The Strength of Strong Ties: University Spin-offs and the Significance of Historical Relations

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ABSTRACT. This article investigates the relationship between universities and academic spin-offs, with special emphasis on the antecedent conditions of, and the nature of the linkages that the spin-offs form, as well as the means for sustaining them. The present research uses an instrumental case study approach, and is also an instance of a collective case study as four companies of various size and activities have been studied together. The preliminary results indicate that the network relations are characterized by a small number of strong ties to universities, with a high degree of trust and informality. Although fruitful for the transfer of complex knowledge, the strength of the ties also make them difficult to substitute, which may lead to problems as the spin-offs are highly dependent on continued basic research support. This may in turn lead to implications for policy at university, as well as higher levels.

Key words: University Spin-offs, networks, relations, strong ties, entrepreneurship.

JEL Classification: L31, L33, O31, O32, O38

1. Introduction

Recently, national governments have begun to restructure policies for funding science in order to encourage universities to commercialize their research results. As a result, academic science is increasingly being redefined by national policy-makers as a contributing factor to international competitiveness. This is reflected in the rhetoric and mechanisms used by science policy agencies (OECD, 2002; Vinnova, 2002; Government of Finland, 2003), and also in the growing literature on university–industry transfer (e.g. Argyres and Liebeskind, 1998; Bozeman, 2000; Carayannis *et al.*, 2000), and commercialization of academic research (e.g. Slaughter and Leslie, 1997; Jacob, 2003).

One of the mechanisms for transforming scientific knowledge into products and processes is the founding of new firms on the basis of results produced at universities. The closer relationship between science and technology in some areas, and the rise of science-based technologies e.g. biotechnology, has in many cases led to growing costs for pursuing research, this cost being an additional argument for capitalizing more efficiently on new knowledge, e.g. through the creation of new technologies in spin-off arrangements. As new firms often lack resources, academic spin-offs based on high technology are likely to be dependent on continued relations with universities also after the initial phase of spinning off. To date however, there have been very few studies completed on academic spin-offs that provide detailed information on the nature of firm linkages with universities (Rappert *et al.*, 1999), and those that do have primarily taken the viewpoint of universities. Furthermore, there is a shortage of qualitative studies on how these collaborations evolved and were sustained, i.e. the antecedent conditions, the process of managing the collaboration, and its academic and commercial consequences in more detail (Prabhu, 1999).

The aim of this study is to investigate the antecedent conditions, the reasons for continued relations between universities and academic spin-offs, i.e. the nature of these linkages, and how they are sustained. In Section 1 we will provide an overview of the literature of university-spin-off linkages,

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in Section 2 we present four cases of university spin-off companies from the point of view of such linkages. This is followed by an analysis and discussion on the findings. Implications for research and policy are outlined in Section 6.

2. Linkages between universities and spin-offs

Motivations for spin-offs and linkages

While there are plenty of possibilities for academically viable research to become commercialized, and vice versa, many occasions for academically valuable results to emanate from commercial activity (Rosenberg, 1982; Stokes, 1997), there often seems to be a difficulty in combining commercial and academic goals within one and the same institutional setting (Dasgupta and David, 1994; Argyres and Liebeskind, 1998). This point has been empirically supported by among others Goldfarb (2001), who shows that in a population of research engineers, academic goals and practical or commercial goals are unlikely to converge. Therefore, it is argued that external corporate sponsors will be unlikely to build profit-based relationships with 'purely' academic counter-parts.

This would suggest that the maintenance of linkages between universities and spin-offs is to some extent dependent on benefits derived from splitting up corporate and academic activities into different institutional settings. One such benefit has been said to lie in the need to secure inventor compensation in a form that would be difficult in the academic setting, e.g. in terms of salaries, royalty or equity, this being particularly true for public universities (Goldfarb and Henrekson, 2003). This argument is supported by Jensen and Thursby (2001) who show that the preferred relation of inventor to commercial spin-offs is one where the researcher stays in his/her lab and maintains research on the basis of corporate sponsored grants. This attitude however is not observed uniformly across countries and sectors (e.g. Meyer-Krahmer and Schmoch, 1998), and is likely to be related to many factors, for instance the likelihood that universities will make equity investments in start-ups in a way favorable to the academic/founder (Shane, 2002).

In a study on the differential start-up rates of US universities' technology licensing offices (TLOs), Gregorio and Shane (2003) found that a higher inventor share of royalties provides a disincentive for potential inventor-entrepreneurs by increasing the opportunity cost of starting up a new venture. Also, universities willing to take equity stake in licensees in exchange for paying up-front patenting and licensing expenses had considerably higher start-up rates than universities that did not. From the perspective of university spin-offs there are several reasons for maintaining linkages, as well as for creating new ones, one of them of course being the endemic internal lack of an internal resources base in new ventures (Tether, 2002). Such reasons however related to the content of linkages.

Content of linkages between universities and spin-offs

The relation between the university (e.g. department) and the spin-off firm may be of a formal or an informal nature. As examples of more formal linkages, Ndonzau *et al.* (2002) review three institutional relations between universities and spin-offs. Universities can hold some equity shares in the spin-off (financial resources), spin-offs can exploit patented technology owned by universities (intangible resources), and spin-offs can have access to some university facilities (material resources). In the case of the last two, the relation may be bi-directional and the level of informality high (Bozeman, 2000; Berglund and Hellström, 2002). Furthermore, while linkages can be of a formal character, the effects of the knowledge transferred via the linkage can be very informal. Examples of such linkages would be the employment of graduates and faculty by firms, contract research and consulting, and training of firm members (Fitzroy *et al.*, 1994; Schartinger *et al.*, 2002). More informal linkages may involve joint conference attendance, joint publications, joint supervision of graduate students by firm and university employees, lectures at the university held by firm members and reading of publications and patents (Fitzroy *et al.*, 1994; Schartinger *et al.*, 2002).

