

The Actors Involved and the Decision-Making Process Used In the Exploitation of University Patents

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ABSTRACT

The commercialisation of university patents via licensing to established companies or to spin-off formations is the method commonly used by universities to exploit their patents. This paper looks very closely at this process, based on the authors' case study at a university in Scotland where 12 patents or inventors were selected for scrutiny. The study focuses on the actors involved and the decision-making process used by this university regarding exploitation of its portfolio of patents. The findings show that the actors involved were the inventors themselves, industry, and the university's Technology Transfer Office (TTO), or any two of these parties. The decision to commercialise patents via spin-off formations was influenced by factors such as how well the inventors

recognised the commercial potential of their technologies and how motivated they were to see their inventions exploited through entrepreneurial efforts. The decision to commercialise patents via licensing to established companies, however, was made individually by one or more of the three actors involved. The significant difference in the latter instance was that the inventors were not motivated to be entrepreneurs, and were unwilling to take risks in a new business venture. The findings also show that the TTO did not have a special due diligence system to help inventors identify commercial opportunities. The lack of skills, capabilities, and marketing efforts on the part of the TTO in all sectors resulted in the decision to form spin-offs that were based on the inventors' motivation and industry experience.

Keywords: Commercialisation of university patents; spin-offs; licensing; academic entrepreneurship

1. INTRODUCTION

Many universities have recently made efforts to become an entrepreneurial university [Etzkowitz, et al., 2000; Etzkowitz, 2002; Etzkowitz, 2003]. One of the reasons is that, since the early 1980s, central governments in the U.S., Europe, and Asia have reduced the amount of funding to their universities in real terms [Bower, 1992; Etzkowitz, 2002]. This has caused greater competition among universities for research funding. Universities have been encouraged by government to raise funds from third-stream sources. This step has prompted many universities to review their R&D activities and to increase the exploitation of their intellectual properties through licensing to established companies or to spin-off companies [Bower, 1992; Malecki, 1997; Lazzeroni and Piccaluga, 2003]. In other words, universities have become more aggressive and entrepreneurial in seeking new sources of funding. In these new roles, universities would contribute to local economic development by translating their R&D output through various technology transfer mechanisms such as licensing to established companies, forming spin-off companies, consultancies, research contracts, and sponsored research.

In the U.S., the government had for many years played a crucial role in promoting and facilitating university commercialisation activities. Universities need to be innovative and involved in their local regional development [Young, 2004]. The Bayh-Dole Act of 1980 was passed to facilitate commercialisation activities in universities and to increase private sector commercialisation of innovations derived from university research and development [Etzkowitz, 2002]. Also, many government-based venture capital companies were set up to fund early spin-offs.

The success of U.S. universities in exploiting their research has been replicated by universities in Europe, Australia, and Asia. In the U.K., the

Cambridge area [Segal Quince Wicksteed, 1990; Bower, 1992] is the densest site in Europe for high-technology firms, many of which emanate from Cambridge University. In the 1970s and 1980s, that university was the main source of high-tech companies. The spin-off process has now become multi-generational, with spin-off companies becoming the source of further spin-offs [Garnsey and Heffernan, 2005]. In 1985, there were around 300 high-tech firms and 16,000 jobs in the Cambridge high-tech sector. By the end of the 20th century, there were more than 1,200 technology firms employing 36,000 people, approximately 10% of the total Cambridgeshire work force [Garnsey and Heffernan, 2005]. In China, according to Zhang [2008] technology transfers through spin-off formations contributed significantly to the local economy. Japan also started to generate spin-off creations from its universities after government legislation in 1998 removed university ownership of intellectual properties [(Rubin, et al., 2003).

In line with these developments, many universities have increased their patent activities, which effort has led to increases each year in the number of patents in university portfolios [Etzkowitz, et al., 2000; Etzkowitz, 2002; Etzkowitz, 2003]. On one hand, patents are a symbol of a university's innovativeness, but, on the other hand, patents that are not exploited represent opportunity costs to the university.

Although more universities are involved in commercialisation of their research outputs, very limited studies have been conducted to examine the process of how decisions are made to patent and to commercialise university patent portfolios. This paper looks very closely, therefore, at the actors involved and the decision-making process used, based on the authors' case study of a university in Scotland.

2. LITERATURE REVIEW

The success of the entrepreneurial university model can be seen in the Route 128 area around Boston and in the Silicon Valley of California [Dorfman, 1983; Tornatzky, 2002; Etzkowitz, 2002]. The success of U.S. universities in exploiting their research products either through licensing to established companies or through spin-off formations has been replicated by universities in Europe, Australia, and Asia.

Although licensing to established companies is the traditional route of commercialisation of university patents, spin-offs are becoming more important because they are potentially very lucrative, help promote local economic development, and provide continuous income for the university. The spin-off process has now become multi-generational, with spin-off companies becoming the source of further spin-offs [Garnsey and Heffernan, 2005]. In 1985, there were around 300 high-tech firms and 16,000 jobs in the Cambridge high-tech sector of the United Kingdom. By the end of the 20th century, there were more than 1,200 technology firms employing 36,000 people, approximately 10% of the total Cambridgeshire work force [Gamsey and Heffeman, 2005]. The same process has taken place at the University of Twente in the Netherlands,

Linköping University in Sweden, and Katholieke University Leuven in Belgium [Ndonzuau, et al., 2002]. Japan also began to generate spin-offs from its universities after government legislation in 1998 removed universities in the ownership structure of the intellectual property rights of their research output [Rubin, et al., 2003].

