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Research Policy 33 (2004) 147–175
research policy
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Critical junctures in the development of university high-tech spinout companies

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Received 14 October 2002; received in revised form 13 June 2003; accepted 24 June 2003

Abstract

This paper investigates the development of university spinout companies (USOs). Employing a case-based research method, our study found that there are two important elements in their development. First, USOs go through a number of distinct phases of activity in their development. Each venture must pass through the previous phase in order to progress to the next one but each phase involves an iterative, non-linear process of development in which there may be a need to revisit some of the earlier decisions and activities. Second, at the interstices between the different phases of development we found that ventures face "critical junctures" in terms of the resources and capabilities they need to acquire to progress to the next phase. The different phases are critical as these ventures cannot develop into the next phase without overcoming each of the junctures. We identify four different critical junctures that spinout companies need to overcome if they are to succeed: opportunity recognition, entrepreneurial commitment, credibility and sustainability.

Keywords: Technology transfer; Universities; Entrepreneurs; Resources; Capabilities

1. Introduction

The creation of university spinout (USOs) companies represents a potentially important, but as yet under-developed, option to create wealth from the commercialization of research (Etzkowitz, 1998; Bray and Lee, 2000; Birley, in press; Siegel et al., 2003, in press; Shane, 2002a,b). Exploitation of these inventions, in what has historically been a non-commercial environment, raises new entrepreneurial challenges beyond those faced by new high-tech ventures in general.

The difficulties associated with new high-tech ventures are well documented. In general, the novelty of the venture and inexperience of the entrepreneur, give rise to a "liability of newness" (Stinchcombe, 1965; Singh et al., 1986). This barrier constrains the ability of the new venture during the early stages of growth to become an established firm in a market, capable of earning sustainable profits. Entrepreneurs need to overcome this challenge to achieve a succession of transitions from one phase of growth to the next.

University high-tech spinouts can also be characterized as new ventures in transition. Similar to other high-tech start-up ventures, university spinouts face considerable difficulties in achieving sustainable returns and financial profitability. However, USOs also face two fundamentally different difficulties. First, USOs face specific obstacles and challenges as they evolve from an initial idea in a non-commercial environment to becoming established as a competitive

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doi:10.1016/S0048-7333(03)00107-0

rent-generating firm. In particular, universities typically lack resources and academic entrepreneurs may lack commercial skills to create ventures in an attempt to commercialize technological assets. Second, conflicting objectives of key stakeholders such as the university, the academic entrepreneur, the venture's management team and suppliers of finance (such as venture capitalists) may adversely affect the venture's ability to make the transition from one growth phase to the next.

This paper aims to address these issues by providing an inductive empirical investigation into how USOs develop. Drawing on existing research into the life-cycle/stages of business development, and recent advances in the resource-based view (RBV) of the firm we specifically address two questions. RQ1: What phases do USOs go through in their development? RQ2: What are the key challenges these ventures face in their development?

To guide our inductive research, we drew upon two separate literatures to inform understanding of USOs and their development. First, we draw on the literature relating to stage-based models of new firm development. In general, stage-based models identify the organizational characteristics exhibited within each stage of development and suggest the changes required in the behavior and practices of entrepreneurs if their business is to progress to the next stage (Miller and Friesen, 1984; Smith et al., 1985; Van de Ven et al., 1984).[1] Stage-based approaches have increasingly recognized the role of feedback and the potential for non-linear development (Eisenhardt, 1989). We accommodate these aspects while seeking to understand when, how and why these transitions occur in the trajectory of USOs' development. Second, we draw on the resource-based view literature, which considers the firm to be a historically determined heterogeneous bundle of assets or resources tied semi-permanently to the firm's management (Penrose, 1959; Wernerfelt, 1984; Barney, 1991; Lockett and Thompson, 2001). Resource deficiencies, weaknesses and inadequacies may constrain the development of a USO (West and DeCastro, 2001) and may be exacerbated by an un-entrepreneurial university environment.[2]

A resource-based perspective suggests that in order to progress through different phases of development, USOs need to develop both resources and internal capabilities over time.[3]

The next section presents the methods of data collection and analysis. The third section presents an analysis of the empirical evidence, which is sub-divided into two sub-sections. The first sub-section examines the different phases that USOs pass through in their development. The second sub-section examines the junctures between the different phases of development that USOs must overcome as they seek to move to the next phase of development. We find that these junctures characterize the transitions between the different phases of development, and are fundamental impediments to USO development—i.e. they are "critical junctures" to the venture's development. Building on this notion, the fourth section presents a discussion of the underlying forces that give rise to these critical junctures. Finally, we conclude with a discussion of the implications of our findings for researchers and research policy.

2. Research design

This paper utilizes a detailed field study of nine USOs from seven different UK universities. The research design employed an inductive approach in order to obtain a rich understanding of how USOs evolve from research activities in to commercial organizations. The multiple case design permits a "replication" logic (Yin, 1994), allowing the case analyses to be treated as a series of independent experiments (Brown

[1] Several different models have been presented identifying three (Smith et al., 1985), four (Flamholtz, 1986) and five stages (Greiner, 1972; Churchill and Lewis, 1983; Scott and Bruce, 1987; Miller and Friesen, 1984; Van de Ven et al., 1984) in the development of a new venture.

[2] Academic inventors, due to commercial inexperience, may focus too much on the technical aspects of the innovation (Daniels and Hofer, 1993). To alleviate this problem "surrogate" entrepreneurs, as outsiders with commercial experience, may be brought in to work alongside the academic inventor to develop the venture (Franklin et al., 2001; Lockett et al., 2003).

[3] A distinction can be made between a resource as a stock (such as a brand name) and a resource as a flow or competence or internal capability (such as the ability to manage brand integrity) (Teece et al., 1997). This distinction emphasizes the importance of the firm's ability to develop internal capabilities since it is these factors that enable firms to learn over time and generate stocks of new resources (Penrose, 1959).

and Eisenhardt, 1997). This method allows for close correspondence between theory and data, a process whereby the emergent theory is grounded in the data (Eisenhardt, 1989; Glaser and Strauss, 1967).

We define the USO as the unit of analysis in this study as a venture founded by employees of the university around a core technological innovation which had initially been developed at the university (Birley, in press). The USO is created solely to overcome technical and market uncertainties inherent in the perceived commercial opportunity. This definition deliberately excludes those USOs traditionally regarded as *life-style* companies that are not established with the objective of creating a high return for their shareholders. We adopt the definition of high-tech sector as defined by the British Venture Capital Association (BVCA).[4]

The USOs selected were all created to commercialize intellectual property (IP) initially generated within the parent universities. These universities were selected on the basis that they are among the top 10 research elite universities in the UK (as measured by research income earned) and that they are actively pursuing a program of university technology transfer (both through both licensing and USOs). However, each of these seven *parent institutions* had a different orientation towards the commercialization of research, which is reflected in their idiosyncratic cultures, values and institutional norms. The USOs selected were all ventures that were explicitly seeking, or had secured, external equity finance.[5] Therefore, all the USOs in our sample are high-tech ventures that have emerged from universities. The aim of these ventures is to provide a return to their equity investors in a timely fashion. In developing the sample, we intentionally selected the cases from a range of fundamentally different technology platforms covering biological, chemical, physical, and computer sciences as well as engineering. Finally, each of the cases is at a different stage of development, allowing greater insights into specific stage-related growth issues. Table 1 describes the nine cases.

Following Eisenhardt (1989), our sample of USOs and parent universities from which they emerged were selected to contain a substantial degree of variance. This variance includes stage of development, technological focus and university environment. This degree of variance is important to enable us to generate insights into the general process of development of USOs. The variance enables us to be able to investigate possibility of replication logic across cases.

Data were collected using in-depth face-to-face and telephone interviews with representatives from the nine USOs, as well as each of their financial investors and seven associated universities over the 12-month period from July 2001 to July 2002. In conducting each case study, we followed the approach outlined by Eisenhardt (1989). First, background material was collected for each of the institutions about how they organized their technology transfer activities. From this data, a list of interviewees was compiled. For each of the cases, semi-structured interviews were carried out with the head of the university technology transfer office (TTO) (or equivalent), a range of business development managers (BDMs) and the members of a USO who had taken the venture through the process at the university. This included both the academic entrepreneur (inventor) and the externally introduced "surrogate" entrepreneur (Franklin et al., 2001) where applicable. It also included seed stage investors that had provided financial resources in each of the USOs. Finally, we interviewed the head of each department from which the USO originated. The interviews ranged in duration from 1 to 2 hours and were openly recorded and afterwards transcribed. By using a number of key actors from each university, we ensured that we elicited views on the universities' role in the spinout process to cross-check our interpretation of events.

Responses from the interviews were used to develop a case study database, which included table shells to record data (Miles and Huberman, 1994). These table outlines ensured that the data collection was focused on the research questions and verified the same information was being collected for all cases. Once the individual case studies were complete, we used

[4] The BVCA's definition of high-tech relates to the following sectors: Communications, Computer Hardware, Computer Internet, Computer Semiconductors, Computer Software, Other Electronics related, Biotechnology, Medical, instrumentation and Medical Pharmaceutical (see: <http://www.bvca.co.uk>). This definition has been employed in previous studies because it provides and operational way in which firms can be categorized as high-tech or non-high-tech (see: Lockett et al., 2002).

[5] We excluded industry-backed collaborative spinouts as we consider them to be qualitatively different from external equity-backed USOs. Analysis of these ventures is an interesting area for further research.