The informal linkages, apart from being important in their own right, often fill the additional function of facilitating more formal linkages (Rappert *et al.*, 1999). In fact, informal

linkages are often regarded as more important than formal ones (e.g. Meyer-Krahmer and Schmoch, 1998; Rappert *et al.*, 1999) as they "provide a means of receiving general and specific expertise from universities in a manner which responds to the contingencies of innovative activity" (Rappert *et al.*, 1999, p. 886). However, these appraisals are often based on contrasting formal and informal personal contacts or way of working, i.e. doing contract research compared to collaborative research, thus not paying attention to the use of equipment, patents, etc. However, both informal and formal linkages will be of marginal relevance to overall USO competitiveness unless the USO is on the "cutting edge" (Rappert *et al.*, 1999), and the conditions for novel product introduction are essentially derived from basic science discovery (Powell *et al.*, 1999).

The importance attached to either form of linkage can also be related to the perceived benefits of university–industry linkages generally. Meyer-Krahmer and Schmoch (1998) found that knowledge exchange and additional funds were the most relevant advantages seen from the point of view of universities, with emphasis differing between sectors. While additional funds can be obtained via a one-directional relationship such as for example contract research, for knowledge exchange to take place a bi-directional relationship involving more informal links is probably better. Rappert *et al.* (1999) found that, from the viewpoint of USOs, the general benefits were considered to be keeping abreast of university research, access to expertise, general assistance, and use of instruments. Meyer-Krahmer and Schmoch (1998) also found, through patent measurement, that the content of university–industry interaction exhibits a great deal of intra-disciplinarity. In this context, the strength of linkages seems to be particularly important, as weak ties tend to enhance access to relevant findings in fields outside the core areas of the USO. Moreover, the pattern of weak and strong ties seemed to be historically determined to some extent.

Sustaining linkages between universities and spin-offs

A perusal of the literature will show that several factors are thought to be vital for maintaining linkages between universities and spin-offs. The existence of trust is one of these. Trust has been said to exist if both parties expect the other to work towards mutually compatible or supporting interests in a joint effort, rather than to act opportunistically and maximize their own take at the expense of the other (Das and Teng, 1998). In these types of linkages, it is especially important that the partner organization, research center or firm is (1) perceived to pursue compatible rather than competing interests, and (2) to be certain that firm specific knowledge is not leaked to other firms as a result of the type of knowledge sharing that may occur in the broader setting, e.g. in university–industry consortia (Santoro and Gopalakrishnan, 2001). This can be facilitated by clearly articulating priorities beforehand (Burnham, 1997) and by both parties jointly assessing the interests, motivations, constraints, and potential importance of a cooperative venture (Prabhu, 1999). The existence of mechanisms for mutual monitoring, as well as channels for continuous communication has been said to stimulate trust in similar cooperative relations (Hellström, 2003). Mutual monitoring of ongoing activities may be brought about by the existence of a common set of third-party relations, meeting places, and also by physical proximity (e.g. Saxenian, 1994; Deeds *et al.*, 2000). Also the findings of Almeida *et al.* (2003) suggest enduring effects of geographical proximity, while the effects of mobility on external learning are particularly critical in the earliest stages of startups. These types of social and physical proximities provide ongoing information about projects and new relations. For example, continuous communication helps not only mutual monitoring of activities but it also enables partners to coordinate decision making on objectives, investments in new projects and new resource acquisitions/needs, as well as expectations with regard to technology transfer among partners (Lei *et al.*, 1997).

Meyer-Krahmer and Schmoch (1998) found that spin-offs were likely to be associated with sustainable bi-directional interaction if the founding academic part stayed assigned with the university department. This association would presumably be supporting of trust between the firm and the university. In a survey study of 189 firms and 21 research centers in the USA, Santoro and Gopalakrishnan (2001) established that trust was

indeed a key factor for this type of linkage, however that it was dependent on flexible university center policies for IPR, patents and licenses, especially regarding the extent to which the university was willing to customize contractual agreements in order to meet the spin-off firm's specific needs. Geographical proximity was also found to play a role in maintaining linkages, in particular with firms conducting basic research, however, communication to the firm concerning ongoing technology transfer activities in the university did not affect the firms' perceived strength of the linkage (Santoro and Gopalakrishnan, 2001).

Almeida *et al*. (2003) and Rappert *et al*. (1999) have found size and intensity of firm R&D to be key variables in explaining high linkage activity, that is, how many and what types of linkages that are sustained. This may reflect the greater resources of larger firms, which makes them attractive to universities but also the greater awareness of larger firms as to the services available to them from these organizations. Moreover, according to Almeida *et al*. (2003) it appears that the negative effects of size, such as myopia and rigidity, become more pervasive with regard to the informal linkage mechanisms. That is, as the companies grow in size, they rely to a larger extent on formal links. This suggests a corollary to another oft mentioned factor for sustaining linkages built on mutual exchange of knowledge that is the ability to learn from each other. The success of such relationships should ideally be contingent on the level of absorptive capacity (Cohen and Levinthal, 1990), a concept that is extended by Lane and Lubatkin (1998) to show that firms in a student–teacher relationship must have similarly structured relative absorptive capacities. While this points the importance of sharing similar knowledge bases, knowledge assimilation processes, and experience in knowledge commercialization, it also suggests the importance of building a mutual language and symbols in order to foster trust, and thus to increase the likelihood of sustained collaboration (Carayannis *et al*., 2000).

