The Growth and Exit of University and Corporate Spin-outs in the Medical Instrumentation Industry

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Abstract

Incubator organizations are said to exert a long term influence on their spin-outs. However, there is a great diversity in the types of spin-outs (Druilhe and Garnsey, 2004) and in types of incubators (Clarysse, Wright et al., 2005). This diversity is likely to affect the influence of the incubator on the performance of the spin-out. To contrast the impact on (similar) spin out firms of their very different originating organizations we compare two instrumentation spin-outs, one from Cambridge University and one from a technology consultancy firm in the same region. We go on to examine the evolution of the business models of these spinouts, their growth experience and exit routes of founders and investors. The central question is how the incubator organization affects the development path taken in the early life course of their spin-outs.

We find that although university or corporate origin exerts path dependent influence on the early development of these firms, the problems they face in scaling up are similar and largely unrelated to their origins. Critical problems arose from the shift in target market from technophile and early adopters to more mainstream customers as they moved from customized to standardized products, characterised by very different purchasing decisions of customers. Likewise the contrasting exit routes of founders and investors (trade sale and IPO) related to factors independent of the originating organization. We conclude that the business development of spin-outs can only be partly understood through a focus on their incubator organizations; their products and markets are of much greater impact on their development. However we found a shared set of influences on business model evolution, relationship with customers and exit pressures on the spin out companies, in that these were all shaped by knowledge networks and brokers of various kinds as the spinouts moved out of the orbit of their originators to create a network of new relationships on which their performance depended.

The incubator organization undoubtedly exerts an influence. However, this influence is indirect, in shaping the networks that the founders have built up or have access to via the incubator organization. Over time the spin-out co-evolves with an expanding network of relationships. Especially in a knowledge-rich environment such as that surrounding Cambridge, the initial disadvantage of university spin-outs (due to less industry experience and networks) in comparison to corporate spin-outs is less of a constraint. This shows that the direct influence of the incubator organization is relatively small, but that the networks that are developed from, and extended beyond those formed in the incubator organization are key enabling factors in the growth of these spin-outs.

1. Introduction

The commercialization of technology through spin-offs and the formation of HTSFs[1] (High-Tech Small Firms) exist in both universities and corporations. Studies of technology transfer on academic and corporate entrepreneurship tend to however depict spin-outs as a homogenous category (HEFCE and Office of Science and Technology, 2005) and not being differentiated or contrasted in literature. Studies that consider the diversity of spin-outs remain rare and one of the reasons being postulated is spin-out research does not focus on the firm level but rather on their environment and the infrastructure support and public policies that encourage the emergence and growth of companies from the science base (Roberts and Malonet, 1996; Casper and Matraves, 2003; Garnsey and Druilhe, 2004). Oakey (1995) for example criticizes the assumption that all HTSFs are alike, and has recognized the difference between categories of firms. Oakey claims that there are two types of high-technology small firms entrepreneurs, the first being spin-offs from higher education centers (university spin-offs, USOs) and second, spin-offs from corporations (corporate spin-offs, CSOs). At the university level (USOs) there has been a substantial rise in its creation and demand of commercial ideas from the universities into businesses (Lambert, 2003), as universities increasingly view equity ownership in a USO as an attractive alternative to licensing technologies in embryonic industries (Wright, Lockett et al., 2006). Similarly, CSOs have gained prominence of recent in both academic research and industry relevancy (Roberts, 2005). In recent years, the number of corporate spin-offs has accelerated (Chemmanur and Yan, 2004). Often, corporate refocusing and economic growth seems to promote the formation of spin-off firms by encouraging venture managers to leave their existing employment and to establish a company of their own with links to their parent organization (Garvin, 1983; Parhankangas and Arenius, 2003).

These two categories of firms are assumed to need and acquire different types of resources due to their different background (Lofsten and Lindelof, 2005). According to Monck, Porter et al. (1988) for example the firms established by those with an academic background perform differently and respond to different incentives from those founded in the corporate sector. A recent report from the British Ventures Capital Association (British Venture Capital Association, 2005) recognized significant differences between corporate and university spin-outs. They found corporate spin-out are often founded with the explicit aim of satisfying a known customer need and that frequently technology is already proven, customer needs have been established and team members with a mix of technical and commercial experience can be identified, recruited and incentivised. This effectively means that corporate spin-outs are launched at the equivalent of the cusp between market & technology development and product & business development.

This paper analyses the impact of incubating organizations on their spin-out firms by comparing two instrumentation spin-outs, one from Cambridge University and the other from PA consulting, a leading international consulting firm in the same region. Data was gathered from two types of firms with regard to their networks and product innovation. We examine the evolution of the business models of these spinouts, their growth experience and exit routes of founders and investors. The central question is how the incubator organization affects the development path taken in the early life course of their spin-outs.

The paper is structured as follows. We examine two case studies, which commenced operation roughly about the same time namely an USO, BioRobotics and a CSO, Diomed. We compare and contrast the findings from these case studies and draw conclusions on the influence of its incubator organizations over the development path (employment, business model, exit) of the spin-outs. Finally, we investigate some implications of findings from this research.

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[1] There are many other terms used in the literature to describe high tech entrepreneurial start-ups (e.g. New Technology-Based Firms or NTBF and Research-based startups, RBSUs). For the purpose of this paper, the term High-Tech New Ventures is used. These terms are synonymous with each other and may be used interchangeably.

2. The development of spin-off firms

Many new firms originate from incumbent firms in the same or a related industry. Especially in high-tech industries, universities and other public research organizations are increasingly seen as important incubators of spin-offs. Spin-offs are different from other types of start-ups in that there is (to some extent) continuity in knowledge (resources) and networks from the parent organization. This is also likely to affect the performance of the spin-offs, either positively when it enables the identification and exploitation of opportunities, or negatively when it constrains this. The incubator organization can be an important stakeholder, by providing financial capital, intermediate inputs, specific knowledge, and leads for new customers. Especially in the early phases of the life course of the spin-off the support by the parent can be very important due to the lack of resources and legitimacy of the start-up firm. However, once the spin-off has survived the initial years and it has become able to generate its own resources, the influence of the parent organization is likely to decrease.

2.1. Resources and capabilities

What are the advantages of a university spin-out? Ownership of or a license to IP originating in a university can endow the start-up with a unique resource. It has been argued that valuable, rare, inimitable, and non-substitutable resources may endow a firm with a competitive advantage that translate to superior performance (Barney, 1991). This does not automatically lead to a competitive advantage, just as knowledge spillovers from universities and other research institutes cannot be absorbed by all firms. A key element is absorptive capacity: a firm’s ability to recognize, value, and assimilate new external information (Cohen and Levinthal, 1989; Cohen and Levinthal, 1990). The increased absorptive capacity of new firms interacting with academic institutions may provide advantages for developing new products and alliancing with other firms, and ultimately improve the firm’s performance. Empirical studies have shown a lack of (direct) positive effects of these university-industry flows on the post-entry performance of knowledge-based firms; an indirect effect via increased absorptive capacity may be more important (Rothaermel and Thursby, 2005; Roper, Love et al., 2006). Cockburn and Henderson (1998) demonstrate that firms must exhibit substantial absorptive capacity to capture and appropriate rents from publicly available knowledge. Corporate spin-offs can thus also benefit from academic knowledge if they posses sufficient absorptive capacity to turn this knowledge into viable opportunities.