Table 1
Descriptions of the high-tech university spin out companies

Spin out company	Technology	Current growth phase	Venture champion	Initial financing
Optical	Design and manufacture of telecommunications network equipment	Sustainable returns phase	Surrogate entrepreneur	VC invested £ 1 million for a 20% equity share
Silicon Microchip	Design and manufacture of diagnostic monitors and sensors	Re-orientation phase	Surrogate entrepreneur	Angel invested £ 330,000 for a 15% equity share
Human Genome	Anti-viral drug discovery and development	Re-orientation phase	Academic entrepreneur	Angel invested £ 650,000 for a 50% equity share
Software	Diagnostic software for the automotive industry	Re-orientation phase	Academic entrepreneur	Angel invested £ 200,000 for a 15% equity share
Virtual Reality	Virtual reality software for the manufacturing sector	Pre-organization phase	Academic entrepreneur	None received
Biomedical	Drug delivery and patient monitoring equipment	Sustainable returns phase	Academic entrepreneur	Financed through sales
3G Wireless	Mobile telephone equipment design	Re-orientation phase	Surrogate entrepreneur	VC invested £ 250,000 for a 15% equity share
Stem Cell	Drug discovery and treatment development for healing human tissue	Sustainable returns phase	Academic entrepreneur	VC invested £ 8 million for 55% equity share
Materials	Technology for analysis of material surface coatings	Re-orientation phase	Surrogate entrepreneur	£ 25,000 loan

cross-case analysis, relying on methods suggested by Miles and Huberman (1994) and Eisenhardt (1989) to develop common and differential factors. Conceptual insights were in turn drawn out and refined during an iterative process as the case studies progressed. Triangulation was also aided by the collection of archival data (Deshpande, 1983; Yin, 1994), including university level information. Spinout company information such as business plans, patent filings and published press articles were also collected where available. To avoid confirmatory biases, one of the authors was kept at a distance from the field observations and focused on conceptualization and analysis of the material and interpretations developed by the other researchers (Doz, 1996).

3. Empirical evidence

The data suggest three key conceptual findings. First, USOs develop in a non-linear fashion over five distinct phases. Second, by examining the interstices between these five phases our results showed that USOs encounter "critical junctures" that must be overcome in order to make the transition from one phase of development to the next. Identifying these critical junctures is important because they characterize inherent conflicts that exist within the USO venture preventing development. Third, by examining the USO ventures both before and after each transition, we found them to be qualitatively different in terms of their resources, capabilities and social capital. These findings are examined in turn. Importantly, we recognize that USOs emerge not so much through discrete stages of growth but rather through non-linear "phases" of development separated by critical junctures. Furthermore, the imperative for the USOs management is the need to anticipate and focus on how to overcome each "critical juncture" in order to progress towards the next phase of development. We prefer the term "development phase" as opposed to the term "growth-stage" employed in the existing literature, in order to capture the essence of fluidity of USO, which are ventures in transition.

3.1. The phases of growth

In the following section, we present the case material relating to the different phases which the nine cases encountered in their development. These phases

we identify as the: (1) research phase; (2) opportunity framing phase; (3) pre-organization phase; (4) re-orientation stage; and finally (5) sustainable returns phase. Each phase is intended to characterize a specific group of activities as well as strategic focus that the firm must accomplish before it can move to the next phase of development. A diagrammatic representation of the different phases is presented in Fig. 1. Our analysis indicates that USOs move through a number of successive phases in their development in an iterative non-linear way.

A summary of the data relating to the distinct phases experienced by each USO is presented in Table 2. We draw on this data in expanding our arguments below.

3.1.1. Research phase

It is important to state that to begin with each of the USOs, we studied emerged from scientific research that has taken place over a number of years within university academic departments. In the case of Stem Cell, the research program that ultimately led to a commercial opportunity began in 1982 when the academic inventor was a post-doctoral student. Analysis of the case study data demonstrates that the main focus for all the academic entrepreneurs (or academic innovators) interviewed, prior to the commercial opportunity being recognized, was on perfecting academic research and publication of their work towards a particular scientific community. This point was encapsulated by the academic entrepreneur who formed 3G Wireless, who stated that, "... when you're a young academic, the mentality is publish or perish. It's the only way you get recognized and rewarded." Within this research phase valuable intellectual property is created, which then generates the potential opportunity for commercialization. All the academic inventors involved with each USO case we studied were at the forefront of research in their chosen fields and had created valuable know-how and technological assets. This finding is consistent with existing research suggesting that technology USOs are typically founded by the more successful scientists and that inventors in areas where they are not experts in their field run into particular problems with obtaining strong intellectual property protection for the spin-off (Shane, 2003). For example, in the case of Silicon Microchip, the surrogate entrepreneur described how the academic's research findings "... had played a major part in transforming manufacturing in the electronics industry". This research provided the intellectual property to underpin establish the venture.

3.1.2. Opportunity framing phase

During this phase, the transition between a recognized opportunity and the formative steps to creating a new USO venture mainly focuses on the academic and the TTO. In each case, either independently or together, the academic and the TTO worked towards examining whether the recognized opportunity had sufficient underlying value to warrant further effort in pursuing commercialization. This "screening" process first involves evaluating the technology and to ensuring there is sufficient evidence that it actually works and shows sufficient promise for applications outside the laboratory.

Once the opportunity had been evaluated for technological validity and performance, attempts were made to "frame" it within a commercial opportunity. With varying degrees of success, the academic entrepreneurs and TTOs tried to identify alternative "markets", what applications of the technology to develop for those markets and how best to access customers to target with the innovation.

Initially, this proved to be a challenge for each of the academic inventors in all the cases studied and led to opportunities that were defined imprecisely, targeted ambiguously and which turned out to be impracticable. All suffered from a lack of understanding of how best to maximize returns from commercial exploitation and inexperience in framing scientific discoveries in relation to creating commercial value from them. For example, the academic inventor from Human Genome realized her research efforts had produced a novel technology but faced "pervasive uncertainty" over how best to realize the commercial value of the IP in the marketplace. A lack of clarity over suitable applications to develop from the technology, how these applications would perform commercially in alternative markets and the routes available for accessing those markets can lead to insurmountable barriers for the entrepreneur and university wishing to create a new USO venture to commercialize the technology. Unless they either possess or can access relevant experience and specific capabilities to successfully frame opportunities so that they show promise of creating value and generating returns, they are likely to make little

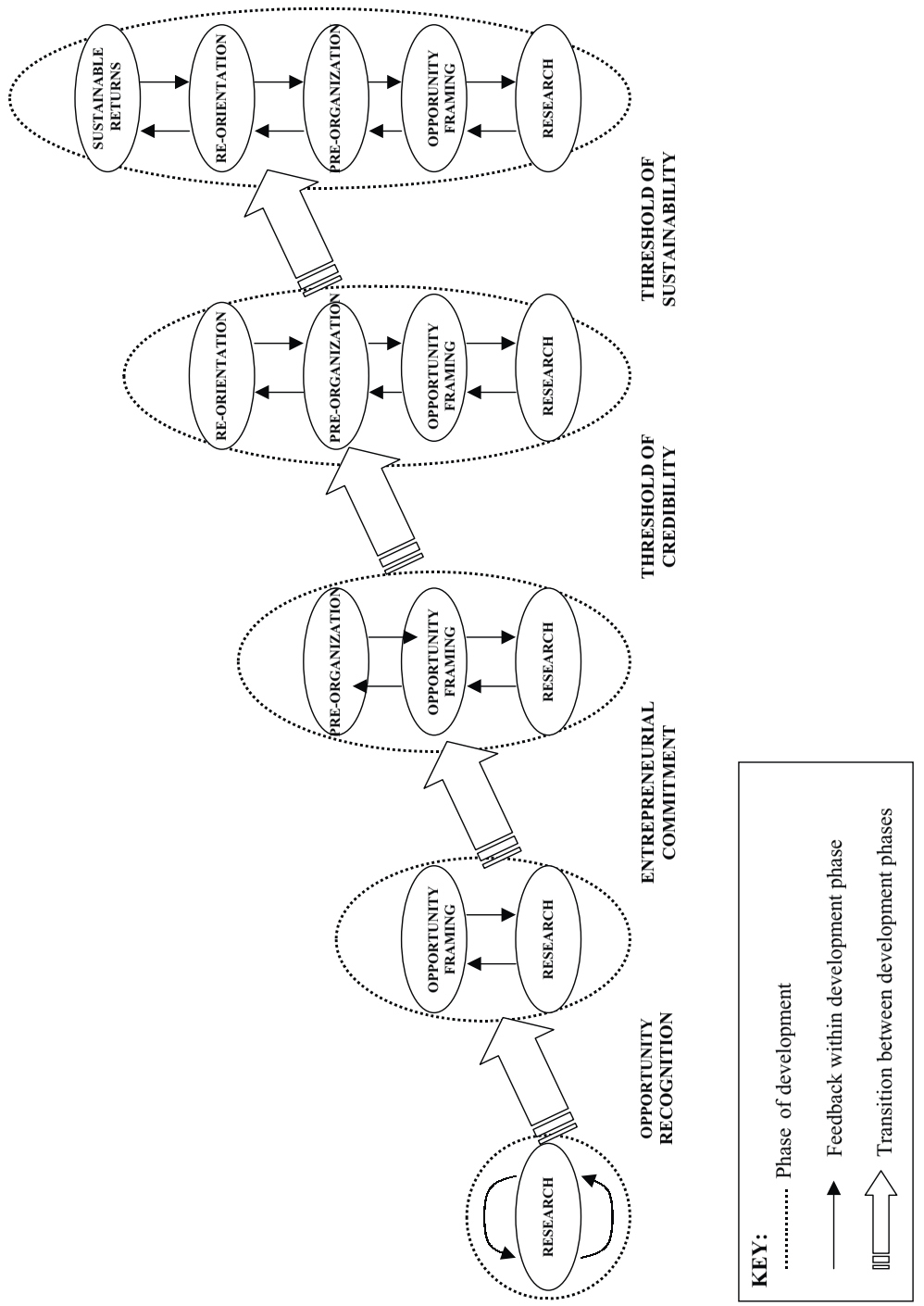

Fig. 1. The critical junctures in the development of university spinout companies.

