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Dynamics of Science-based entrepreneurship

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Abstract This article introduces the rationale for the special issue, summarizes the main themes covered by the papers presented and suggests areas for further research. Previous research has focused on the creation of Science-based entrepreneurial firms (SBEFs) but there is little research relating to their growth and the challenges in ensuring growth occurs. At the macro-level, there is a need to distinguish general versus specific policies and how these vary between different institutional environments. At the firm level, there is a need to consider the factors influencing the development of boards, the growth of SBEFs and their dynamics in terms of acquisitions and IPOs.

Keywords Science-based entrepreneurial firms · Universities · Technology transfer · Technology policy

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1 Introduction

Science-based entrepreneurial firms (SBEFs), i.e. firms that are created with the aim to exploit commercially scientific knowledge developed in universities and other public research organizations, are generally considered as a key driver of the rejuvenation of high-tech industries. In recent years there has been a dramatic increase worldwide in the rate of formation of these firms (Wright et al. 2007). Extensive studies have analyzed the institutional and other influences on the creation of SBEFs (for reviews see for example, Mustar et al. 2006; Rothermael et al. 2007; Siegel et al. 2007), and numerous special issues have been devoted to entrepreneurship and university technology transfer (e.g. Wright et al. 2004a).

Nevertheless, the available evidence indicates that most SBEFs are not gazelles. If in many other cases SBEFs do not achieve high growth, the knowledge they create may significantly contribute to the innovativeness of their customers or may be transferred to and successfully exploited by outside companies through partnerships or mergers and acquisitions (M&As). Consequently, although the majority of SBEFs do not fall into the gazelles category they may still play a very important role for the dynamic efficiency of the economic environment in which they are embedded.

There is thus a need for a better assessment of the role played by these firms in an advanced economy. The central issue is that there is extensive research concerning entry into science-based entrepreneurship, but little research on the evolution, possible exit from it, and the positive externalities it provides to third parties. The aim of this special issue is to help close this gap so as to foster the scientific debate on these issues and to set the ground for the design of more effective public policy measures in this area.

Following a general call for papers, we received 34 submissions. We undertook an initial sift to eliminate those that did not fit with the scope of the special issue. This left the majority of papers which were then sent out for double blind review. Based on the reviewers' recommendations, we selected 12 papers for presentation at a special focused workshop held at Sestri Levante, Italy in April 2008. From our reading of the reviewers' comments it was clear that some papers were acceptable to be presented at the workshop but did not merit further consideration for the special issue; these papers were eliminated from the review process. Authors of the remaining papers revised their articles based on the reviewers' comments and points raised by workshop participants. These versions were returned to the same reviewers for a second round of comments, following which we made our final selection.

2 Themes and contributions of papers in this issue

2.1 Policy level

There are several arguments explaining why SBEFs should receive public support. First, the financial economics literature argues that due to the presence of information asymmetries (i.e. adverse selection and moral hazard problems), obtaining external financing is difficult for these firms, especially in the early stages of their life when they lack a track record (see e.g. Carpenter and Petersen 2002; Denis 2004). Second, while developing radically innovative technological knowledge, SBEFs generate social benefits that are largely in excess of the private returns they can capture (Nelson 1959; Griliches 1992). In particular, it is often difficult for these firms to effectively protect their technological

knowledge from imitation by competitors (Teece 1986). Because of technological spill-overs and other externalities, their incentives to invest in R&D are generally lower than the social optimum.

A further argument explaining public support for SBEFs is linked to the risk associated with these firms. The risk related to the creation of innovative firms can be too important to be assumed by a private actor. There are uncertainties relating to the technology, uncertainties concerning the existence of sufficient demand, significant fixed costs that are not easily recoverable, etc. Intervention by the public authorities allows these firms to finance their risky projects with lower costs. For their part, governments have to organize the timely sharing of risk across various projects while ensuring the effective functioning of product and financial markets.