There are very few literatures focusing on how universities make the decision either to license their patents to established companies, or to form spin-off companies to commercialise their patents. What factors influence their decision one way or the other? These factors are synthesised here.

2.1. The Role of Technology Transfer Offices

This section discusses the technology evaluation problem and the resources of university Technology Transfer Offices (TTOs).

2.1.1. Technology Evaluation Problem

TTOs have been found to be ineffective in their commercialisation efforts. It has been reported that TTOs have inadequate funding, lack due diligence systems, have inadequate staffing levels, and have staff that lack experience in commercialisation activities [Colyvas, et al., 2002]. Many universities in the U.S. and the U.K. do not implement systematic due diligence process during the technology selection stage [Vohora, et al., 2003; Lockett, et al., 2005] to evaluate the impact of newly disclosed technologies and their commercial potential. At this stage, precise identification of which disclosures need patent protection is important [Vohora, et al., 2003; Lockett, et al., 2005]. To identify technologies that have high commercial value is a key challenge to TTOs. The absence among TTO staff of systematic technology transfer policy and their inexperience in commercial and market situations have caused many university patents to remain unexploited. It is becoming clearer that one critical role of TTOs is to identify effective technological opportunities and to frame them in a way that matches technological solutions and market needs [Franzoni, 2006; and Ismail, 2007].

Universities typically do not practice this system because most university technologies are at an embryonic stage, and therefore of little commercial value. Some universities practise this kind of system, though the actual practice differs among universities. A comprehensive systematic selection process has been suggested by Meseri and Maital [2001] and De Coster and Butler [2004]. Meseri and Maital [2001] suggest evaluations on 20 criteria for selecting a project for further action by TTOs in Israel. The selection criteria are in accord with the practices of MIT and the private sector in the U.S. The six main factors scored are: market needs, market size, existence of patent, success at the R&D stage, level of innovativeness, and degree of maturity of the idea. In contrast, De Coster and Butler [2004] demonstrate how to score marks for university projects by looking at various aspects practiced by private sector

assessments. Calculation of the score, however, is not straightforward, but rather a complicated exercise.

2.1.2. TTO Resources

How supportive TTOs are in these commercialisation ventures always relates to the level of resources available [Shane, 2004], and to how helpful the TTOs are [Audretsch et al., 2006] to academic researchers. Some universities invest a lot of money in their TTOs to promote spin-off companies. Formation of a company requires high investment. TTOs have to pay patent agents, conduct market research, and negotiate exclusive licenses, all of which take more time. Given budget constraints, many universities lack sufficient staff to perform these activities adequately, and thus have a lower rate of spin-off formations than others [Wright, et al., 2006], preferring instead to license to established companies. Lockett et al. [2003b] in a survey of 57 respondents in U.K. universities, found that new entrant universities prefer licensing their patents to established firms because of their lack of clear strategies and resources. TTOs prefer to license to established companies to generate 'instant' cash and royalties, compared with spin-offs [Siegal, et al., 2003a; Siegal, et al., 2003b; Siegal, et al., 2004; Siegal, et al, 2007] which they considered risky and requiring special skills, additional expenditures, and expertise from them.

The other factor is whether inventors perceive TTOs as helpful or otherwise, which is based on the perceived adequacy of their resources and their capability. It discourages inventors from disclosing their quality inventions if the inventors perceive that the TTOs have inadequate resources and capabilities [Jensen et al., 2003].

TTOs need staff with business development capabilities in the formation of spin-offs, as well as some business experience. The TTOs should then focus on creating [Wright, et al, 2006; Seigal, et al, 2007]:

- (i) clear process for conducting intellectual property evaluations and due diligence to ensure IPR is identified and fully evaluated before commercialisation process could commence
- (ii) clear policies, processes, and routines for creating and developing university spin-offs, including legally protected intellectual properties, as well as the managerial and marketing skills, premises, and financial resources to enable spin-offs to prosper
- (iii) enhancement of experience and the expertise of the TTO personnel
- (iv) a regional collaboration among universities in knowledge and expertise

2.2. Inventors

This section discusses motivation, networking, and the industrial experience of inventors at universities.

2.2.1. Motivation

The most critical factor when creating a new company is the presence of a champion. The champion can be one of the inventors, an entrepreneur, or an investor. The inventor of a university technology plays an important role in the exploitation of his or her research output. According to Shane and Venkataraman [2000], research output can be exploited through two major routes: the creation of a new company, or the sale of the idea to existing companies.

Previous research suggests that university spin-off companies or new venture creations are founded by inventors or entrepreneurs who have certain psychological and motivational characteristics, such as a disposition to act, the willingness to take risks, a high energy level, a willingness to give full commitment to the venture, and extrovert qualities that make it easy to network with others [Khilstrom and Laffont, 1979; Oakey, 1984; Shapero, 1984; Olofsson et al., 1987; Doutriaux, 1987; Doutriaux and Dew, 1992; Blair and Hitchen, 1998; Nerkar and Shane, 2003; Shane, 2004; Ismail, 2007, O'Shea et al, 2008]. Non-psychological factors that influence them toward the formation of firms include their level of education, family background, and previous work experience.

