of a VC bias could be different depending on the context which is analyzed. Pisano (2006), in the biotechnology field, tries to answer the question about whether and how efficiently the biotech industry has transformed its 'knowledge growth' into a 'profit growth'. He suggests that in the so-called 'science-businesses' the potential mismatch between the objectives and requirements of science and those of finance is particularly pronounced. MNT is a second example of science-based business, characterized by the existence of enterprises that attempt to both create science and capture value from it. Also, Zucker et al. (1998) demonstrate empirically that the commercialization of a technology (as biotechnology) is joined with the development of the underlying science. In these specific contexts, therefore, the economic value of the enterprise for VC investors is ultimately determined in large part by the quality of the science upon which it rests. Thus, a science-based business entails unique challenges that require different kinds of organizational and institutional arrangements and different approaches to management. Put simply, across businesses several differences exist so that 'what works well in other settings may not work as well in a science-based setting' (Pisano, 2006).

A second aspect which has to be taken into consideration regards the stage of development of the enterprises. The previous literature has missed to consider an important feature that private and academic ventures have in common. Both are seed/early-stage firms and, thus, they share the same problems and challenges typical of companies in their initial phase of development of a new technology: they need to secure capital, allocate scarce resources (human, financial, intellectual) to highly uncertain projects, design contracts to obtain the financial resources needed to improve their businesses. Investors generally want to finance spin-offs that have reached later stage development. 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 principles of its technology, but later on, when the enterprise is engaged in a 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, in the evaluation of an academic spin-off, VCs could face the same problems as in the case of a private venture, due to the lack of a clear performance of early stage ventures which does not allow to adopt conventional financial methods. Indeed, it is well-known in the literature how the major

criticality of VC investments is the difficult and uncertain valuation on which the screening and selection process are based (Tyebjee and Bruno, 1984; MacMillan et al., 1985).

Finally, the claim that VC firms have a bias against academic spin-offs ignores the wide heterogeneity which typically characterizes this type of new venture. Several contributions have highlighted that academic spin-offs differ across a whole set of dimensions, including the resource endowments, the type of business models adopted, the 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 to receive VC financing.

The above mentioned argumentations, therefore, lead us to advance a competing hypothesis with respect to Hp.1a, as follows:

H1b: It does not exist a significant 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: understanding if VCs have a bias against investing on academic spin-offs. Now, we will more deeply investigate this issue, addressing a second research question: which are the factors that affect the access to VC funding by university spin-offs? A deep understanding of the heterogeneity among research-based ventures becomes relevant in designing policies and strategies for academic spin-offs to face their above-mentioned challenges. Indeed, the presence of specific characteristics describing the nature of such enterprises could explain why their likelihood to receive VC financing could be different among academic spin-offs. In the next sections, we try to address this issue, focusing on a set of academic spin-off's features: the number of assigned patents, the presence of collaborations with business partners, the type of their business model and the scientific excellence and prestige of their university of affiliation.

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

A key starting point in analyzing 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 research-based new ventures. The paper by Mustar et al. (2006) presents a strong conceptual foundation to describe how academic spin-offs can be different to each other. The authors suggest that academic spin-offs can be analyzed using different approaches. A resource based view, which highlights the importance of resources as a differentiator and predictor of competitive advantage; a business model approach, describing the different activities that are developed by spin-offs; an institutional perspective, focusing on the relationship that academic spin-offs have with their parent organization, in this case the university. In this paper, we propose a set of hypotheses following this theoretical research classification. In particular, regarding the resource based framework, we analyze the role played by technological (spin-offs' 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 considering three different types of business model which the academic spin-offs could have: product-based, technology-based or service-based. Finally, the institutional perspective studies whether and how parent organizations facilitate spin-off creation and development through direct or indirect approaches. Universities can directly help their spin-offs with formal contracts, or indirectly acting as signal of the reputation of the research organization to investors. We focus on the second aspect investigating whether academic spin-offs from universities with a high research quality in the spin-off's domain have or not a higher probability to receive VC funding.

The resource-based perspective: technological and commercial resources.