Despite government subsidies potentially being helpful for SBEFs, they may have some serious shortcomings. Failure rates are naturally high among SBEFs; public support may weaken the competitive selection process, subsidising inefficiencies and leading to distortion of competition (Holtz-Eakin 2000; Santarelli and Vivarelli 2002). Moreover, if governmental bodies in charge of providing subsidies to SBEFs adopt a "cherry picking" strategy, public subsidies may crowd out private investments (Lach 2002).

Takalo and Tanayama (2009) develop a theoretical framework to examine the interaction between private and public financing of innovative projects in the presence of adverse selection problems. As was argued above, these problems are especially severe for young SBEFs that are involved in the development of radically innovative technologies. The authors argue in favour of the complementarity between public and private financing; under certain conditions, public subsidies can reduce the financing constraints of SBEFs. In their model, the subsidy reduces the capital costs of innovative projects by reducing the amount of market-based finance required. More importantly, the screening mechanisms adopted by government based programs to allocate funds to firms provide useful information to prospective market-based financiers; the signal of quality associated with the subsidy reduces adverse selection problems faced by financiers and contributes to the removal of the financing constraints of SBEFs.

Lerner (1999, 2002) provides evidence for the US in line with this argument. However, the positive effect of public subsidies highlighted by Takalo and Tanayama's model depends on both the "selective" nature of the supporting scheme and the screening ability of government bodies. Absent these characteristics, public subsidies may well crowd out private financing. This points to the importance of (1) designing effective public supporting schemes for SBEFs and (2) assigning responsibility for their implementation to bodies with appropriate competencies. Unfortunately, the available empirical evidence on these issues is limited and as regards Europe, almost non-existent. In spite of a few recent studies that have tried to assess the effectiveness of policy interventions in support of European high-tech start-ups,[1] among which SBEFs play a prominent role, it is fair to recognize that our understanding of these important issues still is rather limited.

An important obstacle faced by studies in this area is that it is not clear to what extent the effects of policy interventions are contingent on the specific institutional context of a given country. If they are, best practices cannot be effectively transferred across countries.

[1] A few recent studies have analyzed the impact of public subsidies on the innovation (Schneider and Veugelers 2008) and growth (Colombo et al. 2008) performances of (German and Italian, respectively) high-tech start-ups. They suggest that policy interventions generally fail to make a difference for these companies. However, better results are obtained with selective supporting schemes, especially when recipient firms are very young.

In particular, the European institutional context is heterogeneous across countries, which themselves have differing long-standing traditions of policy development regarding innovation and technology transfer (e.g. Wright et al. 2006). Hence, it is not obvious that policies that have been successful elsewhere can feasibly be adopted in different European countries (e.g. see Mowery's views about the replicability of the Bayh-Dole Act outside the specific US context, Mowery 2001).

The analyses of Cosh and Hughes and of Mustar and Wright, from micro and macro perspectives respectively, add further to this debate. In particular, they address issues concerning the development of policy relating to the role of universities in stimulating SBEFs. This also raises questions about the validity of Mode 1 versus Mode 2 approaches to research and about applying the Triple Helix approach (Etzkowitz et al. 2000) as a single kind of model for the role of universities. Although they have attracted the attention of international agencies such as the OECD and the EU, these approaches have been critiqued because of their high level of generality and because they lack an empirical basis of support at the level of research institutions (Mowery and Sampat 2005; Grossetti and Bès 2001; Shinn 2002; Pestre 2000). The Cosh and Hughes and Mustar and Wright papers highlight the dangers of attempting to transfer universalistic models into different contexts (a point also made in Wright et al. 2007), and hence the difficulties in implementing policies to stimulate SBEFs that have been developed in other institutional contexts.