The recent theory of entrepreneurship [Shane and Ventakaraman, 2000; Shane, 2003; Shane, 2004] suggests that entrepreneurs are different from others because they have not only distinctive characteristics, but also the ability to recognise an opportunity to be exploited. These factors lead inventor-entrepreneurs who have 'entrepreneurial' characteristics to assume an important role to champion the new venture. They also must have an ability to combine the limited scale of production and transform it into end products. All these characteristics make individuals who are different, who lead people, who have greater appetite for uncertainty to become entrepreneurs, whereas people with less appetite choose to become employees or choose to license their technologies to established companies [Khilstrom and Laffont, 1979].

2.2.2. Networking

Universities usually license particular technologies to established companies when there are personal contacts with the companies, which were established before the research project was completed [Thursby and Thursby 2000; Thursby, et al., 2001; Colyvas, et al., 2002; Jensen and Thursby, 2003; Thursby and Thursby, 2004; Ausdretsch, et al., 2006; Ismail, 2007]. Colyvas et al. [2002] used 11 patents in a case study at Columbia University and Stanford University in the U.S., and found that personal contacts with industry, by locating academic staff in industry, create an awareness of the importance of university research to industry. This awareness makes it easier for university inventions to be exploited. The study also found that one patent was not exploited solely because the inventor did not have any contact with industry.

All these studies focused solely on general licensing activities, and the discussions are more about the roles of inventors and TTOs in finding licensees.

The studies also focused on ‘what would happen’ after the inventors disclosed their inventions rather than ‘what happened’ before the disclosures. In addition, no part of the study examined thoroughly the decision-making process of the chosen route. Audretsch, et al. [2006], in a survey of 146 scientists who received a National Cancer Institute grant in the U.S., concluded that inventors who have strong social capital with industry end up licensing their inventions to established firms, and that inventors who are not very active in social networking ended up with spin-off formations. (In this case, those who have not assigned their patents to TTOs venture it out through spin-offs.)

For spin-off formations, informal and formal networking is important at the pre-start-up and start-up stages. Strong networking at an early stage has a positive relationship with success in new ventures [Birley, 1985; Hsu and Bernstein, 1997; Rappert, et al., 1999; Davidsson and Honig, 2003; Elfring and Hulsink, 2003; Siegal, et al., 2003a; Shane, 2004; Walter, et al., 2005]. Through formal or informal networks, a new firm can access funding, advice, new knowledge, and leads to wider networks, can overcome information asymmetry problems, obtain resources below market prices and endorsements of new products, sell the first product, and link with customers and suppliers (Rappert, et al., 1999; Perez and Sanchez, 2002; Shane and Stuart, 2002; Shane and Cable, 2002; Meyer, 2003; Nicolaou and Birley, 2003; Walter, et al., 2005).

2.2.3. Industrial Experience

Opportunity recognition is an important stage in evaluating the technological validity and performance of the ventures in order to identify market applications and customer needs [Wright et al., 2004; Shane and Venkataraman, 2000]. Industrial experience enables academic inventors to recognise commercial opportunities and to evaluate the technologies that other people were unable to do [Shane and Venkataraman, 2000; Shane, 2000a; Shane, 2000b; Shane, 2004; Park, 2005; Ismail 2007]. Normally, opportunities are recognised by individuals who are more ‘alert’ and thus more able to ‘notice’ [Lockett et al., 2003a: 188]. Academics may not be the best people to recognise opportunities. In some cases, opportunities are imprecisely or ambiguously targeted, which in turn makes the technology impractical [Vohora et al., 2003]. The TTO and academics basically lack understanding of how best to maximise returns and create commercial values from the technologies that they patented [Vohora et al., 2003].

External sources also may help the university to recognise opportunities [Lockett, et al., 2003a], such as potential surrogate entrepreneurs or some external private sector organisations that could help in the exploitation of its technologies [Franklin, et al., 2001; Lockett, et al., 2003a; Wright et al., 2004]. A company that has sponsored research or contract research with universities usually recognises the opportunities, and normally intends to license the resulting technologies [Thursby et al., 2001; Colyvas et al., 2002; Thursby and Thursby, 2004; Ismail, 2007].

2.3. Technology Stages

The characteristics of university patents or technologies affect the route of exploitation. The characteristics of patents exploited through the formation of spin-offs and the licensing to established companies according to Shane [2004] are shown in Table 1.

Table 1
Characteristics of Technologies That Lead
to Being Licensed to Spin-Off or Established Firm

Spin-Off Firm	Established Firm
1. Early stage	1. Late stage
2. Radical, significant customer value and major technical advance	2. Incremental, moderate customer value and minor technical advance
3. Tacit	3. Codified
4. General purpose	4. Specific purpose
5. Strong IP protection	5. Weak IP protection

Source: Shane (2004:103) with modification.

Early-stage technologies are often linked with uncertain market and greater risks, and need more funding to develop up to the commercially viable stage; it can be difficult to capture value and there is a longer time horizon to market [Thursby and Thursby 2001; Thursby and Thursby 2004; Shane, 2004]. Thursby, et al. [2001] also note that most university technologies are at an embryonic stage at the time they were licensed. Since the technologies are at this stage, universities are likely to license their patents to small firms or spin-offs [Tornatzky, et al., 1999; Thursby and Thursby, 2003; Shane, 2001a; Shane, 2001b; Shane, 2002, 2003, 2004; Ismail, 2007]. Also, technologies that have radical, tacit knowledge, are general purpose, and have strong IP protection usually lead to spin-off formation; whereas, the technologies that are at the later stages of development have moderate customer values, with codified knowledge, specific purpose, and weak IP protection; they would tend to be exploited through licensing to established companies. However, Markman, et al. [2005] and Ismail, [2007] contend that both early-stage and later-stage technologies tend to be licensed to established companies if the technologies are commercially viable.