In order to commercialise technical intellectual property, organizational knowledge is required by the new firm. This latter type of knowledge is the fundamental source of competitive advantage of firms (Grant, 1996). Opportunities must be identified by entrepreneurs and resources must be accessed, secured and mobilised in order to generate returns. Key problems facing the start-up venture must be solved by developing a repertoire of problem-solving skills or competence. As learning is built up to overcome these problems, competences and dynamic capabilities are developed(Hugo and Garnsey, 2005). Competences can be viewed as individual and team-based knowledge and skills which yield economic benefit. By accessing, developing, and integrating new and existing knowledge, firms will be able to reconfigure the nature of their resource base, which is necessary to achieve sustainable competitive advantage in a technologically dynamic environment (Teece, Pisano et al., 1997; Eisenhardt and Martin, 2000). The way firm growth is managed affects whether internal resources are developed and successfully matched to opportunities (Kogut and Zander, 1992; Penrose, 1995; Garnsey, 1998). In the case of the young knowledge-based firms, the key dynamic capability is the group’s ability to detect opportunities for their new technologies and to use their competence to sustain innovation. This capability is more likely to have been developed in a corporate context than in a university context, and this provides corporate spin-offs with a better starting point than university spin-offs with respect to the recognition and exploitation of opportunities. There are several reasons why CSOs may be in a advantageous position as compared to USOs (British Venture Capital Association, 2005): their technology has already been proven; customer needs have already been established; customers may have been closely involved with specifying and testing the solution and will place orders; teams with a mix of technical and commercial experience may well have been working together for some time and additional known people can be identified, and recruited; team members are more experienced technically and commercially; the concept has been sheltered, developed and funded in a commercial environment. However, this lagging position can be caught up when the founding entrepreneurs of the university spin-off attract members with a corporate background, and/or when they are able to learn and develop these capabilities during the early life course of the firm.

2.2. Developmental processes

Different types of resource base are built and used in different ways, depending on the activity and business model of the firm (Chesbrough and Rosenbloom, 2002). Developmental processes may occur in parallel when firms build capabilities for one product or service while being at an early stage in developing other planned offerings, as in the “soft to hard” strategy of product development funded on early service provision (Bullock, 1983). While each firm is unique, there are common processes that bring about development and common problems that have to be resolved. Common processes include opportunity recognition and resource matching, resource mobilization, resource generation and resource accumulation. These make possible the development of competences and capital in a base made up of productive, commercial and financial resources. Problems originating within or outside the firm may deplete this resource base, leading to a turning point in the life course of these firms. These have negative consequences when problems are not solved, but positive consequences when they lead to new solutions and the development of new competence that extend the firm’s resource base. Hugo and Garnsey (2005) showed that the difficulties faced by new firms provide a stimulus to creating technological competence and marketing capability which propel their growth. Initial disadvantages are addressed by mobilizing resources in new ways, by resource economy (‘asset parsimony’: (Hambrick and Macmillan, 1984)) resource leverage (‘bootstrapping’: (Bhidé, 2000)) and by creating new resources (e.g. ‘bricolage’: (Baker and Nelson, 2005)). These efforts are linked in a dynamic process of problem-solving that requires strategic relations with others. Resource economy is achieved internally by rearranging the firm’s activities and resources in order to produce more with less. New growing firms use their initial resources to gain further leverage. When faced with a resource deficit that cannot be remedied externally, the firms set out to build their own proprietary resources. Cooperative interactions with other parties, including funders, regulators and suppliers, are used to mobilize resources and open further opportunities. When market solutions proved unavailable, this barrier to the pursuit of the original business idea may be an opportunity to develop a new business idea. A key feature of entrepreneurial responses to adversity is cognitive. Entrepreneurs view the situation they face as a soluble problem which they can address proactively and on which they can have some impact. They reconsider their situation and find ways to turn obstacles to their advantage by re-routing the firm. Recurrent problem solving of this kind enables these new firms to build capability on a cumulative basis. As Penrose (1995) anticipated, to succeed they have to match their resources (in particular the competence they had developed) to shifting opportunities. Information asymmetries, technologies advancing ahead of market provision and government regulation are examples of sources of opportunity. Entrepreneurial opportunities often emerge when leads and lags in market needs and provision create asynchronies between supply and demand and stimulate innovative responses to ‘market failure’ (cf. (Metcalfe, 2004)) drive entrepreneurial activity.

Not any and every deficiency can be transformed by entrepreneurial problem-solving into an asset. The cliché that every problem is an opportunity does not recognize that problems can combine in such a way as to close off opportunities and crush motivation. Undoubtedly early endowments (financial and human capital) are facilitating and attract other favourable attributes in a self-reinforcing process.

In this sense, corporate spin-offs are likely to have a better starting position than university spin-offs as they are more likely to have built up production and marketing experience. Timing also plays a large part in securing favourable outcomes for these new firms. But more than good luck is involved in repeatedly identifying and exploiting resources and timely opportunities so as to improve productivity and build capability. Alliancing is essential, but the new firm must have something to offer partners in return. Building competence in response to problems makes it possible to establish useful partnerships that further increase the firms' capability. Not only opportunities but impending threats can be turned to advantage when they spur creative thinking about objectives and new strategic moves. Though most new firms are held back by the continual difficulties besetting growth, those that find their way around these problems grow to be major players in their industry.

Entrepreneurial founders do not necessarily have the problem-solving skills required by good entrepreneurial managers. People with the right combination of skills and experience are scarce and the assimilation and motivation of staff can create serious difficulties (Witt, 1998; Witt, 2000). As the firm grows management information becomes increasingly complex (Greiner, 1972). The difficulty for decision-makers in assimilating and making considered judgements increases under conditions of rapid growth. Where reserves have been run down, delays and ill-judged decisions can bring growth to a halt. As new firms grow they face increasing organizational complexity; according to some authors this will require periodic restructuring (Greiner, 1972; Romanelli and Tushman, 1994; Vohora, Wright et al., 2004). Competence based scholars have pointed to benefits of paced growth (Penrose, 1995; Teece, Pisano et al., 1997; Hugo and Garnsey, 2005), while organizational ecologists have undertaken studies which show why radical organizational changes impair growth prospects and even survival in young technology based firms (Hannan and Freeman, 1984; Baron and Hannan, 2002).

2.3. Blueprints

How the founders of new technology based firms approach organizational and HR challenges in the early days of building their firms may have enduring effects on the firms (Baron and Hannan, 2002, p.8-9). This is the issue addressed in several papers based on the Stanford Project on Emerging Companies (SPEC) (see for example (Baron, Burton et al., 1999; Baron, Hannan et al., 2001; Baron and Hannan, 2002). This study found an important determinant of growth of technology based firms to be organizational models or blueprints that entrepreneurs use in launching their new ventures. These blueprints guide entrepreneurs' thinking about how to organize employment and manage personnel. If the origin of the firm is formative for its subsequent development (Hannan and Freeman, 1977; Hannan and Freeman, 1984), blueprints are likely to be enduring in the life course of new fast-growing firms. Barron and Hannan (2002) showed that changes in organizational blueprints are in general very destabilizing to young technology firms, adversely affecting employee turnover, financial performance, and even survival. These findings suggest that disruption may be considerable when investors replace technical founders who have had a formative role in the company. Selecting people who fitted into the organization and coordination via peer control and, or, culture was more commonly found among firms that achieved an IPO (Baron and Hannan, 2002). Selection based on exceptional talent, intrinsic work attachment, and professional standards of coordination, most often found in biotech firms, was common in firms that fared best in the post-IPO phase (Baron and Hannan, 2002). These findings demonstrate the importance of dedicated people and a sense of community for the longer-term success of the firm. The initial blueprint is likely to differ between university spin-outs that are oriented towards developing a particular products and corporate spin-outs that are stimulated to grow substantially and eventually exit via sell-off or IPO. In addition, when these blueprints are radically changed in the early life course of these spin-offs this might lead to stagnation and unfavourable exits.