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 this section, we analyze the presence of a proprietary technology, which is particularly important in the field of academic spin-offs. Indeed, as suggested by Wright et al. (2004), an university spin-off "is a new company

founded by employees of the university around a core technological innovation which had initially been developed at the university”. Thus, the creation of an academic spin-off is directly linked to the role played by the intellectual property rights (IPRs). The category “technological resources” refers to the firm-specific products and technology developed by the company (Borch et al., 1999) and is a critical key driver for VCs to differentiate among new ventures in terms of degree of innovativeness (Wright et al., 2007).

More precisely, we suggest that private investors tend to favor university spin-offs with strong patents portfolio for two main reasons. First, patents are widely considered a measure of a firm’s ability to innovate. Second, patent is recognized as the main tool of protection of a technology. Joined together, these two aspects suggest that patents provide external evidence of a competitive advantage, which investors positively evaluate. In other words, investors can be confident that a spin-off with high patenting rates is able to develop innovations, appropriate the returns and succeed in the subsequent commercialization of its technology. In the specific context of the academic spin-offs a further clarification is needed. The incidence of patents awarded to academic scientists or universities has been growing in many countries over the last two decades and many university have now technology transfer offices (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 VCs. Investors might be uncomfortable about investing in university 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. Clarysse et al. (2007) confirm this aspect, suggesting that the rise in number and quality of academic spin-offs is accelerated by the ownership of intellectual property rights by TTOs, when compared with that of faculty. Their findings support the existence of a positive relationship between perceived quality of the technology and amounts of starting capital obtained from VCs. As investors usually have difficulties in valuing new spin-offs, they need to rely on indirect indicators to measure the potential of a new venture. Patents represent one of these tools. In the previous literature, this topic has been widely investigated in the broader context of start-ups (not only academic, but also private). For instance, the work by Baum and Silverman (2004) found that start-ups having a high number of patent applications and grants generally

obtain more VC financing. The same result is also pointed out by Mann and Sager (2007) in the software and biotechnology industries: patenting is positively related to the likelihood of start-up firms to receive VC financing. Thus,

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

In addition to the importance of the spin-off's set of technological resources, also the presence of commercial abilities to introduce the new technology into the markets is critical for the VC's assessment of the quality and potential of an academic spin-off. It is widely recognized that private sector investors in university spin-offs tend to favor 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 characterized by teams with highly scientific-based skills, but where the commercial expertise to exploit a new technology is missed. In this context, a fundamental requisite to enhance the probability of receiving VC funding and obtain the right amount of financing could be the creation of a set of complementary assets supporting the commercialization of the new product/technology. Join the scientific knowledge with the capability to transform it into a profit, could be a strategic way to increase the probability to receive VC funding.

This aim can be pursued by university ventures through the creation of relationships with private start-ups which could help them in the commercialization of their project and function as intermediary between the university spin-off and the private investors. In the exploration of the problems related to the commercialization of the technology developed by an academic spin-off, the collaboration between the private and the university worlds may be an effective tool for the academic spin-off to overcome its resources constraints. Shane (2002) suggests that the creation of an university spin-off can follow two different models: university faculty starts a new company with the aim to commercialize an university discovery, or an external entrepreneur searches collaboration from the university to improve his own company. These options have been subsequently extended to a third option by Wright et al. (2004): 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-offs presents several advantages. First, seeking support from external parties to resolve the problems related to the lack of commercial capabilities needed for the full exploitation of the spin-off’s technologies is one of the main benefits deriving from this kind of collaboration. Second, the private firms’ prior knowledge of their industries, in terms of how to serve markets and address the customer problems, may be a tool for academic spin-off 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. Forth, the signalling theory suggests that the reputation of the private firm can be a key driver in the ability to access and obtain financial resources (Wright et al., 2004). Finally, the probability of success of a JVSO could be higher as the transparency in the relationships between university and private partner is greater than those between academic spin-off and VC. All these aspects could increase the probability to attract VC financing. Focusing on the cases in which a VC participation is required, we thus 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 to receive 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 to receive VC financing. The question is: what types of business ventures are more likely to involve VCs? We try to address this issue by examining three different types of business model: product-based, technology-based or service-based. This classification perfectly matches the distinction, proposed by Stankiewicz (1994), based on the main modes of activities in which the firms operate: academic spin-offs