Table 2
Characteristics of the different growth phases

Spin out company	Research phase	Opportunity framing phase	Pre-organization	Re-orientation	Sustainable returns
Optical	Academic team focused on maintaining its world-wide reputation through publishing the results of its scientific research into the application of fiber optics in materials and telecommunications	A surrogate entrepreneur who had worked in the telecom industry commissioned a feasibility study into potential market applications of the researchers technology	Surrogate used his network of contact to gain access to necessary resources. A business plan was prepared. An initial investment of £ 1 million was secured from a venture capitalist	Early prototypes failed Team had developed sufficient IP and market intelligence to realign strategy towards new opportunities Company reorganized with changes in human resources to reflect requirements of the new strategy	The business is profitable and continues to grow by exploiting new IP created by its engineers and the university The VC reinvested £ 6 million
Silicon Microchip	Technology emerged from a large, well-regarded team of physicists and chemists dedicated to researching the fundamental science of silicon-based nano-technology	Results from industry sponsored research showed the lead academic that the new technology significantly increased the speed of obtaining results, enabled improved device performance, cost reduction in comparison to existing technologies	The academic developed a prototype device Social and industry networks were used to identify possible routes to market Surrogate developed a business plan, recruited engineers and management, and secured seed finance	Team searched for premises in a commercial environment, off university campus A financial director joined the company The activities of the company were reorganized in order to better position it attract venture capital	The spinout has not yet entered this phase
Human Genome	A biomedical scientist worked on designing new protein molecules based on an industry sponsored research project	The scientist realized from experiments that he had created a set of new protein molecules that could combat a particular viral infection in humans	Patents were filed for and acquired for the new invention A business plan was written and used to secure public funding for early stage clinical trials	The team continued to develop the technology and discovered new market applications that were more lucrative A chairman and CEO came on board to help commercialize the technology in these new markets	The spinout has not yet entered this phase

Table 2 (*Continued*)

Spin out company	Research phase	Opportunity framing phase	Pre-organization	Re-orientation	Sustainable returns
Software	A team of academic scientists and engineers from industry were researching methods to computerized control vehicle systems. A large automotive manufacturer sponsored the research	Whilst working with an industry partner, the academic identified key applications to fulfill the need for intelligent software and diagnostic systems to serve the automotive industry	Academic brought together a team to support the venture Team designed a product development plan based on their industry and academic backgrounds Team networked with contacts to acquire market intelligence Licenses acquired from university	Original business plan became irrelevant as the team interacted with potential customers Better applications for the technology were discovered The commercialization strategy diversified to target profitable niche markets	The spinout has not yet entered this phase
Virtual Reality	Academics took existing technology from the lab and began to carry out research into novel applications of it across a range of industries	From interacting with industry research partners, the academic found out that the technology had potential commercial applications in a number of manufacturing sectors	Research was carried out on existing and competitor products Academic liased with the university technology transfer office to create a business plan. Prototypes were developed	The spinout has not yet entered this phase	The spinout has not yet entered this phase
Biomedical	A team of academic scientists carried out industry sponsored research to transfer discoveries made in the field of physics into areas of medicine and biochemistry	The academics discovered a new approach to a drug delivery mechanism in the human body and began running early laboratory trials to develop the mechanism	Academic team searched for and located commercial premises on a nearby science park Academic team financed development and testing by themselves Key personnel identified to direct operations	The focus turned to attracting profitable customers and developing the technology to serve their needs A major difficulty was managing rapid growth and learning how to integrate new resources into the venture whilst keeping focused on growth targets	The business became profitable shortly after formation Annual revenue growth has averaged 65% over five years 140 staff employed The entrepreneurs are now positioning the business for an IPO or trade sale

3G Wireless	A leading academic in the field of electronics and telecommunications was sponsored by industry to carry out research to design new telecom systems	A surrogate entrepreneur with industry experience guided the academic into developing a platform technology that could be applied to several different electronic device markets	Business plan created around the most lucrative market opportunity Key human and physical resource identified Prototype devices developed Venture capital firms contacted	Seed funding used to develop the technology to a state of market readiness Teams structures were built around projects The original target market crashed and customers disappeared Alternative market opportunities were investigated and product strategy redefined	The spinout has not yet entered this phase
Stem Cell	Pharmaceutical industry sponsored a research group to study cell and tissue behaviour under certain conditions	The research provided sufficient evidence to compel the lead scientist to develop a treatment for human skin complaints. Sponsored by industry, the group filled over 100 patents	Academic used industry and social contacts to learn how the market operated Research staff and management identified for new venture IP due diligence carried out	The academic entrepreneur became the CEO and recruited high quality human resources from industry Knowledge from experts was integrated to create organizational structures functions and routines An R&D lab was created off campus to generate new IP for commercialization	There is strong growth in new patents and development of products ready for commercialization Early products have become successful in the market The entrepreneurs are positioning the business for second round funding and a future IPO
Materials	The research group focused upon determining the fundamental factors governing growth and formation of new synthetic materials	Tests carried out in partnership with industry confirmed efficiency improvements of 97% over existing methods and hence presented a potential market opportunity	Networks of contacts used to acquire information, lab equipment, facilities and finance Market research carried out to benchmark competitors Business plan created	The team focused upon identifying new markets for the technology in order to build revenues It was challenging to grow the company organically, and acquire necessary resources whilst financially constrained	The spinout has not yet entered this phase

progress. This point was described by the VC that rejected a business plan submitted by Virtual Reality:

> At this early stage the fundamental problem is that what universities have is not what VCs want to receive. Universities have lots of well-developed technologies but with little proof of concept, no proof of market, and no commercial management. In general there isn't the commercial expertise or resources within universities to overcome these deficiencies and develop an opportunity that is fundable.

Other VCs we interviewed echoed similar descriptions of these deficiencies that lead to poorly developed opportunities. Evidence collected across all nine cases leads us to propose that initial opportunities recognized were not the best means of exploiting the full potential commercial value of the technological resource. These opportunities did not define precisely which complementary resources (human, physical, financial, technological) were required further down the line, where to access these resources or how to acquire them. We found that only in Stem Cell, Optical, Biomedical, and 3G Wireless did the USO entrepreneurs thoroughly explore alternative commercial scenarios for a variety of potential applications of their technology. These same entrepreneurs were the only ones to scrutinize these opportunities together with potential investors, customers and others in their industry in order to discover and assess potential risks from inherent weaknesses, deficiencies and inadequacies. For these entrepreneurs, framing and re-framing the opportunity became an iterative exercise played out over many months and even years where Biomedical and Stem Cell were concerned. For example, the academic entrepreneur from Stem Cell encountered difficulties pursuing his original opportunity when trying to attract industrial partners that had sponsored the scientific research to co-develop his technology into product applications:

> Commercial partners and industry were not interested. It was so early stage they thought it was a bit wacky. They all had first option to acquire the patents that had been filed from the sponsored research but did not take any of them up which left the university in an interesting position with a huge patent portfolio to exploit commercially.

As a result the opportunity was re-framed in order to take account of what the academic had learnt: industry's lack of desire to license or co-develop early stage technologies in this field and a preference instead to market later stage technologies that showed a high probability of generating commercial returns. Instead of selecting licensing or co-development as route to market, the academic entrepreneur had learnt that the best route to market was to assemble the necessary resources and develop the capabilities required to exploit the IP himself through a USO venture.

3.1.3. Pre-organization phase

Having framed the opportunity during the previous phase and committed to commercially exploiting it, the management of the USO venture can develop and start to implement strategic plans during the pre-organization phase. For all cases, this involved taking decisions over what existing resources and capabilities to develop, what resources and knowledge to acquire now and in the future, as well as when and where to access these resources and knowledge. In general, it was found that decisions taken at this early stage had an unforeseeable impact upon the entire future success of the USOs since they directed the path of development and alternatives that were available to the firm at a later date. Mistakes made when the venture has a limited resource endowment can be detrimental to the venture's future success. The surrogate entrepreneur from Silicon Microchip explained:

> Prioritizing what markets to focus our efforts on and how to use our limited time and money were the most important early decisions taken when putting this business together. The outcome [of these decisions] has made an impact upon the results we have been able to achieve up to now, particularly with reference to demonstrating proof of concept and proof of market to potential investors .... In hindsight we really ought to have selected engineers with more experience to form our product development team and we should have put more effort into finding our own premises somewhere away from the university campus .... These mistakes have slowed our progress and lost us potential market share.

The importance of these early decisions and how much they can cost an entrepreneur in greater time to

market, lost revenue and a lack of venture capital investment, places prior entrepreneurial experience, human capital and access to networks of expertise at a premium. From examining each case, we propose that the pre-organization phase represents the steepest learning curve for the *academic* entrepreneur. This is particularly likely if they have little or no commercial experience or knowledge of how their target industry operates and few existing relationships with business people, surrogate entrepreneurs, business angels and venture capitalists.

In the case of Optical, Biomedical, 3G Wireless and Stem Cell, these entrepreneurs were more attuned to the challenges of accessing, acquiring and coordinating the allocation of resources. In fact, the entrepreneurial teams involved in these USO ventures spent more time and effort in developing existing resources and capabilities as well as acquiring new resources and the knowledge to assemble new capabilities. These entrepreneurs went to great lengths to gain the commitment of key individuals who would supply the initial capital and knowledge to enable the venture to commence business operations. Achieving this commitment relied heavily upon the level of social capital the entrepreneur was able to leverage, through their own network of contacts (e.g. Biomedical), through the networks of their investors, or by employing professional head-hunters to screen, evaluate and benchmark new members of the management team (e.g. Stem Cell). In the case of 3G Wireless and Optical, the TTO's venturing experience and social capital helped the entrepreneur to access and secure resources and expertise.

In contrast, during the pre-organization phase, the entrepreneurs involved in Silicon Microchip, Human Genome, Software, Virtual Reality and Materials attempted to launch their USO ventures with inadequate levels of relevant resources. This leads us to propose that insufficient entrepreneurial experience coupled with limited access to mentors, advisors and other sources of business venturing expertise to guide them through shaping an embryonic USO venture affects their ability to achieve strategic objectives in later development phases. The outcome of any "mistakes" became clear during later interviews we conducted which highlighted the decisions taken during the pre-organization phase that subsequently created resource weaknesses, inadequate capabilities and social liabilities in later development phases.

3.1.4. Re-orientation phase

Once the USOs had gained sufficient credibility to access and acquire requisite resources to start-up the business, they each attempted to generate returns by offering something of value to customers. As a result of these attempts, during the re-orientation phase, the entrepreneurial teams faced the challenges of continuously identifying, acquiring and integrating resources and then subsequently re-configuring them (Galunic and Eisenhardt, 2001; Eisenhardt and Martin, 2000; Teece et al., 1997). This re-configuration was particularly prevalent if the venture was formed with poor endowment of capital and inexperienced management. Along the way these teams learned how to develop newly acquired resources, information and knowledge and assembled new capabilities. Assembling these capabilities and organizational routines was necessary for the USOs to generate returns from productive activities. All entrepreneurial teams that had reached this phase of development exemplified this imperative, as articulated by the academic entrepreneur from Biomedical.