3. Research method

The exploratory nature of the research question required the use of the case study method as it offers an opportunity for in-depth exploration and results in rich understanding and a clear picture about the research issue (Gilgun, 1994; Rowley, 2002). A case study is “an empirical inquiry that investigates a contemporary phenomenon with its real-life context, especially when the boundaries between phenomenon and context not clearly evident” (Yin, 2003, p.13). Other methodologists described the case study as inquiry of a system bounded by time and place and the case is the event being investigated (Creswell, 1998), and, from the postgraduate research perspective, as a research methodology which relies mostly extensively on interviews (Perry, 1998).

The literature on case study provided a variety of typologies, for example, case study may be exploratory, descriptive or explanatory (Yin, 1984; Yin, 1989; Yin, 2003), particularistic, descriptive or heuristic (Merriam, 1988) and snapshot, longitudinal, pre-post, patchwork or comparative (Jensen and Rodgers, 2001). Accordingly, the category of the selected case studies of the current research is exploratory according to Yin’s typology (Yin, 1984; Yin, 1989; Yin, 2003) as the research adopted the inductive approach in an attempt to add, combine and develop new aspects of the existing theory in the area of strategic management, marketing and entrepreneurship.

In spite of the criticism that has been directed towards case study strategy (e.g. lack of statistical generalization), it is extensively employed in many fields of social and business research because compared with other methods the strategy provides insights and rich understanding about the event being studied (Rowley, 2002).

4. Two Spin-offs in the Medical Instrumentation Industry

4.1. The Medical Instrumentation Industry

The medical instrumentation industry encompasses an extremely large variety of products and technologies. It covers hundreds of thousands of products that range from more traditional products, such as bandages or syringes, to sophisticated devices that incorporate bioinformatics, nanotechnology and engineered cells. These are often designed for use by practitioners, patients and healthy individuals in a variety of settings: hospitals, surgeries and private homes (Pammolli, Riccaboni et al., 2005). Although the medical devices market is not as large compared to the pharmaceuticals or consumer electronics market, innovation in medical devices, especially in Cambridge, Oxford, Silicon Valley and Boston have been extraordinary promising.

The high regulatory process for medical devices marketization and commercialization has set up a situation where innovation and creativity is high in the first few stages of the innovation value chain. However due to 510K[2], PMA (Premarket Approval)[3] and other FDA regulations the continuation of innovation and firm growth is heavily depended on whether products are approved and passing the clinical trial.

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[2] Section 510(k) of the Food, Drug and Cosmetic Act requires those device manufacturers who must register to notify FDA, at least 90 days in advance, of their intent to market a medical device. This is known as Premarket Notification - also called PMN or 510(k) . It allows FDA to determine whether the device is equivalent to a device already placed into one of the three classification categories. Thus, "new" devices (not in commercial distribution prior to May 28, 1976) that have not been classified can be properly identified. Specifically, medical device manufacturers are required to submit a premarket notification if they intend to introduce a device into commercial distribution for the first time or reintroduce a device that will be significantly changed or modified to the extent that its safety or effectiveness could be affected. Such change or modification could relate to the design, material, chemical composition, energy source, manufacturing process, or intended use.

[3] Premarket approval (PMA) is the FDA process of scientific and regulatory review to evaluate the safety and effectiveness of Class III medical devices. Class III devices are those that support or sustain human life, are of substantial importance in preventing impairment of human health, or which present a potential, unreasonable risk of illness or injury.

4.2. Diomed

Diomed, a consulting spinout from Cambridge, UK pioneered the commercialization of endovenous laser treatment (EVLT®), an innovative minimally invasive laser procedure for the treatment of varicose veins caused by greater saphenous vein reflux. In September 2001, the company was the first company to receive the CE mark of the European Union for approval for endovenous laser treatment with respect to marketing EVLT(R) in Europe. In January 2002, Diomed was also the first company to receive FDA clearance for endovenous laser treatment of the greater saphenous vein. In December 2004, it received FDA clearance to expand the application of EVLT$^{(R)}$ to other superficial veins in the lower extremities.

Diomed Inc has an incredible didactic and varied history as a medical devices company. Its history combines the experiences, skills and talents of one man, Dr. Anthony Raven and several of his close associates at several consulting companies in Cambridgeshire, United Kingdom. This affiliation, drawn together by chance and in the words of Dr. Raven "fate" combined their international diverse skills of its members to launch, grow and eventually thrive, expanding into a successful public company listed on the American Stock Exchange. Its history is fraught with uncanny coincidence and opportune twists of fate. The case study illustrates the role of path dependent influence from incubator organizations and the role it played in providing the initial financing and intellectual property development. However as the firm grew these networks are developed from, and extended beyond those formed in the incubator organization as the key enabling factors in the growth of Diomed.

The Beginning

Dr. Anthony Raven graduated in Physics from Manchester University and obtained his MSc and DPhil from Oxford University. Subsequent to graduating he worked at Rutherford Appleton Laboratories (RAL) at the Chilton/Harwell Science Campus, a UK scientific research laboratory near Didcot in Oxfordshire and Osaka University in Japan. RAL hosts ISIS, the brightest spallation neutron source in the world, which uses neutron scattering to study the structure and behaviour of materials, providing research capabilities for around 1600 scientists from a range of disciplines. At Rutherford, Tony worked primarily at the Central Laser Facility, which houses the Vulcan and Astra lasers. During his visit to Osaka University he met valuable research and business contacts, most notably at Olympus. Both his educational background and his experiences at Rutherford and Osaka were to provide invaluable contributions to his entrepreneurial success.

The Years at a large Cambridge Consulting Firm

Tony joined a large consulting firm, PA Consulting in 1983 at its Cambridge office. The firm was one of the two dedicated applied technology facilities in the world, the other being at Princeton, NJ, USA. Tony was employed with the PA Consulting in the 1970s, and at that time the firm had several years of slow growth with weak revenues. The company was never very profitable and endured a number or financial crises which progressively weakened the company. Part of the consulting firm's problem was its ownership structure, but the other part was it was involved in several consulting disasters.

Despite these reservations Tony highlighted the importance of "getting out" into the dynamic consulting industry. He emphasized that vital but sometimes underrated role consultants have played in the "Cambridge phenomenon". Tony observed that the "Cambridge phenomenon" owes as much as to consultancy organizations in Cambridge than other institutions. He believed that consulting firms have "the best of two words" - works on the leading edge of technologies but also in a very commercial environments.

One positive aspect during Tony's employment at PA Consulting was despite the general decline in revenue there was the emergence of what has probably become the world's best Technology Consulting practice, located in Cambridge, UK. The firm rapidly built up a major strength in advising companies on multiple arcane technologies and their potential application to business issues. Arising out of this success, major technology centers were built around the world, including one located near Princeton University in Princeton, USA.

A Consulting Firm Spinoff

The consulting experience gave Tony an extraordinary number of contacts and network affiliates. However, PA Consulting continued to be plagued by management difficulties and internal problems. The Chief of Technology at PA Consulting in 1986 was Professor Gordon Edge, a well known entrepreneur and management consultant in the Cambridge area. Gordon had minor disagreements with the Board over the running of the company and had announced his resignation, to the consternation and shock of many in the company. Gordon's plan was to start a consulting company not only providing the same technology based services of PA Consulting, but with added management consulting service offering under a different business model. Sensing this to be an exciting opportunity, Tony and a few colleagues wrote to the Professor requesting to join the new venture. The group met during Christmas 1986 and Scientific Generics was subsequently formed in the beginning of 1987.