can be *product oriented*, *technology oriented*, or *consultant*. The product oriented mode is organized around a well-developed product concept, the technology asset oriented mode is related to the development of technologies sold through licenses/partnerships, while the consultancy mode supplies services exploiting competence shortages. On one hand, research services require activities which are not generally based on patents and do not demand significant technology development. In contrast, the creation of a product/technology requires a huge investment capital along each step of the technology development process (Druilhe and Garnsey, 2004). Thus, the product-oriented business models are considered “high potential companies” created to exploit commercial research findings. The service-oriented companies, typically labelled as “lifestyle”, are instead created to exploit tacit knowledge accumulated from academic experience (Timmons, 1994). Thus, this last group seems to strengthen the non-commercial nature characterizing academic spin-offs in general. For these reasons, VCs firms could be less confident in investing in service-oriented business models, characterized by scarce possibilities to appropriate returns from the scientists’ research (due to the lack of patents protection), when compared to product-oriented activities, which instead have a clearer physical output protected by intellectual property rights, positively evaluated by VCs. Thus, the following hypothesis is suggested:

H4: Academic spin-offs having a business model based on services have a lower likelihood to receive VC funding.

The institutional perspective: university’s reputation and prestige.

The institutional perspective suggests the presence of different relationships between the research-based spin-off and its parent organization. More precisely, depending on the scientific quality and prestige of the parent organization, academic spin-offs can have different probability to succeed and attract the attention of VCs. Academic spin-offs created by “top universities” with a large critical mass of researches and experience in entrepreneurial businesses, having well-built links with the private sector and with a strong propensity to patent their technology could be a critical help in the search of financing in the venture capital market. Shane (2006) points out that the ability to raise private capital for early stage companies varies across institutions. More precisely, spin-offs from the more prestigious

institutions are more likely to raise external capital from the venture capital market at the time of the spin-off formation. This rational perfectly fits with the institutional perspective suggested by Mustar et al. (2006), where it is analyzed how the parent institute shapes the starting configuration of its spin-off. In particular, the strength of the parent-venture link seems to be related to the proximity and the 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 reputation of the research organization may be an important signal of the quality of the new venture to private investors. In this paper, we consider the ‘top universities’ following a technology-based prospective in terms of ability of the university in obtaining patents in the same field in which its spin-offs operate. The underlying principle is that the scientific excellence and the prestige of the academic institution of origin can reduce the high level of information asymmetry surrounding academic spin-offs and help the research-based ventures to obtain access to external financing (Di Gregorio and Shane, 2004).

H5: Academic spin-offs from universities with a high research quality in the spin-off's domain have a higher likelihood to receive VC funding.

METHOD

The context: the field of micro and nanotechnology in the United Kingdom

Nanotechnology can be defined as the study and use of the unique characteristics of materials at the nanometer scale, between the classical large-molecule level to which traditional physics and chemistry apply and the atomic level in which the rules of quantum mechanics take effect (Lemeley, 2005). Peculiar characteristics of nanotechnology reside in its inter-disciplinarity, attracting scientists from many areas of science, and in the wide spectrum of potential market applications, which can involve very 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 “boom” in the number of nanotech patents and start-ups created all over the world during the last years, and a significant amount of VC investments has been dedicated to the promises of the new technological revolution. In a

narrower definition, nanotechnology involves the study and control of phenomena and materials at length scales below 100 nm. However, it is difficult to find a unique and universally accepted definition of what nanotechnology is. The inaugural issue of *Nature Nanotechnology*, for instance, asked 13 researchers from different areas what nanotechnology means to them and their responses suggest the existence a variety of interpretation for this technological field. In order to circumvent such definition problems, in our study we apply a broader definition including both micro and nanotechnology as the study and use of the unique characteristics of materials between the micron and nanometer scale. We decided to focus on such context for several reasons.