3. Methodology

The case study approach

In qualitative research, investigators must typically think purposefully and conceptually about sampling (Huberman and Miles, 1994). The present research builds on an *instrumental* case study approach, in that the cases have been instrumental in elucidating a particular phenomenon, here university – spin-off linkages (Stake, 1995). The sampling approach associated with the instrumental case study has been purposive or theoretical sampling, where actors or phenomena relevant to the research question and/or the theoretical focus at hand are actively sought out (Glaser and Strauss, 1967). The present research is also an instance of a *collective* case study approach, as several companies have been studied together with a focus on the specific and generic properties of spin-off linkages. The authors recognize that the present cases are operating within a number of contexts (financial, social, physical etc.), and that many of the conclusions drawn are affected by situational factors. While aware of the dimensions of atypicality present in each case, it is nevertheless believed that the phenomenon of linkage activity displayed within each case is critical to understanding the general nature of the phenomenon, through presenting it in a meaningful action context. However it is important to keep in mind, that in some sense the case always represents itself, and is mainly a tool for understanding instantiation of theory (Manning, 1982).

The spin-off companies

All of the companies were from high-technology fields; biotech, functional foods, instrumentation and laser systems. Their age spanned from 8 to 24 years, and their size varied between 13 and 50 employees. They were all spun-out from the universities in one way or the other (see case descriptions). The locations of the spin-offs were overall very close to the sources that they had most frequent interaction with, and often also with the originating university.

Data collection and analysis

The participating case companies were selected through purposive sampling (Miles and Huberman, 1984) to cover a broad disciplinary spectrum, as well as to span from fairly young to older. Although all of the companies were

Swedish, geographic distribution was taken into account and companies from different university towns were selected. Founders and CEOs were contacted for face-to-face interviews. These lasted for between 1-2 h, and were documented through intensive note-taking by one or two of the participating interviewers (there was an interviewee reluctance to have interviews taped). Interviews were conducted in an informal, conversational manner, during which questions were posed about founding conditions, linkages with the university and other Public Research Organizations (PROs), limitations and benefits in these regards, and plans for the future with respect to linkage activities. Interview notes were transcribed into case descriptions, which were read by all participants for coherence and accuracy.

4. Four cases of university – spin-off relations

Alfa foods

Alfa Foods is active in the area of Functional Foods and was established in 1994. The firm has a staff of 13 equally distributed in R&D and production/sales. Their turnaround in 2001 was around 4 million US$. Alfa Foods develops, produces and to some extent distributes an oats-based milk beverage, for direct consumption, or as a foundation for other traditionally milk-based products such as ice cream, yogurt, or sauces. The process technology for producing this product, as well as the basic bacteria which is central to the production, has been patented, and is the platform for a range of oats-based milk products manufactured by Alfa Foods. Alfa Foods expects to grow rapidly in the next few years, partly due to growth in the Asian and European markets.

History of the company and its links

The founder of Alfa Foods has his roots as a researcher at a university chemistry department, where he was working close to a professor who, in 1963, discovered the mechanism behind lactose intolerance. The professor also had an outspoken market orientation in his research, with links to a nearby multinational company that specialized in packaging. In 1990, on the basis of subsequent research into lactose intolerance, as well as a chance suggestion from an agricultural researcher, the founder decided to develop a non-dairy milk-replacement from oats. The company was born from this idea and the founding team consisted of four researchers. Once the company was established, the founder reduced his employment at the university to 20%. The founding researchers took out an early patent for the process technology, which they funded themselves, and short thereafter received additional funds from a farmers' cooperative.

At this stage the only input from the university consisted of informal staffing of the company orchestrated by the founder, as well as that of the research knowledge brought over into the patent. The founder also had some experience from previous commercialization activities, among others with starting up a medical equipment company. Alfa Foods brought their product to a limited European market between 1996 and 2000. In 2001 they received new growth capital from an international venture capital firm and a private placement from the founder's brother. Some researchers from the original team were bought out during the same period. From 2001 onwards, Alfa Foods increased its research effort into health promoting oat milk products and focused on high cholesterol, intestinal functions and lowering of the glycemic index. They have hired staff mainly from their research network, but also a new Managing Director from the private sector, who had previously worked with the founder on a university–industry development project.

Current links with the university and other PROs

Alfa Foods has always worked closely with the university, and considers the continuation of this connection to be critical to its future. The chemistry department from which the technology spun-out is still the most important research partner, but now there are also a number of smaller research groups, loosely related to this department as well as a research relation to clinical R&D at a university hospital. The preferred linkage to the university consists of sponsoring and supervising doctoral students on research projects of relevance to Alfa Foods' product development. This way Alfa Foods can retain a

strong linkage with the university, without simply 'co-opting' new staff. They also have a considerable input on project formulation and execution. The university has traditionally been seen as a place to do research, and not as central to the later stages of Alfa Foods' business cycle (product refinement, marketing and sales). With most of the research that Alfa Foods needs located at the university in these types of cooperative arrangements, this means that Alfa Foods can focus on coordination of product development and commercialization in-house, and together with other companies. They have not been in contact with any of the available 'bridging organizations' in the region, simply because the need has never arisen (and partly due to the fact that they had not yet been established at the time of the founding). However, they have had help from a network at the neighboring science park, which is a local 'meeting-place' between different kinds of academic and commercial interests. This is mainly to be seen as a pre- or non-competitive idea network.

