University Spin-off Formations: How decision making process has been made?

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Abstract

Commercialisation of intellectual property (IP), particularly patent becomes an important agenda in most universities. Patents that were licensed to established companies in return for royalties recognised as a traditional mode to commercialise university IPs. As government funding are getting harder to obtain, and demand from the stake holders to see universities play more important role in local economic development, universities are prompts to look at spin-off formations as an alternative route for technology commercialisation. This paper is trying to look into the process of decision making in commercialisation of university patents through spin-off formation.

A single case of one university in Scotland is adopted in this study. Six patents from university portfolio's patents were selected, which were licensed to spin-off companies. Companies that licensed know-how or IPs other than patents were excluded. The inventors of these 6 patents were interviewed in depth using semi-structured questionnaires, which were recorded and later transcribed. The data were then analysed using a case basis and cross-case analysis aided with Nvivo software.

The study found that the decision making to seek patents protection was made by the inventors, and the Technology Transfer Office (TTO). On the other hand, the decision to commercialise the patents through the spin-offs creation were initiated by the inventors alone, not by the TTO. The study also revealed that the stage or performance of the technologies and the entrepreneurial characteristics of the inventors lead their patents were commercialised through spin-offs. Inventors industrial working experiences prior to their research positions in the University, were able to recognise the potential values of their technologies. This factor was found to be the most significant that drove them to form spin-offs. Their experiences meant they had better knowledge about potential market, market size as well as the standing of their technologies in the market place. Other important factors were the role and supports of Technology Transfer Office as well as the availability of funding. The result of this study could help policy makers in universities to consider: what are the characteristics of the inventions and the inventors, the availability of funding as well as the roles of technology transfer offices in their decision-making to spin-offs.

Keywords: Spin-off formation; commercialisation; technology transfer, inventor-entrepreneur

1. Introduction

The importance of university spin-off companies towards local economic development has been studied extensively (Etzkowitz, 2002; Etzkowitz, 2003; Shane, 2004, Shane 2008). The influence Route 128, Silicon Valley in the US and the Science Park in Cambridge in the UK (Oakey, 1995, Etzkowitz, 2003) are recognised by policy makers as sources of industrial innovations that could trigger and stimulate local economic developments. Even though extensive research has been done on spin-off formations, only a few studies have used patents as an unit of analysis in the study of company formations by universities (Shane, 2001a; Shane, 2001b; Shane, 2004). This paper attempts to answer the question: *what are the features of university patents that are commercialised through spin-off formations?*

2. Literature reviews

There are four major factors that influence whether a patent is likely to be exploited through spin-off companies.

2.1. Individual characteristics, motivations and ability to recognise opportunities

There is substantial research on entrepreneurship which focused on personal characteristics as a predictor of entrepreneurial activity (Roberts, 1991a) or champions to new ventures. Roberts' (1991a) study of the high technology entrepreneurs demonstrated that the factors that led inventor-entrepreneurs to form spin-off companies are outgoing characteristics; extrovert personalities; are from families with business background; independent, have work experience; achieved higher educations and skills; and are dissatisfaction with existing jobs. The main factor that pushes inventors towards being entrepreneurial is the desire to see their inventions being commercially exploited and only then followed by their desire for wealth creation and independence (Blair and Hitchen, 1998; Shane, 2003; Shane, 2004).

2.2. Organisational resources and capabilities

Spin-off ventures are different from other start-ups, because they develop out of a non-commercial environment. Thus, during their formation these companies would acquire different resources from other start-ups. The resources that are required at the launch period are: the technologies, funding availability, a strong network, participation of the inventors in the product development, and skills/capabilities of TTO.

2.2.1 Characteristics of technologies

Spin-offs occur in situations where technologies are at an early stage, have strong patent protection, multipurpose and involve technological breakthroughs (Shane, 2001a; Shane, 2001b; Shane, 2004).Early stage technology tends to be exploited by spin-off formation. Established firms refuse to exploit multipurpose and radical technology that would cannibalise their existing production process. They also tend to exploit ready-made technologies (Shane, 2000a; Shane and Khurana, 2003; Shane, 2001a; Shane, 2004).

2.2.2 Research funding

Research funded by industry tend to increase the number of patents, which lead to publications and commercialisation (Roberts and Peter, 1981; Powers, 2003; Coupe, 2003; Dietz and Bozeman, 2005) compared to government fundings which normally only lead to publications. There has been a long debate, suggesting that industry funding impacts on the direction of university research, discouraging blue sky and curiosity research amongst academic staff and encouraging a focus on applied and short term research (Lee, 1996; Shane, 2004; Gulbrandsen and Smeby, 2005; Stransburg, 2005).

Industry funding sometimes prevents free dissemination of their knowledge. The work of Lee (1996) showed that there has been some resistance by faculties towards commercial activities as they are concerned that they will be required to divert from basic research.

2.2.3 Spin-off funding

Funding is a crucial resource needed to start a new venture. It is difficult for spin-offs to obtain external funding as the technology is at an early stage and usually with uncertain market (Shane, 2004; Vohora et al, 2003, Binks et al., 2005; Wright et al., 2006). Pre start-up and start-up stage, government funding, through various programs, is crucial to the facilitation of a new venture as demonstrated by the SBIR Program in the US (Etkowizt, 2002) or University Challenge Fund in the UK (Lambert, 2003). However, this type of funding is not adequate for further development at the start-up and post start-up phases. Thus, external funding is crucial to the further development of technology to enable it to reach the prototype stage whence a company can convince customers (Mansfield, 1995; Shane, 2003; Shane, 2004).