There are also different reasons for our decision to focus on the UK. First, the UK is one of the most advanced country in Europe for the development of research and business activities in the emerging field of MNT. Part of this growth has been spurred by a strong commitment of the Government which has envisaged nanotechnology as a sector playing a strategic role in the industrial policies. According to a 2004 report of the UK Department of Trade and Industry, the UK has the second highest funding level in MNT Sector in Europe after Germany. In July 2003, the Science and Innovation Minister Lord Sainsbury announced a cash injection of £90 million (124 Million Euros) over the next six years to help industry harness the commercial opportunities offered by nanotechnology. Within this initiative, the DTI has allocated £50m for an applied research programme that will support collaborative research and development projects and technology transfer initiatives, and £40m for Capital Projects for a UK Micro and Nanotechnology Network (MNT Network), set up with the objective to manage this process for a three year period and kick-start the exploitation of MNT within the UK. The MNT Network was funded in 2004, receiving half of its budget from the Department of Science and Innovation and the other half from all the regional and development agencies combined. One of the first activities realized was that of conducting a detailed survey in 2004 in order 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. (2007) using three data-sets based on patents, co-publications, and firm data, has shown that university spin-offs play a significant, although not dominant role, in the field of nanotechnology in the UK. The nanotechnology sector in the UK is fairly evenly divided among three main actors: multi-national companies; new technology based firms, founded by non university affiliated entrepreneurs; and university

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 represents an ideal context to study the relationship between VC investments 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 United Kingdom using the *Industrial Map of UK MNT in 2004/05* compiled by the MNT Network in association with the UK Department of Trade and Industry. This survey identified 372 companies active in MNT (defined as the study and use of the unique characteristics of materials between the micron and nanometer scale²) in the UK in 2004. The quantitative survey provides a profile for each company, including technical information (a description of the MNT activities in the classes of materials, devices or processes) and non-technical data (turnover, employees, corporate origin, year of incorporation, business model). According with such information, we were 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 centers of established corporations active in the MNT field, whereas the last two classes respectively refer to new ventures created by academic or non-academic entrepreneurs. Based on such definitions, 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-off, as new ventures created to commercially exploit knowledge, technology or research results initially developed within a university (Birley, 2001; Wright et al. 2004)³.

We then used the *Venture Expert* database, provided by Thomson Financial, in order to identify all the MNT new ventures of the sample which have been financed by VC funds as of December 2007. To fully capture all the VC-backed companies, we eventually complemented

² More precisely, MNT was categorized according to products or processes. A first classification of MNT companies in three different classes (Materials, Products, Processes) was further split into 14 different sub-classes.

³ A narrower definition, such as the one adopted by the AUTM, defines academic spin-offs as companies that are dependent upon licensing a university's technology for initiation.. We decided to use a broader definition in order to include also academic spin-offs which adopt business-models based on services to exploit the tacit knowledge and expertise of their founders. This kind of so called "lifestyle" spin-offs is indeed diffused in the UK and, more generally, in Europe.

information taken from *Venture Expert* by consulting also the research by Shah (2004)⁴ and the companies' websites. We thus identified 61 VC-backed new ventures operating in MNT in the UK. Among them, 39 were 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 4 different classes (independent, financial, corporate, other venture program).

In order to correctly test competing hypotheses H1a and H1b, a critical issue is that of separating new ventures funded by private VC from those funded by Government supported VC programs. In fact, starting from the mid 1990s, the United Kingdom has implemented a wide range of policy initiatives to improve the access of small firms to equity financing (OECD, 2003). Among such actions, government equity has been used to leverage private VC financing for small deal sizes. New venture capital 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 into 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 the companies in our sample (both academic spin-offs and other new ventures) which were financed by at least one government-supported fund⁵. Ultimately, we were able to identify in our sample three different categories of VC-backed companies: companies funded exclusively by private VC funds (37); companies funded exclusively by government-supported VC funds (12); companies (12) funded by public/private funds (in which at least one government-supported VC fund co-invested with one or more private VC funds).

⁴ This work analyzes 60 spin-offs active in MNT in the UK and, by means of survey data, identifies those which have received support from venture capital providers.

⁵ We classified a VC fund included in our sample as government-supported by adopting a two steps procedures. We first checked whether the fund was classified by *Venture Expert* as "Other Venture Program". This category is used by *Venture Expert* to tag business development funds, government affiliated programs, university affiliated programs, incubators. In order to complement information taken from *Venture Expert*, we then identified from the Internet the names of all the VC funds launched under the following actions - University Challenge Fund, High Technology Fund, Regional Venture Capital Funds, Community Development Fund, Early Growth Fund – and checked whether the VC funds included in our sample were part of such list. In such cases, we coded the fund as government-supported.