From its launch in 1986 as Scientific Generics the central characteristic of the company had been a drive to innovate and to create value from technology. This was achieved many believed by a corporate culture in which there was minimal hierarchy, and in which project teams were built from the best people for the job. Gordon believed vigorous interaction between peers and the encouragement of individual freedom. Most importantly, there was a strong emphasis on the polymath – the person whose knowledge base encompasses both technology expertise and business acumen.

Spinout of Diomed

One of the first projects Tony undertook at Scientific Generics was with a colleague with ophthalmic surgery background. The two enduring friends had long pondered whether one can use semiconductors lasers[4] to conduct eye surgery. Tony had held the opinion that they were not powerful enough.

In its early days Scientific Generics' employees were encouraged to be innovative and creative. Looking for a project to do, the duo re-explored the idea of applying semiconductor lasers to medicine and medical surgery. Tony illustrated vividly how the solution to the problem came to him. He termed the moment "spotting serendipity".

> *I've come to use a phrase, which is spotting serendipity... it just happened as a casual conversation.. a number of things which you could never predicted came together at a point in time and spotting that was an opportunity.*

Tony described the serendipitous moment occurred when somebody had sent him a competitive patent that another party had just filed with the UK Intellectual Property Office. Tony perused the document and from his physics background immediately hypothesized the invention could not work. The problem however was Tony could not prove why the device could not work. Whilst driving to

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[4] Semiconductor laser is a laser in which semiconductor serves as photon source. Semiconductors (typically direct band-gap semiconductors) can be used as small, highly efficient photon sources. Such semiconductor photon sources find application in displays, optical storage, communications, printing, surveying, and as small efficient optical pumps for other optical processes. Semiconductor photon sources come in two major categories -- laser diodes and light-emitting diodes. Although both photon sources are fundamentally the same (in other words, a failed laser diode is an LED); application-based manufacturing differences mean that laser diode and LED products are constructed in fundamentally different ways -- and so possess fundamentally different optical properties.

Sheffield Northern General Hospital, Tony sat on motor way (incidentally in traffic congestion) thinking of the reasons why the device could not work and ways to improve on the imperfections. It suddenly dawned on him.

> *Then it dawned on me why it didn't work..I knew immediately from something I had done before.. how to make it work. They were trying to create a smooth curve, that is, new curve in the shape at the front of the eye to change the optical properties. They were trying to do it by making the laser beam stronger at the edge and weaker in the middle. I realized the process is very nonlinear in intensity so I said no you don't do that, what you do is you make it uniform. You actually make a couple of series of small incremental steps, so you remove a ring, then you remove a slightly smaller concentric ring and a slightly smaller ring still… everything. at the nanometer. What you get is like a Mexican Pyramid but when you look at a distance, it looks smooth.*

With this "eureka" discovery Tony got in touch with a company called Keela, a large ophthalmic instrumentation company. Keela had been a company Tony was introduced to whilst he was employed at PA Consulting. Through some gentle persuasion he managed to convince the company to back the project.

With the seed money from Keela they built and launched a semiconductor lasers for retinal surgery. This became quite successful within a year and captured a good proportion of the market in the United Kingdom. With this success Diomed was formed in 1991, and subsequent patents were lodged with in a local patent firm in 1992. Seeing the potential for medical devices, the duo decided to seek new capital and larger partners. They first tried securing sources from venture capitalists, but this route did not provide to be a fruitful route. Instead, they utilized their old networks at PA – which lead unusually to the investment bank Bears Stern. Again, through social contacts they had built up at PA, they were able to persuade the investment bank to back their new venture.

Having secured the capital, they used the money to enter the market for general surgical applications. Again utilizing their contacts from their times in consulting, the pair needed more capital, but more importantly technical and strategic expertise. They were introduced to a Finnish company by the name of Instrumentarium (now part of the PaloDEx Oy Group). The company operates in the international healthcare market, focusing on X-ray technology applications used in dental imaging. The alliance was a nature fit. Instrumentarium was a global leader in the design and production of state-of-the-art digital and analog dental imaging equipment for both intra and extra-oral applications as well as offering innovative software enabling superior image management capabilities. The company was a pioneer in bringing the first dental panoramic x-ray, Orthopantomograph®, to the market in 1961, and in the use of computed radiography (CR) systems for indirect digital image capture in dental since 1994. Instrumentarium's technical and financial expertise, in particular its investment in Diomed's early stage development in laser diode devices was instrumental and indispensable to Diomed's early stage growth. The partnership offered Diomed strong strategic fit, alignment, technical and financial support. More interestingly, throughout this alliance, Diomed was not subjected to any costly litigation, unlike its counterparts in the same industry.

Diomed had soon reached a thorough penetration of the private clinicians' (non-NHS) UK market. Coincidentally, at a trade show in the US Diomed's management had met a large medical devices distributor agent in Korea and was tempted by the opportunity for foreign expansion. The Korean market was unlike that of neither the US nor the UK. Diomed was able to leverage on the "viral" nature of fashion and cosmetic surgery in the country. This was unseen in the UK[5]. The customer and end users, and ultimately the surgeons desired to have the "latest and the best". Direct marketing was deemed and indeed proved to be the most effective method of market penetration and growth in Korea. Diomed however had been more familiar with the UK model of advertising to its end users and

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[5] Minimally invasive medical procedures (such as Endovenous Laser Treatment for varicose veins) was popular in the UK but had not reached the "fever demand" in Korea.

customers - as the NHS would not entertain direct selling approaches. The NHS ran on a 12 month budgetary cycle and most of it was spent on salaries. Unfortunately this meant any direct marketing of medical instruments and equipment required a myopic view of ROI. Diomed had 18 months to 2 year pay back period. Again, Tony was able to leverage key resource contacts he had previously built up at the University of Osaka (where he had spent some years during his post-doctorate) and Olympus. Diomed leveraged these resources at these institutions and capitalized on the networks and its technology. It mobilized its human resources and concentrated its efforts on direct marketing to surgeons. This flexibility allowed Diomed to thrive in the Far East. Eventually, the Far East market proved to be a spectacular success[6]. This was due in part to the creation, leveraging and building a resource economy in a foreign market combined with its ability to evolve and adapt by matching its internal resources (experiences, human capital, supply chain) to its new environment.

Diomed is a case that grew out of "well spotted serendipity". It is the ability of the founders to spot this serendipity, combined with ability to utilize the tacit knowledge that contributed to its success. By 2005, Diomed had reached sales of US$13.85 million pounds and a profit of 1.2 million dollars.

IPO and Move to the US

Diomed took a strategic decision to directly manufacture and sale in the US in the early 1990s. It had initially faltered in the US, because it had followed its traditional patterns of hiring managers from large corporations in the UK and relied on the local hires to execute supply agreements. This method broke down in the US - citing disagreement with its local Texan distributor over earnings and disapproval over management style with a locally hired manager from a large corporation[7]. In short, the outside manager ("hired gun") did not fully appreciate the matching of Diomed's critical resources with how the DMU was organized within its customers' organization.

Diomed was able to learn from these experiences and adjusted its strategies accordingly. Eventually the company showed flexibility and recruited a manager from a small company - who had significant experience in the US medical devices sector. Sensing the huge opportunity in the US, Diomed made an executive decision to relocate - whereby the UK operations would be acquired by the US parent company so that it may gain better access to capital and markets in the up-and-coming Boston medical devices cluster. Again, it was able to show adaptability by leveraging greater financial capital in the US. Unfortunately nine-eleven delayed IPO for Diomed, but again it was able to create resources by raising capital from alternative sources during the intervening period. Eventually on August 29, 2003 Diomed made a successful debut on the American Stock Exchange.