Cosh and Hughes (2009) analyze the relative strength of the university–industry ecosystems in stimulating innovation and science based entrepreneurial firms in the UK and US. Using a matched sample of over 1,900 UK and US businesses for the period 2004–2005 in the manufacturing and business services sectors they show that in both countries universities per se play a quantitatively smaller role as a source of knowledge for business innovation than either the business sector itself or a variety of organisations intermediating between the university and business sectors. However, they do identify differences between the two countries. The UK possesses a much more diffuse university-industry ecosystem in which a higher proportion of businesses claim links external to themselves in their pursuit of knowledge for innovation and a higher proportion report directly connecting with universities. In contrast, US firms are more likely to access knowledge through a combination of business and intermediary sources and are less likely to have established formal collaborative or partnership agreements in the three years prior to the survey. However, a higher proportion of US firms place a very high value on their connections with universities and are much more likely to commit resources to support such innovation related university interactions. UK firms are more likely to be in receipt of assistance, but receive far less per firm in absolute terms and relative to their R&D expenditures. They conclude that the UK university-industry ecosystem is characterized by a greater width than quality of interaction.

Mustar and Wright (2009) address these issues from a macro-policy level. They examine attempts by French and UK governments to fill the gap between the US and Europe with respect to the creation of SBEFs. Their analysis shows that there is no convergence of national policies to foster the creation of firms by academics. Rather, the two countries demonstrate different rationales and approaches to policy in this area. In UK, the rationale for SBEF policy is mainly to develop a third stream of financing. SBEFs are a part of a policy to commercialize technology and knowledge created by universities. Policy is at the university level, leading to the creation of diverse structures. Public schemes bring public money directly to universities. In France, the rationale for policy towards the creation of SBEFs is the development of high technology new ventures as part of a technological entrepreneurship policy. The notion of a third stream of financing for

universities is an argument that is never advanced. The UK has placed the universities at the heart of policies aimed at the creation of SBEFs, this is not the case in France.

2.2 Firm level

2.2.1 The role of TMT and boards

Founding teams in new ventures cannot be considered as a static concept (Vanaelst et al. 2006). Over the life of the venture, the team's composition will likely change as new members are added, including surrogate entrepreneurs (Franklin et al. 2001) and others leave the team. Core founding teams in SBEFs appear to be unbalanced in terms of being highly experienced in research and development, but lacking in commercial functions and applied technological experience (see e.g. Colombo and Piva 2008). However, adding new team members often does not seems to be associated with bringing in of individuals who can add to the cognitive heterogeneity required to help the firm to grow (Vanaelst et al. 2006). This problem may prolong the incubation period of SBEFs and lead to delays in ability to adapt business models to attain sustainable growth.

As SBEFs develop, they need to develop formalized boards, especially when the firm is created as a legal entity (Uhlaner et al. 2007). The boundaries of the founding team evolve into two new, overlapping teams, that is, the management team and the board. The board likely includes members of the founding team, the 'privileged witnesses' (such as TTOs) who have been advising on the development of the firm, and new members such as venture capital representatives.

In one of the few empirical studies in this area, Clarysse et al. (2007) examine the determinants of board composition in high tech start-ups and highlight the tensions that exist between the founding team and other stakeholders in determining board composition. They show that firms with powerful external stakeholders such as venture capitalists are more likely to develop boards that have complementary skills in contrast to those of the founding team while more autonomous teams tend to look for outside board members with similar human capital.

Bjørnåli and Gulbrandsen (2009) extend this work by analyzing 11 cases to provide insight into the dynamics of boards in SBEFs. Drawing on resource dependence, social network and stage-based theories, they explore board formation and changes in board composition occurring in Norwegian and US SBEFs. They find that the process of board formation is mainly driven by social networks of the founders. Although there are differences in the initial board compositions in Norwegian and US firms, there is convergence over time in subsequent board changes, which are mainly driven by the social networks of the board chair. Additions of key board members are associated with the progress of a SBEF from one development stage to another.