Finally, we used the *Delphion* database to identify the patent applications requested at the European Patent Office by the companies included in our sample. In addition to that, we identified all the EPO patents in the nanotechnology class assigned to universities from the United Kingdom, 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 1 if the start-up received VC financing as of December 2007. *Private VC funded* is a dummy taking the value 1 if the start-up was financed primarily by private VC funds, and 0 in all other cases⁶. From this latter group, therefore, are excluded those companies financed exclusively by public VC funds, such as business development funds, government affiliated programs, university affiliated programs, incubators.

Independent variables.

Academic Spin-off is a dummy taking the value 1 for all the university based spin-offs included in our sample, and 0 in all other cases. We used this dummy variable to test the two competing hypotheses Hp. 1a and Hp. 1b. In order to test Hp.2, we constructed the variable *Patents*, measuring the number of patent applications requested at the European Patent Office by each company up to December 2007. In order to test Hp.3 on the sole sample of academic spin-offs, we created the variable *Joint-venture Academic Spin-off*, identifying those academic spin-offs (12 companies) jointly formed by universities and industrial partners. In such cases the dummy variable takes the value 1, whereas it takes the value 0 in all other cases. With respect to Hp. 4, 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 the these business models. The set of companies with a business model characterized as *Integrators* is taken as the

⁶ 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 a larger amount of money than public funds. In such cases, the dummy variable Private VC funded assumed the value 1 (and the value 0 in the opposite case). We repeated the

baseline case for such dummies. These companies do not realize products directly based on MNT, but they integrate an MNT process in the manufacture of their products. The three dummies, instead, indicate the start-up's adoption of one of the following business models, according with the taxonomy provided in the seminal paper by Stankiewicz (1994): *Technology-Based*, *Product-based* and *Service-based Business Model*. The first group includes companies engaged in the design and prototype of MNT products/materials. Such companies are generally searching to license and/or upscale a proprietary process. The second group includes companies manufacturing in medium or high volume MNT products/materials or suppliers of MNT equipment/process. The third group includes providers of specialized services to the MNT industry. In order to test Hp. 5 on the sole sample of academic spin-offs, we identified those academic spin-offs affiliated to universities characterized by high reputation and scientific excellence in MNT. The dummy *High-Quality University Spin-Off* takes the value 1 in the case of academic spin-offs from the first four universities active in nanotech patenting in the United Kingdom (respectively Oxford University, Cambridge University, Glasgow University and Imperial College), and 0 in all other cases. Taken together such four universities account for around 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 by the companies in our sample. This variable is created by counting the number of different sub-classes related to MNT (among 14 possible ones) in which the company declared to operate, as reported in the Report "Industrial Map of UK MNT". For each company, *MNT regional density* measures the number of companies (subsidiaries, R&D labs, new ventures) active in MNT in its region, according to the Industrial Map of UK MNT. To calculate such variable, all companies are aggregated in 12 different regions of the UK: East Midlands, East of

analyses adopting a narrower definition of *Private VC funded*, taking the value 1 for companies which received financing exclusively by private VC funds. Results did not significantly differ from the analyses reported in this paper.

England, Greater London, North East, North West, Northern Ireland, Scotland, South East, South West, Wales, West Midlands, Yorkshire and Humberside.

ANALYSES AND RESULTS

Descriptive statistics

We first present some descriptive analyses in order 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 found by Wright et al. (2006) in the distribution of academic spin-offs in the UK. Indeed, about 30% of the academic spin-offs are concentrated in the first four universities (Imperial College London, 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 (Cambridge University, Oxford University, Southampton University, Imperial College). If we look at the distribution of spin-offs funded by private VC firms, excluding therefore those primarily funded by public VCs, the concentration ratio becomes 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 not to be evenly distributed across UK universities, but they concentrate in a restricted set of universities characterized by a high excellence in scientific and technological development.

--- Insert Table 1 around here ---

Table 1 shows descriptive statistics for the whole sample and for the sub-sample of academic spin-offs. 25% of the companies in our sample (31% in the case of academic spin-offs) received funding by a VC at the end of 2007, whereas this percentage decreases to 20% (24% for academic spin-offs) if we consider only private VC firms. On average, the companies in our sample have an age around 8.7 years (8.3 for academic spin-offs) and presented 4.6 (4.04)

patent applications at the EPO. The majority of them tends to adopt a technology-based business model (46% for the whole sample, 54% for academic spin-offs), followed by service-based (21% for the whole sample, 17% for academic spin-offs) and product-based business models (17% for the whole sample, 14% for academic spin-offs), with the so-called “integrators” representing the remaining cases. 12 academic spin-offs in our sample were formed as joint-ventures between universities and industrial partners.