4.3. BioRobotics

Founded in 1993, BioRobotics exemplifies the start up and growth of a successful manufacturing company in the Greater Cambridge Area. The secret of BioRobotic's success was to identify a niche market that was growing rapidly and to establish superior relationships with customers in that specialist niche. This was only possible because their product was well designed and met innovative customers' needs at a competitive price, outperforming the competition. They produced in-house until they had found local suppliers to whom they were able to outsource.

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[6] Diomed had gained the most traction in the Far East of all its international markets.

[7] *"He had a very impressive CV from a very big corporate but actually that's where I learnt people from big corporates are very skilled at delegating not in doing so.. he had not done the job himself, he had always given it to someone else to do it…so I he actually always delegating."*

Origins

In the 1980s genetic research was expanding rapidly. Cambridge England was a centre of research into genetics. The structure of DNA had been identified in the 1950s and monoclonal antibodies developed at the Medical Research Council (MRC) (Kohler and Milstein, 1975). As the field matured, experiments were being conducted on an increasingly large scale. Unlike physicists, biologists had no tradition of creating their own research instrumentation. Researchers in this field were encountering problems that were brought to the attention of Dr Tom Bligh, a design engineer in Cambridge University Engineering Department. Peter Jones, a geneticist who was a lodger at the time Bligh was working at the Medical Research Council (MRC). Peter complained to Tom after having to pick 50,000 cultures by hand one weekend. Tom was asked to try this task and learnt at first hand how work in genetics research could involve time consuming and tedious manual procedures. Tom Bligh was sure that the process could be automated on a more effective basis than was currently available. This would remove a constraint limiting the volume of cultures on which geneticists could experiment. He produced a sketch of a fully automated machine using a robotic arm in 1991. He suggested that one of his students conduct a preliminary design study at the MRC as his final year project. Tom Bligh mailed his design notebooks to the Bursar of his college as proof of the date of the invention.

After graduation, the former student was funded by the MRC to carry on development work based on his design project. Tom Bligh had met Martin Davies, who had a PhD from the Engineering Department and had been working on vision in engines at Cambustion, a small spin-out from the department. He recommended Martin to the MRC to join the project. Together they developed the designs for the Biopick to the point where a prototype could be constructed, using the facilities of the manufacturing division of the engineering department. However Dr. Bligh and the staff at the MRC had different ideas for the prototype. The MRC preferred to manufacture and sell a prototype derived from the original design whereas Bligh argued that, to market the product successfully it was necessary to redesign the product along simpler, more reliable and easy-to-use lines. The prototype was based on a collection of sub assemblies and Bligh argued that it would be much less costly to produce if redesigned for manufacture.[8]

The idea to form a company to automate lab equipment was mooted by Tom Bligh, Peter Jones and Martin Davies. They approached a number of seed capital funds in Cambridge. The MRC did not believe they were capable of producing a professional product and proposed to license the design to a US company for manufacture. On hearing of ensuing disagreement, one of Dr Bligh's teaching colleagues, John Vince, showed interest in the idea of a commercial venture. He had a small amount of capital from a company he had set up earlier, which he was prepared to invest in a start up. However it was decided to do further work on the design in the department workshop before founding an independent venture.

The Original Prototype

The entrepreneurial team consisted of Tom Bligh, John Vince, Martin Davies, who wrote the software and Peter Jones, the geneticist. Tom Bligh, John Vince and Peter Jones were employed by the university but Martin Davies needed a salary. He had written the software for the MRC machine but had chosen to carry on working with Tom Bligh. Until the first machine was sold, the funding to pay Martin Davies and buy equipment was transferred from Cambridge Project Engineers, John Vince's company. John Vince provided £30 000 from Cambridge Project Engineers and his own pocket. However the venture was still short of finance. The head of the University Liaison Office, Eric Howell, suggested that they overcome their disagreement with the MRC and offer them a 10% equity stake in the venture. This proposal was not well received by their contacts at the MRC, who had already spent £600,000 on a team of technicians and engineers developing the original designs and had licensed them to a UK instrumentation firm, Hybaid.

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[8] This sections draws on interviews and a write-up on these issues by Philippa Katz in a study of BioRobotics for coursework in 1996.

Tom Bligh knew that another centre of genetics research in Cambridge was the Pathology Department. He approached Professor Ferguson Smith (whom he did not know) and asked for 15 minutes of his time. He convinced him that their ideas for the Biopick would work where other designs had been ineffective. Professor Ferguson involved a colleague, Nabeel Affara, who had funds available from selling genetic markers. They opened an account in the pathology department for Bligh and his team to draw on to a total of £25,000 and were prepared to pay the Engineering Department for tools and materials used. In return the Pathology Department received the first Biopick. It was agreed that the product would be delivered the following spring. They worked flat out by the day in the university and when the lab closed at night they moved to Tom Bligh's workshop, machining well past midnight. Looking back on this period, Martin Davies wondered why they had endured the uncertainty and relentless labour. "I was too busy to stop to think why I was doing it," he reflected. Tom Bligh devoted his sabbatical leave to the project. Because funds were limited, they carried out all the work themselves, and did no sub-contracting to save expense. The Motorola driver board they used intermittently issued faulty instructions to the equipment, causing it to crash. Since this bug was irregular it took much time and effort to identify the problem. Martin Davies worked on developing their own software, which made them independent of the third party driver. With these and other problems overcome, they developed the product to the point where it could be used for demonstration purposes, with some contrivance to conceal limitations which were later overcome. When they ran late, their sponsors in Pathology insisted that they move the development work into the department. This had the benefit of enabling them to interact closely with the researchers who would be using the equipment. When development was complete, the Pathology Department had paid £28 000. The pricing of the Biopick was thus somewhat arbitrary, based as it was on available funds.

The Competition

The MRC continued in its attempts to manufacture and sell the original prototype after their disagreement with Tom Bligh. The design was licensed to Hybaid, a company with experience in this field. The design had been refined at the MRC at considerable expense, through extensive consultation with users, but it had an excess of features and functions. The design had not been simplified to meet manufacturing requirements as Tom Bligh had recommended. Finding that Tom Bligh owned the IPR on the original design, Hybaid tried to purchase BioRobotics, but the terms offered were not attractive. The six machines Hybaid had produced turned out to malfunction and were returned by customers. Hybaid withdrew from this line of business.

A viable colony picker had been developed under Hanz Lierach of the Imperial Cancer Research Group (ICR). This machine was developed to pick cultures on a very large scale. It was said to be very reliable, but was much larger and more expensive than the Biopick. This made it less suitable for sale and manufacture to any but the largest laboratories.

Setting up BioRobotics

When a second order for a Biopick was received in May 1993, John Vince and Tom Bligh decided that it was time to set up an independent company rather than relying on the resources of Cambridge Project Engineers and the University. The head office of the company was at this stage in John Vince’s back room. The department's workshop and help from the manufacturing division's technician, Charlie, (an arrangement supported by the head of division, Professor Colin Andrew) helped keep early production overheads low.

No external funding was used. The aim was to avoid the cost of interest repayments and to keep control of the company after their loss of control over the first design and licensing to the MRC group. They had not attempted to use Tom Bligh's ownership of the intellectual property rights to wrest it back through the lawyers. This would have been unpleasant and they could see benefits in a redesign. But they were reluctant to lose control of their reconstituted enterprise to venture capitalists. As Tom Bligh put it: "We wanted to produce world class products, but we wanted to manage the company ourselves. When venture capitalists invest, they want to run the company. We wanted to do what we wanted to do, not what someone told us to do." The company was completely owned by the four founders, John Vince, the majority shareholder having 40%, Tom Bligh and Martin Davies 30% and Peter Jones 10%.