2.2.4 Networking and involvement of the inventors

Studies indicate that inventors with strong networks and social ties, either formal or informal, would facilitate spin-off formations. These networks help the founders of new ventures to access external funding to set up their firms. In certain situations parent organisations and the firms that the inventors had worked as consultants, would become first customers for the new companies (Perez and Sanchez, 2002).

Shane and Cable (2002) studied investors who had made seed stage investments to 136 individuals. The results showed that direct and indirect ties led to strong and positive relationship in investments from financiers. Shane and Stuart (2002) further examined why some university start-ups are more successful than others and found that ventures whose founders had social ties to venture capitalists before the founding of their firms were more likely to receive funding and were less likely to fail. Venture capitalists are more inclined to support spin-offs whose founders are recommended by a third party through their networks. This alleviates the information asymmetry problem (Shane, 2004). Universities that have strong networks showed evidence of increase in the number of spin-offs compared to those who do not stress the advantage of networking (Shane and Cable; 2002; Lockett et al., 2003b; Shane, 2004).

Lockett et al. (2003b) reported that the top ten universities in the UK have external networks that facilitate the process of spin-off formations. Nicolaou and Birley (2003b) supported the view that internal and external individual networks influence the type of spin-offs formed, either as an orthodox spin-off, hybrid spin-off or technology spin-off.

In addition to networking, the commitment of the inventors is important to product development. In fact, commitment begins at the opportunity recognition stage and continues until the company has been formed and sustained. Inventors' commitments are important because most of the university technologies are at an embryonic stage when the companies were formed, which involve tacit knowledge (Thursby et al., 2001; Shane, 2004).

2.2.5 Resources and capabilities of TTOs

TTOs should have skilled and experienced officers, well versed with the legal aspects of patents and patenting. TTOs also need to have a good link with inventors and faculties, industry, private financiers, which would lead to quality approach to inventions and thus could secure funding for spin-off formations. The skills and capabilities of the TTOs are important in the selection of what to patent and then which route to commercialise the patents. It was emphasised in literatures that wrong selection can lead to many poor quality patents being granted and not exploited. Wrong selection and high market expectation (McAdam et al., 2004) may lead to an increased number of low quality spin-off companies which would perform poorly and would be unsustainable (Lambert, 2003; Raven, 2006).

The TTOs skills and capabilities are associated with affecting the availability of resource (Lockett et al., 2003a; O'Shea et al., 2005) from which they are able to employ quality surrogate entrepreneurs or patent agents to evaluate disclosures before proceeding further (Franklin et al., 2001; Siegal et al., 2004).

Lockett et al. (2003a) further noted that the availability of resources (stock of technologies, and skilled staff), incentives and rewards, business development capabilities and the ability to access external finances and networks, were the main factors that facilitates the formation of spin-off companies in universities. It could be further concluded that the entrepreneurial role of TTOs, their expertise and networking abilities, their ability to recognise opportunities and organise equity ownership for the spin-offs are the characteristics required to succeed in this type of ventures (Lockett and Wright 2005; Powers and McDougall 2005 and O'Shea et al., 2005). However, the studies focused solely on the TTOs' skills and competency but did not look at how the TTOs were involved in the decision making process.

3. *Methodology*

The paper is based on a single case study in one of the universities in Scotland. 6 patents from its portfolio, which were licensed to spin-off companies, were selected. Companies that exploited other IPs than patent were excluded in this study. Inventors were interviewed in depth, using semi-structured questionnaires. The interviews were recorded, transcribed and the data were analysed using case analysis and cross-case analysis.

4. Findings

4.1. Companies profile

Table 1 summarises the profiles of companies that were studied. Four of the companies were founded after the year 2000. At that time the University encouraged its staff to spin-off as a result of the availability of the government's University Challenge Fund. Company D was founded in 1995 and Company F in 1999. Almost all companies were founded by more than two people.

Company A was founded in 2003 by 2 lecturers of the University who invented the technology. The company licensed the technology from the University on exclusive rights. The company targeted market in geosciences for the gas and oil industry. Other markets include the medical sector to help scientists understand the human neurological structure and geo-mapping for military and government applications. The founder-inventor of the company used to be a consultant with Ford Motors, and had designed a 3D system for vehicle design, which replaced the clay models. Work experience with Ford Motors gave him an advantage and helped him to develop the 3D visualisation systems hardware, which is the main product of the company.

Company B, was started in the year 2001 with two founders and five employees, all of whom were university staff. The founders worked full time in the company as the CEO and the Technical Director. The company developed activity-monitoring devices that can monitor the daily activities of humans. The system could be applied for clinical management of a specific health conditions and personal activity applications. The advantage of the technology is data manipulation and processing. The University granted an exclusive license for the company to utilize the patent for the technology. The founders had work experience within the biomedical industry before starting their research in the university.

Company C was formed by two founders in the year 2001. The inventor-entrepreneur was a research fellow in the University, working on a contract basis. His background was in chemistry and his expertise is in developing material gel, and has applied for patent protection for his invention. He had been studying gel materials for more than 20 years. The University did not have any equity in the company, but the university assigned the IP exclusively to the company when it was formed. The patent maintenance fee has to be paid by the company. The company is selling gel materials using a special membrane gel for indoor plants and pots that can control the water level.

Company D was founded in 1995, but the process of creating the company began in early 1991. During that time the university had put little effort into encouraging spin-offs and commercialization of technology. One o the founders was a lecturer at the university and the other was from industry, and was a visiting lecturer to the University. This company was the first that was spun-off from the University and was leading the way in commercialisation activity at the University at that time.