During the last year, Alfa Foods has been involved in an EU-project in the agro-food area, together with three other European universities and five companies. This project is considered an important stepping stone for future products, where the universities represent research, and new solutions are developed and tested cooperatively between the participating companies. Alfa Foods does not consider itself to be able to 'afford' more of a network presence in research or otherwise. Other public research institutes have a latent existence in the networks as indirectly connected to Alfa Foods through their university contacts, but no direct linkages have been established, or are deemed necessary. The main linkage is with the founders' 'home department', where the exchange is rich, relevant and yet low in maintenance cost. The main source of staffing is from the university, and previous contacts with the company. University contacts are considered to be a strength in potential new employees. The informal contacts are the most important: ''the company is built on people – not on written agreements''. In the future, those networks will be interesting which can enable Alfa Foods to identify new product concepts in related but more distant areas.

Beta Technologies

Beta Technologies is a research and manufacturing company that has been in existence since 1985. The company employed about 50 people before it was split into two separate companies in the spring of 2002. Their turnaround in 2001 was ca 8 million US$. Before the split, Beta Technologies was active in two areas: laser technology, where they provide whole laser systems, and fiber optics, where they provide components for high-effect lasers. Both areas are high-technology knowledge intensive, especially the area of fiber optics where their products are based on patented knowledge. The market consists mainly of big Swedish companies for the laser systems part, and big laser systems manufacturers in Germany for the fiber optics part.

History of the company and its links

The company was spun off in the late 1970s from a government financed research project on laser workings at a technical university. The project involved two PhD students and a professor. Halfway through the project, the professor decided to start a company due to new ideas generated in the project and the potential yield from consulting services that these new concepts could generate. The PhD students continued part time at the university and part time at the new company. This company came to focus on laser measurement techniques and laser systems, and in 1984 the laser systems part was spun off and formed Beta Technologies together with another company from a Swedish consortium, which contributed with the funds for the establishment. At the point of establishment, the input from the university still consisted of the ideas developed in the research program which had formed the basis for the company, as well as academic contacts with former colleagues at the university. Over the years to come these contacts resulted in various research collaborations, and also in supervision of PhD-students. Apart from structural changes in ownership relations the company remained the same until the spring of 2002 when it was decided that the two areas of activity within Beta Technologies, laser working systems and fiber optics components, were better off as two

separate businesses. The reason was that since the two areas of activity are rather separate in terms of markets, chances for obtaining new investors for a coming expansion would increase if they were separated into two businesses.

Current links with the university and other PROs

Beta Technologies, and especially the fiber optics part, has always worked closely with the former colleagues at their "home" university where research into the field of their core technology has been undertaken continuously throughout the life of the company. This connection is considered to be very important for a number of reasons. One is that the "home" university is the only one in Sweden which conducts the kind of research on which Beta Technologies' business idea is based. The second is that the technology of the fibre optics field has now developed so that within a couple of years there will be new, fundamental problems concerning materials physics, etc. that will need to be solved. Even with heavy investments in R&D, Beta Technologies cannot afford to build this type of knowledge on their own. They therefore have to rely on basic research conducted elsewhere. So far the exchange with the university has been conducted through informal seminars, research collaboration and supervision of PhD students and master theses. The university and the relevant research conducted there is accessible to employees. Beta Technologies' dependence on basic research conducted at the "home" university means that it is beginning to become concerned that declining funding for the research group on which it is dependent may affect the company's future adversely. Other university links, albeit not very strong, have been forged through participation in EU-projects. Beta Technologies has participated in several such projects over the years, however, not jointly with any Swedish departments or institutes, but rather with German and French actors who contacted them and proposed collaboration. Within these projects the foreign partners deal with administrative matters. This is a requirement for Beta Technologies, since they do not perceive themselves to have the time to engage in the cumbersome bureaucracy of the EU-projects.

Gamma Biotech

Gamma Biotech was established in 1989 and currently employs 35 persons after selling out a production unit in the summer of 2002. The turnover in 2001 was over 2 million USD. The business idea is based on biotechnology, bordering on Functional Foods. Gamma Biotech's business model is to never enter the final market themselves but rather to develop concepts, verify these, securing the manufacturing process and the possibilities to make products, and then sell this to interested companies producing for end customers. The technology is built around two basic micro organisms and the application of these to allergy and stomach-related diseases. They expect to grow rapidly in the near future.

History of the company and its links

In the mid 1980s, a professor from North Carolina State University, USA, took a sabbatical in Sweden for family reasons. Once there he began working together with a professor at the agricultural university, with whom he discovered the antimicrobial properties of the reuteri-bacteria. They patented it, and set up a company called Gamma Biotech in the Research Triangle Park area of Raleigh, NC, because the financing possibilities were at the time quite good there. The founders had some difficulty raising capital for the company in the USA for a variety of reasons and began to look for alternatives and were eventually able to find new investors in Sweden. The two founders have remained on the board and act as external consultants. The company was established with little help from Swedish organizations although they had some contacts with one of the regional organizations set up to assist universities with commercialization. The main source of support throughout the history of the company has come from a biotech Centre in North Carolina. This centre has provided useful contacts, manufacturing equipment, etc. Already from start they also made extensive use of the research networks of the two founding researchers, and put great effort into making themselves well known to relevant researchers and developing relationships with them. This has been especially important for Gamma Biotech since the

technology on which the business idea of the company is based was not generally accepted at the time of the founding of the company. Gamma Biotech's founders were therefore forced to build acceptance and interest by involving known scientists, who in turn could spread knowledge about the technology on a broader basis as well as make it legitimate towards consumers.