The prototype in the Pathology Department was now operational. In the course of developing it, they had acquired a better understanding of users' needs, which confirmed Tom's view that they should redesign radically for simplicity and ease of use. The filler mechanism was reconfigured to allow easier access for the user. The final design was streamlined to take up less bench space. The compact size of the machine was one of its major selling points.

The second order in 1993 was an unsolicited one from the Plant Breeding research lab at Norwich, the result of word-of-mouth recommendation. This had encouraged the BioRobotics team to move to their own manufacturing premises in the village of Comberton, Cambridge. The profits from the sale of the second machine paid the rent and salaries at BioRobotics. They recruited their own technician and trained him to build the Biopick. They now had a 700 square foot industrial unit in a converted farm building, much more space than was needed initially. They let some of it to a Human Resource consultant who subsequently helped them with their HR work.

To begin with, John Vince, the MD, was in charge of the strategic and tactical work. Tom Bligh dealt mainly with the mechanical design and Martin Davies with the software. Though they had originally done all their own work to save money, by 1995 they were outsourcing where it was beneficial to do so. "Cambridge is a great place to subcontract in. There are lots of small companies in printed circuit board production, design, machining and precision metal fabricating. They are near by and easy to work with." Martin Davies explained.

Marketing

BioRobotics was virtually unknown. Potential buyers had to be made aware of the existence of the company's product. The Biopick was a dedicated piece of equipment, its only market being genetics laboratories. The varied backgrounds and skills of the founders provided a strong combination, but they had limited experience of selling automation equipment into genetics laboratories, and the engineers initially lacked the necessary expertise in genetics to sell the Biopick. Peter Jones was too taken up with his work at MRC to be active on this front. Relations with him became tense because BioRobotics had no reserves and ensuring continuing sales was of vital importance.

It was decided to seek an alliance with a business already in the genetics field and having rejected Hybaid, they turned to the US firm, Genetics, who manufactured the microtitre plates used in the Biopick. Microtitre plates normally have 96 wells but the Biopick was designed to use 384-well plates, manufactured by Genetics. However Genetics did not find them any customers. It transpired that Genetics was also promoting the ICR culture picker designed by Hans Lierach. This machine was selling at around £120 000 compared to £50 000 for a Biopick, providing Genetics with a larger margin per sale. It was in violation of sales agreement to sell a competing product and BioRobotics dropped Genetics as their distributor.

BioRobotics then teamed up with Cambio, a Cambridge based company selling chemical reagents for use in biological fields. This seemed a promising alliance as the company was nearby and had the relevant knowledge in the genetics field. However all Cambio's sales experience was in chemical reagents. These are relatively widely used inexpensive products and require a very different sales technique. Cambio tried to market the Biopick through broad advertising campaigns and newsletters. The BioRobotics team believed that this was inappropriate for their product and that seeking out specific potential buyers would be more effective. There were approximately 200 genetics laboratories in the world large enough to afford a Biopick at £50,000. The BioRobotics had set as their objective achieving sales of the Biopick to two thirds of these labs, providing a potential market for between 100 and 150 machines. BioRobotics did not have the marketplace credibility of competitors such as the ICR. They wanted to find specific potential buyers and demonstrate the machine in action. They aimed to persuade potential customers that the Biopick was accurate and efficient at half the cost of competing products.

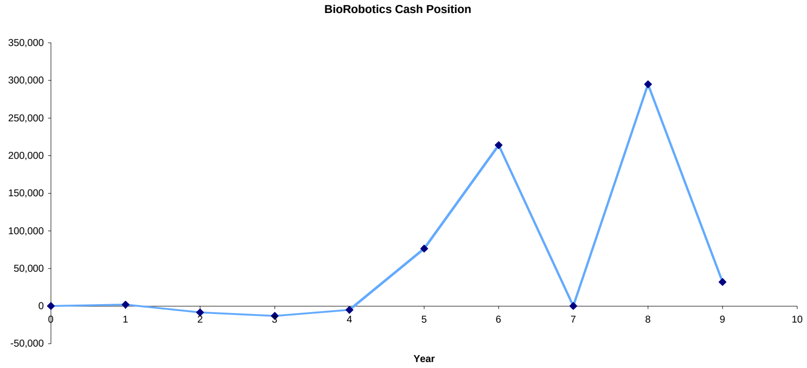
They did not try to conceal the size of the company. They believed that a customer wary of small firms would not be persuaded to buy from BioRobotics, while other customers might prefer them precisely because of their size and service orientation. A customer phoning with a query was guaranteed immediate access to the person in charge. It became apparent to BioRobotics that Cambio were not selling their product either. No Biopicks were sold between July 1995 and January 1996. This was endangering their cash flow. BioRobotics terminated the alliance with Cambio and decided to take on an in-house salesman in February 1996 to maintain tighter control over sales. The sale of four units of their Biopick product to the Japanese Rice Institute occurred just in time to prevent the company going under. (How was this sale made?)

Pricing had been determined by the Pathology Department's funds of £28,000. Components cost around £7000, on top of which were salary costs throughout development and production. When sales were at a low point, they considered dropping the price to £25k. They thought better of this after going through a learning experience while dealing with a leading US customer, Amgen. They had a visit from an Amgen team to whom they demonstrated the product. The Amgen consultant engineer asked such penetrating questions that they assumed their product would be judged unsuitable. Later Amgen phoned to say Biopick was the only product that worked among those they had tried. They required liability cover for the US but seemed unconcerned about price. Martin Davies hazarded £40k. "That's fine," said the Amgen manager. "Will that be that dollars or pounds?" This brought home to them that for a product of this kind, pioneering customers were not concerned about BioRobotics' margin but focused on their own cost savings. If the product was saving them money, these customers were relatively insensitive to price. Meanwhile a geneticist turned UK marketing agent had approached them and offered to sell on their behalf. He suggested splitting the difference if he could set the price above £40k. His first sale was at £57k, reflecting the cost saving to the customer and the price of comparable alternative products.

By this time, the team had built up knowledge about genetics. Martin Davies attended a high tech marketing course at the Innovation Centre and took over direct sales himself. He learned about the innovation diffusion process, based on the work of Everett Rogers, at the marketing college in the Innovation Centre. First versions of an innovative product are bought by pioneering customers who are usually relatively price-insensitive. What matters to them is that the new product meets unmet needs or allows them to do something novel. These technophile customers are in touch with opinion leaders and recommendations are largely by word of mouth. Sales to opinion leaders ensure that the merits of the product are communicated throughout their networks. Opinion leaders shape the buying decisions of their social group. Leading scientists and research labs were opinion leaders for BioRobotics. Professor Nabeel Affara of Cambridge University Pathology Department identified conferences they should attend. He later became a Director of BioRobotics. Martin Roberts realised that it was essential to set up personal relationships with buyers, who were invited to Open Days and events like the company's Fifth Birthday, which was well attended by members of the Cambridge biotechnology community. Customer service was a big selling point. When the first product was sent out to Amgen in California, the carousel was broken by air cargo. BioRobotics had one spare carousel, among very few spare parts. Martin Davies flew out to California with the spare carousel and installed it the following morning. Amgen had never had a machine fixed so promptly. The story contributed to BioRobotics' reputation for customer service and helped sell further products in California.