Insert table (1) about here

The company is now operating in a global market supplying monitoring equipment for gas insulated electricity substations (utilities) to companies such as Scottish Power, National Grid in Britain, Tenaga Nasional Berhad (TNB) in Malaysia, Singapore, Middle East, Korea and Switzerland. There was no monitoring system available for substations anywhere else at that time and the company became the first supplier and consultants in the use of a monitoring system. The company currently has 24 employees and has a branch in Australia. At its founding, the company received various tranches of funding from industry and government. The biggest amount of funding came from Scottish Power and the National Grid at the development stage of the product. These companies gave them full support in the development of the system and were the first buyers of the system. Originally, the University had a share in the company with an investment of £10,000. The company bought back the shares from the University and now has full ownership of the Intellectual Property.

Company E was formed by four founders in January 2003. The inventor-entrepreneur was a PhD student at the University. He registered for his PhD in 1998 and finished it in 2002. The company sells a range of portable devices, which use gas detection system, which is the result of his PhD research. The University has 20% equity in the company and has assigned patent rights to the company. The company now has nine employees including the founders and management team. The initial market for the company was focused on four core areas: defense, airport security, oil and gas industry, and medical diagnostics. The device is the most effective and comprehensive method available for sensing dangerous drugs, explosives and hazardous compounds.

Company F was founded in 1999 with four founders. The University gave an exclusive license to the company. The company specialises in video compression systems and now has 16 employees and a branch in the US with a fulltime staff. Security forces in the United States are the company's main market. The inventor entrepreneur is the CTO (Chief Technical Officer) and a 'champion' of the company, in charge of day-to-day management and the operation of the company. He worked with the mobile phone company Orange as a consultant prior to forming the company. Orange funded the invention to develop video services to be used in mobile phone technology in conjunction with voice system technology. The video and camera technologies were prerequisites to mobile phone service providers to granted 3G licenses. Orange funded the invention hoping to be awarded 3G licenses. Orange later only their technologies for internal use rather than promote the technology they invented for mobile video compression. The company then left Orange for other markets.

4.2. Background of the entrepreneurs

All except one of the inventor-entrepreneurs (from Company B) are doctorates in their respective fields. In fact they are now entrepreneurs because of their research products when they were PhD students or the supervisors of PhD students. These show that their expertise in relation to the technologies to be commercialized. The fact that they left academia also showed their commitment to their inventions.

The inventor-entrepreneurs were aged from 28 years to 48 years when they started their respective companies. This in line with suggestions by McQueen and Wallmark (1982) and Roberts (1991a) who suggested that an entrepreneur should venture out before the age of 35. After that age they might have gone into secure positions or comfort zones, making it more difficult for them to start new ventures.

The inventor-entrepreneurs transition from the University to the business world was also eased by utilising the University's incubator; allowing them to work in the University during the formative years of their ventures.

This soft transition was utilized by 3 inventor-entrepreneurs, while the other 3 immediately started full time in their ventures. Another main advantage of soft starting allows the inventor-entrepreneurs to be exposed to the business world as well as the most current development in the University's laboratories.

4.3. Motivation

The findings demonstrated that the inventor-entrepreneurs decided to form spin-offs due to a number of reasons (Table 2). Money is not the primary factor that drove them to exploit their technologies. The main factor is the desire by them to see their patents commercially exploited (Companies B, D, E and F). This is consistent with the findings of Smilor et al. (1990), Blair and Hitchen (1998), and Shane (2004).
The second reason is to get rich. By observing the success of other people after they had exploited a patent they wanted to do the same. For example, the inventor-entrepreneur of Company A was driven to exploit his patent after a Ford Motors manager resigned and licensed the technology they had invented. In only one case, the company that produces the hydro gel materials (Company C) the inventor was driven to commercialise the invention by the motive of not being satisfied with the contract post he had with the University, thus for him it was a push factor.
Besides wanting the invention to be exploited (need for achievement), other characteristics such as disposition to act, the desire to be independent and in control and willingness to take risks are the factors that differentiate these inventors from others though these were not asked during the interviews.

Insert table (2) about here

4.4. Opportunity recognition and the trigger factors

The initial decisions to exploit the opportunities of the patented inventions were initiated mainly by the inventors-entrepreneurs based on their work experiences in industry. Potential customers and the University also played important roles in the recognition of the opportunities. The identification of opportunities and the trigger factors are summarised in Table 3.

Most of the entrepreneurs are well versed with their patented technologies, thus knew what product to develop and what type of business they should target. In all the cases the opportunities were evaluated and clarified before venture formations, however Companies B and F used external consultants to carry out market research before going for the University approval. In two cases, the opportunities were recognised as a result of customers' demands. For the other four companies, the customer needs had already been identified.

In the case of Company A, the founders recognised the opportunity from the beginning when Ford Motors first consulted them. Prior working knowledge often led the founders to start ventures to produce products or services to be offered first to their former employers, then other clients whom they had worked for as consultants. This is consistent with studies by Shane (2003) and Heirman and Clarysse (2004).

Entrepreneur B was the main player who recognised the opportunity to commercialise the invention, after he was contacted by customers. The University also helped the inventor to identify and exploit the opportunity. The founder had attended entrepreneurship courses in the university's Entrepreneurship Centre. The course exposed the inventor to business training, identified the opportunity and linked him to external networks such as private investors and financiers. Another factor that influenced the research team in recognising the opportunity was that one of founders was a technical director of biomedical company. His experience combined with the new research results helped the team to recognize and exploit the opportunities.

Insert table (3) about here

Inventor-entrepreneur C had been doing research in hydro-gel for 20 years. He was working on a contract basis with the University and felt that his current post at that time was not secure.