3. THE UNIVERSITY CHOSEN FOR THE CASE STUDY

The University chosen by the authors for their case study was established as an institute in 1796 with the opening of its first premises in the middle of Glasgow, Scotland, and developed rapidly during the 19th century. By the 1890s, the institute had become a major technological institution with a strong reputation for research and learning. In the late 1950s and early 1960s, it was decided that the institution should broaden its activities; hence, the College merged with the Scottish College of Commerce, which offered a wide range of business and arts subjects. Shortly afterward, in 1964, the enlarged Royal College was granted the Royal Charter and became the University.

Today, the University is the third largest in Scotland. It has 67 buildings on 500 acres of land. It teaches more than 20,000 students in five faculties: Arts & Social Sciences, Education, Engineering, Science, and Business School. Taking into account distance learning, short courses, continuing professional development, and evening courses, the University provides courses for more than 50,000 people each year, making it the U.K.'s largest provider of post-graduate and professional education.

3.1. Overview of Entrepreneurial Process at the University

The University has changed rapidly from traditional functions toward activities associated with an entrepreneurial university. The Entrepreneurship Centre was established in 2001 with a capital injection of 5 million pounds sterling from a Scottish philanthropist. It has since gained a worldwide reputation for research, publications, and entrepreneurship activities. The Centre teaches entrepreneurship courses at the undergraduate and master's levels, and, since 2008/09, offers the first undergraduate studies in Europe in business, management, and enterprise. All the courses are participative and are hands-on toward enterprise formation and management. Besides that, the Entrepreneurship Centre was awarded a contract from Scottish Enterprise to provide formal training to those on Enterprise Fellowship Programme. This training provides the fellows with a wide range of skills critical to be a successful entrepreneur. The Centre also trains school teachers to adopt the entrepreneurial approach to teaching and learning, thus benefitting school children in enterprise education and career development.

The University has a 'University Entrepreneurial Network,' which was established in 2005, and recently secured funding of 1 million British pound from the Scottish government to spur entrepreneurial activities at the University. It works with a range of partners to develop entrepreneurs for its current students and graduates, as well as new Scottish entrepreneurs. The University also initiated 'Supernovas' competition to find the brightest upcoming business star. Recently, the University has worked with managers of Braveheart Venture Ltd. to create a fund for spin-off investments and other efforts to commercialise intellectual properties. Until now, the University has supported students and alumni to start 36 new spin-off companies. The University has a strong link with

successful alumni entrepreneurs and other successful people to help in mentoring, advising, supporting, and inspiring new entrepreneurs from the University. The University also has its own incubator to incubate and facilitate spin-off formations (Enterprise Matter, 2009). However, compared with Silicon Valley or Route 128 in the U.S., it may be concluded that the entrepreneurial activities at this University are only modest, but are rapidly increasing.

4. METHODOLOGY

This study used the qualitative method. A university in Scotland was chosen as a case study. Two types of exploited patents were selected, totaling 12 patents. The first six patents were exploited through spin-off formations, and the other six were exploited through licensing to established companies. To obtain the University patents portfolio, the authors contacted the University TTO. Through a series of visits and interviews with the TTO director, they obtained the names of the inventors, the route by which the patents were exploited, and details about the role of the TTO in the process. The inventor-entrepreneurs were then contacted through the addresses given by the TTO. Some were identified through Internet search engines, using the names of the companies as given by the TTO. The inventors who licensed their patents to established companies were still employed by the University and were easier to contact. Both types of inventors were called and followed on by letters and e-mails.

In-depth interviews with pre-determined themes were conducted with the inventors and inventors-entrepreneurs. There were 12 pre-determined themes for this research project:

- Background of the inventors or companies
- Decision to patent
- Decision to commercialise
- Stage of technology or technology background
- Opportunity recognition
- Industry experience
- Motivation factors
- Funding
- Inventors' roles
- Role of TTO
- Research and spin-off funding
- University support and incentives

For this paper, however, the discussion focuses on only 7 pre-determined themes:

- (1) Decision to patent
- (2) Decision to commercialise
- (3) Motivation factors
- (4) Industrial experience
- (5) Stage of technology

- (6) Involvement of inventors in product development and networking
- (7) Role of TTO

The interview results were transcribed on a case-by-case basis and cross-case analysis aided by Nvivo software. A total of 143 codes or concepts were established, based on the free coding. In this level of analysis, the 143 codes were clustered or categorised into 12 major headings or selective coding. This was done according to suggestions by Strauss and Corbin [1998]. The software was used to cluster these themes, using node three. At this stage, the duplication of nodes was corrected, as similar concepts were then merged into the same parent node. Some of the nodes were withdrawn because they were not used. Finally, 12 major themes (as in the pre-determined themes) were identified, with no new themes emerging. For this paper, only 7 themes are discussed, as mentioned above. The background of the inventors or companies, research and spin-off funding, and the University support and incentive themes are not discussed in this paper. The discussion on opportunity recognition is integrated with industrial experience.

Triangulations of data were also used to support the analysis. The data were obtained from newspaper cuttings, companies' Web sites, and the University's Web site and newsletters. The University's TTO director was also re-interviewed to better understand the decision-making process and to complement the data from the interviews with the inventors.

5. FINDINGS

This section presents findings relating to the 7 themes identified previously.