Despite these welcome developments, empirical research so far does not adequately reflect the necessary life-cycle in the development of boards. The concept of the life-cycle of corporate governance (Lynall et al. 2003; Filatotchev and Wright 2005; Filatotchev et al. 2006; Zahra et al. 2009) emphasizes that boards serve different purposes as the venture develops. At start-up, where ownership and management typically overlap extensively, the firm may not need a monitoring system. Rather, a governance system which enhances resources and knowledge is likely to be more important. However, for SBEFs to continue on their growth trajectory, there is a need to sustain the recognition and exploitation of entrepreneurial opportunities. Changes to the structural characteristics of boards associated

with professionalization of corporate governance may not necessarily achieve the goal of sustaining entrepreneurship and hence growth.

As SBEFs move through their stages of development, founder teams' contributions to entrepreneurship typically decline and there is a need to institutionalize processes and different sources of knowledge that can sustain entrepreneurship. The development of effective boards of directors may be important in fulfilling these roles. Effective boards protect shareholders' wealth by ensuring managers' accountability and can be a source of wealth creation, especially when outside directors bring in new skills and capabilities. The willingness of external stakeholders' to provide resource needed for growth is likely increased when boards introduce formal controls to increase managers' accountability to shareholders. SBEFs also need to learn new skills in order to develop the requisite absorptive capacity to recognize, assimilate and exploit new sources of knowledge, through expanding their TMT and the composition of the board. Zahra et al. (2009) suggest that boards and absorptive capacity complement each other in enhancing entrepreneurship in SBEFs that are moving beyond their initial stages of development. Further, effective boards can sometimes substitute for poor absorptive capacity and vice versa.

Zahra et al. (2009) argue that when accountability is low, i.e. boards are ineffective at protecting the interests of investors and absorptive capacity of the venture is low, entrepreneurial activities will decline and threshold firms' ability to create value or to grow declines. When low accountability is coupled with high absorptive capacity, high absorptive capacity can compensate for relatively ineffective boards and entrepreneurial activities will be moderate. When accountability is high and absorptive capacity is low, effective boards likely replace managers with low absorptive capacity, yielding moderate levels of entrepreneurship. Positive complementarities will be evident between effective boards and high absorptive capacity, promoting entrepreneurship. Empirical examination of these relationships remains to be undertaken.

2.2.2 Growth

It is often claimed in the entrepreneurship literature that the human capital of entrepreneurs and the (financial and non-financial) support provided by venture capital (VC) investors are key drivers of the growth of high-tech start-ups. Several studies have examined the relationship between the human capital profiles of entrepreneurs and superior firm performance. While there appears to be no consistent patterns of relationships, Shrader and Siegel (2007) have shown that employees with more human capital are associated with more effective implementation of technologies. Interestingly, in their examination of the influences of human capital on the growth of high-tech start-ups in Italy, Colombo and Grilli (2005) find that founders' years of university education in economic and managerial areas had a more significant positive impact than university education in scientific and technical fields. They also found that prior work experience in the same industry as the new firm also had a positive impact, specifically with respect to technical work experience. The commercial work experience of entrepreneurs did not contribute to growth, unless it was associated with industry-specific technical experience. This result points to the synergistic effects generated by a heterogeneous founding team (see also Cooper and Bruno 1977; Eisenhardt and Schoonhoven 1990). Entrepreneurs with prior business ownership experience may have had more opportunities to develop their human capital, particularly the specific human capital associated with identifying and exploiting opportunities. Colombo and Grilli (2005) indeed find that prior entrepreneurial experience results in superior growth.