> Managing growth over the last eighteen months has been the real challenge because our management systems have had to evolve not monthly, not weekly but sometimes daily to adjust to internal and external changes. We were constantly aware of what deficiencies were constraining the company's growth. The problem was knowing how to acquire the resources and expertise to fulfill that deficit and also how to integrate them into the firm. That's the challenge of growth.

From examining the USOs concerned before, during and after this development phase, what transpired was a great deal of change as a result of information and knowledge acquired by the entrepreneurial team from interactions with customers, competitors, suppliers, as well as potential investors. In the case of Human Genome, 3G Wireless, Optical, Silicon Microchip, and Materials, these changes were dramatic enough to alter three key decisions taken in earlier development phases. First, how the entrepreneurial team created value from developing its existing technological resources and capabilities changed. Second, from

whom these USOs generated returns changed. Third, how these USOs generated sustainable returns from the market also changed. For example, after disappointing results in the telecommunications market, 3G Wireless realigned their strategy to target a new category of customers:

> After realizing we could make more money from targeting our current competitors instead of competing with them for business, we literally tore up our original business plan. This realization transformed our perception of what value we could offer the industry with our technology. When we moved up the industry 'food chain' having recognized that our technology platform could span across several hardware markets we found multiple sources of revenue from different market channels . . . which attracted new investors to our venture.

In a similar scenario, Human Genome transformed its business completely having spent a year trying to develop a medical device based on their technology. Not only did the entrepreneurial team recognize that they were wasting their resources and efforts on a market that was too small, but more importantly, they were marketing their technology in the wrong way:

> We failed to get our technology to market the first time around but in the process we realized just how much we had underestimated the value of what we had. In fact if I had known how this industry operated to begin with I would have seen the *real* opportunity much earlier. . . . Yes we did waste time and money doing things we shouldn't have but were lucky our angel investors came round to this realization too . . . they continued to back us financially to make the necessary changes to the business.

In the cases of Human Genome, 3G Wireless, Optical, Silicon Microchip, and Materials, it became increasingly clear that weaknesses, inadequacies and deficiencies that had existed during earlier phases, within individual academic and surrogate entrepreneurs as well as their TTOs lead to problems and crises in later development phases. Prior imprudent strategic decisions and commitments made during these earlier phases meant the value these USOs were attempting to create and exploit could not be realized. First, these entrepreneurs and TTOs were less adept at developing the scientific discovery to create maximum value from technological assets during the opportunity framing phase. It appeared that during the opportunity framing phase too much emphasis was placed on developing the technology and too little on identifying, accessing and targeting key customers in the value chain.

Second, these entrepreneurs were less competent in accessing the right resources, information and knowledge during the pre-organization phase. In the case of Human Genome, 3G Wireless, Optical, Silicon Microchip, and Materials, numerous iterations of resource configurations and strategic refocusing were necessary. The key adaptations these firms undertook included how the technology was applied to meet previously unrecognized customer needs, how to gain access to markets and how to access and acquire further resources.

The knowledge acquired from recognizing and correcting mistakes from previous flawed decisions was continuously applied by the entrepreneurial teams in reassembling and building stocks of resources and internal capabilities as well as perfecting the technology. The surrogate entrepreneur from Silicon Microchip impressed upon us how his USO required:

> . . . continuous repackaging to incorporate technological advances within the business model, as well as closely monitoring a constantly changing marketplace to keep ahead of alternative technologies and rival competitors who are going after the same chunk of venture capital funding.

This "continuous repackaging" illustrates how USOs can be regarded as experiments to test the size of particular markets or whether particular technologies or ways of competing are promising (Cooper, 2001). All the USOs that entered this phase faced some degree of turbulence in their development due to learning how to manage the evolution of different aspects of the business in parallel.

In contrast to the USOs that encountered problems that led to stagnated development during this phase, Stem Cell, Biomedical and Optical all managed to adapt their original business plans to internal resource constraints and external environmental changes more easily. The requisite resources, social capital and capabilities that enabled these USOs to perform better when faced with adversity or strategic uncertainty all relate back to the opportunity framing

and pre-organization phases. We would propose that the success of USOs in progressing from this phase of development into the next is largely dependent upon the preparatory work done during these earlier phases by the entrepreneur and the TTO. In particular, the path dependent effects on the USOs we studied of inadequate initial resource endowment, social liabilities lack of entrepreneurial coaching and insufficient business assistance to develop entrepreneurial capabilities, stifled the growth of Silicon Microchip, Human Genome, Software and Virtual Reality during this phase.

3.1.5. Sustainable returns phase

The final phase is characterized by the USO attaining sustainable returns. The fundamental objective of the entrepreneurial teams is to access and re-configure resources to assemble the capabilities which enables the venture to reach such a phase. In arriving at this phase of development, the USO will have addressed many of the early uncertainties via the resolution of its precise business model. For example, Optical had achieved exactly that and emerged from the re-orientation phase as an aggressive, highly focused business. On behalf of his team, the CEO highlighted what enabled it to become established as a sustainable firm.

> We knew we had moved on from becoming a chrysalis university (high-tech) spinout to a proper high-tech company when we started to get some traction in the marketplace. We hammered home to the whole team that we're a business which exists by winning orders, shipping products and making money—the science and technology are just part of that equation.

Optical, Biomedical and Stem Cell had all overcome numerous obstacles to achieve a more sustainable phase of development based upon achieving sufficient returns from productive activities. Continued development was supported by further rounds of financing by existing and new syndicated investors. An executive at the VC firm that was the lead investor in Stem Cell described how this was achieved:

> Our sole objective was to get next round funding for this venture. The only way to get next round funding is by doing the right things in the business that translates into boxes that you can tick that say 'value' to the next round investor. There needs to be professionally managed development of the technology platform and new IP being created. There needs to be a management team with solid commercial experience. The business needs to have an identity of its own to emerge from the shadows of the university to become a tangible business.

Biomedical was a USO that had managed to successfully achieve this transition and become a firmly established competitor in its market as the founding academic described:

> We reached critical mass twelve months ago and we've grown the company by 77 percent in the last financial year, at a turnover of £6.7 million. We're now on target to do £11.2 million in the current financial year, and have grown to a staff of 140 people. If I walk away now, the business is sufficiently established to sustain itself.

Typically in this phase, USOs such as Biomedical move off the university campus into a commercial environment, perhaps within a university affiliated science park or incubator. However, even though the USO has moved out of the research laboratory and established its own commercial identity and self-sufficiency, it will almost certainly have retained close links with the university. This occurred via at least one of the academic inventors remaining at the university engaged in scientific research whilst acting as a technical advisor to the USO.

3.2. The critical junctures

In order to develop its full potential and become an established firm generating sustainable returns, the USO venture must successfully make the transition between the different development phases outlined above. These transition phases create what we term "critical junctures" for the firm. We define a critical juncture as a complex problem that occurs at a point along a new high-tech venture's expansion path preventing it from achieving the transition from one development phase to the next. The venture reaches a performance threshold from where its continued development is constrained.

These critical junctures are identified as: (1) opportunity recognition; (2) entrepreneurial commitment (3) venture credibility; and (4) venture sustainability. In

order to demonstrate these points, we have inserted the critical junctures into Fig. 1. The following section presents the case study evidence relating to each critical juncture. A summary of the evidence is presented in Table 3 and is referred to below in the text.

3.2.1. Critical juncture A: opportunity recognition

The critical juncture of opportunity recognition lies at the interface of the research phase and opportunity framing phase. Opportunity recognition is the match between an unfulfilled market need and a solution that satisfies the need (Bhave, 1994) that most others have overlooked (Ucbasaran et al., 2001). Thus, opportunity recognition involves capturing break through ideas that trigger an evaluation, as a precursor to the formation of commercialization effort (O'Connor and Rice, 2001). Relatively little is known about the process leading from opportunity recognition to the creation of a new business (Delmar and Davidsson, 2000). However, we do know that the possession of idiosyncratic information allows people to see particular opportunities that others cannot, even if they are not actively searching for such opportunities. The importance of idiosyncratic information was illustrated by the co-founding academic entrepreneur of Stem Cell:

> The discovery was a chance insight based on research we were doing in a different field at the time, and it struck me as amazing. I began a dedicated research program to investigate why this phenomenon occurred. From previous work I had done in industry I knew there and then that there were potential commercial products to come out of this because it solved a major medical problem more effectively than current treatments. The potential to deliver benefits to patients was clear.

The ability to make the connection between specific knowledge and a commercial opportunity requires a set of skills, aptitudes, insights, and circumstances that are neither uniformly nor widely distributed (Venkataraman, 1997). From our case evidence, we are able to identify overcoming the critical juncture of opportunity recognition as the ability to synthesize scientific knowledge with an understanding of markets that is enhanced significantly by higher levels of social capital in the form of partnerships, linkages and other network interactions.

The inherent conflict we found at this juncture was that universities and academics possessed significant technological know-how yet had insufficient knowledge of how to serve markets and unrealistic expectations of the profits that could be derived from the technologies they had discovered. This point was made clearly by a VC that had invested successfully in Optical:

> A lot of the propositions that we have seen from universities looking for seed funding for a spinout resemble research grant applications focused on further principle research. They need to put a commercial flavor on top of that to show how they are going to create commercial value for investors. From the market's perspective, in general universities just don't know, and are not best placed to know, what 'good' looks like.

This leads us to propose that without developing, acquiring or accessing the capability to combine scientific knowledge with a commercially feasible offering that satisfies an unfulfilled market need, academic scientists would not be able to proceed towards commercializing their technologies.

3.2.2. Critical juncture B: entrepreneurial commitment

Bird (1988) asserted that an entrepreneur's ideas and intentions form the initial strategic template of a new organization and are important underpinnings of new venture development. Since intention precedes venture formation, it plays a critical role in the initial conditions of the new venture (Gersick, 1991). In practice, intentions are no substitute for sustained persistence and committed actions in order to add value to an emerging business venture (Erikson, 2002). In order to move from the opportunity phase to the pre-organization phase the critical juncture of entrepreneurial commitment must be overcome. Entrepreneurial commitment is necessary for a potential venture to be taken forward from a vision that the academic has created mentally, to the formation of a business that is operational and engaged in business transactions.