He realised that the technology could only be exploited if a company was formed. A meeting with the entrepreneurship centre of the University triggered the decision to form the spin-off company.Company D supplies monitoring equipment to electrical utilities in Britain and worldwide. The inventor-entrepreneur used to work in industry before he joined the University. A trigger factor that leads him to identify the opportunity was that his friend at National Grid was appointed as a visiting lecturer in his department.
Through their prior working experience, they designed and developed the system during the period of 1990-1995. The company was a pioneer in the supply of the system; and the goal is to supply to worldwide market.

Scottish Power and National Grid gave full support and gave them grants as trigger factors to motivate and commercialise the technology. In 1991, they developed a full system and installed a trial system. The system was successful. In 1993, it was a very important step in the company's future, when Scottish Power and the National Grid accepted the system onto their network and became their first customers. Acceptance of the system by two established organisations made it easier for them to penetrate the worldwide utilities market. Inventor-entrepreneur of the Company E, whose company produces gas sensor system, also recognised the opportunity from his prior working experience with the National Physical Laboratory in London.
Once more, it was triggered by the entrepreneurship centre of the University. He pursued his PhD in 1998-2002, in the area of Physics, trying to refine the development of a gas sensor system. From the beginning the inventor realised the opportunity to commercialise the research that he had been doing in the University.

Company F, is producing a leading edge video compression technology device. The images they produced are of very high quality, can be compressed and transferred to particular places in real time. The opportunity to exploit the technology came after the group finished the project with Orange. They were doing more research and were able to patent two more inventions that emerged from the existing technology. The original application of the video compression technology was targeted to be use in mobile phones, but Orange who initially licensed it could not exploit the technology further. The technology was not compatible with the international standards in mobile phones was the main reason it could not be used. This led the team to form the company to market the technology to different sector, especially the high quality multipurpose video compression market.

5. Characteristics of patents suitable for spin-off

These findings show that technologies licensed to a spin-off company are consistent with Shane's studies (2001a; 2001b; 2002; 2004; Nerkar and Shane, 2003), which suggest that a technology at the very early stage, radical, multipurpose and with strong patent protections, would generally be licensed to new spin-off companies. Five of the six patents were at proof of concept stage and only one was at the prototype stage during the founding period of the spin-off companies.

5.1. Early stage technologies

All the companies were founded to commercialise early stage technologies. (Table 4). Only one technology was at the prototype stage when the company was founded whereas the others reported that they only had proof of concept stage technologies. Companies A and D, are still developing their products to prototype stage so were considered to be still at proof of concept stage. Further development of the products was done as soon as the companies were founded.

Insert table (4) about here

The study suggests that the experience of the founders in working with industry and the University gave the added advantage of a much quicker route to the nearly mature technologies as suggested by Heirman and Clarysse (2004). Only one company had a ready prototype (Company C) while three only had proof of concepts (POC). For Company C, the technology was developed whilst the inventor was still in the University.

The technology is simple, but is considered to be novel as the processing technique uses gel as a membrane to control the water level for indoor plants. The other three companies (Companies B, E and F) had developed prototypes and then sold their products after the companies were incorporated. The finding is consistent with previous research which found that early stage technologies are difficult to license to established companies because the technologies were not proven, risky and investments would be needed for further research and development in order to bring the technology to the commercial stage (Thursby et al., 2001; Shane, 2001a; Shane, 2001b; Thursby and Thursby, 2002; Nerkar and Shane, 2003; Thursby and Thursby, 2003; Jensen et al., 2003; Shane, 2004; Thursby and Thursby, 2004).
Established firms normally focus on existing operations and tend to buy ready-made products because they do not want to devote resources to development. The technologies that the spin-off companies were based on were not suitable to be licensed to established firms.

5.2. General purpose technologies

The finding show that five companies (the exception is Company C) have broad application patents, this supports Shane's (2001a, 2004) findings. University spin-offs tend to exploit general-purpose technologies, or basic inventions with broad applications. Established companies are reluctant to exploit general-purpose technologies because they do not clearly demonstrate specific purpose or immediate applications (Shane, 2004).
For example, the technology applications from Company E can be applied in various sectors such as the oil and gas sector, medical diagnostics and security and defence industries, but it could not find a ready licensor. General-purpose technologies also allow founders to change the market application when the first application fails for some reasons (Shane, 2004). For example, Company F had changed their main target application of their video compression technology. The main target was to use the video technology in mobile telephone however; the international standard (Mpeg standard) imposed by all phone manufacturers prevented their technology from entering the market. The standard had already been accepted and approved before their technology, which is a lot better, become available to the industry. They tried to lobby for their technology to be used as part of the standard, but failed as a big hardware manufacturer had already invested a lot of money in the standard system.

That was a very critical point and a very difficult time for the company after they had spent the first round of funding of £1.4 million they the company had to identify new markets, new customers and new venture capitalists (at the beginning the existing venture capitalist was not willing to reinvest after the first market collapsed) to invest in the company. They were fortunate when the security sector in the US approached them and became their first and main customer but the application of the technology has had to adapt to the security market.

5.3. Strong IP protection and wide patent scope

In all cases, the entrepreneur-inventors claimed that their patents have a broad scope of patent and strong patent protection. They have been advised by Patent Agents to claim as broad a patent as possible. The reason is that the broadest patent would hinder other parties from using the technologies without having to get the companies' permission and pay royalty fees to them. New spin-off companies sometimes solely depend on their strong patent protections and broad scope of patents for competitive advantage (Shane, 2001b; Shane, 2004; Heirman and Clarysse, 2004) and to access funding from external sources to further develop their technologies.