Current links with the university and other PROs

As mentioned above, Gamma Biotech has already from the beginning worked closely with universities, and they currently have direct contact with a vast number of researchers at different universities around Sweden. These links to universities take on various forms. They supervise PhD students at various universities, and finance them either themselves or jointly with for example the Swedish Agency for Innovation Systems. The more research-oriented staff at Gamma Biotech also have their own personal networks that are used for meeting up with relevant researchers to discuss issues or projects. As they have gained reputation after 10–15 years in business, researchers also contact them in order to discuss possible projects, and if mutual interests can be found, it often results in collaboration. It has however taken a long time and a lot of hard work to be recognized and build this network. The main factors behind it is active use of informal networks and contacts, an aim for long and lasting relations, and putting effort in finding mutual interests. Their links to academia are of vital interest for them for three reasons. First, they build their business on the findings that come out of the various collaborations and projects. Second, they need to spread the word and gain further acceptance for their technology, something that was especially important at the outset of their business. Due to this, they demand researchers that they collaborate with to publish their findings, otherwise they are not interested in collaboration. Third, they are in no position themselves to pursue all research necessary for their business due to their limited resources being a fairly small company. There are usually no problems in the joint projects with academia as the general frameworks are explicitly set beforehand. Moreover, researchers mostly enjoy working with small companies and also have possibilities to influence the strategic orientation of the company through their findings. Other modes of interaction are conferences and seminars within academia. They almost exclusively use contacts with academia, and do not have collaborations with institutes or other organizations. Institutes are considered to make contract works and cannot add anything to the business of Gamma Biotech. Moreover, they prefer the 'free thinking' inherent in the academic model, and are into long-term relationships, not short-term assignments.

Delta sensors

Delta Sensors is active in the area of micro sensors. They have been in existence since 1994 and merged in 1999 with a German company. Currently they employ 23 people, 11 of whom are work in Sweden, another 11 in Germany, and one person in the USA. Most of the staff is in development and production, and half of them have a doctoral degree. Delta Sensors develops, produces, and markets chemical sensors components and sensor modules for air quality control, and their main customers are in the automotive, heat and ventilation, air condition, and environmental care industries. Delta Sensors has recently completely refocused its business and as a consequence their turnover was approx USD 279, 000 in 2001. They are however expecting to grow rapidly in their new line of business in the next few years, with a break-even in 2004.

History of the company and its links

Delta Sensors has its roots in a technical university and research on Field Effect, started in the 1970s. In 1989 they started doing research on chemical gas sensors, building on Field Effect technology, and in 1994 there was a company spun-off as an independent business man was given the opportunity to buy the patent. Together with some of the researchers in the research group, the company was founded as Micro Instruments with a focus on developing "electronic nose" instruments. At about the same time a German company, Micro Sensors, was

founded as a couple of researchers left their research group. Micro Sensors also focused on "electronic nose" instruments and sensor components but based their products on other technologies; Metal Oxide Semiconductor and Quartz microbalance. In 1999 the companies decided to merge into Delta Sensors.

Before the two companies merged they had mainly links with former colleagues at the two universities from which they had spun off, i.e. the Swedish university who also provided facilities and equipment, and the German university. Also after the merger these contacts remained the strongest. They also had some contacts with other universities, laboratories, and research institutes but only because these were regarded as customers or potential customers for their products and thus important for the sake of feedback. In 2000 Delta Sensors realized that they had to change focus and try to reach mass markets in order to make a profit and grow. Thus they abandoned the 'electronic nose' and instead turned to sensor components and sensor modules. In doing so they have not maintained contacts with these institutes, laboratories and universities more than to the extent that they still provide help or test equipment when asked for it.

Current links with the university and other PROs

They still maintain close contact with the two universities that the current company has spun off from, both informally in terms of personnel keeping contact with former colleagues, as well as formally in terms of research collaboration programs. At the Swedish office, Delta Sensors participates in a formal research collaboration that is a direct cooperation between their "home" university and about 10 industrial firms where they jointly decide upon, finance and pursue different research projects. The companies in collaboration are of various size, and of various areas of specialization where Delta Sensors is the only firm specialized in gas sensors. The German part of Delta Sensors has a similar arrangement with the university of origin. Another important link to the university is through the financing and supervision of doctoral students. Moreover, they attend different conferences in their area of interest as well as participating in different EU-projects that involves many different industries and universities throughout Europe. The main benefits altogether of the these contacts with the universities are stated to be threefold; they acquire research results that they can develop into products, the universities are good bases for recruitment, and it is also stimulant for the doctors working at Delta Sensors to maintain their contacts. Especially acquiring research results is important because being a small company, they cannot afford doing both research and development. They are thus using the university for the research part and are doing the development themselves, which leaves them with a fairly high dependence on the universities. This is sometimes a bit awkward since they can ask for research to be conducted in some areas, but have to rely on that the university perceives it as challenging and worthwhile to pursue in order to get it done.