5.1. Decision To Patent and To Commercialise

In almost half of the patents studied, the TTO initiated the move to seek patent protections. However, for patents that were exploited through spin-offs, the decisions for exploitation were made by the inventors (see Table 2). This may be due to their realising the importance of their technologies early on. They recognised the potential because of their strong industrial networks. Their entrepreneurial awareness was sharpened later in their efforts to promote their technologies. For patents that were licensed to established companies, the decisions to license were taken together by the inventors and the licensing companies.

Table 2
Actors Involved in Decisions of Route to Commercialisation

Patent/Route to Commercialise	Patent/Co.	Decision To Patent	Decision to Commercialise
License to Spin-Off Companies	1 (Co. A)	Inventors	Inventors
	2 (Co. B)	Inventors	Inventors
	3 (Co. C)	TTO	Inventors
	4 (Co. D)	Inventors	Inventors
	5 (Co. E)	TTO and Inventors	Inventors
	6 (Co. F)	TTO	Inventors
License to Established Companies	7	Inventors & Industry	Inventors & Industry
	8	Inventors & Industry	Inventors & Industry
	9	Inventors & Industry	Inventors & Industry
	10	TTO	TTO
	11	TTO	TTO
	12	TTO	TTO

5.2. Role of Technology Transfer Office

Half of the inventors who formed new spin-offs commented that the TTO was very supportive and was involved from the early process of identifying opportunities immediately after filing for patent protection. However, half of the inventors commented that they did not receive sufficient support from the TTO (Table 3). The opportunities were commonly identified by their industry partners or clients for whom the inventors worked (companies C, D, and F). Assistance in writing business plans was limited and resources for product development and market testing were not available. This led these inventors to believe that the TTO was only capable of licensing patents to established firms, but not capable enough in helping them exploit their patents by forming spin-off companies. The other half of the entrepreneurs (companies A, B, and E) received support in terms of entrepreneurial courses that coached inventors in the identification of opportunities, writing business plans, raising finance, and networking with financiers and local business networks courses. These are organised by the TTO through the Entrepreneurship Centre.

The opportunities for their patents, however, were identified by the inventors. The TTO was still not capable enough to identify opportunities, and had no due diligence system as to how to evaluate new technology disclosures, although it claimed to have been involved with spin-off company formations since 1982. The TTO totally relied on the information given by the inventors. This finding indicates that the TTO staff have insufficient skills to evaluate all technologies, but lack the resources to market the technologies. All spin-off

inventors reported that the TTO is good in patent application or management and helped them by taking equity in their firms.

Table 3
Role of the TTO

Patent Number/ Company	Spin-Off Formation						Licensing to Established Companies					
	1 A	2 B	3 C	4 D	5 E	6 F	7	8	9	10	11	12
TTO Role												
Limited resources/budget	×	×	×	×	×	×	×	×	×	×	×	×
Good in patent management	√	√	√	√	√	√	√	√	√	√	√	√
Insufficient skills to evaluate and market	×	×	×	×	×	×	√	√	√	√	√	√
No comment												
Full support	√	√			√		√	√	√	√	√	√
Little support			√	√		√						
Equity	√	√	√	√	√	√						
Coaching business; plan	×	√	√	×	√	×						
Has due diligence in technology evaluation	×	×	×	×	×	×	×	×	×	×	×	×

In the case of patents that were licensed to established firms, all inventors reported that they were satisfied with the services given by the TTO. All of them commented that the TTO was very supportive, knowledgeable, highly skilled, and highly capable, and were experts in negotiation skills. However, for this type of patent, the inventors also stated that the TTO has insufficient budget and skills to market all of their inventions and did not have special due diligence systems in the evaluation of their patents.

5.3. Inventors

This section discusses inventors' motivation, networking, industrial experience, and technologies.

5.3.1. Motivation

In the case of patents exploited through company formation, the findings show that the inventor-entrepreneurs spun off from the University for a number of reasons. Money was not the main factor that drove them to exploit the opportunity. The main factor was the desire by the inventors to see their patents exploited (companies B, D, E, and F). This finding is consistent with the findings of Smilor, et al. [1990], Blair and Hitchen [1998], and Shane [2004].

The second factor was the money, or the desire to get rich. After observing the success of other people who had exploited their patents, they wanted to do the same. For example, the inventor-entrepreneur of Company A was driven to exploit his patent after a Ford Motor Company manager resigned and licensed the technology they had invented. In only one case, Company C, the company that produces hydro gel materials, the inventor was driven to commercialise the invention by the motive of not being satisfied with the contract post he had with the University.

For the case of patents licensed to established companies, all inventors were mainly motivated by the desire to see their inventions developed and utilised. Although they possessed some entrepreneurial characteristics such as the need for achievement, they were risk-averse and not interested in involving themselves in commercialising their technologies. Only one inventor reported financial consideration as the next reason for licensing the patent.

One of the inventors said:

“ . . . I got involved with the research . . . and left the original negotiations and other tasks to professionals, Pharmalinks, and I am not interested in making money. It was up to Pharmalinks and RCS (Research and Consultancy Services, the TTO of the University) who got the contract arranged.”

Two inventors (patents 10 and 12) initially were not interested in licensing their technologies at all. The inventors who then licensed their technology to Orange were helped by the TTO to search for a licensee. This current finding is consistent with the study by Lowe [1993], who reported that, in a university, there are technology originators and technology harvesters. The role of the TTO is to identify which technologies have potential values, link them with industry, and try to exploit them. As Lockett, et al. [2003a] suggest, the TTO should recognise an opportunity better than the inventors and any external bodies.