A limited number of prior studies have analyzed the relationship between VC backing and firm growth, providing mixed evidence. Hellmann and Puri (2000) examined a stratified random sample of 149 VC and non-VC backed firms in Silicon Valley during the period 1994–1997 and found that VC backed firms, especially innovators, had a faster time to market. Manigart and Van Hyfte (1999) find that VC backed firms have higher asset growth than non-VC backed firms in Belgium. Engel and Keilbach (2007) use propensity score matching to identify a control sample of non-VC backed firms in Germany and find that VC backed firms generate faster employment growth. In contrast, Burgel et al. (2000) find that VC backing has no impact on the growth of firms in Germany and the UK. Other studies of the growth of VC and non-VC backed firms that went to IPO also show mixed results, with Jain and Kini (1995) and Audretsch and Lehmann (2004) finding positive effects of VC on growth, while Bottazzi and Da Rin (2002) find no effect.

Important problems with these studies include their often cross-sectional nature and a typical failure to address the issue of endogeneity in VC backing. Bertoni et al. (2008) using a 10 year panel study of 550 Italian high-tech start-ups show that VC backing, especially by financial VCs rather than corporate VCs, strongly spurs employment and sales revenue growth. A Spanish study of firms by Alemany and Marti (2005) using panel data analysis of VC-backed start-ups shows that both VC backing and its amount are associated with higher performance. Davila et al. (2003) show that VC backed firms have faster employment growth.

Interestingly, the interdependence between VC investments and entrepreneurs' human capital has gone almost unremarked in the literature. Colombo and Grilli (2008) is an exception. They examine the influence of the human capital characteristics of founders on the growth of VC backed and non-VC backed high-tech start-ups. Using a sample of 439 Italian firms and after controlling for survivor bias and the endogeneity of VC funding, they find that once a firm receives VC backing the role of founders' skills becomes less important in contributing to firm growth. This result points to the importance of the coaching function performed by VC investors in enhancing the performance of portfolio firms.

In addition to VC investors, SBEFs may receive a positive contribution to growth from interaction with other institutions. Among them, universities play an important role. Colombo et al. (2009) analyze empirically under which circumstances the universities located in a geographical area contribute to the growth of a special category of local high tech start-ups, those established by academic personnel (academic start-ups, ASUs). They examine the effects of a series of characteristics of local universities on the growth rates of ASUs and compare them with the effects of the same university characteristics on the growth of other (i.e. non-academic) high-tech start-ups. They estimate an augmented Gibrat law panel data model using a longitudinal dataset composed of 487 Italian firms observed from 1994 to 2003, of which 48 are ASUs. They find that universities do influence the growth rates of local ASUs, while the effects on the growth rates of other start-ups are negligible. Importantly, the scientific quality of the research performed by universities has a positive effect on the growth rates of ASUs, yet the commercial orientation of research has a negative effect. This study demonstrates that universities producing high-quality scientific research have a beneficial impact on the growth of local high-tech start-ups, but only if these firms are able to detect, absorb, and use this knowledge. Thus the authors caution that a greater commercial orientation of university research that leads to a reduction of the knowledge available for absorption by these companies can be detrimental.

2.2.3 Exit

Although there has been attention to the growth of SBEFs in the product market, their growth in the context of the financial market is also important, particularly if they are VC backed. Although IPOs tend to be most high profile, several studies have also pointed to the importance of trade sales as an exit route (Cumming and MacIntosh 2003, 2006; Murray 1994).

Bonardo et al. (2009) look at M&A dynamics of a sample of 131 SBEFs in Europe that went public during the period 1995–2003. They find that most of these firms were acquired after the IPO, notably by companies operating in the same industrial sector. After controlling for intellectual capital and other factors, SBEFs were more likely to be acquired than other independent firms. University affiliation enhanced attractiveness to other companies but was negatively related to the propensity to acquire. The higher availability of internal technological resources was an important contributor to the reduced propensity of SBEFs to pursue acquisitions. They suggest that the acquisition of a SBEF is the final stage in the process of knowledge transfer involved in academic entrepreneurship. SBEFs may have very strong growth prospects as they seem more likely to have platform technologies than other high-tech start-ups (Van de velde et al. 2008); this may both make them attractive acquisition targets but also reduce their need for acquisitions.