5. Analysis of the cases

Alfa foods

In the case of Alfa Foods, the university linkage was dominated by the fact that the initial founder group were all academic researchers, and that the founder retained a 20% employment at his university department. The core technology was continuously derived and extended from the university's research, likewise was the initial and continuing staffing conducted on the basis of this linkage. Thus, intellectual capital as well as human resources was bound up in this tie. The founder and his department were the central nodes in the relation. While this is not an uncommon phenomenon, the case of Alfa Foods suggests an additional quality in the way in which these nodes become difficult to disaggregate: the department's knowledge was also the founder's knowledge, and the department's human resource base was also the founder's friends. Even the Managing Director, recruited from outside of academia, had a historical connection to the founder via a university–industry cooperative project.

For Alfa Foods, the university is not just one link among many, rather it is perceived to be critical to the very existence of the company.

This observation is all the more significant considering that the nature of the link appears to be fairly informal and relaxed. Since the preferred way of sustaining this linkage appears to be sponsoring and supervising of doctoral students, participating in research projects etc., the actual benefits to the company will be dependent on informally acquiring knowledge through communication, 'participating by doing in the projects', and through staffing. This suggests a number of mechanisms that falls outside of traditional intellectual property regimes, and that such arrangements may even hamper or destroy informal and well-functioning knowledge transfer, i.e. to weaken the strength of the tie developed (cf. Rappert *et al*., 1999). It is also clear that, in this process, Alfa Foods does not want to appear to 'co-opt' staff or knowledge, but must be seen to 'put something back' into the department's research. A result of this is that the company has decided to engage with academe in terms of academic imperatives for producing knowledge, that is, by doing research. Subsequent parts of the business process do not figure in the linkages with the university, but is a concern solely for Alfa Foods itself. This seems to work fine, but runs at the same time counter to innovation policy conclusions which encourage universities to engage in business development *on their corporate collaborator's behalf*. It is also clear from looking at Alfa Foods that in terms of invested time, network presence is a costly affair and that such investments must be made with prudence, especially given high stability of the core technology.

Beta technologies

Beta Technologies' historical ties to the university are very strong, in the sense that the company was in fact spun-off from an actual university research project and staffed by the project personnel. The founder saw a 'personal value proposition' in the project already halfway through its execution and managed to involve project members in the venture, most likely by employing his dual role as professor and entrepreneur. However, students were able to continue to pursue their degrees in their home department; a situation which likely ensured a continued flow of knowledge between the department and firm. This arrangement is probably to be preferred to a situation where the company is seen as a competitor with the department for labour. This connection also enabled Beta Technologies to continuously participate in supervision of doctoral students, which is clearly a very popular and also functional type of linkage in the transfer of research knowledge (cf. Alfa Foods).

The research collaboration between Beta Technologies and the university department was not based on a 'one-shot' invention, but was rather a matter of the department continuously generating input into the company's products, i.e. allowing Beta Technologies to innovate incrementally on the basis of research performed at the department. The exclusivity of this partnership is partly due to history and location, but also to the specialization of the knowledge component of the products offered as compared to the research generally available in the national science system. However, the reliance on cutting-edge research, which is conducted in only a few locations and which is also dependent on public funding, creates a problematic dependency for Beta Technologies. Innovation and survival becomes dependent on continued public funding for a particular science area: that is a sort of 'science policy risk' is involved for the spin-off from relying on this link. One way of controlling for this risk is to forge contacts with research centres in other countries; however this particular strategy proved to be too expensive for Beta Technologies in terms of time and other resources. This is one of the dilemmas involved in forging links with cutting-edge research collectives: the entry barriers are not only highly knowledge dependent; they are also often dependent on local professional networks, similar to the one that Beta Technologies themselves forged over many years. This may explain why EU-project participation is somewhat restricted in terms of returns to firm innovation, and that it is very contingent on available time from core activities.

Gamma biotech

In the case of Gamma Biotech the ties to the initial founders, both being established researchers, have remained strong over time by the company

keeping them on the board and using them as external consultants. Due to resource constraints Gamma Biotech carefully chooses the networks in which to participate, but rather than relying on only a few strong links to the university, it has worked from the outset to form more linkages, particularly through the extended networks of the founders and through recruitment. Many of these ties can be said to be strong in the sense that building many long lasting relations has been an active strategy. In the case of Gamma Biotech, the use of many strong ties to the university could be linked to previous observations that networks are more prevalent within the biotech field generally (e.g. Powell *et al.*, 1999). However, other aspects of their technology may also explain this. At the time of founding this was a completely new technology and in order to create awareness and gain acceptance for it the founders deliberately attempted to stimulate research on it on a wide institutional basis, and also required researchers they collaborated with to publish the results.

Apart from creating awareness and gain acceptance, this multitude of linkages was vital in order to maintain a broad base for staffing. An additional reason is the stated preference for the 'free thinking' way of working in academe, which may be related to the fact that many of the employees are themselves academic researchers. The preferred linkages are collaborative research projects and supervision of PhD-students. These links are formally constituted, but build on a high degree of informality and are often created through the informal ties of the research-oriented staff, often originating by university researchers approaching them with project proposals. It is also important to note that Gamma Biotech puts efforts into finding mutual interests and create win–win situations, and sees this strategy as an important factor in making collaborative relationships work (cf. Das and Teng, 1998).

Delta sensors

Out of the four companies studied, Delta Sensors is the only one where the university had an active role in the spin-off process, by deciding that the time was ripe for company formation around the initial patent. Staffed by people from a research project, as well as starting out using facilities and equipment at the university, Delta Sensors' historical ties to the university were strong. As it has developed, Delta Sensors now actually consists of two spin-offs that have merged, thus leaving them with strong historical ties to two different universities.