5.3.2. *Networking*

All of the inventors who commercialised their patents through spin-offs were very enthusiastic, energetic, and hard working. One of the entrepreneurs said he spent almost 95% of his time looking for venture capital, working long hours and coping with problems as they arose.

Prior to forming the company, the inventors from Company D had established contacts with two large companies through their informal network and consulting work. The two large companies helped identify the opportunities, funded the project, and became the first customers, thus supporting the conclusion of the study by Wright, et al. [2004]. However, these companies did not take any equity nor license the patent. One of the inventor-entrepreneurs commented about the importance of networking:

“. . . What we did at the beginning was, we talked to Scottish Power and National Grid to get them to sponsor development. We convinced them that this would be useful for them and asked them to support the work. They did so. At the beginning these were the key people that we talked to, beside the University. We are going from a concept to something that could be designed for industry. We published a lot and talked to key industrial people”

This study shows that both informal and formal networking of the inventors and the TTO are important to market the patents. For patents that were commercialised through licensing to established companies, half of the patents (patents 7, 8, and 9) were marketed through the informal contacts of the inventors and the licensees, and the other half (patents 10, 11, and 12) through formal marketing by the TTO. This finding partially supports other studies, which found that informal networking with industry is crucial and increases the chances that inventions would be exploited [Thursby and Thursby, 2001; Colyvas, et al., 2002; Jensen and Thursby, 2001; Agrawal and Henderson, 2002; Thursby and Thursby, 2002; and Thursby and Thursby, 2004; Ismail, 2007].

In the case of patents 7, 8, and 9, the inventors and industry initiated the efforts to find licensees. The reason was the inventors had been networking with the companies from the start of their research projects; thus, they knew the companies' staffs before-hand. For example, in one case (Patent 8), the inventors and the licensee company were working in the same technology area. These prior networks between the companies' staffs and the University inventors were the strong reason why the companies licensed the inventions. These collaborations resulted in the invention fulfilling the customers' needs, and the target markets were very clear from early on in their research.

For patents 10, 11, and 12, the TTO initiated the patent filing and the search for licensees. There were two reasons. The first reason was that the technologies were at later stages of development and had clear target markets. These factors attracted companies to invest in the technologies. The second reason was the characteristics of the inventors, who were driven by the need to

achieve something, but were risk-averse, and were likely still to depend on the University for their careers, as suggested by Birley [2003] and Blair and Hitchen [1998]. They were unwilling to take any risk and were aware that the technology needed huge investments so licensing them out was the logical alternative. These types of inventors prefer to stay in the University because they have comfortable and secure jobs (most of them are professors). Because of the potential market for the technologies, the TTO took the initiative to lead the efforts in finding licensees. One inventor said:

“ . . . the chief engineer in the company shared the work together. We knew each other [before starting the project] and he got the company job. He got the good project from the company, but other surgeons also had networked with other manufacturers at that time. So that gave advantages. We did not contact anybody [outside the group]. . . . ”

5.3.3. Industry Experience

Industry experience is very important because it leads to exploitation of research results. Previous knowledge and experience in industry helps inventors identify customer, manufacturing, and sales needs that pose opportunities for the use of new technologies, and determine which products to develop and what type of business they should be in [Vohora, et al., 2003]. In all the spin-off cases, the opportunities were evaluated and clarified before venture formations because the inventors had prior network connections with industry. This finding is consistent with previous studies that suggest that inventors who have prior knowledge from industry are more likely to form companies to exploit their inventions [Shane, 2000a; Shane, 2003; Shane and Khurana, 2003; Shane, 2004; Elfenbien, 2005].

In the case of the inventors who licensed their patents to established firms, their prior work experience in industry as consultants or employees helped them get contacts to license their technologies. This is consistent with the work of Colyvas, et al. [2002], Thursby and Thursby [2000]; Thursby and Thursby [2001]; Thursby and Thursby [2003]; and Ismail [2007].

5.3.4. Technology

In this study, the majority of patents from all categories were licensed at the proof-of-concept (POC) stage. It can be said that 50% of the technologies that were licensed to spin-off companies and 50% of the technologies that were licensed to established companies were at the POC or embryonic stage. This finding supports Thursby, et al. [2001], who reported that 75% of the technologies that were licensed were at the POC stage. Only 12% were ready for manufacturing and 8% were at the stage where manufacture was feasible immediately (as shown in Table 4). Only two patents were at the prototype level. They were exploited through established companies. Three patents that were licensed to spin-off companies were also at the prototype stage. Of these, one

patent had gone past its prototype stage and another two patents were being upgraded to prototype stage at the time the firms were being founded.

Patents that were licensed to spin-offs were also considered radical, multi-purpose and have strong patent protections; whereas, patents that were licensed to established companies have the opposite characteristics. These are shown in Table 1 earlier.

Table 4
Stages of Technology for Different Types of Patents

Types of Patents/ Stages of Technology	Early-Stage Technology	Proof- of - Concept Stage	Prototype Stage	Total
Number of patents that have been exploited via spin-off	0	3	3*	6
Number of patents that have been exploited via licensing to established company	1	3	2	6
Total	1	6	5	12

* Two of the three are on their way to prototypes.

6. DISCUSSION

This discussion focuses on the decision to patent and to commercialise, the role of TTOs, inventors, and the stage of technology.