5.4. Radical technologies

All the cases reported that their technologies are a big jump in technological development. In other words they are radical, which are difficult to license to established firms. The finding supports Shane (2001a; 2001b; 2004) who suggested that the more radical the technology the higher the likelihood it would be exploited through spin-off formations.

6. Funding

6.1. Research funding

The findings show that both industry and government research funding contribute in equal importance to spin-off formations. Each source funded four spin-off companies (Table 5).Table 5 shows the sources of research funding before start-up and funding at the start-up stage for the new ventures. Government funding is provided through EPSRC grants (4 cases). Industrial funding (the name of the industry was not mentioned by the inventors) occurred in four cases. This finding is consistent with Powers and McDougall (2005) who suggested that government and industrial funding is important for spin-off formations.The findings partially support O' Shea et al. (2005) and Wright el al. (2006) who suggested that research funding from industry would increase the chances of spin-off formation.
Government funding is important both for curiosity driven research and application type research (Strandsburg, 2005) but industry funded research projects, especially at the later stages of research would tend to result in spin-off creations as the research would have shown signs of potential applications and markets.

6.2. Spin-off funding

The technologies adopted for the most university spin-off companies are leading edge technologies, thus need huge amounts of capital to develop into marketable products. Universities cannot afford to fund such technology developments and bring them to the market place. Therefore external funding is crucial for the spin-off companies to commercially develop those technologies.

In this study, all cases received external funding from various sources. It included government grants, venture capitalist, private investors, personal savings and bank loans. The government grants are only given as seed money to develop the patented technologies to prototype stage, which is consistent with Shane (2004), Binks et al. (2005), and Wright et al. (2006). Five companies (Companies A, B, C, E and F) received funding from various government grants such as the University Challenge Fund or Synergy Fund (Syn. Fund), funds from Scottish Enterprise through various grants such as Scottish Technology Fund (STF), Scottish Equity Partners (SEP) and the Scottish Executive (SE). However, for Company E, many individual inventors invested in the company besides the main investors.

Insert table (5) about here

The literature shows that university spin-off companies have difficulty getting access to external funding for early stage development. The only company that received funding from venture capitalists at the time of this series of interviews is Company F[1]. It was also the company that received the highest amount in funding. The inventor received EPSRC funding for his PhD project and Orange funded the development of the research while he was working as a consultant with the company after completing his PhD. Then the spin-off company headed by the inventor was funded by 3i Ventures with first round funding of £1.4m. Second round funding for market development was received from Aberdeen Asset Management (AAM) and Scottish Equity Partners to the total of £900,000.

Companies C and D are distinctive cases in this group. Company C obtained funding from a private investor or business angel as well as personal savings and a bank loan but did not receive anything from government-based venture capitalists or other venture capital companies. The private investor became the company Managing Director. The University did not take any equity in the company, may be due to the company's technology is only of single application, nor does it involve future research, which would be of higher benefit to the University. Furthermore, the company's technology, according to the founder, is involved with the process of membrane gel, which does not lend itself to a vision of growth.

[1] Company E also received venture capital funds subsequent to the interviews.

Company D received various funds from industry for the inventors to carry out research, but it did not receive any government funding for it at any point through the research tenure. The biggest funders were Scottish Power and the National Grid as was explained before, and the two companies became the first customers when the inventors decided to for the spin-off.

6.3. Problems in obtaining funding

All of the companies had problems in getting external funding; each of them took more than a year after they were founded to raise funding to really start operations. All of the companies were therefore forced to use bootstrap funding during the start-up period. Company F reported that almost 95 percent of their time was devoted to finding funding. One of the reasons the Company had difficulties in accessing funding was because they did not have the knowledge and experience on how to get access funding sources. Moreover, some investors purposely waited until the companies to be very desperate for additional capital, in such situation the companies' value would be reduced thus increasing the bargaining power of the investors, which would improve the terms and conditions for them to invest. Timing also influences the ability to secure funding from investors.

Company B started their company in 2001. However, because this coincided with the time that the technology market crashed, investors refused to invest in technology companies, considering all the technology companies at that time to be very risky. They could not convince investors that their technology had potential and they could create niche markets. This finding is consistent with previous studies that found that companies which obtained funding from industry through either consultation or contract research found it easier to obtain funding for further development of their technologies and then for commercial exploitation of the technologies (Companies A, D, and F) (Shane, 2004; O'Shea 2005). It is also noted that previous success in obtaining funding through consultancy, gave signals to other parties of further successful rounds of funding.

Company A was funded by Ford Motors and it also won the Smart Award from the Scottish Enterprise. With these initial successes, the company is well into getting the second round of funding after this series of interviews. Company D was funded by two major corporations, for developing its technology. The two corporations later became the first customers of the new spin-off. In comparison Company C, which sells plant gel, found it difficult to get early stage funding. The most likely reason was that investors felt the company did not have growth potentials or have only limited potential as it was only selling one single product. It was perceived that there would be no market niche and no significant technological advancement. This company only obtained a little support from Scottish Enterprise in terms of identifying markets and they also did not receive any funding from the University.

The findings revealed that Companies A, D, E, and F, who owned leading edge technologies and with strong patent protections found it easier to obtain funding from venture capitalists as well as from government based venture capital companies.

7. The roles of the inventor-entrepreneurs

This section examines the involvement of the inventor-entrepreneurs in the spin-off companies.

7.1. The roles of inventor-entrepreneurs in networking and product development

7.1.1. Networking

The involvement of inventor-entrepreneurs in networking is important to access funding and market knowledge in the spin-off ventures. Formal and informal social ties through the inventor-entrepreneurs' personal contacts and paper presentations could initiate referrals to the right people that controls funding, and reduce the information asymmetry problem (Colyvas et al., 2002; Shane and Cable, 2002; Shane and Stuart, 2002; Shane, 2004).