Cross-tabulation analyses

We then perform bivariate cross-tabulation analyses to assess whether the start-up affiliation to a university increases the likelihood to receive 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 that the 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 reported in Table 2 indicate that the likelihood to receive VC financing is higher for academic spin-offs, in a statistically significant way (at the 5% level). Indeed, almost one-third (31.71%) of MNT academic spin-offs in the UK received VC funding, whereas this percentage decreases to 17.74% for non academic start-ups.

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

However, if we focus on investments made by private VC firms, thus excluding those companies primarily funded by publicly-supported VC funds (Table 3), the percentage of VC-backed academic spin-offs still remains higher than that of VC-backed other new ventures (respectively 23.58% vs. 16.13%). In this case, 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 business as MNT. It seems therefore that newly created companies which aim to develop and commercialize 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 in comparison to other newly established companies.

Regression analyses

Finally, we use 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, whereas 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 Hp. 1a and Hp. 1b on the whole sample of 247 new ventures, including both academic and non-academic spin-offs, the main dependent variable of interest being the dummy *VC funded*. In the second model (Table 5, Column 2), on the contrary, the dependent variable is represented by the dummy *Private VC Funded*, as we consider the likelihood to be financed by a private VC firms, thus excluding the new ventures primarily financed by public VCs (i.e. state/regional funds, University Challenge Funds, other university funds, incubators) which could have the direct and explicit mission to support university-based new companies.

In the first model, the coefficient of the dummy *Academic Spin-off* is positive (.933) and significant at the 1% level, signalling that the affiliation to an 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), in order to exclude the influence of public VC funds which are deliberately created to promote technology transfer from universities (such as University Challenge Funds), the coefficient of the dummy *Academic Spin-off* remains positive (.628) and statistically significant, although at the 10% level. In both Model 1 and 2, the coefficients of the variable *Patents* are positive (respectively .041 and .050) and statistically significant (in both cases at the 5% level), thus suggesting that the possession of a large patent portfolio facilitates the access to external financing. The strong presence of MNT facilities in the region has also a positive impact on the likelihood to receive 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 the obtainment of VC financing, given that in both Model 1 and 2 the variable *Service-based Business Model* is negative (respectively -1.053 and -1.153) and significant at the 10% level. To sum up, in both models, 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 VCs only, as done in Model 2. MNT is indeed an example of a science-based business, characterized 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 determined in large part by the quality of the science upon which it rests, and the strong linkages with university research represent a strategic resource.

--- Insert Table 5 around here ---

We then move to test Hp. 2, 3, 4 and 5 in order to investigate in more depth the factors which facilitates the access to VC financing by academic spin-offs. Column 3 and 4 of Table 5 report the results of logit regression analyses performed on the sub-sample of 123 academic spin-offs, using respectively the dummies *VC Funded* (Model 3) and *Private VC funded* (Model 4) as dependent variables. We find support for Hp. 2 in both Model 3 and Model 4, given that the coefficient of the variable *Patents* is positive (.095 and .154 respectively) and statistically significant (at the 5% and at the 1% level respectively). On the other hand, we notice interesting differences in the test of the remaining 3 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 Hp. 3, the coefficient of the variable *Joint-venture Academic Spin-off* is positive in both Models 3 and 4 (.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 to gain access to commercial capabilities, financial means and managerial expertise. From the JVS0 point of view, this result also suggests that this form of academic spin-off seeks to gather huge sums of capital from private VCs as they tend to provide greater

amounts and more dedicate support in respect to public VCs. Turning to Hp.4, 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 tend not to invest in academic spin-offs adopting a business models based on service, presumably because of the limited growth opportunities of this kind of strategy.