Whereas entrepreneurial intentions define a state of mind, entrepreneurial commitment can be defined as acts which bind the venture champion to a certain course of events. The co-founding academic

Table 3
How spinouts encountered the critical junctures

Spin out company	Opportunity recognition	Entrepreneurial commitment	Threshold of credibility	Threshold of sustainability
Optical	The surrogate entrepreneur recognized the opportunity almost by accident whilst engaged with academics in the design of applications of their technology	The senior academics on the research team did not want to leave their posts The surrogate entrepreneur was strongly committed to commercializing the technology	Academic and surrogate entrepreneur realized they needed to form a strong team and put the building blocks into position before approaching a venture capitalist	The first two development projects failed, due to design mistakes and a shift in the market, making the original opportunity technically unfeasible and unprofitable The spinout had to adapt and stay on course for profitability despite project failures
Silicon Microchip	The technology had been created by he academic did not have any wish to pursue profits from his research	The academic would not leave his research post and only committed to the venture once the surrogate entrepreneur agreed to become the CEO and manage the day to day running of the business	The surrogate realized that to get investment the entrepreneurial team would need to demonstrate that the technology worked and that the team had the right credentials to exploit it	Temporary university post-docs were used for development and testing but a dedicated team of engineers would be needed to enable the spinout to achieve sustained growth
Human Genome	The scientist had developed a technology that created a new market but had no realization of how to exploit it	The academic lacked confidence in her ability to run a business, by herself. She assembled a team of advisors from industry to provide advice and offer assistance in making decisions and managing the business	The team had to learn how to best present the opportunity to potential investors This involved carrying out market research, attracting potential quality human resources as acquiring a valuable portfolio of patents	The spinout has not yet reached this critical juncture
Software	Whilst working on collaborative research with industry, the academic spotted a need for an application of the technology	The academic had no business experience but was unsatisfied with a career in academia, so decided to take the risk following encouragement from colleagues, friends and family and work part-time on the venture	Without adequate funding, the small team could not penetrate the market and sales growth was very slow during the first year, as products had to be adapted to meet customer requirements more closely	The spinout has not yet reached this critical juncture
Virtual Reality	Existing technology in the university department was not recognized as commercially valuable by the academic until it was applied to an industry sponsored research project and generated interest from the industry partner	The academic did not want to leave his research post, having built up a career in academia, and having no commercial experience. He decided to retain his academic post and work part-time on the venture. His knowledge of business was very limited	On presenting the business plan to venture capitalists the plan was rejected as not being credible. This was due to factors concerning the team's lack of experience, poor market research and an unviable business model in a very competitive market	The venture has not yet reached this critical juncture

Table 3 (*Continued*)

Spin out company	Opportunity recognition	Entrepreneurial commitment	Threshold of credibility	Threshold of sustainability
Biomedical	During studies to investigate how a particular technology could be applied to new areas of science the research team recognized a new application that presented a real commercial opportunity	Early test results encouraged one member of the academic team to carry out market research and to develop a business plan in order to assess the potential in commercializing the research. The academic formed a company and initially ran the business in his spare time, in order to test the market	The team realized it needed to quickly assemble resources to create a professional image for the firm in order to attract customers and more revenue	The team struggled to maintain its high rate of growth and become a market leader, whilst continuing to develop and commercialize new innovations. It became more difficult to co-ordinate and control activities as the venture became more successful
3G Wireless	The scientist had been working for nearly 10 years on science that did not have an obvious market application. The technology provided a solution to a market need that the surrogate identified	The scientist's biggest weakness was that he did not have the business experience or the managerial expertise to grow a business. He did not want to give up his research post at the university because it provided him with the infrastructure to create new technologies	The credibility of the entrepreneurial team and the potential of the technology were excellent. The entrepreneurial team was able to package and sell themselves as a business with all the necessary resources ready to be put in place in order to attract venture capital investment	Unfortunately the entrepreneurial team raised too little seed finance to support their growth plans and the venture stagnated in a period when the venture capital market for high-tech investments had gone flat
Stem Cell	The academic and his large research group were working on an extensive research program out of which a discovery had been made by accident. The scientist knew that potential commercial products to could result, because it solved a major medical problem	Commercial partners and industry were not interested in commercializing the technology because it was too early stage. The academic resolved to set up a spinout and commercialize the intellectual property himself	The CEO was careful in signaling credibility to investors by hiring headhunters to independently recruit a management team. He also carried out extensive due diligence and patent protection over the IP and secured lab facilities on the university science park	Through ensuring a large first round of funding, the team has acquired 48 scientists, over 200 patents, a management team of industry experts and assembled organizational structures and routines to enable the spinout to manage rapid growth
Materials	An opportunity was recognized not directly related to the issue being researched but to the way in which the research results were measured and analyzed. Through industry interaction, the value of this technology was realized to be commercially lucrative	Both the academics were unable to fulfill the role of the venture champion and recruited a surrogate entrepreneur from industry with product development and commercial experience necessary to manage the growth of the company	The team worked hard to create the perception that they were not linked to a university or that they were academics. Instead they presented themselves to customers as having industry and commercial experience as well as technical and engineering expertise in order to generate sales revenues	The CEO sees a major barrier to becoming sustainable being lack of sales and marketing capabilities to generate more revenues and fuel growth into new markets. Unless this capability can be acquired and developed, the spinout will suffer from cash-flow problems

entrepreneur from Stem Cell illustrates the necessity of entrepreneurial commitment:

> Early on I had to make a personal choice about what I wanted to do about setting up the company ... whether to remain as an academic and become a consultant to it or to throw myself into it full-time. There are implications that you have to think about early on that affect how investors will perceive you, the amount of investment you can attract and therefore the model of the venture you eventually create. That's why I am intellectually resolved to leaving my academic post and focusing purely on helping my management team build this business.

A VC echoed these comments:

> For us, there is no substitute for a new venture team led by an experienced commercial manager and who are all emotionally committed to the business full time because that's what all our investors coming on board in the next funding round want to see.

Our research suggests that in USOs, the critical juncture of entrepreneurial commitment arises due to the conflict between the need for a committed venture champion to develop the USO venture and the inability to find an individual with the necessary entrepreneurial capabilities for four key reasons.

First was a lack of access to successful entrepreneurial role models for the academic entrepreneur. Initially, this caused the academic inventors we interviewed varying amounts of reluctance to commit to taking the idea forward and actively exploring the commercial potential of commercializing their scientific discoveries. They felt strongly that doing so would mean going against accepted conventions held by their peers and reinforced by incentives, and promotion policies set by their institutions. The surrogate entrepreneur from Silicon Microchip explained how,

> ... the academic would never have taken the technology forward and done anything about commercializing it by himself because he feels uncomfortable about doing so. He doesn't want to be involved in the commercial world.

One VC commented that "most academics have contacts that are academics involved in research", pointing out that in general their social capital was restricted to networks within academia and did not extend to business and finance.

Second, the academic inventors associated with Silicon Microchip, Human Genome, and Materials, suffered from a lack of prior business experience together with a lack of faith in their own abilities to cope in an "alien" commercial environment. The academic entrepreneur from Human Genome disclosed,

> I was reluctant to commercialize the invention by myself and found not knowing the risks involved in running a business to be a daunting prospect. It was completely outside my field of expertise.

Initially, feeling unable to frame the opportunity with sufficient clarity created decision uncertainty and decision complexity discouraged them from making a commitment to pursue the venturing process wholeheartedly and impeded their progress in exploring further how to commercialize their scientific discoveries.

According to the heads of academic departments, TTO managers and some of the academics themselves, a common characteristic of academics is a "reluctance to accept and live comfortably with ambiguous situations". What makes some academics great scientists or engineers clearly does not usually give them the necessary entrepreneurial human capital to start and grow a business.

Third, from all our interviewees, we uncovered an insight relating to the lack of self-awareness over personal limitations and sometimes a lack of humility on the part of some academics. According to one TTO executive who had helped to establish 3G Wireless:

> The really smart academics are the ones who know that they add value when it comes to the science and know not to get in the way when it comes to designing the marketing plan or negotiating terms with a venture capitalist. They know when to take a back seat and leave it to the experts. The not so smart or really insecure academics want their hands over everything. These prima donnas make a complete mess of things, get nowhere with their companies and end up disappointed professionally and financially.

It is difficult for distinguished academics who are already directors of large research groups not to be involved with projects at a detailed level. The majority of the academics we interviewed found difficulties in

delegating and sharing responsibilities when it came to the commercialization of their intellectual property. The problems of delegating and sharing responsibilities are perhaps to be expected, given many years of scientific training and little or no training in business and entrepreneurship, which is confirmed by the academic entrepreneurs we interviewed. The problem of not having the commercial expertise necessary for the successful exploitation of their intellectual property is compounded by the fact that these academics "do not like being told what to do or how best to do it, even if they are not the expert", according to one TTO manager.

Finally, in the case of Software, Human Genome and Virtual Reality, the academic inventors and TTOs found it extremely challenging to identify, access and acquire the services of a surrogate entrepreneur. Primarily, this was a result of limited social capital leaving them unable to identify and access suitable individuals from within their own networks (e.g. Software). A second contributing factor was offering insufficient rewards and incentives to acquire a suitable surrogate due to a lack of resources (e.g. Virtual Reality). Third, the inability of the academic to relinquish control of what they stubbornly held to be "their company" to anybody else (e.g. Human Genome).

If these issues cannot be tackled at this juncture, we would propose that a suitable venture champion with the necessary entrepreneurial capabilities who can make a solid commitment to developing the USO venture into an established business is likely to remain elusive. Human Genome, Software and Virtual Reality, were not able to resolve these conflicts completely and made do with the academic inventor working on the USOs part-time. This lead to inherent deficiencies, weaknesses and inadequacies in these USOs that restrained entrepreneurial activity and the amount of value created in the subsequent development phases, particularly as a result of the failure to establish sufficient credibility.