This work suggests interesting avenues for future research. First, SBEFs' growth trajectories may be influenced by the extent to which they are an important input to the development of further products by mature corporations, which may be a precursor to acquisition by the corporate partner. In other words, the possibility of becoming the target of an acquisition and thus the strategic position of a SBEF in the "market for assets", clearly has a bearing on its growth strategy in the "market for products". As a corollary, growth and acquisitions with SBEFs being either acquirers or targets, need to be studied jointly, a task that so far has not been undertaken by the extant literature. Second, it is interesting to investigate factors that may be important in filtering potential trading and acquisition partners. Technological and market relatedness are likely to figure prominently among them. In the M&A literature there is increasing interest in, and some divergence of findings regarding the effect of pre-acquisition technological and market relatedness on post-acquisition innovation and growth. Hagedoorn and Duysters (2002) found that market relatedness had a significantly positive impact on post-M&A output, while technology relatedness had no significant effects. In contrast, Cassiman et al. (2005) found that market relatedness negatively affected R&D input and R&D efficiency, while both R&D inputs and efficiency increased when merged firms were technologically complementary and decreased when they were substitutive. One may wonder whether these results also hold true for acquisitions of SBEFs. Third, one needs a better understanding of the innovation impact of these acquisitions on both the acquiring and target firms. The (limited) evidence available on acquisitions of high-tech start-ups by larger incumbent firms show that in spite of great popularity, these acquisitions often lead to dismal results (see e.g. Ernst and Vitt 2000; Paruchuri et al. 2006; Kapoor and Lim 2007): a large number of acquired inventors leave the company after the acquisition and those that remain exhibit poor innovation outcome. Studies that have tried to explain why these acquisitions often fail have placed overwhelming emphasis on whether after the deal, the acquired entity is kept as a separate subsidiary or is integrated into the acquirer's organization (Puranam et al. 2006, 2008; Kapoor and Lim 2007; Puranam and Srikanth 2007). While structural aspects of the post-deal reorganization are important, one needs to go a step further and consider management practices in greater detail. Colombo et al. (2009) argue that the degree of post-deal decision

autonomy granted to the individual acquired key inventors affects both the nature and the outcome of their innovation activity. The extent to which this occurs may be linked to asymmetries of inter-dependence between large corporations and SBEF partners associated both with size and bargaining power (Pfeffer and Salancik 1978).

2.2.4 Policy implications

The papers presented in this special issue have indicated that there is a proliferation of schemes to promote SBEFs and that these schemes differ across countries. Policymakers need to consider the potential for conflict between different policies and the different targets of policies. For example, policies to stimulate the growth of SBEFs may need to be more fine-grained than policies to stimulate entrepreneurial ventures in general. Moreover, policy schemes stimulating the creation of SBEFs are likely to differ from those required to support their post-entry development. Policy makers also need to recognize that acquisitions by and alliances with incumbent firms are often the most efficient mechanism to exploit commercially the innovative technological knowledge developed by SBEFs, and that policy schemes need to be adjusted accordingly.

How can the performance of this type of company be evaluated? Most studies show that the majority of SBEFs remain very small or grow slowly. Only 1 or 2% of them become fast-growing firms listed on the stock exchange. Consequently, job creation or financial returns for public-sector research institutions cannot be a valid reason for promoting the emergence of this type of SME, nor a criterion for evaluating their benefits. However, Mustar (1997) has shown that firms created by researchers are both very close to their clients/customers—who participate in the design of their products and services—and very close to research—with which most firms maintain ties. Thus they constantly serve as a medium for adaptation and interaction between science and the market—the very definition of innovation. In this way they act as a mediator between the research and industrial worlds (Mustar 1998). It is certainly in this role of translator, catalyst and mediator that the main advantage of this type of firm lies, for regional, national and European innovation networks (Mustar 2001).