Because their product was so specialised, BioRobotics needed to establish a global market as soon as possible. An agent was found in Japan, with an arrangement whereby the distributor received a set sum per machine sold. This provided the motivation to the agent to sell as many items as possible. It became clear after attendance at major conference in Heidelberg that genetics conferences provided their major marketing opportunity. BioRobotics were able to demonstrate their equipment in action at the equipment stands of the conference, increasing awareness of BioRobotics among scientists in the genetics field.

Many of BioRobotics' potential customers were also severely resource constrained. To ensure that their customers had access to funds, laboratories capable of receiving funding had to be persuaded to apply for a grant for a Biopick. For example, a laboratory in New Zealand was targeted in early 1995 and obtained funding to purchase a Biopick. The Biopick had a finite market in human genetics and it was important to develop other markets and products. There were opportunities for BioRobotics to widen its market into animal and plant genetics. A broader product range was essential to smooth out the uneven cash flow that resulted from intermittent sales of a high value product. Parts cost £7000, and were bought in batches of five. Since revenues came in irregularly, the potential for a cash crisis was considerable. There were difficulties in paying salaries before revenues came in from the subsequent sale.



When a French Ministry was late paying for the purchase of a Biopick in September 1994, for the CEPH laboratory in Paris, the impact on cash flow was serious.

The Development of New Products

The Biopick's function was to automate the first of a number of relatively standard tasks required to create a genetic library. By now the team had learned a good deal about genetics research and its requirements. The design of new products was based on what they now knew about other processes involved in building genetic databases and which were suitable for automating. One process involves gridding. Like picking, this is a repetitive procedure which consists in placing cultures on a mesh at as high a density as possible. A gridder for automating this process would be highly marketable. A former student, Stuart Elmes, was taken on to produce a design.

The development of the Biogrid was entirely self financed from retained earnings, allowing the company to continue its policy of financial self sufficiency. There were competitors producing a gridding product. A lesson learnt from the Biopick was that its small size was a useful selling point. The Biogrid was therefore designed to sit on a bench and to take up a minimum of space. This became its key selling point as its competitors were floor standing and so much less practical for use in overcrowded labs. The first machine was sold in the Autumn of 1995.

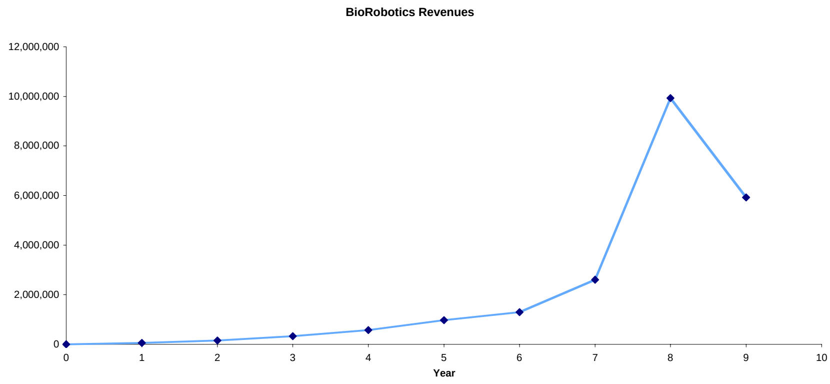
Stuart Elmes, the former student, was to have spent six months at BioRobotics before taking up a job he had been offered at Shell. However at the end of six months he opted to stay with BioRobotics. Final year students have also conducted marketing surveys for the company. Project students and students on vacation work have provided a stream of labour, with mutual benefits for the department, the students and BioRobotics.

A further product developed was the Biofill, a stand-alone filling machine. This had low development costs as the filling mechanism was identical to that on the Biopick. The idea for this machine came from customers . It is difficult to fill 384-hole titre plates by any other method. The design work on the first machine was carried out by Jo Appleton, a student on her year out between school and university. The first filler was sold in December 1995. Students from the Cambridge University Engineering Department carried out a redesign of the filler mechanisms with the aim of improving the sales of the Biofill.

The number of people taken on increased over these years, though because much of the work was sub-contracted to local firms, they only reached thirty employees in 2000. All the same, they were engaged in intensive recruitment efforts because of shortage of skilled people in the area.

The company founded in 1993 broke even in 1995, ending the financial year with a small profit. There was an influx of orders in 1998, when they launched their Microarray Grid, the first commercially available robot of its kind. Turnover had been doubling with each year of trading (Figure two).

Figure 1: Revenues BioRobotics 1993 - 2002



By 1999 it seemed that cash flow was no longer a problem. The company was for the time being cash rich and had the funds to reinvest in R&D. Over the next few years, the company grew on all measures, winning a "Rapid Growth Company" award in 2000. But though cumulative profit was looking good, operating profits were at risk should sales revenues. This was among the reasons why a trade sale was attractive.

The entrepreneurial team had shifted from being reactive, "engaged essentially in fire fighting", according to Martin Davies, to pursuing a proactive strategy. They had started without a business plan, but had subsequently developed one for operational and management purposes, rather than to reassure any external funders. They were aiming either for an Initial Public Offering or a trade sale, once the company was worth around £25 million. In 2000 the market for high tech IPOs collapsed. They sold the company to a US high tech company, Apogent, in March 2001. Apogent's press release made clear the extent to which BioRobotics was expected to create value, for customers and for a new parent company.

This was not to be, however. Performance plummeted during and after the change of ownership, and Apogent divested within three years.

5. Conclusion and Discussion

The case studies show how business development of spin-outs can only be partly understood through a focus on their incubator organizations; their products and markets are of much greater impact on their development. Through the case studies we found a shared set of influences on business model evolution, relationship with customers and exit pressures on the spin out companies. These were all shaped by knowledge networks and brokers of various kinds as the spinouts moved out of the orbit of their originators to create a network of new relationships on which their performance depended.

Although university or corporate origin exerts path dependent influence on the early development of these firms, the problems they face in scaling up are relatively unrelated to their origins. Critical problems arose from the shift in target market from technophile and early adopters to more mainstream customers as they moved from customized to standardized products, characterized by very different purchasing decisions of customers. The cases of Diomed and BioRobotics in the UK market demonstrated this. Likewise the contrasting exit routes of founders and investors, in the case of Biorobotics a trade sale and IPO for Diomed related to factors independent of the originating organization. We conclude that the business development of spin-outs can only be partly understood through a focus on their incubator organizations; their products and markets are of much greater impact on their development.

The incubator organization undoubtedly exerts an influence. However, this influence is indirect, in shaping the networks that the founders have built up or have access to via the incubator organization. Over time the spin-out co-evolves with an expanding network of relationships. The initial disadvantage of university spin-outs (due to less industry experience and networks) in comparison to corporate spin-outs became less of a constraint over time. This shows that the direct influence of the incubator organization is relatively small, but that the networks that are developed from, and extended beyond those formed in the incubator organization are key enabling factors in the growth of these spin-outs. Networks and marketing capabilities are an essential part of any business, but this is especially the case when HTNVs are constrained by resources.

References

Baker, T. and R. E. Nelson (2005). "Creating something from nothing: Resource construction through entrepreneurial bricolage." Administrative science quarterly **50**(3): 329-366.

Barney, J. (1991). "Firm Resources and Sustained Competitive Advantage." Journal of Management **17**(1): 99-120.

Baron, J. N., M. D. Burton, et al. (1999). "Engineering Bureaucracy: The Genesis of Formal Policies, Positions, and Structures in High-Technology Firms." Journal ofLaw, Economics, and Organization **15**(1): 1-41.

Baron, J. N. and M. T. Hannan (2002). "Organizational Blueprints for Success in High-Tech Start-Ups: Lessons from the Stanford Project on Emerging Companies." California Management Review **44**(8-36).