3.2.3. *Critical juncture C: credibility*

At this stage in the development of a USO, the academic or surrogate entrepreneur has conceived an opportunity, and committed him/herself and a team to developing it into a USO. The critical juncture that faced all nine cases we researched was the entrepreneur's ability to gain access to and acquire an initial stock of resources, which are required for the business to begin to function. During this pre-organization phase, a key imperative is raising sufficient financial resources (seed finance) with which to acquire other necessary resources. For all nine USOs studied, finance was the key resource without which the entrepreneur was prevented from carrying out the transition from the venture being a "pre-organization" to a fully operational business that is able to engage in productive activities. The finance issue creates a second problem as academic and surrogate entrepreneurs found that it was necessary to identify the required resources, so that they could be acquired when sufficient financial resources were available. One academic entrepreneur likened this to putting the building blocks of the venture "on standby" ready for the formation of the venture. However, these necessary resources could not be acquired without either some initial financial investment or through co-optation of resources (Starr and MacMillan, 1990) through existing relationships and external networks (Aldrich and Zimmer, 1986). We term this critical juncture the *credibility threshold*, as a lack of credibility constrains the entrepreneur's ability to access and acquire key resources: seed finance and human capital to form the entrepreneurial team.

Virtual Reality failed repeatedly to raise seed finance and as a venture capitalist that had reviewed their business plan and presentation told us:

> The technology was undoubtedly novel and world class [but] we questioned the academic team's commercial and managerial skills [and] expressed doubt about the senior academic's ability to attract new commercial people in order to grow the company.

Each time the academic entrepreneur in Virtual Reality met with investors to discuss his business plan he failed to demonstrate sufficient credibility, and was unable to secure any investment. Resource weaknesses, deficient social capital and inadequate entrepreneurial capabilities that remained unresolved from the both the opportunity framing and pre-organization phases were causing considerable inertia at this critical juncture. In this particular case, the academic had repeatedly failed to accept the feedback from investors and his TTO too and transform his existing resources, social capital and capabilities to overcome this critical juncture. As a result, he could not attract a manager of

sufficient caliber with whom he was willing to work alongside, and was unable to show that any customers existed to buy applications of his technology. The VC summed up his frustration:

> The greater effort required to manage the risks involved in this type of deal is a real turn-off. When these guys come in here and I look them in the eye I want them to make me believe they can offer me a financial return. Why on earth should I invest in business proposal that lacks a sound management team and shows no evidence of a market? We're not handing out research funding to academics here!

The business angels, and particularly the venture capitalists, interviewed who had invested at seed and subsequent rounds of financing in Optical, Silicon Microchip, 3G Wireless and Stem Cell, consistently asked the same questions of the entrepreneur. What is it I'm buying here?" What am I getting for my money? These questions sought to validate proof of market, proof of concept and the entrepreneur's credentials. We encountered evidence that frequently the difficulty that each entrepreneur encountered with developing fundable investment propositions is that apart from intangible technological assets in the form of know-how and IP there was often very little else they had to demonstrate their credibility other than their own published scientific research. Paramount to the investor's decision to commit financial resource was being able to see that a team was in place that "could show to us that it has the ability to create and deliver value and is emotionally committed to achieving that" according to one VC we interviewed.

We also suggest that the critical juncture of credibility relates to the acquisition of key customers for USOs. In the case of Biomedical, the entrepreneurial team all agreed that in order to attract more clients, and revenues per client, they had to appear reputable, and business-like:

> Creating the perception of quality and professionalism for our clients was important for us to be able to charge them higher fees for using our service. We needed to get our own commercial facility with our own name above the door away from the research environment of the university. Staying within the university labs would have lead pharmaceutical companies to perceive us as a potential source of cheap labor.[6]

Along with Biomedical, the entrepreneurial teams in Materials, Optical and Stem Cell recognized that so long as their USO ventures remained embedded within university departments and failed to project a "distinctive corporate identity", both customers, suppliers and certain investors would not value the products and services they had to offer, even though the underlying technological capabilities remained the same.

The process by which customers learn about a new venture and come to perceive it as established will affect its risks, as well as its organizational momentum, legitimacy and organizational trust (Singh et al., 1986; Aldrich and Fiol, 1994). We suggest that without this initial credibility, new high-tech ventures will not be able to overcome skeptical customer perceptions, gain access to markets and successfully achieve the transition from a "concept" to a "legitimate business" engaged in transactions in the market.

For Stem Cell, Biomedical and Optical in contrast to the other six USOs, the evolution of resource stocks, capabilities and the level of social capital up to this critical juncture provided the ability to access the right resources, information and knowledge to secure significant resource endowments or lucrative contracts from new clients. These entrepreneurial capabilities were either rooted within the respective entrepreneurial teams, or were accessible through their own networks and the contacts offered by their TTOs.

In contrast, for Silicon Microchip, Human Genome, Software, Virtual Reality and Materials, these entrepreneurial capabilities were not available or took considerable time to develop. Initially, these six USOs were unable to access and acquire external equity finance, key customers and collaborative agreements with existing firms. We recognized these as symptoms that these USOs had inherent resource weaknesses and inadequate capabilities and deficient social capital. It took several attempts for these USO ventures to access, acquire and assemble the requisite "building blocks" to be sufficiently credible with customers, financial intermediaries and other resource providers.

[6] We are not suggesting here that high quality space is a necessary condition for a new venture to create credibility with a market but rather that credibility may involve a movement away from the university campus.

Each attempt to achieve this transition brought new insights into how to change current resource configurations, what capabilities to assemble and whether certain relationships were a liability, or would prove to be valuable.

Our research indicates that the path dependence of USOs, emerging from a university environment, may present specific challenges to USOs as opposed to new high-tech ventures in general. External financiers and customers may be suspicious of the extent to which universities' non-commercial cultures may have an influence over the USO. As a result, certain ties to the university may be perceived to be a liability. In addition, academic entrepreneurs (and the staff of many newly formed TTOs) may have insufficient social capital outside the academic environment.[7]

3.2.4. Critical juncture D: sustainable returns

Once the venture has received seed financing and embarks upon the process of commercially exploiting its technological assets, our research shows that it comes up against a final critical juncture, which we define as the critical juncture of sustainable returns. Sustainable returns may take the form of revenues from customers for services or products sold, milestone payments from collaborative agreements or investment from existing or new investors. This is a sign that the entrepreneurial team has the ability to create value from having developed the appropriate resources, capabilities and social capital.

At the critical juncture of credibility, the entrepreneurs were required to access, acquire and assemble resources with which to commence business operations. In contrast, at the sustainable returns juncture, the ability to continuously re-configure existing resources, capabilities and social capital with new information, knowledge and resources was required. This ability enabled Optical, Biomedical and Stem Cell to continue creating value from existing technological resources and capabilities as well as from new opportunities recognized.

At this critical juncture, Optical, Silicon Microchip, Biomedical, 3G Wireless, Stem Cell and Materials, all required their existing configurations of resources, capabilities and social capital to undergo significant transformation in order to generate returns in a sustainable manner. During previous phases of development, some of the resources acquired, capabilities developed and relationships formed had now ceased to become valuable to the ability of these USOs to generate sustainable returns. In particular, Silicon Microchip, 3G Wireless and Materials exhibited resource weaknesses, inadequate capabilities and social liabilities that prevented them from progressing beyond this critical juncture.

The imperative at this critical juncture is for the entrepreneurial teams to acquire the ability to continuously re-configure existing resource weaknesses, inadequate capabilities and social liabilities into resources strengths, distinct capabilities and social capital that will enable the USO to generate returns. We found that in comparison to developing capabilities, USOs found it easier to develop physical, human and technological resources as well as improving social capital. In large organizations, elaborate policies, procedures and routines (Nelson and Winter, 1982) simplify decision-making and hence reduce uncertainty and complexity facing managers (Busenitz and Barney, 1997). These established firms have, and continue to develop, internal capabilities that help managers to manipulate resources into new productive combinations in the context of changing markets (Galunic and Eisenhardt, 2001; Eisenhardt and Martin, 2000; Teece et al., 1997).

However, in the USOs we studied, the entrepreneur (and team) had to assemble an organizational structure, devise policies and routines that enable the allocation of scarce stocks of resources to be coordinated and the rate of their consumption to be controlled in order to achieve appropriate returns. The entrepreneur also needed to constantly adapt these routines and internal capabilities. According to the surrogate entrepreneur from Optical, "as a USO our mission was simple: to *evolve* and to do it *quickly*". Informal structures also need to be developed in order to facilitate communication within the organization. This dynamic of constantly reconfiguring the venture's resources in order to overcome this critical juncture was common across individual cases. The Chairman of Optical explained:

> Growing a high-tech spinout company isn't for the faint hearted, the anxious or the suicidal. Sure, one

[7] We acknowledge that there is a considerable degree of variance between the different cultures and commercialization experience across universities.

> day you may have a big problem to resolve, but the chances are in three weeks time it will be replaced by yet another one. The only certainty is that the pace of change just keeps on and on. Without creating the right infrastructure, and putting checks and controls in place we would simply have descended into chaos by now and run out of cash.

Optical, Biomedical and Stem Cell all placed great importance on developing the entrepreneurial capabilities to overcome deficiencies, weaknesses and inadequacies in the USO, as well as developing organizational capabilities within the USO to coordinate productive activities. The imperative for doing this became clear once commercial implications are considered, as highlighted by the surrogate entrepreneur from Optical:

> We knew that we would not be able to grow quickly enough organically and reach critical mass by trading our way to success. To achieve a level of sustainability, we needed to put the infrastructure in place to support a £20 million turnover, and initially that takes a lot of resources for a high-tech spinout. We had already perfected the technology and had acquired managers who were capable of growing the business as we went along. However without developing internal systems and competencies to survive in a tough marketplace we will not achieve further rounds of venture capital financing.

This point was verified by other USO entrepreneurs and investors interviewed. Unless USOs can demonstrate to investors that they have the entrepreneurial capabilities to create value by developing the USO into an established business that generates sustainable returns, they will also encounter serious difficulties in raising first-stage finance. The Optical and Stem Cell were able to obtain first round finance by demonstrating to investors their "sustainable" business model, which was achieved by expending resources in a market and "learning by doing", i.e. re-orientating their business model as it is implemented in a market to satisfy recognized market needs.