6.1. The Decision To Patent and To Commercialise

For patents that were licensed to new spin-off companies, the decisions to seek patent protections were made by the inventors, the TTO, and industry, or jointly by two of these three parties. However, the decisions to form spin-offs were mainly made by the inventors themselves. The TTO made minimum efforts to market the inventions. The inventors generally recognised the opportunities for their inventions early on, and before anybody else. The inventor of Patent 5 had the idea to form his own company at the start of his research project. This idea, together with his high personal motivation, steered his research toward technologies that could be used in saleable products; hence, he would be seeing his products used, which is the main motivation of many academic inventors in patenting.

For patents that were exploited through established companies, most of the initial decisions to patent the technologies were initiated by the TTO. The notion that the TTO was the real initiator in seeking patent protection is strengthened by the fact that nearly half of the inventors in this group were initially not interested in the exploitation and commercialisation of their inventions, hence not really seeking to protect them. It could be said that they were 'real' scientists who saw their roles as doing research and being idea originators rather than idea exploiters [Roberts and Peters, 1981]. Most of the inventors of patents that were licensed to established companies were not interested in involving themselves in commercialisation activities at all.

6.2. Role of TTO

Generally, the TTO in this study encouraged licensing to established companies rather than forming a new spin-off company. Networks with established companies have been formed with the ultimate objective to license out the inventions. Spin-offs are formed based on motivation of the inventors and as a last resort decision after failing to find a licensee. Patent 6, which was initially licensed to Orange, but was not exploited by the company, was finally licensed to a new spin-off (Company F) after a concerted effort by the inventor.

Traditionally, universities get cash quickly when licensing their patents to established companies. Forming a new company requires a university to incur initial investment costs, requires extra efforts on the part of the TTO, and results in the university receiving a financial return only when the company is sold or an IPO occurs. Another issue is that major activities in licensing to established companies stop (just need to monitor the companies) when the licensing agreements and contracts have been signed, especially for late-stage technologies; whereas, in a spin-off, the university still needs to invest a lot more effort to make sure the ventures succeed.

Only recently, the TTO in this study changed its effort to encourage spin-offs. Prior to the year 2000, the University was more focused on licensing efforts to established companies. Spin-off formation activities at the University were in their infancy, driven mainly by 'entrepreneurial scientists' who had work experience with industry. Since 2000, the policy of the University changed to give more support to spin-off formation activities. Although more proactive policies were introduced, initially, individual motivations and initiatives were identified to be the main drivers for company formations. The capability of the TTO to support spin-off has also increased since 2000.

Because of the emphasis given to licensing activities to established companies, the importance of having a due diligence system at the TTO has been largely overlooked. Patents are typically evaluated by the industry that has experts in that particular field and that normally would license the technology if it were commercially viable. To set up a due diligence system, quite an effort would be required to bring the TTO staff up to the high level of competency required to analyse and evaluate new technologies and then manage their

commercialisation process, as contended by Vohora, et al. [2002]. The due diligence system might reduce the number of patents that are not exploited and increase the number of exploited patents.

Regarding the support given by the TTO to encourage licensing and spin-offs, this study found a significant perceived difference in the support given by the TTO to inventors whose patents were licensed to spin-off companies and those whose patents were licensed to established companies. The latter were more satisfied with the TTO. This could be due to the fact that the TTO was originally formed when University spin-offs were not in fashion; hence, the expertise in the office was based on marketing patented technologies to established companies. The University also has two life-sciences-based centres, which also help market the technologies in related field.

Over and above all the considerations discussed, the TTO has to take into account the University's overall objectives and strategies for commercial exploitation of their patented technologies. In this study, the director of the University's TTO revealed that the main objective of the University is licensing for cash and attracting sponsored research, though this is not officially mentioned in the University policy. This is understandable as this policy is the least risky. The University is capable enough in marketing life science inventions compared with invention in other fields of technologies, due to the fact that the University has two life science centres that are very active in finding licensees.

6.3. Inventors

All of the inventors who licensed their patents to spin-offs had a very high motivation to see their inventions exploited. For them, seeing products using their inventions was a mark of success in their career. Here, industry experience, networking, and consulting work helped them recognise the opportunities for their exploitation of their technologies, and being involved in the exploitation effort contributed to their satisfaction. For them, monetary factors were a secondary reason for them to exploit their technologies.

All inventors who licensed their inventions to established companies also had a high motivation to see their inventions exploited. They were risk-averse, however, and thus happy to let the TTO commercialise their inventions through licensing to established companies.

This study found that the commercialisation skills required within the TTO to facilitated spin-off formations were due diligence competency, business potential analysis, and knowledge of legal, marketing, sales, science, and technical matters, as suggested by Markman, et al. [2003] and Lockett, et al. [2003a; 2005]. The TTO could achieve greater competency by training its staff in these skills or by bringing in experienced personnel through offers of higher pay or some kind of reward [Siegal, et al., 2003a; 2003b; 2005]. The TTO would also be able to retain the more qualified personnel it already has. Upgrading and increasing the skills of its staff eventually would increase the number of spin-off

formations and improve the universities' technology transfer and commercialisation rates, as noted by Markman, et al. [2003].

6.4. Stage of Technology

Generally, 80% of the technologies that were exploited in this study were at the embryonic stage when patent protection was sought. The remaining few were at the prototype stage or the 'lab' proofing stage. Even though most of the patents were at an early or embryonic stage, they differed in maturity and potential market.