The evidence presented by Colombo et al. (2009) adds to other evidence that emphasizes the importance of having a critical mass of high quality scientific research as a basis for the development of successful SBEFs (Wright et al. 2008a). Colombo et al. also stress that there is a need for absorptive capacity. While leading research universities may both possess a critical mass of high quality research and originate firms with the requisite absorptive capacity, this may be more difficult for mid-range universities being exhorted by policy makers to become more entrepreneurial. Mid-range universities may need to develop a broader portfolio of university-industry linkages both in terms of the scope of activities and the types of firms with which they interact.

There may also be an important role for developments in education for scientists and engineers to include exposure to issues relating to entrepreneurial activities. To the extent that scientists and engineers have been exposed to technology management education and training, this has traditionally focused upon structuring the product development cycle, making technology roadmaps and positioning technology strategy within the overall strategy of the company. In response to the demands to create SBEFs, there appears to be a move towards introducing more entrepreneurship-related training, including the development of the notion of 'bootcamps', that is intensive practical courses focusing on technological opportunity identification and business start-up (Clarysse and Mosey 2008). These demands raise major challenges for policy and practice. An important challenge is

the need for faculty with the expertise to provide entrepreneurial material. In universities, traditional business school academics likely do not possess the necessary context-specific business creation skills that are increasingly needed (Wright et al. 2008b). Instead, there is an emerging integration of business school type of education in engineering and technological faculties. There may be a need for more cross-faculty programs involving business schools and science and engineering schools and the employment of faculty with industry knowledge rather than research expertise per se and associated development of parallel career structures.

2.2.5 Further research

This special issue has focused upon SBEFs as the principal form of science-based entrepreneurship. However, a broader definition could include contract research and consulting; consulting as a route to entrepreneurship; and licensing and patenting as entrepreneurship (Wright et al. 2008a). Further research is needed to examine the conditions under which each approach may be more effective. These conditions may relate to the nature of the scientific context within which entrepreneurship emerges.

Studies have provided some insights into the development of boards in SBEFs. However, further research is needed to chart the transition of boards from their initial stage of formation through to their development in preparation for IPO and beyond. Similarly, while boards may emerge they may not be effective (Zahra et al. 2009), yet we know little about how ineffective boards may be changed to become more effective. TTOs, venture capitalists and corporate finance advisers may be used at different stages to introduce new board members with different skills appropriate to the particular stage the company has reached. For example, TTOs may be able to appoint outside directors who can both help academics to develop effective management and control systems as well as ensuring that the university's interests are met. VC investors may be better placed through their social networks to identify and introduce new CEOs with substantial experience in developing and listing high-tech firms, to enable the firm to prepare for exit. They may also be able to use their contacts to take the board to the next level of professionalization as it prepares for an IPO by bringing-in independent directors who are more likely to be credible to institutional investors, for example people who have run larger listed corporations. We have little detailed analysis of the processes through which these changes take place. For example, what conflicts arise in the transition from boards designed to protect university's interests to boards that meet the corporate governance standards of IPOs?

Studies are beginning to appear on the growth of SBEFs, but as yet there is limited work on the extent and scope of international growth by these firms. Bonardo et al. (this issue) show that academic start-ups are more likely to engage in cross-border M&A activity. Yet, international growth may be especially important for SBEFs to exploit the most important scientific innovations (Clarysse et al. 2005).

Social capital is important for entrepreneurship and has been identified as key to the successful negotiation of the early stages of SBEF development (e.g. Vohora et al. 2004). Mosey and Wright (2007) observe that the nature of social capital may be associated with the degree of prior entrepreneurial experience by scientists, with habitual entrepreneurs developing more external commercial social networks, while nascent academic entrepreneurs have more restricted social networks that TTOs do little to develop. Intermediaries may play a central role in the development of social capital that can help stimulate the growth of SBEFs. It is evident that intermediaries are heterogeneous, ranging from internal providers such as TTOs through to external providers like regional development agencies

and VC investors (Wright et al. 2008a), yet we have little systematic evidence on the comparative effectiveness of different types.