Finally, we notice that the spin-offs from the first four universities in the UK for number of nanotech patents, as a proxy for their excellence in this area, have a significantly higher probability to receive 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 result does not hold also in the model considering only deals by private VC firms (Table 5, Column 4), given that the coefficient, although positive, is now not significant. A possible explanation for this finding resides in the fact those high-level universities, such as Cambridge, Oxford and Imperial College, have also 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 importantly contribute in the financing of spin-offs emerging from such institutions, thus explaining 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% level 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 empirically tested the existence 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 recognized the heterogeneity of academic spin-offs and analyzed the impact of company-specific characteristics on the likelihood to receive 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 research-based spin-offs, "[...] a little examined topic is the impact on firm performances of differences in the resource endowment, institutional links, and business model of RBSOs". We tried to make a step in this direction by focusing on the

following characteristics, emerging from the analysis of the review of the literature on academic entrepreneurship: technical resources endowment, with reference to the possession of IPRs; linkages to business partners, by comparing the so-called joint-venture spin-offs to independent ones; types of business model, separating service-oriented, product-oriented and technology-asset oriented business models; institutional affiliation, comparing companies spun-off from high-quality universities with the remaining ones. Third, we point out that there exists a high heterogeneity also among VC firms in their financing decisions: private and public investors have different behaviours towards academic spin-offs.

Focusing on a sample of 247 new ventures in the specific case of a science-based business such as micro and nanotechnology, our results suggest that the presence of a bias by VC firms against academic spin-offs operating in this field does not exist. This finding is confirmed both considering all types of VC investments (without splitting the population between private and public VCs) and focusing only on deals made by private VC firms. A possible explanation of these findings regards the nature of MNT. VC firms investing in a science-based business (as MNT) 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 determine the economic value of the enterprise. The second part of the paper, instead, investigates in more detail the nature of university spin-offs to capture the heterogeneity at the base of differences in their performance, measured in terms of accessing to VC funding. In particular, we show that the existence of a strong technological portfolio (IPRs), the scientific excellence and reputation of the mother university and the presence of a high number of MNT companies (subsidiaries, R&D labs, 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 VCs, except for the role played by patents. Excluding public VC firms from the original sample, two further interesting results emerge: first, the adoption of a business model based on services reduces the probability to attract private VCs. Second, private VC firms seem valuing the creation of collaborative relationships with industrial partners as a positive signal which enables academic spin-offs to address the well known 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 signal of their ability to promote technology transfer. The wide differences observed among spin-offs in the ability of

attracting external financing show the existence of strong differences in their quality and growth potential. In the valuation exercise which can be carried-out by the same Universities' TTOs or by regional or Government agencies, the access to VC investments, 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 emphasized by the Lambert's Report in the suggested guidelines for the science and innovation policy of the UK, when it highlights that: "[T]he best way to judge quality is by looking at the ability of a spinout to attract external private equity. [...] But almost a third of the universities that created spinouts 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 spinouts, 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 TTOs 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 interact is necessary. It is critical not only exploiting the technological excellence of the researchers, but also developing more lucrative commercial opportunities from such scientific abilities. As pointed out by Wright et al. (2007), this goal can be achieved either increasing the number and the quality of collaborative relationships with industrial partners or promoting the association between business schools and university 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 VCs. This means that the agency problems between investors and TTOs regarding the IPRs ownership have to be resolved. VCs are more favourable in financing academic ventures with assigned patents rather than licensed. However, TTOs tend to be reluctant in facilitating this process due to the potential loss of economic value. Third, the influence of TTOs on the way in which academic spin-offs start their businesses has not to be underestimated. The objectives of the TTOs have a direct impact on the commercialization 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

to receive VC financing (as shown by our analyses). Finally, due to the heterogeneity in the selection criteria used by investors in their financing decisions, the probability of an academic spin-off to receive VC financing directly depends on the type of VC selected by the entrepreneurial team. Thus, to increase the chances to attract the attention of VCs, an academic spin-off needs to precisely decide which type of investors is more appropriate. If the choice falls on private VCs, efforts made by academic researchers to increase their commercial abilities through joint ventures or other forms of tight collaborations with industrial companies are needed. However, service-based spin-offs seem to have minor probability to attract this type 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 has to leverage on the correct characteristics to increase the likelihood to be financed by the VC selected.

To conclude, some limitations and directions for future research. First of all, our analysis relied on data from a single sector characterized by high degree of newness and uncertainty. However, this kind of specificity raise problems about the generalizability of our results to other contexts. The same problem can be pointed out also for the country specificity: focusing only on the UK environment does not allow to capture the industry or technology differences among countries. Indeed, it is plausible to suppose that such peculiarities have impact on the type of academic-spinoff developed by universities. Future research could extend these analyses in both the directions. Second, as VCs' 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 the academic spin-offs. There are therefore interesting opportunities to analyze if other determinants of university-spinoff link are directly taken into consideration by VC firms in their investment choices. Third, in the construction of the measure which captures the prestige and excellence of universities to understand the signalling effect of reputation of the mother organization, we rely on a proxy based on nanotech patents. The underlying logic is investigating if 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 an university.