Patents that were licensed to spin-off companies had technologies that were generally more advanced, of a broader scope, and at a multi-purpose stage at the time the company was formed. This is consistent with conclusions by Shane [2001a; 2004] and Nerkar and Shane [2003]. For some of the patents, such as those licensed to companies A, D, and E, the technologies were considered 'first to market'; that is, available during the time the companies were launched.

Most of the patents licensed to established companies were single-application technologies, even though the inventors claimed that they were of a broad scope and incorporated advanced technologies. This finding only partially supports Shane's [2001a; 2004] studies.

Three patents that were licensed to established companies were at the proof-of-concept stage, and one patent was licensed at an early stage. Exclusive rights were given to the licensing companies in order to allow them to develop and exploit the technologies to the maximum capacity. These findings are consistent with the study by Markman, et al [2005], who contended that established companies licensed all stages of technologies as long as they have potential market for the technologies.

7. LIMITATIONS OF THE STUDY

This study provides important insights into the decision-making process for the commercialisation of university patents. It has a number of limitations, however. First, the study is based on a case study of patents of one university, which may affect its generalisability. Second, the TTO staff selected the patents and the corresponding inventors to be interviewed. This may provide unknown sample selection bias. There is also a potential of non-response bias.

The study involved interviews with the inventors, inventor-entrepreneurs, and other key informants. Many inventors who licensed their patents to established companies refused to be interviewed as they feared the projects would become known to other parties. In addition, many of the inventor-entrepreneurs were too busy to be interviewed. Thus, the data presented in this paper is limited to those willing to be interviewed and not randomly selected.

Another limitation is that one individual in a company or a research group provided the data. Although the respondents comprised inventor-entrepreneurs and heads of the research groups who were responsible for the management and

development of the firms and the projects, the possibility that a common response bias might have inflated the findings of this study cannot be ruled out.

8. FUTURE RESEARCH

The current study has revealed opportunities for further work. It would be beneficial, for example, to carry out a larger research study that covers multiple cases from several universities. The study should not be confined only to patents, but should also include other types of intellectual properties, such as registered designs and copyrights. Some universities enter the commercial world by selling expertise and know-how without publishing this information. It would be informative to learn who makes the decision not to patent or publish these secret inventions and why, to discover the salient features of these technologies, and to ascertain the factors that led to the chosen route of their commercialisation. Other factors that affect the choice of commercialisation route should be further explored, thus improving the understanding of the process of commercialisation of university research output. Knowledge gained from these studies could reduce the waste within university patenting and commercialisation budgets.

Future research could also be focused on individual themes. These themes include the motivation factors and the opportunity recognition by the inventors. The study could also explore other factors that may influence the decision-making process in the exploitation of university patents, such research funding, the involvement of the inventors, and TTO skills, capabilities and resources.

Focus group interview technique may also be used among inventors from different types of patents. This may uncover slightly different views of the process when the inventors of different types of patents meet. The 'real' problem of the decision to patent and the route of exploitation may become more transparent by considering the views of inventors of other types of patents. Future research may also emphasise that the ownership of the inventions may affect the effectiveness of the commercialisation process. Other future studies could compare patents that are licensed to spin-off companies or established companies that went bankrupt, and could take a close look at non-university start-up companies (companies created without university equity). Future research also could be done using mixed methods of data collection – a combination of surveys and interviews would result in a larger sample size and would result in a greater understanding of the process. The mixed method may produce more comprehensive results, but the research questions should be changed to suit the methods adopted.

9. CONCLUSIONS

This paper answers the research question of this study; i.e., what are the features of exploited patents? The paper identifies the actors involved in the process and explains how the decision-making process works with regard to patent selection and exploitation.

In terms of the actors involved, this study found that the process of commercialisation began when an invention was disclosed to the university's TTO office. The decision to make the disclosure was made by the inventor or research group. The TTO did not initiate the process. In other words, it did not scout out inventors nor scrutinise inventions prior to disclosure by the inventor. Thus, inventors disclosed only those inventions that they thought were patentable. Some of the inventors preferred to publish rather than patent and derived their financial returns through consulting work.

The decision to seek patent protection involved a combination of actors – from the inventors alone, to the TTO and the inventors, and, in some cases, to the companies that funded the projects. Both types of patents – the exploited and the unexploited – demonstrated a specific pattern in the process toward commercialisation.

In this study, inventors and the TTO played crucial roles in the decision to exploit patents. Interestingly, the decision differed between patents that were licensed through spin-off companies and those that were licensed to established companies. All the decisions to exploit the patents through spin-off formation were made by the inventors. On the other hand, the decision to license the patents to established companies involved a combination of players. It was the decision of the inventors and the licensees, or the inventors alone, or the TTO alone, or the TTO and the inventors. This study found that the TTO always played a proactive role and that it was an important actor in helping identify opportunities for inventors with quality inventions who were not interested in commercialisation efforts. For this type of inventor, the TTO would normally decide to license the patent to an established company.

With regard to how the decision-making process worked, this study identified five major interlinked themes or factors which influenced the decision on which route to use in exploiting patents:

- Motivation factors

- Recognition of opportunity through industry experience

- Networking among inventors

- Role of the TTO

- Stages of technology

The skills and capabilities of the TTO with regard to evaluating patents through a systematic due diligence system will help inventors to market their inventions and to reduce the number of unexploited patents. These are the important factors that influence the route of commercialisation.

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