In particular, the USOs that were more successful in transforming their existing resources, capabilities and social capital in order to do this achieved a clear route to market that provides the means to achieving profitability. In acquiring key customers, Biomedical, Optical and Stem Cell were able to legitimize their venture through generating crucial sustainable revenues. This took the form of milestone payments from co-development deals, in the case of biotechnology USOs such as Stem Cell. Evidence from the VCs interviewed shows these act as an important signal to new and existing investors that the USO is capable of achieving sustainable growth under the stewardship of the management team. It is therefore more likely that it will be supported with endowments of additional financial resources with which to further increase the value of the venture.

The juncture of sustainability proved to be particularly problematic to those USOs that were unable to foresee and resolve deficient levels of social capital, resource weaknesses and inadequate internal capabilities. The academic entrepreneur from Human Genome describes the difficulties she faced born out of particular deficiencies, weaknesses and inadequacies at this critical juncture:

> At this stage we didn't have the resources or the experience to take the technology we had spent years developing onto the next stage. At the same time, speed became the important priority, because unless we could show that we were going to get to market quickest, we'd lose out on a further round of financial investment and cede market share to competitors.

We suggest that USOs such as Human Genome are likely to stagnate because financial (and other) resources became depleted before sustainable returns are achieved (Brüderl and Schüssler, 1990). Resource weaknesses, inadequate capabilities and social liabilities inherited from decisions and commitments made in early development phases may now be too difficult to resolve. This may further constrain the entrepreneur's ambitions for the success of the venture, in which case the USO will find it difficult to progress beyond this critical juncture.

4. Discussion

This paper has explored the transition phases experienced by USOs. In particular, our study helps develop understanding of the problems faced by new high-tech companies spun out from universities.

Conceptually, we propose that there are two important elements (Fig. 1). First, the case study analysis indicates that USOs go through a number of different distinct phases of activity in their development. Each venture must pass through the previous phase in order to progress to the next one but each phase involves an iterative, non-linear process of development in which there may be a need to revisit some of the earlier decisions and activities. Second, at the interstices between the different phases of development we found that ventures face "critical junctures" in terms of the resources and capabilities they need to acquire to progress to the next phase of development. If the critical junctures remain unresolved for a prolonged period of time, the venture will eventually fail. We summarize the themes raised by each of the junctures in Table 4. These factors clearly signify that critical junctures arise due to a deficiency in social capital, resource weaknesses and inadequate internal capabilities which act together to impede the value creation process. We discuss each of these elements in more detail below.

4.1. Phases of development

We identified five phases of the development of USO activities: research, opportunity framing, pre-organization, re-orientation and sustainability. We propose that each phase can be characterized as an iterative process of development. In the opportunity framing phase, there is iteration to find the appropriate commercial proposition and iteration to identify the appropriate commercial resources that will be needed later. In the pre-organization phases, there is an iterative search process to develop and acquire the necessary resources. The re-orientation phase is characterized by a re-configuration of resources as previous decisions need to be altered in the light of new information and knowledge. At the sustainability phase, there is a need for further iteration of activities to achieve the critical mass to serve the market in order to obtain further rounds of funding resources.

In reaching each successive phase, the USO has overcome critical junctures but in order to continue the development of the venture there is a need to revisit and resolve issues that arose at previous phases of development. As a consequence of having passed through critical junctures, ventures are qualitatively different from earlier phases. Revisiting earlier decisions does not necessitate academic entrepreneurs having to start from scratch. Rather, these decisions are revisited using the resource and capabilities base developed to this point, which may itself need to be augmented. The vertical feedback/iteration loops from each phase to these decisions in Fig. 1 reflect this process.

The process of revisiting earlier decisions occurs within all phases but appears to be most notable in the later re-orientation and sustainability phases when the venture has been created and resource commitments made. In the opportunity framing phase, we propose that once the opportunity has been recognized, academics are likely to return to their research programs and refine them to meet the needs of furthering the opportunity. Interaction with industrial firms and investors may stimulate a need to adapt existing basic research to a more applied strategy. In the pre-organization phase, we propose that academics are likely to revisit the definition and scope of the opportunity as new information provides insights into the feasibility of the proposed venture's business plan. In the re-orientation phase, the entrepreneurial team recognizes the resources, capabilities and networks that will enable sustainable returns to be achieved. Our evidence leads us to propose that existing configurations will have inherent weaknesses and inadequacies. As a result of being recognized as inappropriate to achieve sustainable returns, they need to be developed or replaced. These re-configurations may involve revisiting the technology, the opportunity and the venture's resources, capabilities and networks. In the sustainability phase, our evidence leads us to propose that the ability to access, acquire and re-configure resources, capabilities and networks enables the venture to establish resilience. For example, the continued relationship between the USO and the university is likely to be essential for the USO to develop a continuing pipeline of new technology. In this way, the USO can obtain access to new technologies being developed in the university that can be exploited via licensing-in the rights to exploit new patents. The experience of the entrepreneurial team in the market place is likely to lead them to identify new opportunities for commercializing research and to recognize new opportunities for research that had not previously been identified within the respective university departments.

Table 4
How critical junctures arise

Growth phase	Research phase	Opportunity framing phase	Pre-organization phase	Re-orientation phase
Factors initiating critical junctures	Lack of prior knowledge about how markets and industries operate	Reluctance or inability to act against convention	Inability to attract and secure initial seed finance from investors	Inability to manage growth through the identification, acquisition and integration of resources and capabilities
	Inability to understand and focus upon how a technical discovery can be applied to serve a residual customer need	Inability to accept risks, and tolerate uncertainty	Unable to secure suitable facilities outside of the university department to locate the new venture	Inability to attract and secure next round finance from existing and new investors
	Inability to research, define and articulate a clear route to market for the technology	Little prior business management experience and responsibilities	Inability to secure quality human resources to form a well-balanced managerial and scientific team	Inability to employ resources and develop capabilities to acquire speed to market
	Lack of incentive to think commercially and behave entrepreneurially	Inability to attract surrogate entrepreneurs and experienced managers	Inability to achieve proof of concept and evolve the technology to a state of market readiness	Inability to recognize opportunities and threats and make strategic decisions under pervasive uncertainty
		Lack of self-awareness over personal limitations	Inability to generate or show a clear route to revenues and profitability in order to attract financial resources	Inability to gain traction and build momentum in the market through generating sufficient sales and capturing market share
		Inability to obtain and leverage social capital through social, academic, commercial and industrial networks	Lack of depth and breadth in the technology portfolio to provide sufficient long-term options for commercialization	Inability to integrate knowledge and learning into the venture
			Lack of receptivity for the technology by supply chain distributors and customers in the market	
Resulting critical juncture	Opportunity recognition	Entrepreneurial commitment	Threshold of credibility	Threshold of sustainability

4.2. Critical junctures

Fig. 1 also identifies four critical junctures, which result from the path dependent convergence of deficient social capital, resource weaknesses and inadequate internal capabilities. These problems appear to arise from a series of events occurring outside the control of the USO entrepreneur, together with the outcomes of previous strategic decisions taken by the entrepreneurial team.

Unless each critical juncture is overcome, the venture cannot move to the next phase of development and hence will stagnate. If a critical juncture remains unresolved for a prolonged period of time before the USO becomes able to generate sustainable returns, its initial resource endowment will become severely depleted and as a consequence the venture will fail.[8] The successful transition through these discontinuities in the USO's development demonstrates that the USO's resources, capabilities and social capital have undergone some transformation.

The deficiencies, weaknesses and inadequacies at each of these junctures we term critical, because if the USO does not either develop the necessary social capital, acquire essential stocks of resources and develop necessary internal capabilities it will not be able to progress to the next phase of its development. Critical junctures occur because of the conflict between a USO venture's existing level and type of resources, capabilities and social capital, and those required to perform in the subsequent phase of development. Resources, capabilities and social capital must evolve by re-configuration, replacement or development to eliminate impeding weaknesses, deficiencies and inadequacies.

From our cases, we propose that the problems that a venture faces at a critical juncture are generic. In each of our nine USO cases, the venture faced an impending crisis, which threatened its existence and created uncertainty over how to resolve the cause of the crisis. Most importantly, we suggest that a venture's inability to overcome each critical juncture arises due to three key deficiencies. First, is the scarcity of a particular physical, financial, human or technological resource. Second, is an insufficient level of social capital to enable information and resources to be acquired or even accessed through either a partnership or alliance relationship with another resource provider. Finally, inadequacies in the internal capabilities required by the venture to employ resources and knowledge productively to enhance its performance and value may exist. We further propose that although these weaknesses and inadequacies are generic across all critical junctures, the nature of the required stocks of resources, social capital and internal capabilities differs across each dependent upon the phase of development, described as follows.

4.2.1. Opportunity recognition

The academic's pre-eminence in a research field may be important in providing the basis for a high-tech opportunity to be recognized. It is clear from our study that universities and academic entrepreneurs involved in creating USOs lack the necessary human entrepreneurial capital and social capital synonymous with commercial awareness and prior business experience. As a result, there is sometimes an inability to conceptualize how a technological discovery can be best applied to satisfy a real consumer need and achieve proof of market. We propose that there is a need to acquire the capability to synthesize scientific knowledge with an understanding of the market to which it may apply. This may be facilitated by high levels of social capital resource outside the traditional scientific research environment.

4.2.2. Entrepreneurial commitment

It was found that the imperative during the opportunity phase is largely one of dealing with the intense uncertainty surrounding the technology and the application of that technology in a particular market. As a consequence, we propose that there is a need for an individual to be emotionally committed full time to resolving this uncertainty and intense complexity through championing the venture beyond the start-up phase. As shown in Table 4, a number of factors may prevent this commitment from occurring. The commitment of the academic may be especially important to ensure a continued flow of innovations to enable the venture's product portfolio to develop, but

[8] We argue that feedback from a failed venture can only exist at the level of the individual. Individuals that have been involved in failed ventures may learn from their experiences and thus may have a greater understanding of the spinout process (McGrath, 1999).

this does not necessarily make the scientist the best candidate for the role of venture champion. The critical juncture of entrepreneurial commitment appears to develop through a combination of human capital deficiencies in the academic scientist and an institutional culture that discriminates against those with an entrepreneurial orientation. Primarily, this was a result of universities allocating insufficient resources, failing to realign institutional incentives, neglecting to devise clear policies and guidelines, and not developing a deep network of external relationships with key actors such as financiers, surrogate entrepreneurs and industry in general. To varying degrees, these impediments prevented the academic scientist, surrogate entrepreneurs or venture capitalists from becoming sufficiently emotionally and financially committed to championing the commercialization of university scientific discoveries. These factors appear different from those present in a non-USO start-up in holding back initial progress towards exploiting the value that has been recognized in an opportunity.