Potential investors also would feel more convinced as the inventors are involved directly with the ventures, and the inventors' enthusiasms and energy would play crucial roles in the convincing process. As an example, prior to forming the company, the inventor from Company D, had through his informal networks, and consultation works, established contacts with two large companies. These companies helped identify the opportunity, funded the project and became the first customers, thus supporting Wright et al.'s (2004) study. However, these companies did not take any equity in the company or license the patent.

7.1.2. Commitment of the inventors to the companies and in product development

Lockett et al., (2003b) reported that universities that are more successful in spinning-off companies normally encourage their staff to get involve with companies even to the extent of allowing them to hold shares and becoming partners, and finally letting them go from the university. Some just only became advisors or consultants to the companies. In this way less experienced inventors who are less business savvy would be helped along by the university.All of the entrepreneur-inventors in this study were involved in product development and work full time in the companies (at least one inventor-entrepreneur working as full time for each company).
Full time involvement by the inventors in the companies is crucial because all the technologies were at an early stage when they were licensed and needed further development (Thursby and Thursby, 2000; Thursby and Thursby 2003; Shane, 2004).

7.2. The role of TTO

The level of support given by the TTO towards commercialisation could be divided into four phases; 1. absence of proactive spin-off policies (before 1990); 2. minimalist and selective support (1990-1995); 3. intermediate and selective support (1995-2000) and 4. comprehensive support (since 2000).The TTO's role in facilitating commercialisation activities differed from case to case depending on when the ventures were set up. The University became actively involved in commercialisation activities after 2000. Three factors influenced the University becoming active in commercialization activities; 1) the reduction in government funding to public universities forced them to find other sources of income such as the commercialisation of their research output, 2) availability of support funds for commercialisation such as the University Challenge Funds, which are provided by the government to facilitate spin-off activity after year 2000; and 3) the change in objectives and strategies of the TTO to commercialise the University's research results.

In the case of Companies A, B and E all were founded after the year 2000. The researcher deduced that the University implemented high/comprehensive selectivity and high supportive policies to these companies before they were set-up. In the case of these three companies, the TTO gave support in terms of seeking IP protections, business development in terms of market research, coaching them in the preparation of business plans, and encouraging them to attend entrepreneurial courses and linking them with venture capitalists.

Because of the tacit knowledge that the inventor-entrepreneurs possess about their technologies, they have to be involved directly in marketing and building networks with potential customers, venture capitalists and potential investors. Thus, the involvement of the inventors-entrepreneurs is crucial in the search for funding or partners in the ventures. The TTO office lacks resources and expertise in all sectors of the University's technologies. Thus, it is difficult for the TTO to be directly involved in marketing the technologies and attracting external financiers.

Companies C, D and F received little support from the TTO. Company D was founded in 1995 and Company F in 1999. In this period the TTO may have implemented a policy of 'minimalist and selected support' and 'intermediate and selected support' (Degroof and Roberts, 2004). The TTO was not proactive in spin-off policy and exploitation of opportunities, and relied on the inventors and the scientists to perform R&D and technical consulting work. The TTO only took 25 percent equity of the total shares in Company D and 20 percent in Company F but nothing in Company C. (There was no coaching given for the preparation of business plans, nor help to market the inventions or to link the inventors with venture capitalists). During that period there was very little encouragement from the government as well as from the University to facilitate spin-off activities.

Nevertheless, the entrepreneurs themselves learnt and did all the marketing, networking, and preparation of the business plans to be presented by the companies to the venture capitalists.

Company F differed from the other spin-offs. The young inventor-entrepreneurs who formed the company had only work experience with Orange but they were very highly motivated entrepreneurs. This company lacked everything that is needed for the formation of a new venture company including funding, business and marketing knowledge as well networking knowledge. The TTO during this period did not give very much help because it did not have the expertise, routine, or the capabilities in this sector. The team claimed their technology was very complex and they worked very hard to bring the technology to market. Everything they learned was from scratch in order to transform the idea into a product. The University only took equity in the company. The founder further claimed that the TTO had quite a good experience in licensing the technologies to existing firms but was very naive about the creation of spin-off companies at that time. The process of forming the company was therefore difficult as was finding access to funding, thus the company took nearly one year from concept to start-up.

All the companies except Company B used the University incubator during their founding periods. Research suggests that companies which start in an incubator show high growth rates, better in the adoption of advanced technologies, have the intention of participating in international R&D programs, and are better at establishing collaborative arrangements especially with universities (Colombo and Delmastro, 2003).
Two companies (Companies D and F) have graduated from the University incubator and had found suitable spaces for their offices and Company A will follow soon. All the inventor-entrepreneurs pointed out that the University does not consider commercialisation activities in its promotion exercise. However, this did not affect their motivation to commercialise their patents. The real reward for most of the inventor-entrepreneurs was to see their inventions get exploited. Thus, in term of rewards this finding support studies by O'Shea et al. (2005), and Lockett et al., (2003a) who suggested that rewards and incentives are not significant to spin-off formation.

In terms of conflict between publishing and patenting, none of the inventor-entrepreneurs had any problem. The University and patent agents were very efficient in the management to file patents and were relatively fast at getting filing dates from the Patent Office. The TTO is expert at this and has very good IPR officers specially in charge of this process.

8. Conclusion

Every spin-off has its own characteristics and the process of creation differs in every company, even though some of them shared common characteristics such as the difficulties of getting seed funding, the right management team and marketing their technologies.