Baron, J. N., M. T. Hannan, et al. (2001). "Labor Pains: Organizational Changeand Employee Turnover in Young, High-Tech Firms." American Journal of Sociology **106**(4): 960-1012.

Bhidé, A. (2000). The Origin and Evolution of New Businesses. Oxford, UK, Oxford University Press.

British Venture Capital Association (2005). Creating Success from University Spin-Outs. London, Library House and British Venture Capital Association.

Bullock, M. (1983). Academic Enterprise, Industrial Innovation, and the Development of High Technology Financing in the United States. London, Brand Brothers and Co.

Casper, S. and C. Matraves (2003). "Institutional frameworks and innovation in the German and UK pharmaceutical industry." Research Policy **32**(10): 1865-1879.

Chemmanur, T. J. and A. Yan (2004). "A theory of corporate spin-offs." Journal of Financial Economics **72**(2): 259-290.

Chesbrough, H. and R. S. Rosenbloom (2002). "The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies." Ind Corp Change **11**(3): 529-555.

Clarysse, B., M. Wright, et al. (2005). "Spinning out new ventures: a typology of incubation strategies from European research institutions." Journal of Business Venturing **20**(2): 183-216.

Cockburn, I. and R. Henderson (1998). "Absorptive capacity, coauthoring behavior, and the organization of research in drug discovery." The Journal of Industrial Economics **46**(2): 157-182.

Cohen, W. M. and D. A. Levinthal (1989). "Innovation and Learning: The Two Faces of R & D." The Economic Journal **99**(397): 569-596.

Cohen, W. M. and D. A. Levinthal (1990). "Absorptive Capacity: A New Perspective on Learning and Innovation." Administrative Science Quarterly **35**(1): 128-152.

Creswell, J. (1998). Qualitative Inquiry and Research Design; Choosing Among Five Traditions. London, New Delhi, Thousand Oaks, Sage Publications.

Druilhe, C. and E. Garnsey (2004). "Do Academic Spin-Outs Differ and Does it Matter?" The Journal of Technology Transfer **29**(3): 269-285.

Eisenhardt, K. M. and J. A. Martin (2000). "Dynamic Capabilities: What are They?" Strategic Management Journal **21**(10/11): 1105.

Garnsey, E. (1998). "A theory of the early growth of the firm." Industrial and Corporate Change **7**(3): pp. 523-556.

Garnsey, E. and C. Druilhe (2004). "Do Academic Spin-outs Differ and Does it Matter?" Journal of Technology Transfer **29**(3_4): pp. 269-285

Garnsey, E. and P. Heffernan (2005). "High Tech Clustering through Spin Out and Attraction;the Cambridge Case." Regional Studies **39**(8): 1127-1144.

Garvin, D. A. (1983). "Spin-Offs and the New Firm Formation Process." California Management Review **25**(2): 3.

Gilgun, J. F. (1994). "A case for case studies in social work research." Social Work **39**(4): 371-380.

Grant, R. M. (1996). "Toward a knowledge-based theory of the firm." Strategic Management Journal **17**(109).

Greiner, L. E. (1972). "Evolution and Revolution as Organizations Grow." Harvard Business Review **July-August**(37-46).

Hambrick, D. C. and I. C. Macmillan (1984). "Asset parsimony - managing assets to manage profits." Sloan Management Review **25**(67).

Hannan, M. T. and J. Freeman (1977). "The population ecology of organizations." American Journal of Sociology **82**: 929-964.

Hannan, M. T. and J. Freeman (1984). "Structural Inertia and Organizational Change." American Sociological Review **49**: 149-164.

HEFCE and Office of Science and Technology (2005). Higher education-business and community interaction survey, Department for Employment and Learning, Higher Education Funding Council for England, Higher Education Funding Council for Wales, Scottish Higher Education Funding Council and Office of Science and Technology.

Hugo, O. and E. Garnsey (2005). "Problem-solving and competence creation in the early development of new firms." Managerial and Decision Economics **26**(2): 139-148.

Jensen, J. L. and R. Rodgers (2001). "Cumulating the intellectual gold of case study research." Public Administration Review **61**(2): 235-260.

Kogut, B. and U. Zander (1992). "Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology." Organization Science **3**(3): 383-397.

Kohler, G. and C. Milstein (1975). "Continuous cultures of fused cells secreting antibody of predefined specificity." Nature **256**(5517)): 495-497.

Lambert, R. (2003). Lambert Review of Business-University Collaboration. Norwich, UK, Controller of Her Majesty’s Stationery Office.

Lofsten, H. and P. Lindelof (2005). "R&D networks and product innovation patterns--academic and non-academic new technology-based firms on Science Parks." Technovation **25**(9): 1025-1037.

Merriam, S. B. (1988). Case study research in education: A qualitative approach. San Francisco, Jossey-Bass.

Metcalfe, J. S. (2004). "The Entrepreneur and the Style of Modern Economics." Journal of Evolutionary Economics **14**: 157-175.

Monck, C. S. P., R. B. Porter, et al. (1988). Science Parks and the Growth of High Technology Firms. London.

Oakey, R. (1995). "High Technology-Based Firms, Variable Barriors to Growth." International Small Business Journal **13**(3): 103-104.

Pammolli, F., M. Riccaboni, et al. (2005). Medical Devices Competitiveness and Impact on Public Health Expenditure. Brussels, European Commission.

Parhankangas, A. and P. Arenius (2003). "From a corporate venture to an independent company: a base for a taxonomy for corporate spin-off firms." Research Policy **32**(3): 463-481.

Penrose, E. (1995). The Theory of the Growth of the Firm. Oxford, Oxford University Press.

Perry, C. (1998). "Processes of a case study methodology for postgraduate research in marketing." European Journal of Marketing **32**(9/10): 785-802.

Roberts, E. B. and D. E. Malonet (1996). "Policies and structures for spinning off new companies from research and development organizations#." R&D Management **26**(1): 17-48.

Roberts, M. J. (2005). "Vidient (A)." Harvard Business School Cases: 1.

Romanelli, E. and M. L. Tushman (1994). "Organizational transformation as punctuated equilibrium: an empirical test." Academy of Management Journal **37**: 1141-1166.

Roper, S., J. Love, et al. (2006). The Scottish Innovation System: Actors, Roles and Actions, Aston Business School and Cardiff University.

Rothaermel, F. T. and M. Thursby (2005). "University-incubator firm knowledge flows: assessing their impact on incubator firm performance." Research Policy **34**(3): 305-320.

Rowley, J. (2002). "Using case studies in research." Management Research News **25**(1): 16-27.

Teece, D. J., G. Pisano, et al. (1997). "Dynamic Capabilities and Strategic Management." Strategic Management Journal **18**(7): 509-533.

Vohora, A., M. Wright, et al. (2004). "Critical Junctures in the Development of University High-Tech Spin-Out Companies." Research Policy **Vol.33**.

Witt, U. (1998). "Imagination and leadership: The neglected dimension of an evolutionary theory of the firm." Journal of Economic Behavior and Organization **35**(161-177).

Witt, U. (2000). "Changing Cognitive Frames - Changing Organizational Forms: An Entrepreneurial Theory of Organizational Development'." Industrial and Corporate Change **9**(4): 733-755.

Wright, M., A. Lockett, et al. (2006). "University spin-out companies and venture capital." Research Policy **35**(4): 481-501.

Yin, R. (1984). Case study research. Beverly Hills, CA, Sage Publications.

Yin, R. K. (1989). Case Study Research, Design and Methods. Newbury Park, CA, Sage Publications.

Yin, R. K. (2003). Case study research: Design and methods. Sage Publication, Thousand Oaks, California.