4.2.3. Credibility

Credibility is recognized as a general problem for new ventures (Birley and Norburn, 1985). Similarly, for USOs, credibility was identified as a key issue in obtaining seed finance to establish the venture. Without finance, the business cannot acquire the necessary resources to commence operations. The issue of credibility seems to be more significant for USOs when compared to many other business start-ups. The initial resources of the USO are intangible, comprising mainly technological assets and related know-how within a set of patents or licenses. In addition, the very nature of the USO means that it is likely that the founding entrepreneur and initial team have little or no track record of working in the particular market, managing a product development process or managing growth in high-tech ventures. Furthermore, the nature of the academic environment, its culture and values impeded the commercialization of scientific discoveries, despite the rhetoric of senior university management. Difficulties in generating sufficient credibility to be able to transact with potential customers and access stocks of resources from suppliers and partners can lead to key resource providers such as venture capitalists believing USOs to be high-risk investments.

As a result of exercising greater entrepreneurial human capital and social capital, it was particularly important to access surrogate entrepreneurs and acquire initial resource endowments including seed finance, space and human resources. Knowledge gained from prior industry experience allowed greater understanding of how best to integrate resources to create value, thus enabling internal capabilities to be assembled. In order to attract a potential surrogate entrepreneur, it may first be necessary for the USO, at the pre-organization stage, to develop some credibility with the surrogate. Universities can demonstrate the credibility of their USOs to the market by presenting IP as a potential portfolio of products, demonstrating proof of concept of technological assets, clarifying the route to market and profitability, and being able to locate the venture off the university campus in order demonstrate clear intentions to develop the technology commercially. To this end, the seven universities studied were at various stages of their development and were learning how best to assist new USOs. In particular, we noted differences in the existence and quality of formalized systems and mechanisms through which USOs were formed and created, as well as the level of social capital that had been developed with external sources of expertise and resources.

4.2.4. Sustainability

The primary difference between those USOs that moved beyond this critical juncture and those that remained within the preceding phases of development was the ability to continuously re-configure existing resource weaknesses, inadequate capabilities and social liabilities into resources strengths, distinctive capabilities and social capital that enabled the USO to generate returns. Not only were these successful firms able to perform this and create value from existing technological resources and capabilities, they also evolved by recognizing and commercializing new opportunities.

We propose that achieving this transformation depends on the ability of the entrepreneurial team to develop entrepreneurial capabilities to overcome and re-configure deficiencies weaknesses and inadequacies in the USO that have been inherited from decisions and commitments made during earlier development phases. Furthermore, we propose that there is a requirement for the entrepreneurial team to

develop organizational capabilities within the USO to coordinate productive activities.

Finally, utilizing these internal capabilities enables the USO to cope with the challenges of growth and to generate revenues. For a USO, developing the necessary organizational processes, routines and capabilities from scratch is costly and time consuming. The majority of cases endured a highly turbulent growth pattern due to ad hoc routines and procedures having to be constantly re-configured to cope with changing internal and environmental conditions.

As a result of the idiosyncratic development of each USO through each development stage, deficient social capital, resource weaknesses and inadequate internal capabilities were all dependent upon the unique evolutionary path each USO followed. Unless, the USO entrepreneurs managed to overcome these social capital deficiencies, resources weaknesses and inadequate internal capabilities, their ventures did not have the infrastructure or absorptive capacity (Cohen and Levinthal, 1990; Zahra and George, 2002) to compete within the market and hence failed to become established as rent-generating businesses. Our findings suggest that it is the individual entrepreneur in the earlier development phases who needs to acquire the requisite human capital that embodies these entrepreneurial capabilities. Just as dynamic capabilities are considered the source of sustained competitive advantage in dynamic markets, enabling firm managers to 'integrate, build and re-configure internal and external competencies to address rapidly changing environments' (Teece et al., 1997: p. 516), so the entrepreneur is the source of dynamic capabilities in the new high-tech venture we studied. However, over time as growth became more turbulent and complexity of the challenges increased, the entrepreneurial capabilities to deal with later junctures become located in the team which may have expanded to include a venture capitalist. Therefore, we propose that a shift occurs in the locus of entrepreneurship in the USO from the initial entrepreneur to that of the team as the venture develops.

5. Conclusions and implications

This paper has sought to model the formation and early growth over time of USO companies. In doing so, we have identified that the growth of these high-tech ventures is characterized by a number of distinct stages of development, the interstices between which we term "critical junctures". These junctures are critical because a USO needs to overcome them to progress to the next stage of development thus creating an imperative for the entrepreneur and entrepreneurial team to act to overcome them. The findings have a number of implications for research and for policy makers and practitioners.

5.1. Research implications

Our work adds to existing research into the development of USOs and new high-tech ventures in a number of different ways. First, our model focuses on how firms achieve the transition from one growth phase to the next. It is only by capturing the specific micro-processes involved during these inter-phase transitions that an understanding of how new ventures originate, emerge and evolve into established firms can be achieved.Second, our work extends studies by Kazanjian and Drain (1988, 1989) to address the dominant problems arising along the evolutionary growth path of new technology-based firms (NTBFs). In particular, we demonstrate why these difficulties emerge and the implications of their emergence. We conclude that during the evolution of USOs, a series of critical junctures are encountered which must be overcome to ensure that the venture becomes established within its market as a sustainable rent-generating firm.

Third, our work examines the role of social capital, resources and internal capabilities in the context of USOs. It is important to recognize that USOs are by definition resource limited. The task of the entrepreneur and entrepreneurial team is to identify, acquire and integrate resources to create strategic assets and internal capabilities, which eventually enable the venture to generate sufficient revenues under its own momentum and compete effectively. This is in sharp contrast to the context of established firms where research on core competencies and capabilities has been developed (Grant, 1996; Teece et al., 1997; Eisenhardt and Martin, 2000). In large established firms, capabilities are the organizational and strategic processes by which managers manipulate resources into new productive assets in the context of changing markets (Galunic and Eisenhardt, 2001). In new high-tech ventures with poor initial resource endowments, no such

organizational and strategic processes exist to sustain the momentum of growth. Rather, there is reliance from investors on the combined social and human capital of the entrepreneurial team to acquire, imitate and construct them, as well as dynamically re-configuring them over time to evolve the firm towards profitability. The initial venture champion will play the key role in providing the required entrepreneurial capabilities for opportunity recognition and interacting with social networks to bestow credibility to the venture. However, as the venture progresses and the complexity of the critical junctures increase, so the locus of entrepreneurial capabilities for value creation will increasingly shift to the entrepreneurial team.

The study explicitly focused on academic entrepreneurs that were seeking to commercialize scientific discoveries through a USO backed by business angel or venture capital investors. Further research might usefully explore the process relating to the decision to select this route to commercialization versus the decision to commercialize through a joint venture with an industrial partner. To what extent is this decision influenced by the initial nature of the research funding and focus? Also, to what extent is this choice an explicit one made ex ante or based on an iterative process influenced by analysis of the ability of the venture to function as an independent entity? Our analysis has also suggested that the academics developing the high-tech ventures are typically leaders in their fields. Further empirical work might usefully examine the extent to which USOs are created by academics who are less strong as researchers and who are frustrated by lack of academic recognition. To what extent are there differences in the high-tech and commercial natures of the ventures created by strong and less strong researchers?

5.2. Implications for research policy

The analysis provides the actors concerned in this process with insights concerning focused intervention at different phases of spinout development. The process was characterized by extensive iteration in each phase by ventures that were both successful and unsuccessful in moving across phases. For the successful ones, iteration occurred as adaptation was necessary in the light of new information and knowledge. For unsuccessful ones, there was the added problem that while resources and capabilities may have been acquired at earlier phases these were of lesser quality and were only likely to enable the venture to achieve a limited trajectory. These points highlight the importance of path dependencies in the development of USOs and suggest a key role for practitioners in helping academic entrepreneurs acquire the appropriate resources from the earliest phases. Practitioners should, therefore, consider carefully where and how universities could add the most value to new USOs. Many of the VCs interviewed expressed frustration that universities still had some way to go in learning how to present viable investment propositions. It was considered rare for proposals to present details of how ventures would achieve proof of market and proof of technology. Nor was there widespread evidence that TTOs were carrying out effective IP due diligence prior to submitting proposals. This highlights the importance of obtaining the capability to synthesize scientific knowledge with an understanding of the relevant market and in iterating towards the appropriate commercial proposition. Practitioners within universities either need to develop the skills to carry out these tasks effectively or to develop high levels of social capital with surrogate entrepreneurs who do have the skills.

Our research also highlights the need to acquire the resources early on that will enable the venture to be launched with adequate and appropriate resources that will provide the basis for continuing development. Key to this aspect is the need for appropriate entrepreneurial commitment to the venture. There is a need for greater career support and entrepreneurial training to be provided to academics who wish to participate in the commercialization of their academic research. Whether academics choose an entrepreneurial career path by acquiring the patents to their research and commercializing it themselves, or prefer to remain in their research post, their commitment to the entrepreneurial team engaged in the commercialization process is fundamental. Without this commitment, the vital knowledge necessary to make the technology function in the marketplace is likely to be missing and the chances of the USO becoming a sustainable venture are therefore likely to be slim. As some academics may not wish to become committed full time to the venture, or may not be the appropriate skills to lead the venture successfully, practitioners may again need to develop social capital to identify suitable surrogate

entrepreneurs. To further assist practitioners, an area for future research would be to focus more specifically on the capabilities of TTOs, the nature of their networks and how these are developed.

Acknowledgements

Financial support from the Economic and Social Research Council grant no. R00022250207 is gratefully acknowledged. Thanks to Sue Birley, Harry Sapienza, the editor, two anonymous referees, referees for the Academy of Management Conference and participants at the Babson Entrepreneurship Conference (at Boulder) for comments on an earlier draft.

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