Future works could also take into consideration the possibility to gather data about the mass of researches and experience in entrepreneurial businesses, the rating score of graduate schools, the number of links and collaborations with the industrial sector and the 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 by investors and potential partners, in order to reduce the extent of information asymmetries. It could also be important introducing the effects of direct efforts made by universities in creating occasions of contacts and links with potential investors or partners for their spin-offs.

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TABLES AND FIGURES

Figure 1

Distribution of nanotech patents, MNT spinoffs and VC-backed MNT spinoffs across UK universities (%)

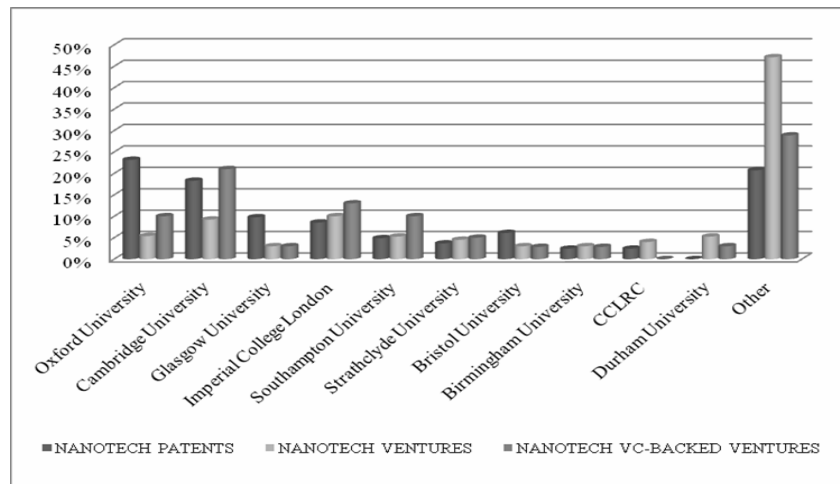


Table 1

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

Variable	Full Sample (N = 247)				Academic spin-offs (N = 123)			
	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 to receive VC financing (Table 2) or private VC financing (Table 3). (Percentages are in parentheses.)

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

Table 2. Pearson chi2 = 6.4757 Pr = 0.011

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

<i>Variable</i>	(1)	(2)	(3)	(4)
	<i>Full sample</i>	<i>Full sample</i>	<i>Academic spin-offs only</i>	<i>Academic spin-offs only</i>
	<i>Dep. Variable: VC Funded</i>	<i>Dep. Variable: Private VC Funded</i>	<i>Dep. Variable: VC Funded</i>	<i>Dep. Variable: Private VC Funded</i>
Academic Spin-off	.933*** (.337)	.628* (.356)		
Patents	.041** (.021)	.050** (.023)	.095** (.048)	.154*** (.0516)
Product-based Business Model	-.023 (.568)	-.204 (.592)	.008 (.917)	-.522 (.923)
Technology-based Business Model	-.242 (.457)	-.427 (.478)	.082 (.711)	-.854 (.732)
Service-based Business Model	-1.053* (.628)	-1.153* (.664)	-1.056 (1.026)	-2.287* (1.223)
Age	-.050 (.040)	-.040 (.042)	-.061 (.060)	-.064 (.067)
MNT Scope	.397 (.262)	.213 (.283)	.696* (.387)	.386 (.425)
MNT Materials	.205 (.376)	-.024 (.406)	-.085 (.560)	-.525 (.631)
MNT Devices	-.250 (.376)	-.259 (.400)	-1.101* (.590)	-1.395** (.650)
MNT Regional Activity	.018** (.008)	.017* (.009)	.027** (.0127)	.0212 (.014)
High-quality University			1.070** (.514)	.230 (.583)
Joint-venture Spin-off			.408 (.790)	1.309* (.765)
Constant	-2.408*** (.809)	-2.110** (.843)	-2.48** (1.134)	-1.40 (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