The linkages to the two universities are very important because of a deliberate split between research and development, where the universities or research collaborations are used for the former part while the company conducts most of the product development themselves. The reason for this division is simply that they cannot afford to have both in-house research and development to the extent needed. As in the previous cases, the preferred linkages are research collaborations and supervision of PhD-students, which together with contacts with former colleagues permit knowledge to flow informally between the company and the universities. However, they also have much more formalized research collaboration, including other manufacturers as well, in the science park where they are situated as well as with other European PROs through participation in EU-projects. Professional, academic historical relations, as well as to a lesser extent geographical proximities, however, constitute the strong links of this spin-off to the university.

Summary of the cases

Although from different sectors, of various age and size etc., the cases still exhibit some important similarities that are summarized below along with the more specific findings.

The remainder of this paper will now discuss these dimensions in further length.

6. Discussion and conclusions

Although the cases presented above are too few to make generalizations, a comparison of the cases and the literature provides enough material to form a basis for some observations which may be of use either in future research or in policy-making. In three of the four spin-offs, firm formation was actualized on the initiative of the researchers and in the cases presented here the most frequent cited reason for spinning out

seems to be personal interests or value propositions rather than university policies. Delta Sensors is the exception to this rule in our sample (see Table I). The fact that in Sweden, researchers generally have the legal right to any intellectual property accruing from their research findings explains this situation to a certain extent. Incentives for individual researchers to commercialize their findings are high for would-be innovator-entrepreneurs because of the potential financial gains compared to for instance a smaller percentage of the possible income of a patent or license held by the university (e.g. Goldfarb and Henrekson, 2003). According to Gregorio and Shane (2003) this should increase the likelihood of university spin-outs. However, in the Swedish case this advantage is somewhat attenuated by the costs of patenting and eventual commercialization. Thus despite the high incentives, Swedish researchers are comparably behind in rates of commercialization. This phenomenon has not unexpectedly been a central issue in the debate on intellectual property rights in Sweden and initially it was thought that the ownership convention was an actual obstacle to commercialization. Recent developments suggest a shift in position to a view that fits more closely with the above, i.e. that the low rate of spin-outs may be more of a reflection of the costs of commercialization rather than who owns the intellectual property. In keeping with this the most recent policy proposal on this subject in Sweden proposes to keep the intellectual property rights situation intact but to give universities the possibility to finance commercialization efforts if employees are so interested.

Another dominant trend of the cases here and the literature on the subject is that founders tend to retain their positions in academe, either part time or full time, in our cases it is as high as three out of four founders (see Table I). This suggests that some of the vital forms of exchange, e.g. transfer of research and personnel are dependent on boundary spanning individuals who have a 'right to belong' in the two different worlds. The reasons for retaining the linkages are many. First and foremost the researchers at the home departments are former colleagues, and likely also friends, between whom a strong sense of trust and lasting reciprocities has evolved,

Table I
Summary of Findings

	Alfa Foods	Beta Technologies	Gamma Biotech	Delta Sensors
Origin of initiative for spinning off	Individual	Individual	Individual	University
Primary motivation for maintaining links	Research	Research	Research and to build acceptance	Research and access to equipment and facilities
Network presence	Limited. A few strong ties and more weak ties — e.g. EU-projects	Limited. Mainly one strong tie and a few weak ties — e.g. EU-projects	Extensive. Many fairly strong ties, as well as a number of weak ties	Limited. A few strong ties and more weak ties — e.g. EU-projects, the Science Park
Nature of relations	Staffing (e.g. PhDs) Intangibles. Informality and bi-directionality preferred	Staffing (e.g. PhDs) Intangibles. Informality and bi-directionality preferred	Staffing (e.g. PhDs) Intangibles. Informality and bi-directionality preferred	Staffing (e.g. PhDs) Intangibles Informality and bi-directionality preferred, Also important with formal network
Ways of promoting sustainability	Mutual interest. Founders part time in academia. Geographic proximity, etc.	Mutual interest. Founder full time in academia. Geographic proximity, etc.	Mutual interest. Founders full time in academia.	Mutual interest. Geographic proximity

often over a long time preceding the creation of the spin-off. Another important reason noticeable in all the cases was that like traditional SMEs, spin-offs are extremely short of resources. Initially this concern may have more to do with a need to access equipment and facilities, but over time the need to develop additional knowledge in terms of firm R&D becomes vital for purposes of competition. While previous studies have recognized the mutual dependence between universities and their spin-offs in areas such as the use of equipment and facilities (e.g. Rosenberg, 1982; Berglund and Hellström, 2002), the potentially more decisive and longer-lasting effects of research dependence has not been equally well reported. There is also a need for a systematic study of this issue both for the purposes of informing science policy as well as developing a better understanding of the R&D dynamics of small knowledge intensive firms.