The spin-off formation process started once the opportunities for their research result were recognised by their inventors and patent protections were sought. Initial opportunities were normally recognised by the inventor-entrepreneurs. The decision to exploit the invention was also decided by the inventors-entrepreneurs alone. However, in some cases the decision to patent was a joint decision of the TTO and the inventors.

Another crucial factor in the creation of spin-off companies is the characteristics of the inventor-entrepreneurs who own the patent. The inventors were very highly motivated with a strong desire to see their inventions exploited. This similar to the findings of Roberts (1991a) and Lockett and Wright (2005), the inventions in this study had been researched in the university labs, and had taken several years before they could be commercialised. The inventors were very highly motivated, and were driven by the desire to see the their inventions being commercialised and utilised, even-though there were long time horizons (Shapero, 1975; Shapero, 1984; Gartner, 1985; Roberts, 1991a; Oakey, 2003; Shane, 2003). Their entrepreneurial characteristics and leadership emerged during the research projects in the University labs (Etzkowitz, 2002), which are normally led by a group leader who is the most familiar with the invention and is more knowledgeable than the followers (Clarysse and Moray, 2004). The group leader normally becomes the champion of the new venture, and is very highly motivated and always wants the invention to be commercially viable.

The findings demonstrated that patents that have strong protection with broad scope, early stage and multi purpose technologies tend to be exploited by spin-off creations which is consistent with Shane (2001a), Thursby et al. (2001) and Shane (2004). In the early stages of the technology cycle, it was difficult to license to established firms, and this is push factor towards spin-off formations and this exemplified by most of the technologies did not have a prototype when the company was founded. On the other hand, those patents for cutting edge technologies and novel inventions have clear target markets and if the markets are global it is easier to obtain funding from venture capitalists or corporations. This would then lead to the 'growth' of the spin-offs (Shane, 2001b; European Commission, 2002; Shane, 2004). Examples of these are Companies A, D, E and F. On the other hand, the findings show that patents that lead to 'life style' spin-offs are normally targeted at local market and have difficulty in getting external finance.The findings showed that not all CEOs appointed by the investors were good or knowledgeable especially in marketing new technologies. This was demonstrated in Company F and supported the study by Clarysse and Moray (2004) that an academic entrepreneur can be a good CEO of a spin-off company.

The findings also support previous studies (Roberts, 1991a; Shane, 2003; Shane and Khurana, 2003; Shane, 2004; Dietz and Botzman, 2005) that industrial experience of the entrepreneurs-inventors of the patents provided a substantial advantage in the creation of the new venture. The main advantage that industrial experience conferred was that it helped the academic to be up-to-date with the latest technological advances and the target market in their project field. Industrial experience gave a new idea to one of the inventor who was then granted several subsequent new patents. These patents have been exploited in his current company.

The roles of the TTO to support commercialisation activities particularly in spin-off formations have changed after the year 2000. From that year the TTO was more supportive through its coaching programme and helped linked the founders of the new ventures to the business world. This supportive environment gives advantages to the founders to speed-up the formation of their ventures and thus their products into the market. The grants provided by the government to encourage spin-off formations may be one of the factors that caused the changes. Before the year 2000, the TTO was not supportive of spin-off formations and the commercialisation activities were more focused on licensing to established companies. Lack of resources, capabilities and knowledge in spin-off formation inhibited the TTO from becoming more involved in the spin-off activities. This was strengthened by the fact that the government did not fully support this activity in that period. The inventor-entrepreneurs (Companies D and F) that formed their companies in the 1990s did so through their own efforts. In these cases, the inventors were doing quality research, had patented technologies with potential markets, had corporate funding, and were supervised and monitored by large companies. Companies A, B, C, and E that were formed after the year 2000 also had carried out marketing on their own but had better information and links to venture capitalists, and were able to prepare their business plans, with coaching from the TTO.

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Table 1: The companies' profile.

Company	Founded	Founders	Technology/patent	Filing	Application	Ownership /Exclusivity of patent	Employees	Initial funding
A	2003.	2	3D hardware visualisation images	27/3/03	Oil and gas and medical	University/ exclusive patent	2 FT 2PT	Funding for research came from industries and the largest Ford Motors (1M). The University took 20% equity in the company. Obtained first round funding from Proof of Concept Fund, and Smart Award Scheme, from Scottish Enterprise and Synergy funding.
B	2001	4	Activity monitor devices	27/03/03	Ordinary people and medical institutions/ hospitals	University/exclusive rights	5	The University took a 20% equity. Obtained seed funding for 2001/02 of £25 000 from Scottish Enterprise The University £20 000. The bank £10 000.Shareholders £15 000 each. In 2003 first round funding £130 000, (share holders and bank loan £80,000)
C	2001	2	Hydro gel	28/04/98	To monitor water level for indoor plant	Company	5	Private investor £25 000 and bank loan £50 000. No equity from the University and no funding from Scottish Executive.
D	1995	2	Power monitoring system	23/06/99	Supply monitoring equipment to monitor gas insulated substation.	Company	24	Most grants were from industry. The biggest came from Scottish Power and National Grid grants. First order payment used as rolling and working capital for the next projects
E	2003	4	Gas sensor systems	9/4/02	Gas detection and environmental measurement, pollution medical diagnostics	Company	9	Received £26k initial finance from Upstarts. Obtained first round funding £1million.Investors; Synergy Fund, Bus. Growth Fund, SPUR, RSA, Individuals and Bank of Scotland. The University initially took 20 % equity.
F	1999	4	Video compression	01/12/9920/08/0207/01/03	Security market	University/Exclusive rights	16	Funding for research received from Orange, First round funding from 3I venture capitalist-£1.4m. Second round funding £900,000 from Scottish Executive partner and Aberdeen Management Asset. Looking for third round funding of £3.5m. The University took 20% equity.