There is some evidence that experienced entrepreneurs are associated with greater growth in SBEFs. However, experienced entrepreneurs are heterogeneous in the nature of their business ownership experience. Specifically, entrepreneurial experience may be gained serially (serial entrepreneurs) or concurrently (portfolio entrepreneurs) (Westhead and Wright 1998; Westhead et al. 2005) and the behaviour of these entrepreneurs may be different. Ucbasaran et al. (2005, 2009), using a representative sample of all private firms, find that while portfolio entrepreneurs pursued innovative opportunities relative to novice entrepreneurs, serial entrepreneurs did not. These differences may be associated with the different mindsets of the two types of entrepreneur. Serial entrepreneurs tend to be concerned with autonomy while portfolio entrepreneurs are driven by wealth and growth, perhaps leading the latter group in general to pursue innovativeness in the opportunities they identify. The innovative behavior of experienced entrepreneurs may also differ according to whether their previous ventures have been successes or failures (Ucbasaran et al. 2009). As yet, we know little about the impact of this heterogeneity of entrepreneurial experience in the context of science-based entrepreneurship and this would seem to be a fruitful area for further research. For example, do science-based entrepreneurs become more risk averse if they have experienced failure? Do they seek to base subsequent ventures on broader technological platforms in order to reduce risks?

Further research is also required that examines the influence of VC investments on the performance of SBEFs. There is growing recognition in the VC literature that it is not simply the presence of a VC investor that is important but the role and expertise of the VC investor. Wright et al. (2004b) note the different expertise of VC investors in the context of early stage development of spin-offs in the UK. Bottazzi et al. (2008) find that VC firms whose partners have prior business experience are significantly more active in investee firms, while the influence of a science background for executives is weak. Bertoni et al. (2008) points to differences between financial and corporate VC in supporting the growth of portfolio firms. Analysis of this kind is needed in the specific context of SBEFs.

Indeed, as noted above, most SBEFs exhibit limited growth. It is then fundamental to get a better understanding of their contribution to society. For this purpose, it is important to closely examine their competitive and collaborative interactions with other firms. These include acquisitions by and alliances with other firms, including customer-supplier relations. The different channels through which the innovative technological knowledge developed by SBEFs may involuntarily spill over to and be absorbed by other parties also deserve a closer examination.

There remains a paucity of evidence regarding the failure of SBEFs. Recent rapid growth in the numbers of SBEFs may have involved the creation of firms that never get to the point of producing a product, let alone generating revenue. Some of these SBEFs may be able to raise significant amounts of VC and even achieve an IPO. Therefore, their failure may involve substantial welfare losses, as these resources may have been more effectively invested elsewhere. There is a need for research that examines the rationales for the failure of SBEFs at different stages of their development, and highlights the societal contribution of failing SBEFs.

Lastly, further research is also required that examines the issue of public intervention in this field. Evaluation of the existing schemes to foster the creation of SBEFs is lacking. Further, there is a strong absence of understanding of the complementarity between the diverse initiatives taken to promote these new ventures. A large number of issues are still open in this field. Are too many SBEFs being created in Europe? Since the number of spin-

offs created is becoming an indicator of the performance of universities and public research organisations, many very small firms without a real business model but with significant public support from national and local governments have been created in Europe. Are they created too early without even a preliminary proof of concept? It seems that in different European countries, there is a strong focus by existing schemes on the creation phase. But what about the development of these new firms? A large number of existing schemes aim to fill a presumed financial gap. Yet it seems that a knowledge gap prevails over the financial one (Wright et al. 2007). To fill this gap, intermediary structures (such as, advisors, coaches, TTOs and incubators) play a crucial role. The lack of quality or at least the lack of focus of many of these existing structures (which are mainly funded by public authorities) remains one of the main challenges in this field.

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