In our sample, the academic spin-offs are for the most part products of research universities and the universities still provide much of the continuing research needs, while later stages of the product development process is left entirely to the company, thus turning them into some kind of 'business developers of university research'. Taken together with our earlier observations about the high level of dependence of many spin-offs on university research a number of conclusions of interest to policy may be posited. One of the first is that the long term consequences of continued dependence on the university for research may be problematic for the spin-off in question. As shown in one of our cases, this is a situation that already worries some companies. The vulnerability in the Swedish context where universities are for the most part public and are dependent on the whims of policymaking for their budgets is especially high. Despite the use of the system metaphor in all policy thinking on innovation, the reality is that university research is dependent on budget allocations from the state and the ability of those who allocate budgets at this level to access information about the dependences in other parts of the system is limited to say the least. Thus, the firm is dependent for its research on an organization that is in turn dependent on a well meaning but not equally well informed benefactor. An alternative scenario and one which policymakers may be betting on too wholeheartedly is that spin-offs expand to the point where they can fund their own research needs either in house or through an arrangement with the university. Optimism in this regard should also be tempered with existing evidence about the R&D funding behavior of large firms. Even in these cases, there is a critical dependence on university research and ironically enough just when policymakers are advocating that universities do more applied research and commercialization, such enterprises are pleading for continued public support to basic research.

Except for one case, where a wider network of weak and strong ties served as part of an active and purposeful strategy for gaining legitimacy, the academic spin-offs reviewed here are rather limited in terms of network presence, with generally two discernable types of relationships to universities (see Table I). (1) A few strong ties, often related to the home departments of the spin-off, and (2) weaker ties to other universities or institutes, often mediated through EU-projects. This pattern of relatively few strong ties is supported by Liao and Welsch's (2003) findings that technology-based entrepreneurs benefit more from strong ties and a dense network than from an extensive social network. The reason is that this promotes trust and cooperation and so facilitates freer exchange of fine-grained, high-quality information and tacit knowledge. The high degree of informality that obtains in these circumstances in spite of the crucial importance of these arrangements to the firms suggests that the spin-offs are retaining the gift-market-gift cycle of exchange relations that is common in academic contexts. A corollary to this observation is that several studies have found preferences among university researchers for bi-directional, collaborative relationships rather than one-directional relationships, like those usually found in contract research (e.g. Meyer-Krahmer and Schmoch, 1998). Our study suggests that the preference for bi-directionality also exists within the academic spin-offs, which is manifested in for example the expressed desire for finding mutual interest, and in the strong emphasis on informality in personal contacts and knowledge exchange (see Table I). This could be due to the fact that many of the

employees share the same academic background and values as their academic counterparts. But this relationship is likely also promoted because of the sustainability and the development of trust involved in, and facilitated by further knowledge transfer (Carayannis *et al*., 2000).

Sustainability seems to be a key characteristic of these linkages, considering the long history of many relationships and the general preference for long term commitments. In view of the importance of knowledge transfer processes between the spin-offs and universities this is not surprising, since such transfer is likely to require a mutual language, similar knowledge assimilation processes (Cohen and Levinthal, 1990) and again trust. The recurrent emphasis on putting efforts into finding mutual interests is also likely to promote sustainability and generate trust (Das and Teng, 1998). However although trust and informality may be of great importance, this alone does not guarantee smooth and effective collaborations. The cases suggest that in order for these to work on a long-term basis more hands on practices and as well as formal mechanisms may be needed. These more formal aspects may include explicitly and beforehand setting up a collaborative framework, while maintaining flexibility within relationships when it comes to publication of results, IPR rights, etc.

From the point of view of national policy it is important to note that although policy attention emphasizes the university qua organization with regard to commercialization and knowledge transfer, it is the department, groups of researchers therein or networks of departments with which spin-offs have relations. This finding in the cases reported above is supported by studies from other countries (cf. Jones-Evans *et al*., 1999; Benneworth, 2001). Reasoning from this we may posit that centralized mechanisms for managing commercialization efforts may be superfluous since commercialization and follow up activities appear to take place at a lower level in the structure than that at which such services are usually placed. This is not to say that liaison offices have no place in commercialization however it may be that their effectiveness could be increased if they were to be restructured according to a regime that is based on coordinating and facilitating relations between departments and the networks that they create.

Academic spin-offs are highly dependent on a sustainable link to university research for a number of reasons, thus it should come as no surprise that their network relations are characterized by a small number of strong ties which are in turn characterized by a high degree of trust and informality, which due to history, reciprocity and location (social capital aspects), and the specificity of the knowledge transferred, becomes difficult to substitute.

From the point of view of the spin-off companies, the continued need for help with research coupled with the difficulty to substitute the strong ties, make these ties something of a double-edged sword. The cost to build and maintain them must be contrasted with the risk of becoming too dependent not only on one department, but also on that department's ability to attract funding from other sources. One way to mitigate this risk may be to engage in a wider network of weak ties which, in time, may be developed to become strong ties. Although helpful, the development of such research collaborations does not have to involve geographical proximity (cf. Gamma Biotech), however, finding mutual interests, emphasizing informality and bi-directionality, as well as safeguarding by articulating priorities on beforehand, ought not to be overlooked. One particular arrangement that seems to fulfill this to a large extent, and which was preferred by all firms in our study, was the joint supervision of PhD-students. The development of such relations may also be facilitated if the founders retain a position in academia, thereby being able to act as boundary spanning individuals between the two worlds.

In summary, academic spin-offs are the product of an evolution of ties between individual researchers, departments and successive generations of students. The cases above show that spin-offs have a similar relationship to universities as larger research intensive companies in that they depend on universities to do the majority of the research thus being enmeshed in a much tighter web of social, economic and knowledge ties with the university. This makes their dependence and vulnerability greater to shifts in national innovation and science policy trends. If the present policy trend of promoting commodification were to continue, policymakers may find that

they will have to take into account potential impact of research funding policies on spin-offs. Universities may also potentially increase their leverage in policy by pointing to the growing interdependence between departments and spin-offs.

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