Table 2: Background of the inventors-entrepreneurs[2]

Companies/ Entrepreneur background	Age of the entrepreneur	Education background	Faculty	Field of research	Industry experience/funding
A	32	PhD in Applied optics in Mechanical Engineering	Mechanical Engineering	Applied optic in Mechanical Engineering	Consultant to Ford Motors. Funding from Ford Motors.
B	43	Used to be a Research Fellow in Strathclyde University	B. Engineering	B. Engineering	EU funded telemedicine project. Worked on a design to deliver medical stimulator to mass manufacturer.
C	45	Research Fellow in Strathclyde University and was a PhD student	Chemistry	Hydro gel material	Patented a few patents from the same field and related fields.
D	47	PhD	Electric and Electronics Engineering	Power system	Used to work with industry
E	28	PhD	Physics	Physics	Used to work with industry
F	43	PhD	Computer Science	Computer system	Used to be a consultant with Orange

[2] The founder or the CEO of the companies. Other inventors background are. not included.

Table 3: Opportunity recognition and the triggers factors

Co.	Industry experience / background	Potential of the technologies	Decision to patent	Opportunity	Decision to commercialise	Trigger/motivation factors
A	Obtained funding from industry. Used to be Ford Motors Consultant.	From the beginning the inventor realise that the invention has potential value. Had planned to commercialise from day one.	Inventors	3D hardware visualisation. Existing technology users have to wear dark glasses in dark room to see 3D images. This break-through means 3D images can be accessed using ordinary computers. The company produces computer hardware for that purpose.	Inventors	- Consultant to Ford Motors and financed the initial project -Scottish Fellowship Scheme. -The father missed the opportunity to go into business with his friend. The business now is the biggest contractor company in the UK.
B	Industry background ./ Used to work for industry to produce a similar product.	Technology better than existing technologies. Provides more accurate data and information for sedentary activities.	Inventors	Activity monitoring devices. The devices can monitor daily activities of a human being. More accurate data is obtained compared to existing technology	Inventors	-Attended course at Hunter Centre for Entrepreneurship -TTO supports the activities –Customers were asking to buy the product - Consultant to a big manufacturer, designed and produced similar devices.
C	The inventor has 20 years experience in gel develop-ment particularly for indoor plants.	The gel can control the water level for indoor plants. No other gel claims to do the same job.	TTO	Hydro gel. Twenty years of research in polymer and biomaterial. The gel can control water level for indoor plants.	Inventors	-Working in the University on a contract basis. -Obtained support from Hunter Centre to commercialise the products. - No support from University. It was a start-up company, not a spin-off.

D	The inventors used to work in industry. Joined the University as a lecturer and at the same time became a consultant to various companies.	No such technology available at that time. The company is pioneer in this area.	Inventors	Power monitoring system. Supply monitoring equipment to monitor gas insulated substation. The system can prevent failure of equipment, network disturbances or loss of availability.	The inventors. Another inventor (also old friend) is a visiting scholar from industry to University	-Another inventor was from industry -Scottish Enterprise - Scottish Power National Grid gave full support and grants. -Pioneer spin-off company from the University. -TTO support with equity only. -Worked very hard to educate utilities substations about their invention
E	Used to work with National Physical Laboratory to develop gas sensors Aware of the weakness of existing technology.	The existing technology in the market has weaknesses. His PhD, aimed at improving the technology.	TTO and Inventor	Gas sensor systems. Produced gas detection systems. The market has a vast, coverage defense industries, security, and oil and gas industry and medicine.	Inventor	-Attended course at Hunter Centre for Entrepreneurship. -TTO supports the activities and took the equity
F	Used to be a consultant for Orange	Initially the technology has potential value in the mobile telephony. (The technology is more advanced than the standard) Divert to another market – US security systems market.	TTO	Video compression. Provides high-resolution video images that can be transferred everywhere in real time. The market initially targeted mobile phone companies. However due to newly imposed international standard – inferior to their technology - the technology had to target another market: the security market in US.	Inventors	-Consultant to Orange to produce video technology for mobile phones to get a 3D license. -Failed with the main target applications for mobile phone due to international standard (which is lower than their technology). Diverted to other market based on customer demand, after the team worked very hard to introduce the product to market. - Entrepreneurs involved in the business on the basis of learning by doing

Table 4: Stage of technology when the companies were founded

Company	*Stage of technology*
A	POC- developed to prototype stage
B	POC
C	Prototypes
D	POC-developed to prototype stage
E	POC
F	POC

Note: POC (proof of concept stage

Table 5: Details sources of funding for every company

	Research funding		**Spin-off Funding**													
Co.	I	EPSRC	STF	SEP	SE	Scot. Ent.	Syn.funds	3i	SA	AAM	BA	RSE	BL	PS	UE	Total
A	√				√		√		√						√	5
B		√				√			√			√	√		√	6
C		√				√							√	√		4
D	√													√	√	3
E	√	√			√	√	√				√		√	√	√	9
F	√	√	√	√		√		√		√			√	√	√	10
Tota l	4	4	1	1	2	4	2	1	2	1	1	1	4	4	5	37

Note: I = Industry, EPSRC = Engineering and Physical Sciences Research Councils, STF = Scottish Technology Fund, SEP = Scottish Equity Partner; SE =Scottish Executive; Scot Entrp = Scottish Enterprise; Syn.funds = Synergy Funds; 3I = 3I venture capitalist company; SA= Smart Award; AAM = Aberdeen Asset Management; BA= Business Angel; RSE =Royal Society Edinburgh; BL = Bank Loan; PS = Personal Saving; UE = University Equity.